

# Chapter 1

## 1: INTRODUCTION TO HOT WATER DRILLING

### 1.1 Introduction:

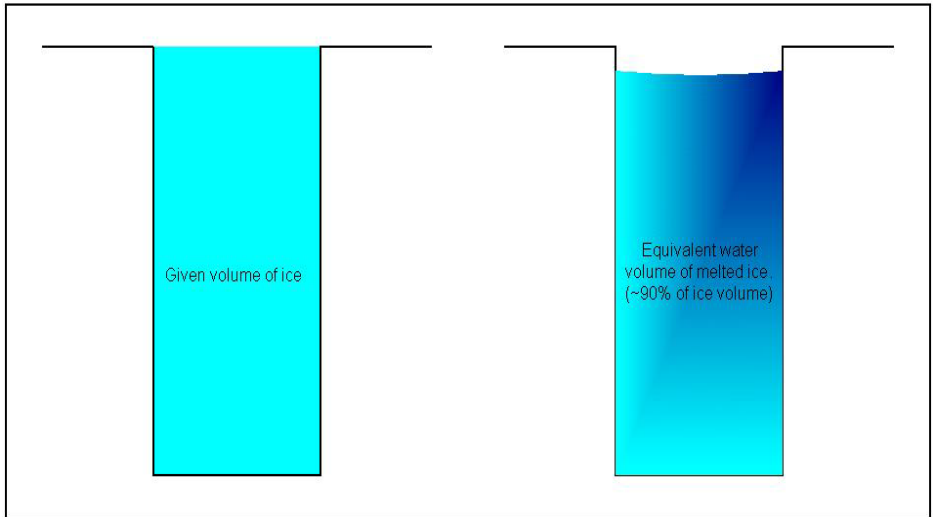
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Hot water drilling is used in situations where access holes in ice are required in very quick time. It is the only currently practical method of making access holes of greater than 200m in days rather than weeks. Using this method, holes from a few hundred meters can be drilled in hours and up to 3 kilometers can be drilled in 2-3 days with the right capacity drill.

The method basically involves pumping water at near boiling point and high flow rate through a nozzle aimed at the ice face which melts the surrounding ice as the nozzle is steadily lowered down the hole. This water is then recovered with a submersible pump located near the top of the hole, heated and re-circulated back down the hole. The water pumped down the hole needs to be recovered for two reasons:

- Recovery is necessary in order for the hole not to overflow with the combined volume of water introduced down the hole and the water resulting from the melted ice.
- Water recovery is necessary in order to alleviate the need to constantly source a large volume of water to use in the melting process.

In practice, not all the water pumped down the hole can be recovered. Due to the fact that a given volume of ice will result in a smaller volume of water when it is melted (as shown in Figure 1.1), the volume of water pumped back out of the hole can only be about 90% of the water deposited. If any more water than that is pumped up, the water level in the hole will quickly drop below where the submersible pump recovering water from the hole is located, making water recovery impossible.



**Figure 1.1** Equivalent Ice/ Water Volume Diagram

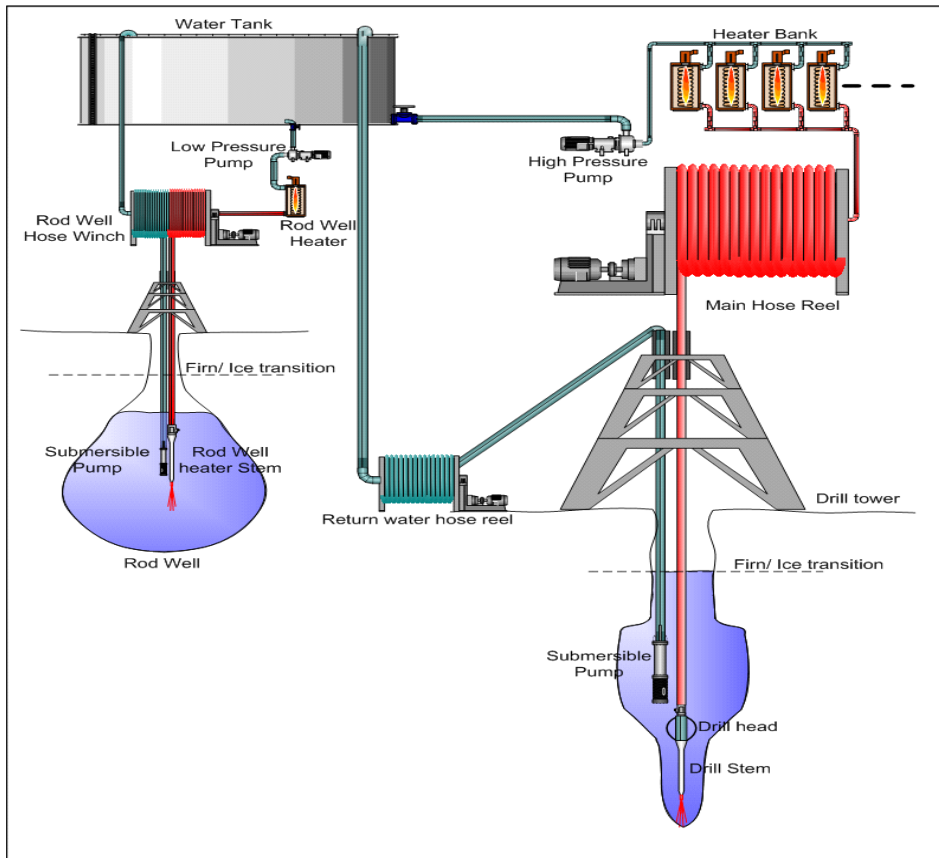
Because of the reduction in volume as the ice is melted, some “top up” water is still required to make this form of melting holes in the ice practical. Sources of top up water can be a nearby melt stream, cutting up and melting ice blocks or developing a “Rodriguez Well” (Rod Well) and pumping the “top up” water from this well. The choice of how the makeup water is produced depends on the circumstances of drilling, what equipment is available and how many holes are being drilled.

Melt streams are not usually readily available or conveniently located next to the hole being drilled, while cutting up ice blocks and melting them can become very labor intensive if more than a few thousand gallons of water is required. Whereas producing and developing a Rodwell can be overkill if not much top up water is required.

If a lot of makeup water is required, a convenient method of producing this water is to drill and develop a “Rod Well”. This involves making an access hole through the firm layer into the ice below, lowering a nozzle and submersible pump into the cavity and heating the water in the cavity by continually pumping hot water down into the cavity, pumping cold water up, heating it then pumping it back down. Over time this causes the surrounding ice to melt and results in a reservoir of water. Water from this reservoir can then be recovered as needed for drilling.

## 1.2 Basic Hot water Drill System:

A basic hot water drill system setup, such as one that would be used for multiple hole production, is shown in Figure 1.2 below.



**Figure 1.2** Basic Hot Water drill system for drilling through ice sheets

The system typically consists of the following components:

- A buffer tank of water.

This tank needs to have enough capacity to allow the start of the drilling to proceed uninterrupted while the submersible pump is lowered into position for water recovery.

- A high pressure pump or pumps.

These pumps need to be scaled to have enough power to overcome the system pressure drops and to provide the required flow rate.

- A heater bank.

The heaters are scaled to provide the required water temperature rise at the required flow rate. Heaters can be added to the system as required to achieve the required temperature at the required flow rate.

- A hose reel with enough hose to reach the required depth.

Depending on the hose type, the hose may need to be supported by a cable as the hose may not be able to support its own weight down the hole.

- A tower located over the hole.

The tower may need to support both the drill hose, return water hose and the supporting cable if necessary

- A drill stem with nozzle.

The drill stem needs to be heavy enough in order to allow the hose to uncurl straight while in the hole. Depending on the level of complexity of the system, the drill stem may also incorporate a drill head which contains sensors and telemetry to provide feedback on the drilling operation. If this drill head is a larger diameter than the main drill stem, the drill stem needs to be long enough to allow the hole to become wide enough to allow the drill head to pass through (see “Basic Drilling Process”)

- A submersible pump down the hole.

The pump needs to be sized to have a pump rate at least 90% of the water flow rate going down the hole.

- A return water pump hose reel.
- A pump for pumping water down to the Rodwell
- Rodwell water heater(s)
- A rod well winch

The winch needs to control two separate hoses; one for hot water down to the Rodwell and one for return cold water from the well.

- Rod well heater stem.
- Rod well submersible pump.

The system depicted is a very basic representation of a hot water drill system. For the purposes of clarity, some components of the system have been left out; such as power cables and cable winches for the submersible pumps, data cable and cable reel for the drill head (if drill head is present), various instrumentation sensors, electrical, network and data cabling.

## 1.2.1 Basic Drilling Process:

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The aim of drilling with hot water is to make a quick access hole through the ice. The reasons for this are varied and may be to undertake measurements in the ice sheet, deploy instruments in the ice, access the bedrock under the ice or punch a hole through an ice shelf to undertake oceanographic work in the water column beneath the ice.

The drilling procedure may vary slightly depending on the situation. For example, producing and developing a Rodwell may not be a “cost effective” method of producing “top up” water if only one hole is required. However the general principle is the same and the description to follow will assume a Rodwell is the method of producing “top up” water.

The process of drilling with hot water relies on water of a constant temperature and flow rate hitting the ice face while the drill nozzle progresses down the hole at a predetermined speed. This determines the hole diameter. The drilling speed can be calculated using the following formula, taken from

“Hot-water drilling and bore-hole closure in cold ice”

Humphrey & Echelmeyer, 1990,

Journal of Glaciology, **36**(124), 287-298.

$$v(y) = \frac{\rho_w c_w Q_w (T(y) - T_{wall})}{\pi R_0^2 L \left[ 1 + \frac{\rho_i c_i}{L} |T_0(y)| \right]}$$

Where:

$\rho_w$  density of water (1000 kg m<sup>-3</sup>)

$c_w$  specific heat capacity of water (2.09 x 10<sup>3</sup> J kg<sup>-1</sup> K<sup>-1</sup>)

$Q_w$  flow rate of water through the hose

$T(y)$  water temperature at depth  $y$  in the borehole (length along hose)

$T_{wall}$  temperature of borehole walls, taken as 0 °C for ice/water interface

$R_0$  borehole radius

$L$  Latent heat of fusion for ice (3.35 x 10<sup>5</sup> J)

$|T_0(y)|$  ambient temperature of the ice at depth  $y$  in the ice

The water temperature at depth is given by:

$$T(y) = T_0 e^{-y/\lambda} + T_{wall}$$

Where:

$T_0$  water temperature at the surface (from the heaters)

$T_{wall}$  temperature of borehole walls, taken as 0 °C for ice/water interface

$y$  depth in the borehole, or length along hose

$\lambda$  a characteristic decay length for specific hose types. This parameter may be given as one of the hose specifications, or it can be calculated as follows:

$$\lambda = \rho_w c_w Q_w Z$$

Where:

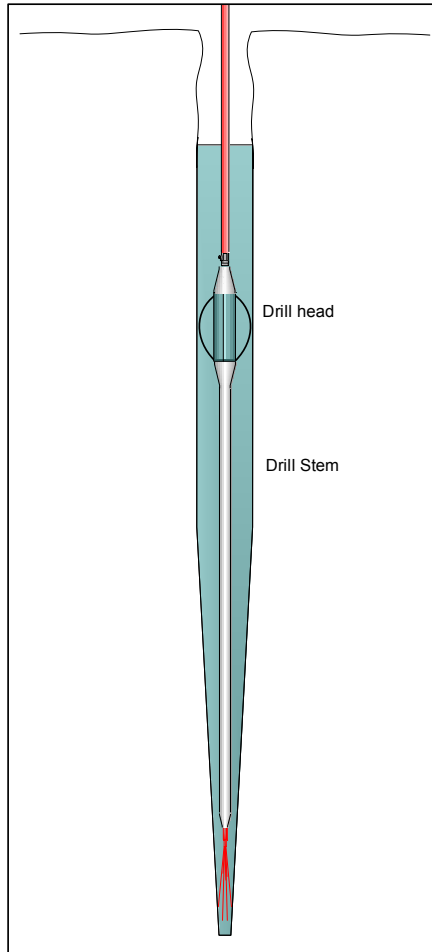
$Z$  effective thermal resistance of the hose (this has been experimentally calculated as 0.27 mK W<sup>-1</sup>)

The formulas above allow the speed of drilling to be calculated for a required borehole diameter, assuming a given constant water temperature and flow rate. Alternatively, if the requirement is to drill a certain depth hole in a given time frame, then the drilling speed can be assumed (along with the water temperature) and the flow rate required to achieve such drill speeds can then be calculated.

The required flow rate and water temperature gives the drill power output. This allows the drill components (such as water tank size, hose size, number of heaters, number of high pressure pumps, etc) to be sized to achieve the required drill power output.

As well as a high temperature and a high flow rate, in practice this method of drilling also relies on the velocity of the water coming out of the nozzle to be as high as feasible and hitting the ice face with full force. For this reason, the drill stem nozzle is chosen to be as small a diameter as the system pressure will allow and also to have a very narrow spray pattern; typically zero degrees. The water velocity concentrated on a narrow spot provides a “cutting” action and, combined with the water temperature and flow rate, “drills” a hole through the ice.

The hole diameter is not fully developed as soon as the water hits the ice face. The drilling process “punches” a hole through the ice, the initial diameter of which is not much bigger than the drill stem and nozzle (as shown in Figure 1.3). The drilling method relies on the hot water in the hole to continue to melt the surrounding ice and widen the hole to the required diameter after the drill stem tip and nozzle has passed by.



**Figure 1.3** Hole Profile at Ice Face

Sometimes the drill stem will have a drill head with an instrument package attached, as shown in Figure 1.3. This instrument package may be a bigger diameter than the drill stem. In this case the drill stem needs to be quite long in order to allow enough time for the hole diameter to increase sufficiently before the drill head reaches that point in the hole.

Referring back to Figure 1.2, the basic drilling process starts off with having the buffer tank full of water in preparation for drilling. The drill stem and drill head are then assembled in the hole. Water is brought up to temperature by having it circulating through the system in closed loop, then the water hose (and electrical cable for the drill head, if employed) is connected to the drill head and drill stem. Once the right flow rate is obtained, the winch is started and set to lower at the speed necessary to achieve the required hole diameter for the given water temperature and flow rate.

Once the drill has passed the level at which water is pooling, the submersible pump is lowered into position, submerged sufficiently below the water to minimize the likelihood of running the pump dry. The pump is then switched on and set to recover about 90% of the water pumped down the hole, with the extra 10% necessary to maintain a constant level in the hole obtained from the Rodwell. Drilling then proceeds at the calculated drill speed to give the required borehole diameter for the given flow rate and water pressure.

Up until the pump is down the hole and running, the drilling operation is proceeding without any water recovery from the hole. This can be for a significant length of time, in the order of one or more hours. It is therefore important to size the buffer tank correctly so that for the given drilling flow rate, the tank holds enough water to allow drilling without water recovery for the maximum length of time it is expected to take to deploy the submersible pump.

While drilling, hot water is continually pumped down the Rod well and cold water brought up to continue developing the well. When required during drilling, as mentioned above the 10% of extra water required to top up the hole (as a result of ice melting) is obtained from the Rod well by pumping less water down than the amount being brought up. This obviously has the effect of lowering the Rodwell level. It is therefore important to keep pumping heat into the Rodwell and develop it to make more water. It is important to employ the right technique of developing the well by lowering the hot water nozzle and submersible pump at the proper rate in order to make the well wide and shallow, rather than narrow and deep. If the well is made too deep too quickly, there is a risk that the water level becomes too low and there is not enough hose or cable to allow the pump to reach the water. Rodwell production is covered in a separate chapter.

The same method of drilling a hole through ice cannot be used to drill a hole in the firm layer at the top of the hole. A different drilling technique is necessary for firm drilling, as discussed below.

### **1.2.1.1 Drilling in Firm:**

The top part of an ice sheet or ice shelf is generally comprised of snow, known as firm. This firm increases in density with depth, until it reaches a “close off” point where it is no longer porous to air and becomes ice. This transition



can be as deep as 115-120m. However at around 35-40m, the firm will be solid enough that it will allow water to pool.

Up until that point in the hole where water pools, the drilling method used for ice (with a narrow spray angle) will not work in the firm layer. The narrow nozzle angle will “punch” a hole through the firm as for the ice, but the water will dissipate in the surrounding firm, rather than pool in the hole. It will therefore not be possible for the secondary action of the hot water to continue to widen the hole.

For this reason, different techniques are employed to drill through the firm layer. This may range from simply employing a nozzle with a wider spray pattern to coring the top part of the hole using a mechanical coring drill, using an electric hot point, or using a closed loop heated glycol system to transfer heat to the ice face. Each system has its attributes and its problems.

The wider spray nozzle will melt the firm quite fast, but it will use a lot of water which can't be recovered as it is lost in the firm. This will necessitate the need for significantly more water production than for drilling through ice.

The mechanical coring drill is the most economical in terms of power requirements, but it is a fairly slow process and, depending on the diameter of the required hole, it may be an impractical or impossible to achieve the required borehole diameter.

The electric hot point method will again be a fairly slow process and will require a lot of electrical energy. The melt head can however be scaled, with a resultant increase in power, for larger diameter boreholes.

The closed loop heated glycol system is again slow, requires a lot of energy to heat the glycol but is also scalable for larger diameter boreholes.

Another drill technology which can be utilized to drill through firm layers is the RAM drill where a high speed drill head mechanically cuts the firm and compressed air is pumped through the centre of the drill stem to push the cuttings back up the sides of the hole. However this type of technology is still being tested and scaling it for large diameter holes may be impractical.

## **1.3 Manual Objectives:**

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The rest of this manual will be describing the IceCube “Enhanced Hot Water Drill” (EHWD). This drill was purpose built for the construction of the IceCube Neutrino detector array at South Pole station in Antarctica. The array required the drilling of up to 88 access holes in the ice, spaced in a 125m grid with each hole being 600mm diameter and 2500m deep. The drill was designed to have a turnaround time from hole to hole of about 3 days.

The manual will also document the Firm drill used to provide the access holes in the firm layer of each hole. The firm drill used is a unit specially built for the purpose and uses a closed loop glycol heating system.

The objective of the manual is to document the following:

- The design philosophy of the drill.
- A technical description of the drill as a complete system, including a technical and operational description of each subsystem as well as schematics and drawings of each subsystem.
- A technical and operational guide to the software control system.
- An operational guide for the drill system, including:
  - De-winterizing the system
  - System setup and commissioning
  - A description of each major step of the drilling process
  - System winterizing
- Fault diagnosis procedures of various subsystems and components
- Preventative maintenance procedures on various subsystems and components

As a training aid, a video segment of each major step of the operation of the system is also produced, including de-winterizing, setting up, commissioning, drilling, winterizing. Fault diagnosis. These video segments are embedded in the relevant chapter of the manual

The intention is to document the EHWD to a level which will allow a drill crew with no previous experience with this particular drill to put the system together from a winterized state, re-commission the system, perform production drilling as well as diagnose problems and conduct preventative maintenance.

Click on the link below to view a video giving an overview of drilling operations.

[Drill Operations Trailer.mp4](#)

# 1.4 Unit Convention and Acronym List:

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## 1.4.1 Unit Convention:

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The unit convention used in the design of the EHWD and which will be adhered to in this manual is a combination of SI and imperial units. All units are SI units with the exception of the following:

Pressure: psi, psia, psig  
Volumetric Flow: gpm, gph  
Force: lb (force)

This was a compromise decision. The IceCube project is a combination of an Engineering undertaking as well as a scientific undertaking. It is also an international project with collaborators from many countries. The decision was made to use the SI system of units wherever possible in order to maintain consistency within the collaboration and with the scientific nature of the project.

However the drill was designed and built in the United States and in order to maintain consistency with specifications on drill equipment, nameplates, labels, etc, and in order to reduce the risk of confusion and potential errors with unit conversion, the decision was made to keep the above listed units as imperial units.

## 1.4.2 Acronym List

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The following list of acronyms is a standard list of acronyms used by the project as a whole. It covers all aspects of the IceCube project, including drilling, science and logistics. Some of the acronyms may not be used in this manual, but the complete list is reproduced here for reference.

<b>A3RI</b>	UW Antarctic Astronomy and Astrophysics Research Institute
<b>AMANDA</b>	Antarctic Muon and Neutrino Detector Array
<b>AN-8</b>	Fuel (Also JP-8)
<b>ATWD</b>	Analog Transient Wave Digitizer
<b>CAT</b>	Caterpillar
<b>CDC</b>	Clothing Distribution Center
<b>CDR</b>	Critical Design Review
<b>CHC</b>	Christchurch, New Zealand

<b>DAQ</b>	Data Acquisition
<b>DCC</b>	Drill Control Center
<b>DFL</b>	Dark Freezer Lab
<b>DNF</b>	Do Not freeze
<b>DOM</b>	Digital Optical Module
<b>DOME</b>	“Old” South Pole Station
<b>DOMMB</b>	DOM main boards
<b>DOR</b>	DOM readout
<b>DSHR</b>	Drill Supply Hose Reel
<b>EHWD</b>	Enhanced Hot Water Drill
<b>ERD</b>	Engineering Requirements Document
<b>E-Stop</b>	Emergency Stop
<b>FAT</b>	Final Acceptance Test
<b>FMEA</b>	Failure Mode and Effect Analysis
<b>GRB</b>	Gamma Ray Burst
<b>GUARD</b>	National Air Guard – Flies the Planes
<b>GEN</b>	Generator
<b>HA</b>	Hazard Analysis
<b>HPP</b>	High Pressure Pump
<b>ICD</b>	Interface Control Document
<b>ICDS</b>	Ice Coring and Drilling Service
<b>ICDS</b>	UW Ice Coring & Drilling Services
<b>IV&amp;T</b>	Inspection, Verification & Testing
<b>JP-8</b>	Fuel (Also AN-8)
<b>KRC</b>	Kegonsa Research Center (Also PSL)
<b>MCM</b>	McMurdo
<b>MDS</b>	Mobile Drilling Structure
<b>MDS</b>	Modular Deployment Structure
<b>MDS</b>	UW Materials Distribution Services
<b>MECC</b>	Mobile Expandable Container Configuration
<b>MHP</b>	Main Heating Plant
<b>NPT</b>	National Pipe Thread – Type of Fitting
<b>NPX</b>	South Pole Station

<b>NSF</b>	National Science Foundation
<b>OML</b>	Optical Module Lab
<b>PAP</b>	Project Advisory Panel
<b>PDM</b>	Power Distribution Module
<b>PDR</b>	Preliminary Design Review
<b>PEP</b>	Project Execution Plan
<b>PHS</b>	Pre-Heater System
<b>PMP</b>	Project Management Plan
<b>PMT</b>	Photomultiplier Tube
<b>PSL</b>	Physical Sciences Lab in Stoughton (Also KRC)
<b>PSL</b>	UW Physical Sciences Lab
<b>RPS</b>	Raytheon Polar Services Corporation
<b>RPSC</b>	Raytheon Polar Services Corporation
<b>RWCR</b>	Return Water Cable Reel (or Rod Well Cable Reel)
<b>RWHR</b>	Return Water Hose Reel
<b>RWS</b>	Rodriguez well system
<b>S/W</b>	Software
<b>SDP</b>	Software Development Plan
<b>SEMP</b>	System Engineering Management Plan
<b>SES</b>	Season Equipment Site
<b>SEW</b>	Seasonal Equipment Workshop
<b>SSEC</b>	Space Science and Engineering Center, a UW center
<b>STF</b>	Simple Test Framework
<b>TOS</b>	Tower Operations Site
<b>TOS</b>	Tower Operations Structure
<b>TOW</b>	Tower Operations Workshop
<b>TWR</b>	Tower
<b>USAP</b>	US Antarctica Program
<b>VC</b>	Verification Coordinator
<b>WBS</b>	Work Breakdown Structure
<b>WG</b>	Working Group
<b>WT1</b>	Water Tank 1
<b>WT2</b>	Water Tank 2



# Chapter 2

## 2: ENHANCED HOT WATER DRILL (EHWD) TECHNICAL DESCRIPTION

### 2.1 EHWD Design Philosophy

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IceCube construction presented massive challenges, and at the core was a drilling campaign to melt over 17 million gallons of ice over the course of seven short field seasons. The Enhanced Hot Water Drill and its team made this possible, but what was the fundamental philosophy behind the design of the drill?

At the most basic level, why choose a hot-water drilling method? First, hot water is an easy way to make holes of any size at the South Pole, since hot water + ice = hole. Second, hot water drilling is very fast, which was critical to the amount of time the IceCube team had to complete project construction. Finally, both the science and drilling operations require a water-filled bore hole that is allowed to freeze back to ice. The DOMs, very sensitive optical detectors that comprise IceCube instrumentation, become optically coupled with the surrounding ice sheet as the bore hole water freezes. During drilling, the water in the hole supports the hole itself so that it does not collapse in on itself, and also allows water to be recirculated back to the surface to close the drill system's hydraulic loop.

Now with a vision of a hot water based system, the drilling scope needs to be considered. Science objectives dictated that the final detector be comprised of 86 holes, each 60 cm in diameter and 2.5 km deep. This results in 200,000 gallons of ice per hole, and a total of 17.2 million gallons of ice in total. (Note the original scope was 80 holes in total). The target timeline to complete drilling and instrumentation of these holes needed to fit in about 7 field seasons, each about 3 months in duration.

A general template of hot water drill design can be presented as such (black text constrains blue text):

- Define required hole characteristics (how big, how long is the hole available, how many holes - this should generally be dictated by the science requirements).
- How fast do the holes need to be drilled? (Dictated by supportable total length of construction).
- Required thermal power.
- Upper safe limit on water temperature (at South Pole elevation, this is 88°C).
- Required flow.
- Maximize system pressure to Maximize nozzle velocity to Maximize drill speed.
- Pump size, heater size, tank size, etc.
- System specs (above) + budget + available time to build = Component selection.

For the case of the EHWD, since so much energy was to be spent drilling these holes, fuel efficiency was one of the largest design drivers, especially at the component selection level. Of note, once the system was designed, further optimization of drilling operations was made to minimize fuel consumption.

One huge advantage available during EHWD design was the AMANDA drill. AMANDA was the proof of concept for IceCube, and yielded mountains of lessons-learned and technical experience. The most important step in designing the new EHWD was to leverage the AMANDA experience, both by reusing identical equipment that worked well and to utilize people with experience.

The AMANDA drill did its job, but some major improvements were needed to meet the scope of IceCube:

#### Double the Thermal Power Output.

This was accomplished by doubling the water flow from 100 GPM to 200 GPM. Given fuel efficiency as a primary design driver, this may seem a bit counterintuitive at first, but more power yields faster drilling. As drilling is underway, heat is continuously lost from the water in the hole to the surrounding ice, so drilling a big hole faster with more power is actually more efficient than drilling slower with less power.



### Use a "One-Piece" Drill Hose.

One major drawback of AMANDA drill operations was that drill hose was added in segments as the drill got deeper and deeper, meaning regular shut down of flow and significant manual labor. By wrapping up all the hose sections needed to get to depth onto a single massive hose reel, the EHWD is able to minimize total time to drill a hole, eliminate destabilization of the system and labor associated with adding/subtracting hose sections, and make a huge improvement to safety.

### Automated Control.

By automating much of the system, nominal system settings can be maintained by computer control, leading to a more stable system, and potential for human error is reduced. This is crucial given the sheer number of system variables that need to be monitored. Many safety systems are also built into the computer control system, adding an entire layer of safety not seen on the AMANDA drill.

### Two Drilling Structures.

It takes a lot of time to deploy a string of DOMs, clean, and prepare a TOS site to move on to the next location, and then set it up for drilling again. Adding a second drilling structure allows drilling operations to continue semi-independent of deployment and subsequent TOS relocation prep. Only the drilling reels need to be moved, and they are moved to the next location where the other drilling structure is prepped and ready to go. As the season progresses, the two towers leap-frog from hole to hole. This significantly increases the frequency of hole drilling.

### Modular Design.

The harsh environment at the South Pole necessitates housing a large, complicated system like the EHWD inside some sort of enclosure. The enclosure also provides protection during storage. At the same time, the system needs to be moved around from location to location (the drilling structures move each hole, and the hot water generation camp moves each season to a different subset of holes). To meet both requirements, the system is broken into subsystems, each housed in a robust ISO shipping container that has been customized for its subsystem, and mounted on skis. The containers can easily be towed or lifted.

### High Efficiency Heaters.

The bulk of the fuel consumed goes into heating the drilling water, and since fuel efficiency is a primary design driver a lot of effort went into developing heaters that are efficient. The basic heater platform is the same as that used in AMANDA, but the addition of a condensing heat exchanger and molded ceramic combustion chamber improved fuel efficiency from 78% (Lower Heating Value) to over 90% (Higher Heating Value).

### Drilling Strategy.

The borehole can be optimized to be just big enough to provide enough time to deploy the instrumentation before it freezes too small. Any bigger equates to wasted fuel. By developing rigorous dynamic drilling and freezeback models, drill speed is controlled according to an optimized speed vs. depth schedule.

### Independent Firm Drilling.

Although it came later in IceCube construction, the concept of an independent firm drilling platform was another clear way to increase frequency of holes. The first and second generation IceCube firm drills used hot water provided by the primary system and was deployed at the drilling structures. By making the firm drilling process independent, firm holes can be punched out well ahead of deep drilling.

Where the AMANDA drill set the groundwork at a fundamental level to prove this type of drilling technology was going to get the job done, the EHWD was an optimized version of the same concept that improved the areas of fuel efficiency, speed, logistics, and safety.

## 2.2 System and Subsystem Specifications

### 2.2.1 System Specification

	Specification	Value	Unit	Comment
General	Total Power	5	MW	
	Thermal Power	4.7	MW	
	Electrical Power	300	kW	
	Weight	1.4 million	lb	total cargo est.
	Volume	120,000	ft <sup>3</sup>	total cargo est.
	Max Drill Speed	2.1	m/min	oscillation limit
	Max Ream Speed	7.5	m/min	practical limit
	Flow	200	gpm	delivered to drill head
	Temperature	88	°C	delivered to drill head
	Pressure	1,100	psig	primary loop, at pumps
	Main Drill Hose ID	2.5	in	
	Length of Main Drill Hose on Reel	2,560	m	21 x 400 ft sections
Generators	Power Rating (sea level)	250	kW	each (3 total)
	Power Rating (10,000 ft)	165	kW	each (3 total)
	Heat Recovery (10,000 ft)	200	kW	each (3 total)
	Drill Power Consumption (drilling)	250	kW	electrical
	Drill Power Consumption (idle)	90	kW	electrical
Fuel	Burn Rate during Drilling	130	gph	
	Burn Rate during Idle	17	gph	
	Total Fuel per drill Hole (no firm drilling)	4,200	gal	approx. for 27-hour hole, experienced crew
	Total Fuel per Independent Firm Hole	300	gal	
	Base Fuel - Startup	8,000	gal/hole	includes Rodwell development
	Base Fuel - Idle	500	gal/hole	
Daytank Capacity	300	gal		
Efficiencies	Overall System Efficiency	39	%	
	Main Heat Plant Efficiency	92	%	
	Drilling/Melting Efficiency	45	%	
Flows	Main Drill Flow	200	gpm	
	Return Water Flow	180	gpm	
	Makeup Water Flow	20	gpm	
	Idle Flow	30	gpm	
Times	Time to Drill/Ream a Hole	31	hr	27-hour hole
	Frequency of Holes	48	hr	experienced crew assumed
	Hole Lifetime Range	24-33	hr	historic, wider range is also available
Loads	Total Down-Hole Load at 2500 m	6,500	lb	
	Hose Tension Capacity	1,500	lb	limit until damage occurs
	Drill Cable Breaking Strength	20,000	lb	
	Tower Hoist Capacity	5,000	lb	
Nominal Hole	Diameter	60	cm	
	Depth	2,500	m	
	Volume of Ice	200,000	gal	

Figure 2.1 EHWD system specifications

## **2.2.2 Subsystem Specifications**

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### **2.2.2.1 Generators and power distribution**

#### Generator (GEN) 1, 2, and 3

Provide reliable source of electricity that supports the system and all drilling operations. Each...

- Output 225 kW (sea level), 160 kW (10,000 ft)
- Caterpillar 3306TA Engine
- Local or Remote (load sharing) operation
- Heat recovery system (water/glycol heat exchanger)
- Housed in modular ISO shipping container (24'L x 8'W x 8'H)
- Approx. weight 21,000 lb, each

#### Power Distribution Module (PDM)

Combines and distributes power from 3 generators to SES and TOS.

- Three generator inputs
  - 250 amp main breakers
  - Analog voltage, amperage, load (kW), and frequency readouts
  - Remote voltage and speed adjustments
  - Status lights
- Load sharing module with syncing tools
- Power distribution
  - 208 VAC 3-phase back feed for each generator aux. power
  - 20 circuits, 480 VAC 3-phase, 60A and 100A feeds
- Housed in modular ISO shipping container (24'L x 8'W x 8'H)
- Approx. weight 17,000 lb

### **2.2.2.2 MDS modules**

Each MDS Module, unless noted...

- Modular ISO shipping containers (34'L x 8'W x 8'H)
- Insulated walls and freezer-type doors

- 480 VAC 3-phase service, 120/240 VAC 1-phase outlets
- Two 4 kW electric heaters in all buildings
- Main space and electrical closet, separated by pocket door
- Network systems
- Supported on skis

### Drill Control Center (DCC)

Houses computer and network systems, central control system operations

- UPS and additional UPS-fed 120 VAC outlets
- Electric heat only
- 60-amp service
- Approx. weight 21,500 lb

### Rodwell System (RWS)

Houses 9 Stinger heaters, a hose reel, and controls pumps for developing a Rodwell. Maintains temperature and level of WT1. Provides heat recovery cooling water loop for the generators.

- Nine Whitco Stinger heaters
  - 50 kW water heating capacity each (@ approx. 75% efficiency)
  - Oil-fired Beckett SF burner units
  - Redundant flow and temperature safeties
  - In operation, heat 3.3 GPM of water at 125 psig from 10°C to 78°C
- Manual and remotely controlled valving for flexible flow configurations
- Plumbing rated for 300 psig
- Instrumented with flow, temperature, and pressure sensors
- Building pressure airflow dampener, and each heater has it's own makeup air fan
- Unico vector motor drives, 3 x 10 HP, 1 x 3 HP
- Motor driven hose reel, return/supply to Rodwell, 277' of IVG blue surface hose each
- Oil-fired furnace
- 100-amp service

- Approx. weight 25,000 lb

### Preheat System (PHS)

The PHS is used to maintain the temperature and level of WT2. Water continuously circulates between WT2 and the PHS and heated as needed. The circulating water is also filtered. The PHS is also home to the EHWD's condensate collection system, where condensate is collected, filtered, and injected into WT2.

- Three Whitco Model75 heaters + one Sioux prototype heater
  - 125 kW water heating capacity each (@ approx. 90% efficiency)
  - Oil-fired Beckett SF burner units
  - Redundant flow and temperature safeties
  - In operation, heat 7 GPM of water at 125 psig from 20°C to 88°C
- Main Filtration
  - Three bag filters
  - One centrifuge filter
- Condensate Collection System
  - 80 gallon collection tank
  - Three bag filters
- Plumbing rated for 150 psig
- Instrumented with flow, temperature, and pressure sensors
- Building pressure airflow dampener, and each heater has it's own makeup air fan
- Unico vector motor drives, 1 x 10 HP, 3 x 3 HP
- Oil-fired furnace
- 100-amp service
- Approx. weight 26,000 lb

### Main Heating Plants (MHP) 1-4

Each of the 4 MHP modules have 8 to 9 Whitco Model 75 heaters. The MHPs are used to add heat to the high pressure primary water loop for main drilling. Each building...

- Nine Whitco Model75 heaters (MHP4 has eight)

- 125 kW water heating capacity each (@ approx. 90% efficiency)
- Oil-fired Beckett SF burner units
- Redundant flow and temperature safeties
- In operation, heat 7 GPM of water at 1000 psig from 20°C to 88°C
- Plumbing rated for 1400 psig
- Instrumented with flow, temperature, and pressure sensors
- Building pressure airflow dampener, and each heater has it's own makeup air fan
- Oil-fired furnace
- 100-amp service with 60-amp output feeds (MHP1 and 2), 60-amp service (MHP3 and 4)
- Approx. weight average 27,500 lb, each

#### High Pressure Pump (HPP)

The High Pressure Pump module has 4 electrically-driven positive displacement pumps to pump the drilling water through the primary loop.

- Four high pressure pumps
  - Meyers Triplex positive displacement pumps
  - Capable of 60 GPM at 1500 psig
  - Baldor 50 HP induction motors
  - Toothed-belt drive
  - Accumulators and pressure relief valves each pump
- Plumbing rated for 1400 psig
- Instrumented with flow, temperature, and pressure sensors
- Four Unico vector motor drives, 50 HP each
- Building temperature control system
- Five soft-start units for external submersible charge pumps, 20 amp output feeds for each
- 60-amp building service, 100-amp service for each high pressure pump
- Two 75 kVA transformers for phase balancing
- Oil-fired furnance
- Approx. weight 24,000 lb

### Water Tanks (WT) 1 and 2

Water containment tanks

- 10,000 gallon capacity, each
- Insulated walls, stainless steel panel liner
- Central hatch doors
- Screened pump/plumbing cutouts each end
- Approx. weight 15,000 lb, each, dry
- No heat
- No network
- No integrated electrical service

### Mobile Expandable Container Configuration (MECC)

Expandable building folds out to serve as break room, meeting room, and storage.

- Modular ISO shipping container (24'L x 8'W x 8'H) when folded up
- Folds out to (24'L x 24'W x 8'H) via hand crank
- 100-amp building service
- Wired with 120 VAC outlets, and one 480 VAC 3-phase twist-lock for 10 kW electric heater
- Electric heat only
- No network
- Approx. weight 13,000 lb

### Seasonal Electrical Workshop (SEW)

Single-wide workshop used primarily for electrical work and storage

- Electric heat only
- No network
- Approx. weight 19,000 lb

### SHOP

Double-wide workshop used primarily for mechanical work and storage



- Electric heat only (Four 4 kW electric heaters)
- No network
- Approx. weight Left Half without equipment 19,000 lb
- Approx. weight Right Half without equipment 21,000 lb

### Tower Operations Structures (TOS) 1 and 2

Attached to the Drill Towers, these double-wide units can be separated for single use or mated for one large MDS. ½ contains a small computer room and large workspace each separated by pocket door, the other ½ has electrical and motor drive controls and large workspace each separated by pocket door. All hole drilling activities and deployment of in-ice instrumentation are monitored, controlled, and performed in these buildings.

- Large openings to accommodate pairing of halves and tower mating
- UPS and additional UPS-fed 120 VAC outlets
- Unico vector motor drives for reel controls, 1 x 50 HP, 2 x 20 HP, 2 x 10 HP, 3 x 3 HP
- Dynamic braking resistors
- Four 4 kW electric heaters (2 each half)
- Oil-fired furnace in electrical closet
- 3 x 100-amp feeds, with junction box allowing a single 100-amp service
- Approx. weight TOS Right Half 15,500 lb
- Approx. weight TOS Left Half 19,600 lb

### **2.2.2.3 Winches and reels**

Each major reel is supported on skis.

#### Drill Supply Hose Reel (DSHR)

The DSHR holds a continuous length of hose allowing for continuous deep hot water drilling without having to stop and add/remove sections of hose.

- Reel is currently holding 8800 feet of 2.5" ID, 3.7" OD IVG Main Drill Hose.
- Main drum is driven by 20 HP fully enclosed Unico synchronous motor, final drive ratio 1023:1 (gearbox + chain)
- Level wind is synced with drum speed and diameter via Unico drive logic

- Hydraulic rotary union and inlet water manifold with pressure relief valve, burst disk, and reel bypass port
- Large disk brake
- Emergency stop buttons, pull-cords, and hard-limit level wind switches
- Approx. weight 70,000 lb dry; 100,000 lb wet

### Main Drill Cable Reel

The main cable reel both supports the down-hole load of the drill and hose, and provides power and a communications link with the drillhead.

- Reel is currently holding 3300 meters of Cortland cable
- Main drum is driven by 20 HP fully enclosed Unico synchronous motor, final drive ratio 552:1 (gearbox)
- Level wind is synced with drum speed and diameter via Unico drive logic
- Electrical slip ring
- Large disk brake and releasable 1-way clutch
- Emergency stop buttons, pull-cords, and hard-limit level wind switches
- Approx. weight 8,000 lb

### Return Water Cable Reel (RWCR)

The return water cable reel supports the weight of and supplies power and a communications link to the return water pump.

- Reel is currently holding approx. 400 ft of Birns combo cable
- Main drum is driven by a 2 HP Powertec synchronous motor, final drive ratio 14:1 with a selectable 1:1 or 3:1 gearbox
- Electrical slip ring (low voltage signal and 480 VAC 3-phase)
- Disk brake and releasable 1-way clutch
- Approx. weight 6,000 lb

### Return Water Hose Reel (RWHR)

The return water hose reel holds the hose that transports water from the return water pump to the surface.

- Reel is currently holding 400 ft of IVG Main Drill Hose

- Main drum is driven by a 7.5 HP Powertec synchronous motor
- Hydraulic rotary union and outlet water manifold with reel bypass port
- Disk brake and releasable 1-way clutch
- Approx. weight 9,280 lb, dry

#### Rodwell Cable Reel

The Rodwell cable reel supports the weight and supplies power and a communications link to the Rodwell pump.

- Specs same as return water cable reel unless otherwise noted
- Two Enerpac P39 hydraulic brake hand pumps
- Approx. weight 3,780 lb

#### Tulsa Unit 20 (TU20) 2 unit

Powered reel used to deploy in-ice instrumentation cables with fine control and for bigger spooling/unspooling jobs

- 20,000 lb drum capacity
- 20 HP fully enclosed Unico synchronous motor, final drive ratio 220:1 (worm gearbox)
- Magnetic brake
- Approx. weight 10,500 lb

#### Tulsa Unit 15 (TU15)

Powered reel used for general spooling/unspooling

- 15,000 lb drum capacity
- 7.5 HP Powertec synchronous motor, final drive ratio 574:1 (worm gearbox + chain)
- Approx. weight 2,800 lb

#### Robertson Winch and Hole Logger

This piece of equipment is used to log bore holes at high speed using the logging head, or the winch can be coupled with other down-hole instrumentation.

- Winch, Sonde (logging head), sheaves, and control unit
- Winch is currently housed in wooden structure on skis
- Winch has motor, motor brake, disk brake, clamp "parking" brake, auto/manual level-wind, payout counter, electrical slip ring, and approximately 3000 meters of cable
- Sonde is 80 mm in diameter and 3 m long, capable of measuring up to a 1600 mm diameter, and has optional centering bands
- Remotely controlled via pendant (wired to control unit)
- Approx. weight 800 lb

#### Cable Tensioner (CTR)

Used to spool the main drill cable onto the main drill cable reel under tension to assure smooth and even wraps and layers. The Tensioner is placed between the storage spool (un-tensioned unspooling) and the drill cable reel (tensioned spooling)

- Manufactured by Woods Line Equipment ([www.hydra-tension.com](http://www.hydra-tension.com)), model BWT-39-SK
- Bull-wheel tensioner, tension applied by adjustable disk brake
- Tension capacity = 2,000 lb at 4 mph
- Bull-wheels fitted with 3-groove rubber "tires" sized for 1" OD cable (different sizes can be installed and are available from manufacturer)
- Inlet and outlet fairlead assemblies
- Mounted on skis with aftermarket safety enclosure
- Approx. weight 3,000 lb

### **2.2.2.4 Hoses and cables**

#### IVG Main Drill Hose (YLW & GRN)

Custom made hose for deep drilling operations

- Handmade in Italy
- ID = 2.5 inches, OD = 3.7 inches
- Each section 400 foot length
- Rated for simultaneous pressure, high temperature, tension, and bending

- Pressure: 1000 psig
- Temperature Range: 0-90C
- Axial Tension: 1500 lb
- Minimum Bend Radius: 42 inches
- EPDM rubber with Aramid fiber reinforcement (helical windings, bootstraps, and end reinforcement)
- YLW hose is made with low density EPDM (specific gravity < 1), GRN hose is a standard EPDM
- Swaged-on Victualic fittings

### IVG Surface Hose (RED)

Custom made hose used for surface transport of water from SES to TOS

- Earlier design iteration of the IVG Main Drill Hose (YLW & GRN)
- 200 and 400 foot lengths

### IVG Camp Surface Hose

Custom made hose used for water transport between buildings in SES, heated and non-heated

- Handmade in Italy
- ID = 1.5 inches, OD = 2.28 inches
- Rated for 1000 psig, 0-90C
- EPDM rubber with Aramid helical reinforcement layers
- Crimped female JIC 37deg swivel fittings
- Various lengths
- Heated and unheated versions
  - Heated hoses are assembled with heat trace, insulation, and abrasion-resistant outer covering
  - Powered by 240 VAC, single phase
  - Approximately 6 Watts/foot heating power

### Miscellaneous Hose

Other hose used throughout drill system

- 4" ID, low-pressure (150 psig) and suction hose, heated, socket camlock fittings
- 2" ID, low-pressure (150 psig) hose, heated, socket camlock fittings
- 0.25", 0.50", 0.75", 1.0", and 1.5" high pressure, Aeroquip

### Hose Crimper

Aeroquip hose crimping machine

- Aeroquip ProCrimp 1390
- Dies included
- Crimps 0.25" - 1.5" ID Aeroquip fittings/hoses

### Main Drill Cable

Spare main drill cable

- Cortland cable, Impulse molded connectors
- Approx. 3300 meters length
- Multiple signal cable core, surrounded by Vectran strength member and outer sheath
- Breaking strength = 20,000 lb
- OD = 1"

### Combo Cable

Spare combo cable for down hole pumps

- South Bay Cable, Birns Inc. molded connectors
- 4-wire high voltage lines and connectors combined with three separate low voltage signal cables
- Tension-carrying abilities
- OD ~2"
- Length 500'

### Power Cables

High voltage power cables

- Approx. 65 sections of various lengths, total length of ~14,000'
- 1 and 4 AWG, 4-wire
- Appleton connectors, 60 and 100 amp

### Misc Signal Cables

Network, e-stop, control, encoder, and bundles

- Approx. 9000' total
- Military connectors
- Cold-rated, Aerospace cables

## **2.2.2.5 Other and miscellaneous**

Drill Heads (3 Units)

Used to provide real time feedback on hole characteristics. Below the drill head, a long weight stack that holds the drill plumb and directs flow to the drilling nozzle at the bottom.

- Manufactured by PSL
- Has on-board sensors and navigation package for depth (by pressure), tilt, x and y position, theta (rotation), drill water temperature, hole water temperature, hole diameter, sensor cavity temperature and pressure, acceleration, load (drill head and weight stack)
- Weight stack and nozzle are approx. 75 ft in length and consists of 6 coupled sections. Each section is insulated. The bottom-most section is tapered.
- Each unit weighs approx. 1100 lbs (drill head only). The weight stack all together weighs another 900 lbs. (2000 lbs total, dry)

### Independent Firm Drill (IFD)

This self-contained drill is used to penetrate through the porous firm layer with minimal losses and independently of deep drilling operations. The IFD drills firm holes to approximately 40 meter depth and stays a couple holes ahead of the deep drilling schedule.

- Drills 60 cm diameter to max depth of ~60 meters
- Closed-loop glycol circuit, heated in storage tank by six 3-phase electric heaters, ~8 kW each
- Each heater has its own thermostat
- Drill head ("carrot") transfers heat via copper tube to melt firm, and is supported and lowered by a spiral (single wrap) hose reel
- Circuit consists of holding tank with overflow/fill tank, catch basin, charge pump, bag filter, primary pump, bypass manifold, 2-way hydraulic union, self-supporting hose (supply and return), carrot
- Circuit nominally operates at 12 GPM, 100 psig, 70 deg C supply tank temp
- Instrumentation includes flow sensor, differential pressure across hose and carrot, tank temperature, return temperature, load cell on upper sheave, load cell directly above carrot
- Variable frequency hose reel drive with pendant, hydraulic disk brake, and emergency stop
- Requires external, independent generator unit to supply power. Service on IFD is two 100 amp, 480 VAC 3-phase disconnects in parallel. Works great with the CRREL generator at South Pole, which is rated at 165 kW at altitude.
- IFD can be towed with CAT 287
- Approx. weight 13,500 lb

### Fuel Tower / Day Tank

Gravity-feed fuel distribution tank for Seasonal Equipment Site

- 300 gallon capacity
- Auto fill and low/high warning control system
- Integrated containment tank at base of tower
- Manual fill basin, easy-read float level, venting per Code, painted black
- Distribution manifolds for all SES buildings and generators, return manifold for 2-line generator fuel system
- Two vane pumps controlled by control system automatically fill tank from larger fuel supply tanks
- Bag filter and analog fuel volume totalizer
- Approx. weight 3,300 lb



### Portable Generator

30K Watt generator within an enclosed trailer on skis.

- Magnum Mobile Generator, model MMG 35
- 30 kW (at sea level)
- Runs on diesel/JP8
- 480 VAC 3-phase output, 1 x 100 amp and 1 x 60 amp Appleton snouts, 1 x 30 amp twistlock
- Electric start, battery and block heaters, analog readouts
- Approx. weight 4,800 lb

### Weld Trailer

- Welder/generator within enclosed trailer on skis
- Miller Trailblazer 302
- 10 kW generator, 300 amp welder (at sea level)
- Runs on gasoline
- Approx. weight 2,100 lb

### Glycol Storage Tanks

Holds 1200 gallons of fluid with protective cage and lift pockets/points in pallet

- Approx. weight 400 lbs empty

### Drill Computers

Handle EHWD control system, data logging and storage, and provides outside link

- Six drill computers - HP DL360 - G3 (dual processor / 72 GB storage in a raid 1 array)
  - 2 Sunix 8 Port 8169 RS485 cards each
  - 1 GEForce FX5200 each.
- 7 19 inch LCD monitors - various manufacturers
- 1 HP DL360 G4 (quad xeon 3GHz - 1 TB storage)
- 4 Netsys NV-200 ethernet extenders (2 units per pair / master - slave) All masters are in the DCC

### Drill Tower (2 each)

Sits directly over hole, turns hoses/cables from their horizontal to vertical orientation, has hard points and hoist/winch for rigging operations, and provides a shelter for operations occurring around the hole. The drill tower attaches directly to the TOS double-wide structure.

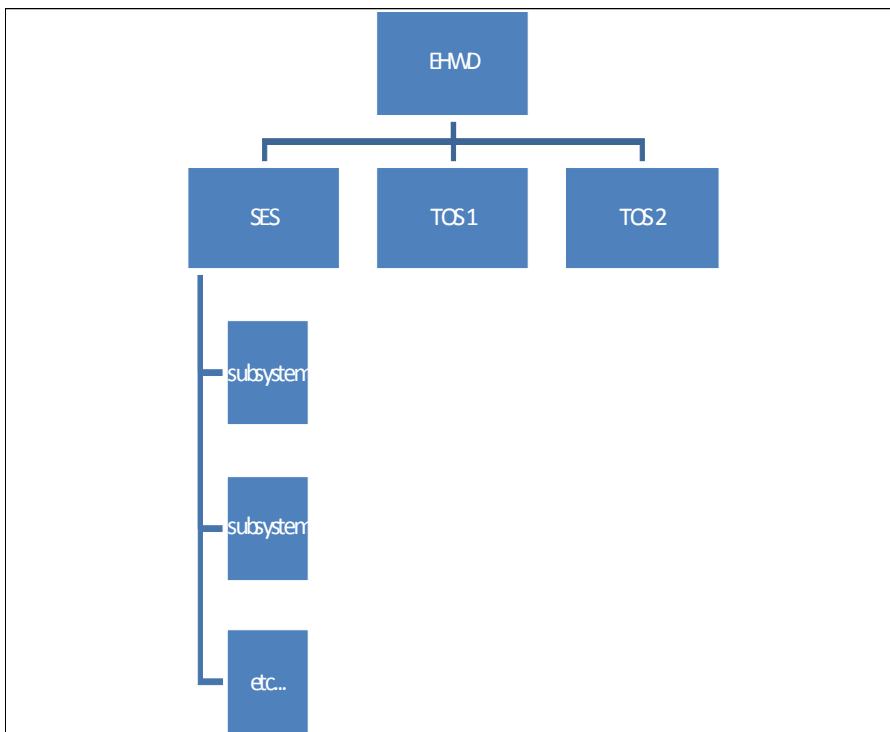
- Aluminum superstructure, bolted in sections to allow for palletization and shipping
- Lower deck
  - Supported on skis
  - Opening for hole
  - Wide opening for attachment to TOS double-wide structure + man door
  - Crystal palace and black interior absorbs and stores solar heat, and provides wall tool storage
  - Hard points located near floor, and capstan winch anchored to lower deck for pulling hoses/cables into tower
  - Hard points located on ceiling for supporting suspended mass
  - Trolley chain hoist and beam
  - Lower main cable sheave mounted outside receives drill cable from cable reel
- Upper deck
  - Railing and toe-boards all around
  - Lapier stairs and second ladder
  - 2 main cable sheaves direct drill cable up and over and center it over hole, assembly hinged with load cell and payout encoder
  - 2 hose crescents with belt, designed around our 3.7" OD drill hose allow for proper bend radius of hose without exceeding high restrictions for drilling near the South Pole skiway. Primary crescent is hinged with load cell and has payout encoder. Secondary crescent has external sheaves to also route the return water pump combo cable up and over the tower.
  - 5000 lb capacity Jeamar hoist with variable speed, failsafe brake, limits, ~1/2" steel wire rope cable approximately 20 feet in length

## 2.3 System Overview and System Diagrams:

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### 2.3.1 System Overview

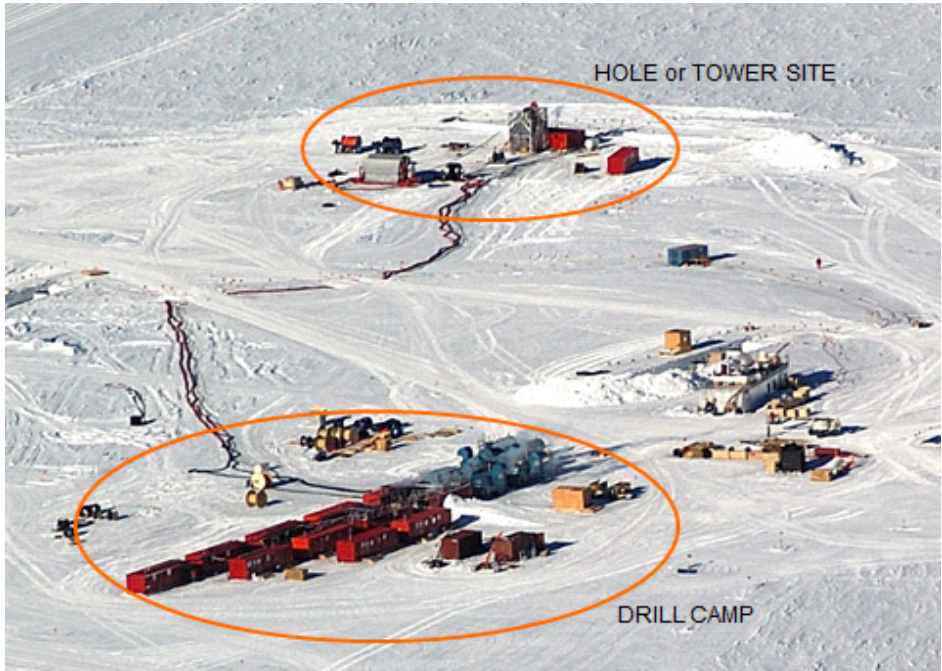
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**Figure 2.2** EHWD broken into its five major parts

The SES, or Seasonal Equipment Site, stays stationary for a given drill season, and the two TOSes, or Tower Operations Sites, move from hole to hole. Hot water and electricity are made at the SES and feed the TOS. Figure 2.3 shows an aerial photo of the SES and TOS, note the hoses and electrical cables connecting them together.

The maximum physical distance between the SES and TOS, which is limited by pressure and voltage drop, is referred to as "reach". During a given drill season, a subset of holes are mapped out within the reach of the EHWD, then the SES is repositioned for the subsequent season to do a new subset of holes. Sometimes the SES can remain in one location for two seasons. The current reach of the EHWD is 1400 feet.



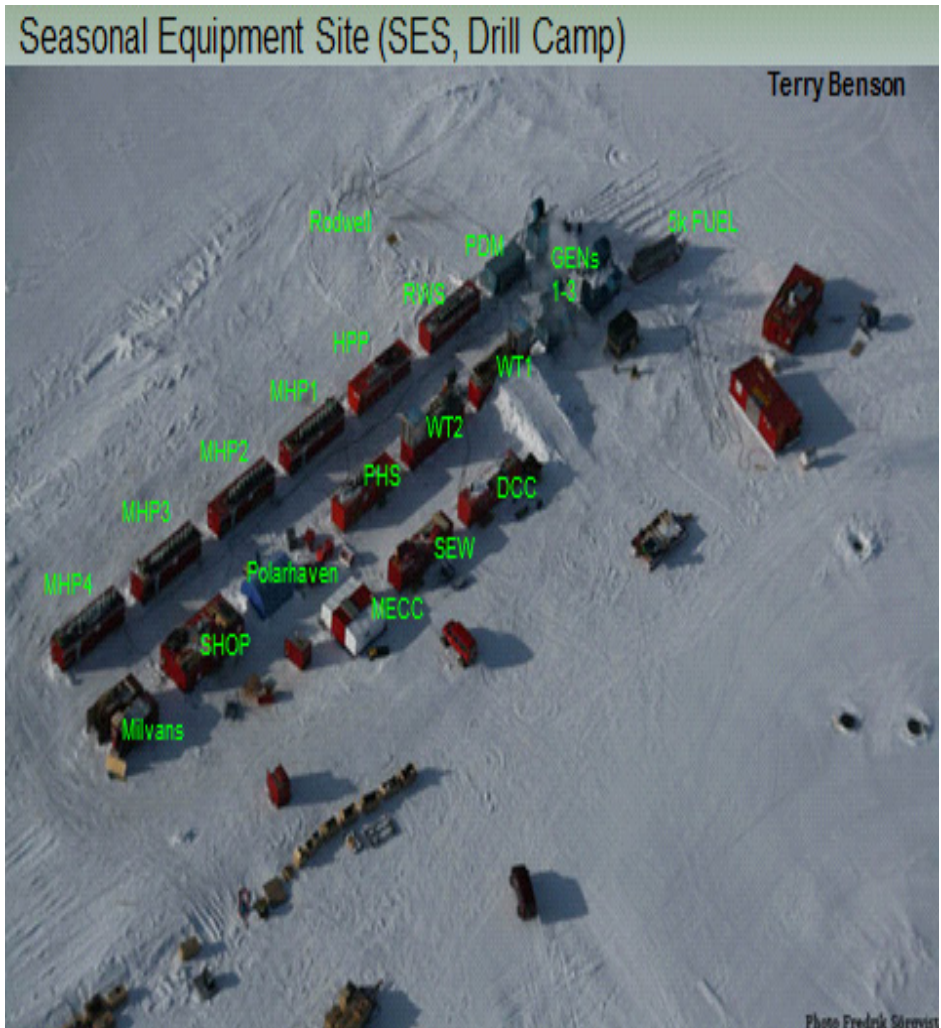
**Figure 2.3** Aerial photo of SES (or drill camp) and TOS (or hole or tower site)

The table in Figure 2.4 and the photos in Figure 2.5 and Figure 2.6 show the major subsystems, buildings and what activities occur at each site:

	Major Subsystems and Buildings	Activities
SES (Drill Camp)	<ul style="list-style-type: none"> <li>• Generators and PDM</li> <li>• Rodwell</li> <li>• Water Tanks 1 and 2</li> <li>• RWS</li> <li>• HPP</li> <li>• MHPs 1-4</li> <li>• PHS</li> <li>• DCC</li> <li>• MECC</li> <li>• SEW</li> <li>• SHOP</li> <li>• Fuel System</li> <li>• Parts Inventory</li> <li>• Graceland (DNF Storage)</li> <li>• Aux. Equip. Storage</li> <li>• Cargo Line</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel Delivery and Storage</li> <li>• Electricity Generation</li> <li>• Water Storage</li> <li>• Pumping</li> <li>• Hot Water Generation</li> <li>• Rodwell Maintenance</li> <li>• Filtration and Neutralization</li> <li>• Drill Command</li> <li>• Communications Hub</li> <li>• Breaks and Meetings</li> <li>• Repairs and Maintenance</li> <li>• Staging</li> <li>• Cargo Handling</li> </ul>

<p><b>TOS (Hole or Tower Site)</b></p>	<ul style="list-style-type: none"> <li>• TOS</li> <li>• Tower</li> <li>• Main Hose and Cable Reels</li> <li>• Return Hose and Cable Reels</li> <li>• TU-20 Deployment Winch</li> <li>• Hole</li> </ul>	<ul style="list-style-type: none"> <li>• Drilling</li> <li>• Deployment</li> <li>• DCM Staging</li> </ul>
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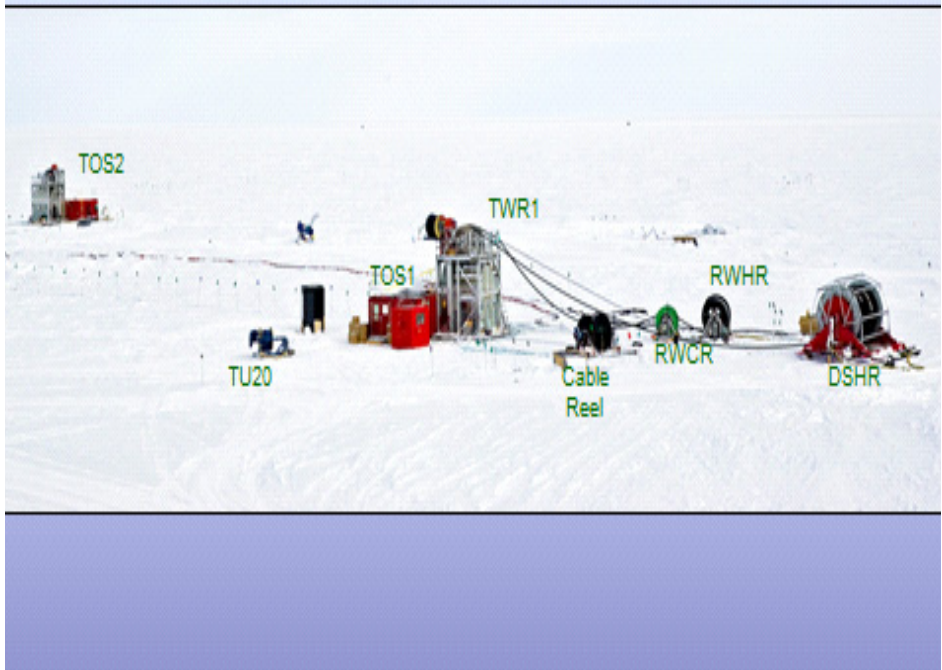
**Figure 2.4** Table showing major component and building functions



**Figure 2.5** Aerial photo of SES with major components labelled

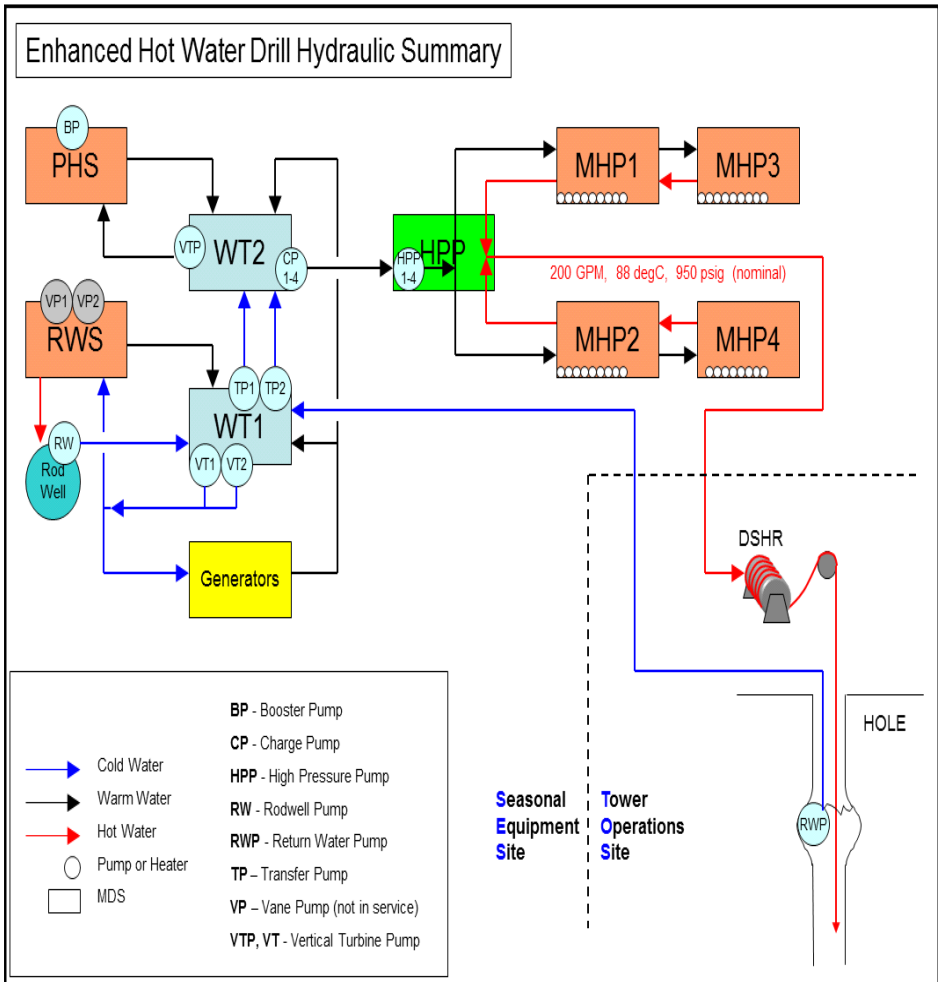
## Tower Operations Site (TOS)

Terry Benson



**Figure 2.6** Photo of TOS with major components labelled

The core of the EHWD is the water handling systems. Water storage, primary pumping, heating, delivery to the drillhead, and recirculation back to the SES is referred to as the "primary" loop. There are also secondary loops that support the primary loop, such as heat recovery from the generators and Rodwell maintenance. The water handling schematic is shown below in Figure 2.7.



**Figure 2.7** EHWD water flow summary

Water is stored in two 10,000 gallon water tanks on the surface. Water storage capacity is sized to allow a comfortable buffer to drill at full flow without recirculating water back from the hole. This is an important consideration during hole startup, for example, while drilling the top of the hole before the return water pump is ready and positioned.

The primary loop is fed by 4 large positive displacement pumps in the HPP building, which provide enough pressure to push 200 GPM through the system plumbing, heaters, hose, and drilling nozzle.

Heat is added to the pressurized water by the primary heaters in the MHPs. All of the heaters are plumbed in parallel. The hot water is then recombined in the HPP, and then flows through the insulated surface hose to the TOS.

At the TOS, the hot water is fed into the Main Hose Reel. The end of the main drill hose attaches to the drillhead. Below the drillhead is approximately 24 meters of insulated, segmented stainless pipe that serves as a weight stack to keep the drill going straight. At the tip of the weightstack is the drilling nozzle, which increases the water velocity and creates a forceful jet of hot water. The optimal nozzle orifice diameter has been found to be 0.720 inches, and is critical in maximizing heat transfer and drilling speed (within acceptable system pressure limits).

Once the drill head is deep enough, a large submersible return water pump is lowered just under the top of the sustained water column. This pump recirculates cold water at the top of the hole back to the SES, so it can be reheated and reused. Due to the volume difference between ice and water, in order to sustain a water column the return water flow needs to be 8-10% less than the drill supply flow.

There is a net loss of water back at the SES due to the imbalance between drill supply and hole return flow. To balance the system, a source of makeup water is needed (about 15 GPM). The Rodwell provides this. At the beginning of each season, startup includes developing a large subsurface well of water, or Rodwell, that acts as a third reservoir in the system, which can reach a volume on the order of hundreds of thousands of gallons.

Growth and maintenance of the Rodwell is done by sending hot water down and bringing cold water up. This circulation loop continues all season long, and net water gain or loss on the surface is controlled by adjusting the flow to/from the Rodwell relative to each other. The RWS subsystem is responsible for this. It takes water from WT1, heats it and delivers it to the Rodwell, and controls the submersible pump in the well that pumps water back into WT1.

The RWS can also circulate water locally to WT1, heating it if need be to control the temperature of WT1. Pumps controlled from the RWS also circulate water from WT1 through the generator heat recovery system. This heated water can be directed to either WT1 or WT2.

The PHS maintains temperature and level of WT2. WT2 is the source reservoir for the primary loop, so it is important that it has a stable temperature. WT1 acts as a buffer for WT2. The PHS also provides constant filtration of the water being circulated between it and WT2.

Drill infrastructure is made up of power generation and distribution, fuel storage and distribution, e-stop system, network (control system and LAN), and condensate collection/filtration/neutralization. These are described in more detail throughout the following sections.

There are also a number of support tools, such as a large air compressor and glycol storage/distribution tank for winterizing the system, auxiliary reel and winches, and rolling stock.





Power to the EHWD starts with three Generator modules containing Caterpillar Gensets rated at 225 kW (~165 kW @ the South Pole). These Generators are cabled to a Power Distribution module (PDM) ( see Figure 2.9) each season. Manual synchronization/switching for the generators occurs in the PDM. A panel at the rear of the PDM provides the connection point for all the system power cabling. A Circuit Breaker panel for the individual power circuits also resides in the PDM.



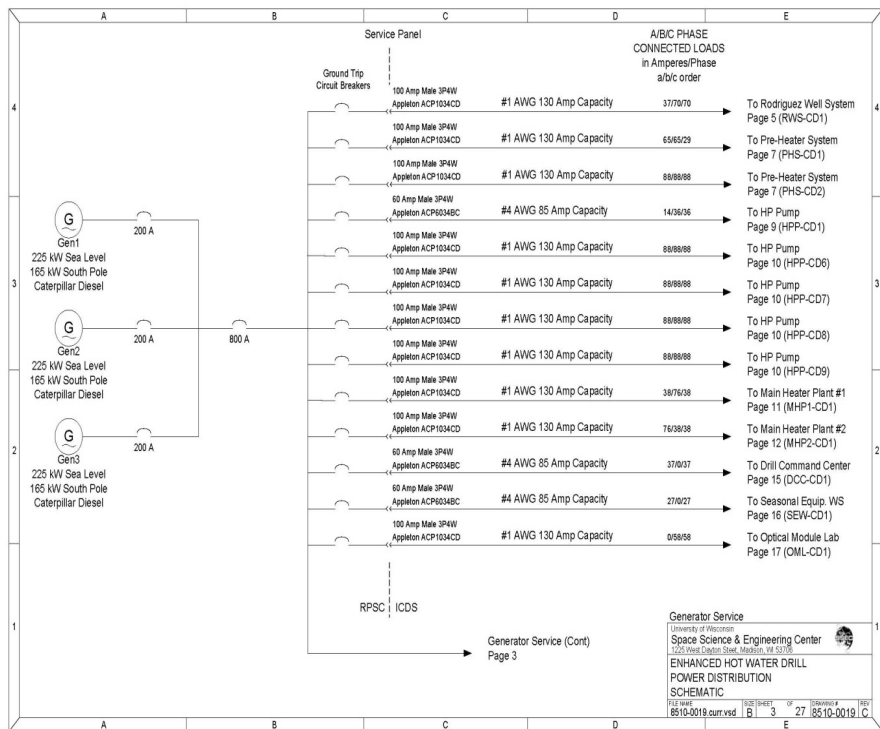
**Figure 2.9** Power Distribution Module (PDM) interior

Each MDS contains a Transformer that converts the 480v 3 ph power from the generators to 120 and 240 volt ac power. This power is applied to the circuit breaker panels and wired inside and outside each MDS.



**Figure 2.10** Individual MDS circuit breaker panels inside PDM

Figure 2.11 is a one line wiring diagram showing the power distribution from each generator to the PDM, then distributed from the PDM via a 600A circuit breaker to each of the MDS'.



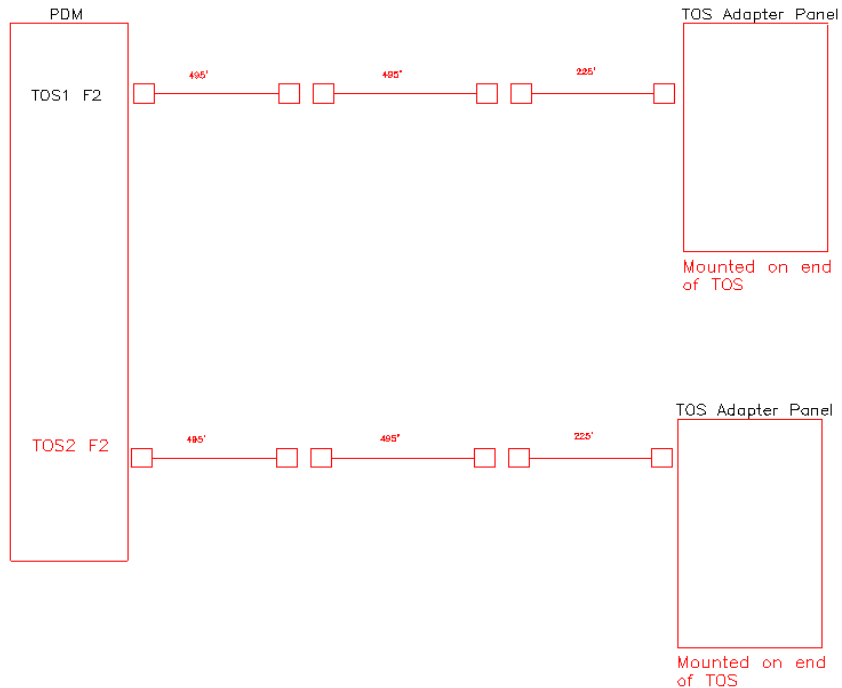
**Figure 2.11** One line diagram showing power wiring

Note the dotted line in Figure 2.11 delineating RPSC's responsibility from the drill crew. RPSC is responsible for maintenance of the generators and PDM while the drill crew is responsible for maintenance after the power distribution panel on the PDM, shown in Figure 2.12.



**Figure 2.12** PDM power distribution panel showing feeder cables leaving to MDS'

The photo in Figure 2.12 shows the feeder cables leaving to the MDS' and to the TOS'. There is one feeder cable feeding each TOS. Each TOS can be up to 1200 feet away, so the feeder cables to them are made up of up to 3 sections of cable chained together and fed to a TOS adaptor panel, as shown in Figure 2.13.



**Figure 2.13** Power cabling to each TOS

Historically, there used to be 3 sets of electrical feeder cables to the operational TOS and two sets to the other TOS in order to overcome potential line losses in the power cables, especially when a TOS is located a long way from the SES. However it was found that one feeder cable to each TOS was enough to do the job, while keeping the voltage drops in the cables to a tolerable level.

As a result of this change, a TOS adaptor panel was installed in each TOS to distribute the single feeder cable to the 3 circuits in each TOS.

Every MDS has an electrical reference card located in the electrical closet. A typical card is shown in

## HPP

### ELECTRICAL LABELING REFERENCE

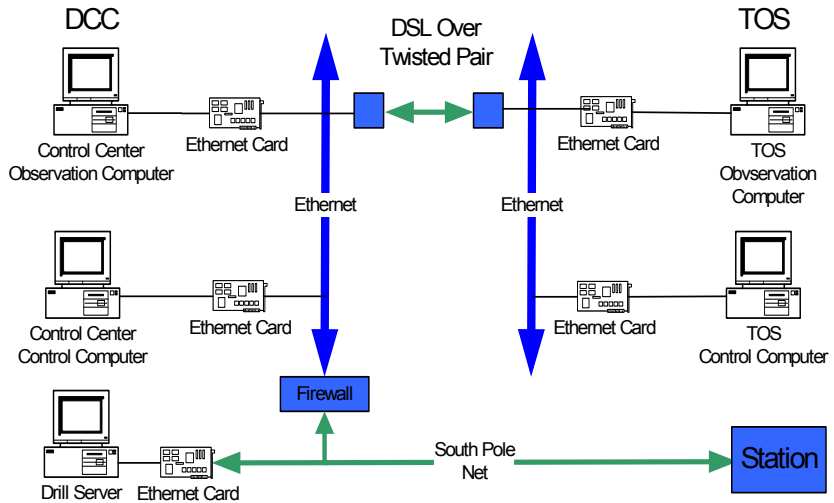
END DEVICE	ONE LINE DESIGNATION	CIRCUIT BREAKER	CONTACTOR / RELAY	DRIVE	CONNECTOR	CABLE	DYNAMIC BRAKE	TRANS-FORMER	CHARGE PUMP MOTOR
CHARGE PUMP 1	HPP-M1	CB7/9/11 (A)	K3	HPP-V1	HPP-CD5	HPP-CD5/C - HPP-M1	na	na	na
CHARGE PUMP 2	HPP-M2	CB13/15/17 (A)	K3	HPP-V2	HPP-CD4	HPP-CD4/C - HPP-M2	na	na	na
CHARGE PUMP 3	HPP-M3	CB8/10/12 (A)	K3	HPP-V3	HPP-CD3	HPP-CD3/C - HPP-M3	na	na	na
CHARGE PUMP 4	HPP-M4	CB14/16/18 (A)	K3	HPP-V4	HPP-CD2	HPP-CD2/C - HPP-M4	na	na	na
HIGH PRESSURE PUMP 1	HPP-M5	CB1 (C)	K3	HPP-V5	HPP-CD6	PDM - HPP-CD6/C	na	HPP-T2	HPP-M1
HIGH PRESSURE PUMP 2	HPP-M6	CB1 (D)	K3	HPP-V6	HPP-CD7	PDM - HPP-CD7/C	na	HPP-T3	HPP-M2
HIGH PRESSURE PUMP 3	HPP-M7	CB1 (E)	K3	HPP-V7	HPP-CD8	PDM - HPP-CD8/C	na	na	HPP-M3
HIGH PRESSURE PUMP 4	HPP-M8	CB1 (F)	K3	HPP-V8	HPP-CD9	PDM - HPP-CD9/C	na	na	HPP-M4
MAIN FUEL VALVE	HPP-MFV	CB20 (B)	K1	na	na	na	na	na	na
FURNACE	HPP-FUR	CB21 (B)	K1	na	na	na	na	na	na
OVERHEAD LIGHTS	HPP-LGT1	CB22 (B)	na	na	na	na	na	na	na
120 VAC OUTLETS	HPP-OUT1	CB16 (B)	na	na	na	na	na	na	na
120 VAC OUTLETS	HPP-OUT2	CB15 (B)	na	na	na	na	na	na	na
240 VAC OUTLETS	HPP-OUT3	CB27/28 (B)	na	na	na	na	na	na	na
120 VAC OUTLETS	HPP-OUT4	CB17 (B)	na	na	na	na	na	na	na
120 VAC OUTLETS	HPP-OUT5	CB18 (B)	na	na	na	na	na	na	na
240 VAC OUTLETS	HPP-OUT6	CB29/30 (B)	na	na	na	na	na	na	na
SPACE HEATERS (Electric)	HPP-EHT1	CB25/26 (B)	na	na	na	na	na	na	na
SPACE HEATERS (Electric)	HPP-EHT2	CB23/24 (B)	na	na	na	na	na	na	na
PUMP ROOM TEMP / VENTILATION FANS	HPP-TVF1 HPP-TVF2 HPP-TVF3	CB14 (B)	HPP-TH1 (Thermostat)	na	na	na	na	na	na
UTILITY CLOSET TEMP / VENTILATION FANS	HPP-TVF4 HPP-TVF5	CB16 (B)	HPP-TH2 (Thermostat)	na	na	na	na	na	na
FURNACE COMBUSTION AIR FAN	HPP-CAF1	CB21 (B)	K1 or HPP-THF (Thermostat)	na	na	na	na	na	na
CIRCUIT BREAKER PANEL	HPP-A	CB1/3/5 (A) Input device	na	na	HPP-CD1	PDM - HPP-CD1/C	na	na	na
CIRCUIT BREAKER PANEL	HPP-B	CB2/4/6 (A) or Main CB (B)	na	na	na	na	na	HPP-T1	na
CIRCUIT BREAKER BOX	HPP-C	CB1 (C) Input device	na	na	HPP-CD6	PDM - HPP-CD6/C	na	HPP-T2	na
CIRCUIT BREAKER BOX	HPP-D	CB1 (D) Input device	na	na	HPP-CD7	PDM - HPP-CD7/C	na	HPP-T3	na
CIRCUIT BREAKER BOX	HPP-E	CB1 (E) Input device	na	na	HPP-CD8	PDM - HPP-CD8/C	na	na	na
CIRCUIT BREAKER BOX	HPP-F	CB1 (F) Input device	na	na	HPP-CD9	PDM - HPP-CD9/C	na	na	na
E-STOP PANEL	HPP-G	CB19 (B)	na	na	na	na	na	na	na
NETWORK DISTRIBUTION PANEL	HPP-H	CB19 (B)	na	na	na	na	na	na	na
MASTER E-STOP	na	na	K2	na	na	na	na	na	na

Rev. A, 10/22/03, TAD

Rev. B, 3/22/04, TDM (As-Built)

Figure 2.14 HPP electrical reference card.

## 2.3.3 System Network Wiring



**Figure 2.15** Drill network communications between DCC, TOS and South Pole

Figure 2.15 is a diagram of the communications network between the DCC computers, TOS computers and the South Pole network.

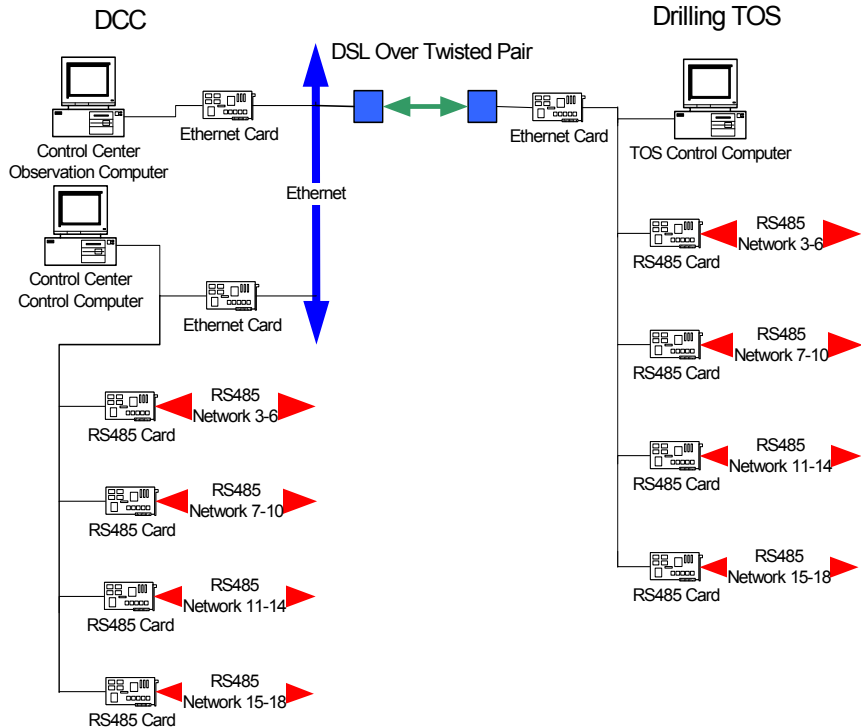
Communications to the South Pole network takes place over a wireless link between the DCC and the IceCube Laboratory (ICL), then to the South Pole network.

Communications to the TOS is via two DSL modems with a communications cable running between the DSL modems in the DCC and TOS. The DSL modems are used for both the drill and phone network. There are two master units in the DCC and two slave units in each TOS. The modems are shown in Figure 2.16.



**Figure 2.16** DSL modem

## 2.3.4 Drilling Control Network Diagram



**Figure 2.17** Drill control network

The drill control system network is a multidrop RS485 network as shown in Figure 2.17. The RS485 network is an advancement over the RS232 network. It allows for:

- Data Rates above 20 kbps
- Distances greater than 50 ft
- More than 1 device on the network

It is a balanced 3 wire differential interface consisting of a:

- Differential pair: pin 1 (DATA-) and 2 (DATA+)
- Common ground: pin 5
- Data signal (DATA+, DATA-) driven from 0 to 5 volts referenced to common ground
- Terminated data lines typically go from 1.6 to 3.4 volts referenced to common ground

The network is split into 2 halves; a DCC and a TOS network. The control computers in the DCC and the TOS each have full control over all equipment attached to either half of the network.

### **2.3.4.1 DCC Network:**

As Figure 2.17 shows, the DCC network consists of 16 multidrop RS485 networks, made up of 2-8 port RS 485 cards, instead of the 4-4port cards shown.

The DCC uses 15 of the 16 networks, with the 16th port reserved for a future generator DGH network.

The drill computers are located in the DCC and multiple RS-485 networks are run to all the MDS' in the SES. Each MDS has one cable, but that cable may carry multiple networks. Network distributions in the SES are as follows:

#### *DCC*

1 RS-485 DGH network

#### *HPP*

1 RS-485 DGH network

1 RS-485 Unico network

#### *PHS*

2 RS-485 DGH networks

1 RS-485 Unico network

#### *RWS*

2 RS-485 DGH networks

1 RS-485 Unico network

#### *MHP 1-4*

1 RS-485 DGH network each

#### *GEN3, PDM*

1 shared RS-485 DGH network

#### *GEN1, GEN2*

1 shared RS-485 DGH network

#### *GEN1, GEN2, GEN3*

1 shared RS-485 DGH Network



### 2.3.4.2 TOS Network:

The TOS also has 2-8 port RS485 interface cards. 4 of the 16 ports are used for the Unico, DGH, Drill head and DDB.

### 2.3.4.3 Network topology examples

#### Mul-tidrop DGH Network

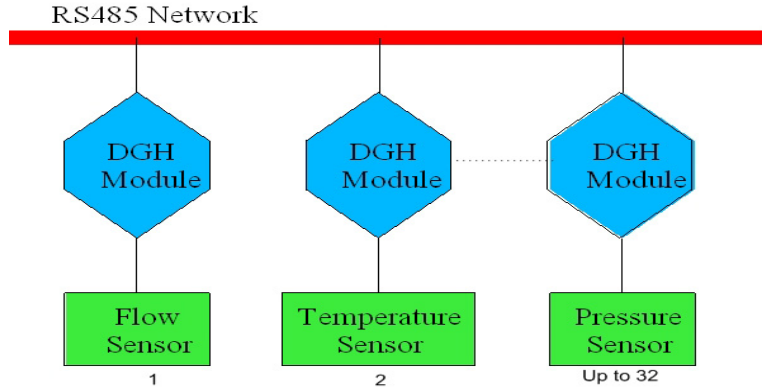


Figure 2.18 DGH network topology

Each DGH multipdrop RS-485 network can consist of up to 32 drops per line, as shown in Figure 2.18. Data rates are up to 38.4 kbps.

Example of DGH network: HPP DGH network (ser2)

#### Multi-Drop Mod Bus Network

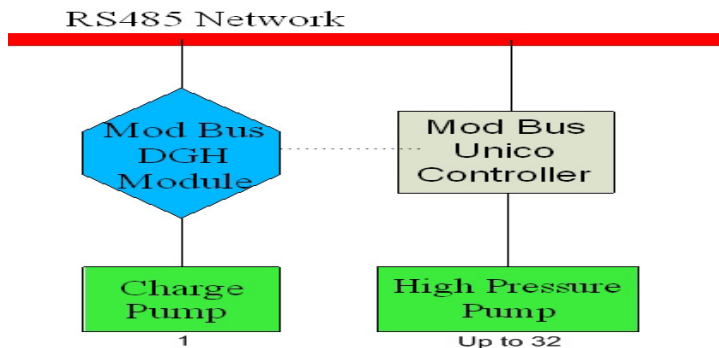


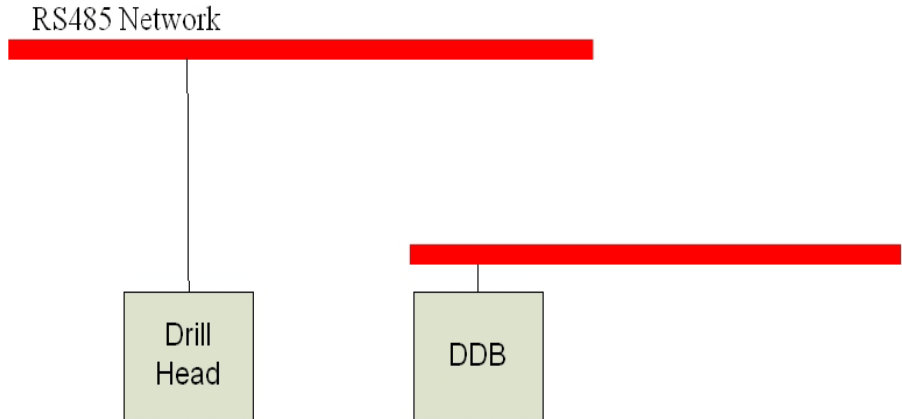
Figure 2.19 Mod Bus network topology

Each multidrop Mod Bus network can consist of up to 32 drops per line, as shown in Figure 2.19. Data rates are up to 32 kbps.

Examples of Modbus DGH: HPP Charge Pump (ser 12)

Examples of Modbus Unico: HPP High Pressure Pumps (ser 12)

### RS485 TOS Single Drop Networks



**Figure 2.20** Single drop RS-485 network topology

Each single drop RS-485 network line has only one network per wire, as shown in Figure 2.20. Data rates are 9600 bps.

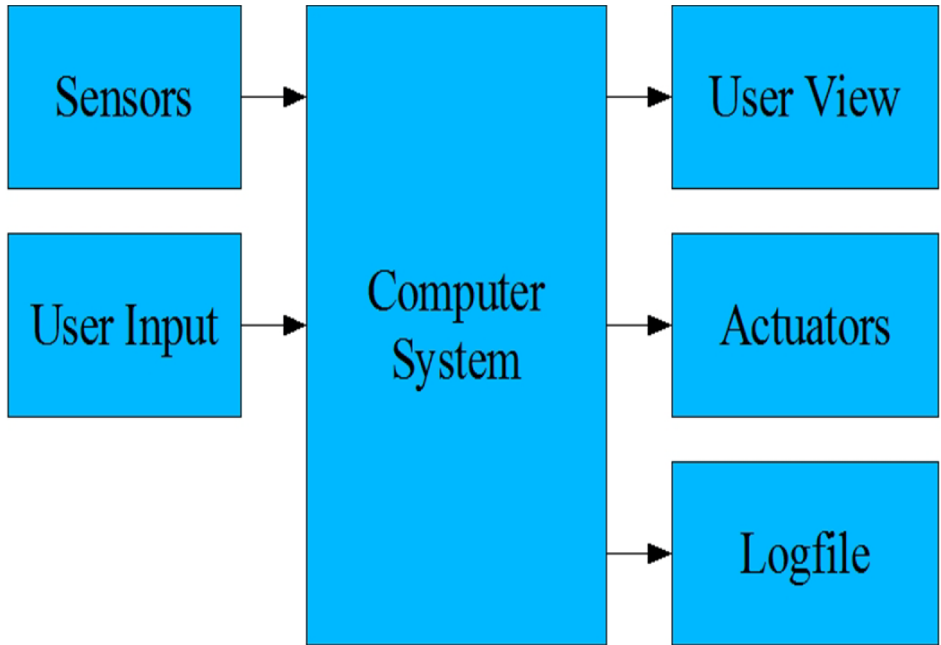
Examples of single drop network:

TOS Drill Head (ser3)

DBB (ser4)

### 2.3.5 System Sensors I/O (Input/Output)

---



**Figure 2.21** System sensors I/O system diagram

Figure 2.21 is a diagram showing the interconnections between system sensors, actuators and the control computer.

The control computer accepts sensor data via the RS-485 network and user input to control the system actuators. It outputs commands to control the system actuators, displays the results of the sensor data as well as log the data to a log file.

Examples of input functions:

Monitor environment:

- CO and smoke sensors
- E-Stop and Reel Stop

Provide system status:

- Water tank level
- Water temperature and flow
- depth by pressure

- drill head data

Output functions:

- Communicate with motor drive controllers to turn pumps and motors on and adjust speed.
- Turn heaters on and off.
- Limited closed loop control such as automatically turn off heaters when too hot

A Full list of all EHWD System sensors can be found in EHWD Control System I/O Summary Drawing #8510-0067.

## 2.4 Subsystem Description and Diagrams

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### 2.4.1 Generators

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The IceCube 480v 3-phase generator system consists of three Caterpillar SR4B generator sets with 3306 Caterpillar engines packaged in individual containers. The units are arranged in a group (GEN1, GEN2, GEN3) at the downwind end of the Seasonal Equipment Site (SES) as shown in “View of the 3 generators, with the PDM in the foreground”. See Enhanced Hot Water Drill Site Plan-Power Cables, 8510-0002 Sheet 4 of 8 for details. All power containers are blue in contrast with the other red SES containers. The generator modules and PDM were designed and built by National Electric Systems Inc. The generators are rated at 225 kW (sea level rating) and de-rated to 165 kW at the South Pole (elevation: 9306 feet).



**Figure 2.22** View of the 3 generators, with the PDM in the foreground

The system is designed to operate with all three generators connected to a PDM (Power Distribution Module). The PDM handles load sharing, generator switching and manual synchronizing operations. Also in the PDM is instrumentation allowing the monitoring of generator output and performance and the main circuit breakers for power distribution to the SES and Drill Towers?

The generators can be operated one at a time or in any combination up to and including all three gen-sets. Two of the three generators operate when drilling. During Idle operations, one generator will run, one is a backup and one is available for maintenance. The use of specific generators rotates to provide an opportunity for routine maintenance.

All the large generators run on AN-8 fuel (polar equivalent of JP-8). The South Pole Logistics Contractor wires each of the generators to the PDM at the start of the season.

Heat is recovered from both the engine water jacket and exhaust. The engines can be run with or without additional cooling water, but during drilling operations run a cooling loop with water provided from the one of the water tanks, connected as shown in Figure 2.23.



**Figure 2.23** Water loop, fuel and network connection input generator

The "Caterpillar" EMCP-II controls on each generator set have been modified so that each unit can be operated independently from the PDM module using the "local/ remote" switch (shown in Figure 2.24) for service, maintenance, testing or early season operation.



**Figure 2.24** Caterpillar generator EMP-II control and “LOCAL/ REMOTE” switch

A fire control/mitigation system is installed in each of the generator buildings. It is a carbon dioxide (CO<sub>2</sub>) system contained in 2 canisters mounted overhead. The CO<sub>2</sub> is released manually from the outside of the generator building with the use of a "pull handle". This is done to minimize the possibility of an accidental release when people are inside the building. A strobe light and audible alarm on the exterior of the generator buildings also warn of a fire danger.

Additional information concerning Dewinterizing and bringing the generators on-line can be found in section 5.3 of this manual.

The EHWD drill system has also used these additional generators:

The "Magnum" generator, 30 Kw (Sea level), 19 Kw (@pole) contained in a white cargo container on skis for portability.

The CRREL generator, obtained from RPSC. Generally used just to power the Independent Firm Drill.

A 3.5 Kw portable generator built by Yamaha for miscellaneous duties around the drill camp.

Click on link below to play a video giving an overview of the 3 EHWD generators:

[Gens wt Audio.mp4](#)

## 2.4.2 Power Distribution Module (PDM)

---

The system is designed to operate with all three generator modules connected to the PDM. The PDM then controls load sharing and generator switching operations. Monitoring of each generator set output is also done from the PDM. Power distribution to the SES is done from the PDM main breakers.

The generator sets can be operated one at a time or in any combination up to and including all three engines for a short period of time. Normal operation is with either one (system at idle) or two (when system is drilling) generators operating.

Inside the PDM are four (4) metal enclosed switchgear cabinets, as shown in Figure 2.25, used in the power distribution system. There are three (3) cabinets for generator control, one for each of the Gensets. In addition, there is one "Main" cabinet providing circuitry for the synchronization and load sharing of the Generators. The switchgear assembly consists of multiple metal-enclosed vertical sections. Compartments are sized to provide uniform height of each switchgear assembly.

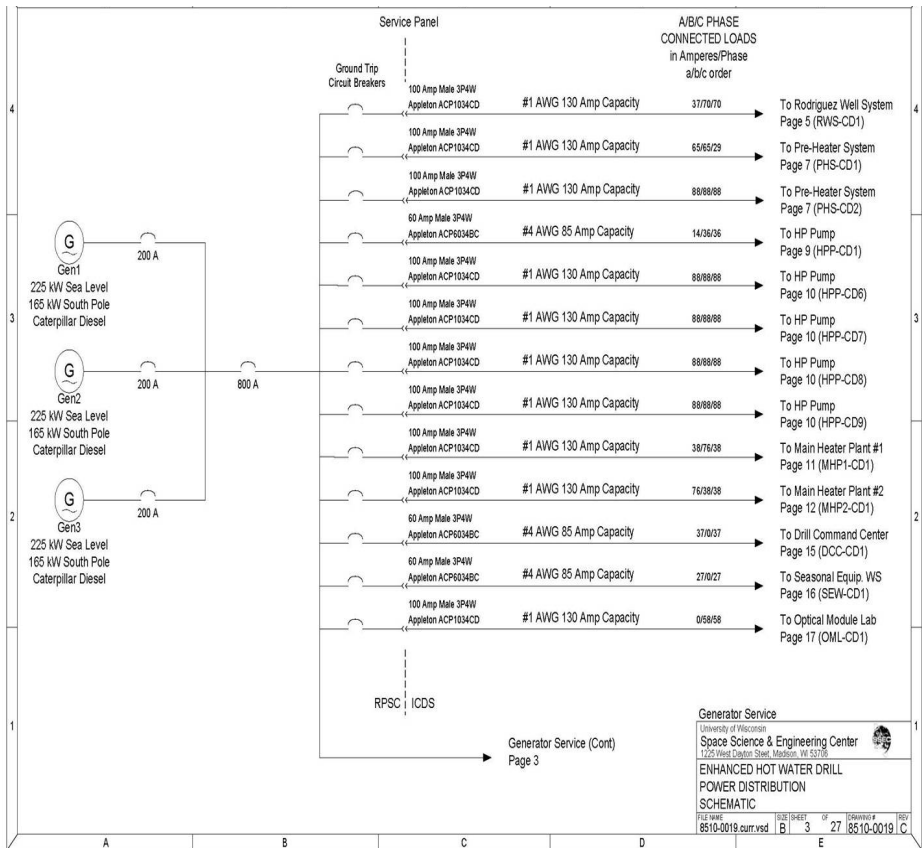


**Figure 2.25** PDM switchgear cabinets

Various components such as circuit breakers, instrumentation and generator control equipment, transformers, relays, three-phase bus work, all internal wiring, connectors, and other supporting equipment are included in each assembly.

A large copper ground bus is mounted at the lower left of the series of switchgear cabinets. At the other end is the main breaker box for the incoming power to the PDM. Across the aisle from the copper ground bus resides the output power breaker box. This box contains all the breakers for the circuits providing power for the entire SES and both TOS's.

The power distribution is shown on the EHWD Power Distribution Schematic 8510-0019 Sheets 3 and 4. A well-marked patch panel allows the connection of 60A and 100A power cables. Appleton "pin & sleeve" reverse-service connectors are used to make these connections.



**Figure 2.26** Power diagram showing connections from generators to PDM and MDS’  
 Click on link below to play a video giving an overview of the PDM

PDM wt audio.mp4



## 2.4.3 Drill Control Center (DCC)

---

The objective of the SES is to supply the TOS with pressurized clean water at a high, steady temperature and flow. The DCC, shown in Figure 2.27, provides the control mechanisms that allow this to happen. Computer Control, communications, networking, e-stop, fuel tank control systems based in the DCC allow an operator to monitor and control the SES to meet the objective in a safe manner.



**Figure 2.27** DCC exterior and interior view

Specifically, the DCC lets an operator monitor sensors and equipment, control hardware (pumps, heaters, valves), and provides a communications center between drillers, and between the drill camp and the South Pole Station.

Some tasks for the DCC during deep drilling include:

- Maintain acceptable tank levels. Transfer water from WT1 to WT2.
- Keep WT2 temperature at a level maximizing output temperature without heaters cycling.
- Keep WT1 temperature at a level making it possible to supply WT2 with water without affecting the WT2 temperature.
- Monitor that HPP output pressure is not exceeding structurally damaging levels.
- Keep output flow at a steady level.
- Monitor and adjust Rodwell water production according to demand. Make sure adequate heat and flow goes down the rodwell to make water.

- Adjust return water pump to bring up water equivalent to drilling flow - 10%.
- Monitor fire, CO, water alarm etc.
- Monitor fuel levels.
- Act as communications center

The DCC is split into two distinct areas - The utility closet and the control room. Each has its important attributes:

The Utility closet contains the following:

- Fuel transfer pump circuit breakers DCC-A
- All other circuit breakers DCC-B
- Power Transformer DCC-T1
- Floor heater (usually not used)
- The Main E-stop Enclosure, 480v DCC-C
- The Main Network Panel
- Drill control Network boxes for TOS1 & TOS2
- E-stop termination cable from the PHS TOS1 & TOS2 breakout boxes
- The Day tank fuel fill and safety control circuitry in the Network panel
- Two Cisco bridges for comm's

The Control room contains the following:

- Two Powerware Ferrups FE UPS's 1 on-line and 1 spare
- Red outlets indicate that they are connected to the uninterruptible power
- Two HP Proliant DL380 computers
- Two Samsung Syncmaster 171s Monitors
- A Kenwood Base station for radio communications
- Two Kenwood IceCube Drill radio battery chargers
- Cisco IP phone
- Control Network connections
- Two Hergo instrumentation cabinets
- The Main E-stop controller
- HP memory bank

- Cisco Network Switch
- Two wall heaters
- One floor heater (usually not used)
- An extensive First Aid kit
- One HPL1906 Monitor
- One HP printer
- Two dry chemical Fire extinguishers
- One Smoke/CO detector
- One Heat rise detector
- Several metal shelves for electrical/electronic component storage

Normally the computer equipment provides enough heat for the container and the supplemental floor and wall heaters are not required. A wall mounted thermostat controls a wall fan to bring in outside air if additional cooling is required.

Figure 2.28 and Figure 2.29 are electrical schematics of the DCC.

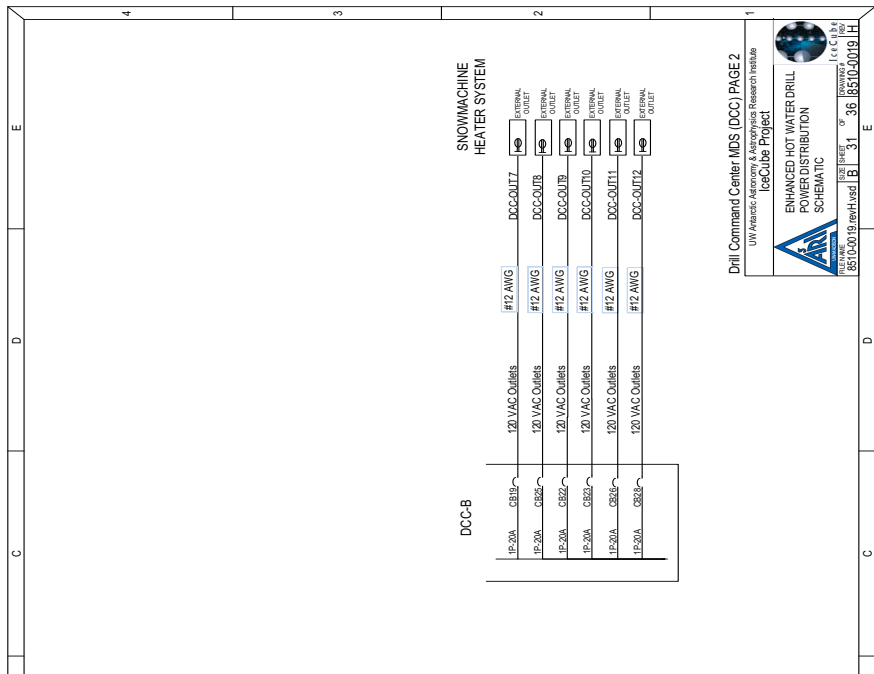


Figure 2.28 DCC Electrical schematic sheet 1 of 2



## 2.4.4 Water Tanks 1 & 2

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The water tanks are utilized as reservoirs that store and provide water for the drill operation. Dry weight of each tank is 7.5 tons. The capacity of each tank is 10,000 gallons. The tanks are modified ISO shipping containers, insulated and retrofitted with stainless steel internal linings. There are 2 large adjacent hatches atop each tank that allow access. On top of both water tanks are weather resistant "doghouses" (enclosed transparent exterior structures) which protect the vertical turbine pumps, and any exposed plumbing connections from freezing. The doghouses and the tops of both tanks can be accessed via side-mounted Lapeyre ladders. Adjacent to tank 1, a snow ramp provides tractor access to the tank's top hatch, which allows large quantities of snow to be easily deposited in the tank to generate water for initial startup.

Two water tanks are used in order to provide water of a relatively stable temperature to be used in the main water loop. The water in tank 1 has various input sources, such as the Rod Well and return water from the drill hole, snow dumps to make more water as well as input from the generator coolant loop, making its temperature vary widely. However the main water loop requires a relatively stable temperature input in order to maintain a constant output temperature without the heaters cycling too much. Water tank 1 is therefore used as the buffer for water tank 2 and the temperature of water tank 2, shown in Figure 2.30, is maintained at a relatively stable temperature by the PHS heaters.



**Figure 2.30** Water tank 2.

## Tank Input/Outputs:

### Tank 1:

- Temperature controlled by RWS
- Receives waste heat deposited from generator loop
- Transfer pumps move water to Tank 2
- Cold water is returned from drill hole

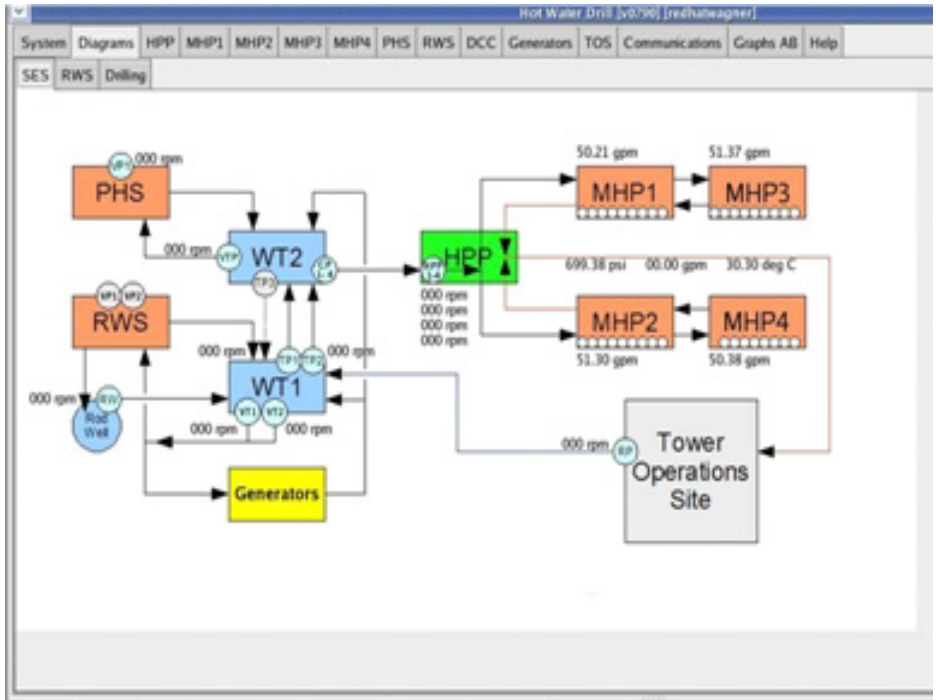
### Tank 2:

- Temperature controlled by PHS
- Receives waste heat deposited from generator loop
- Receives water transferred from Tank 1
- Submersible charge pumps supply water to HPP

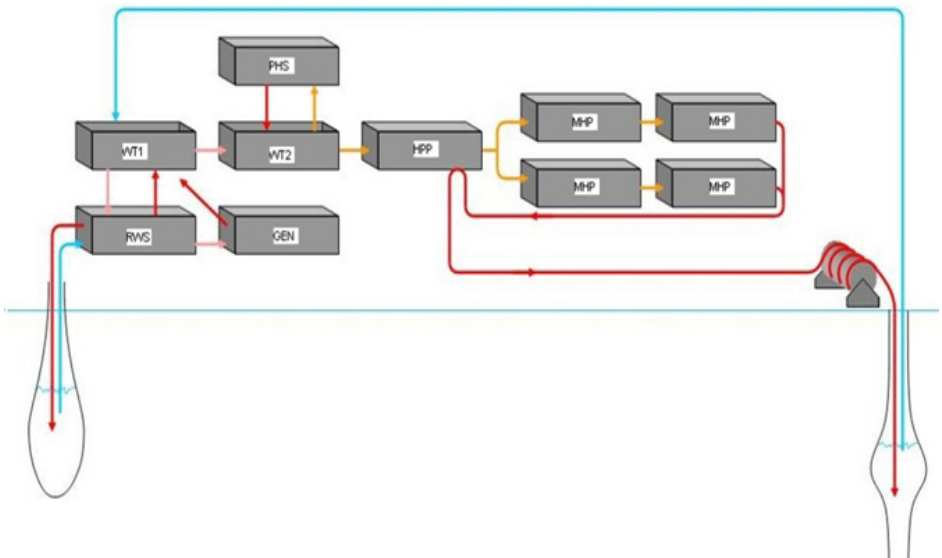
## Flow:

Several thousand gallons of 'seed water' obtained from South Pole Station, is required to initiate water production during drill startup. The 'seed water' is introduced to Tank 1 and circulated through the RWS module by vertical turbine pumps 1 and 2. Heat is added to the 'seed water' in the RWS and more water is generated by the deposition of large amounts of snow into tank 1 that in turn is melted by system heaters. The goal is to produce a large enough body of water to allow the Rod Well development.

Once the Rod Well has been developed and matured to a point where drilling can commence and drilling is underway, cold water returning from the hole is returned to tank 1. Tank 1 acts as a level and temperature buffer for the system. Both cold and hot water are dumped into tank 1, with its level and temperature regulated primarily by the RWS. When water is pumped from tank 1 into the RWS it can be heated and returned to Tank 1, or deposited down the Rod well (short for the Rodriguez, the originator) to generate more water. Additionally, some of the water from tank 1 is diverted to the generators to cool them down as well as scavenge their heat. The hot water that is returned from the generators can be directed toward tank 1 or tank 2. The diagram in Figure 2.31 gives an overall view of the water flow in the system and Figure 2.32 gives a simplified view of the flow.



**Figure 2.31** Water flow diagram as depicted on the control screen



**Figure 2.32** Simplified water flow diagram

Additional water to keep the system full is provided by the Rod well via the RWS module and this water is deposited into tank 1. From tank 1, the water is transferred into water tank 2. Tank 2 acts a holding tank where the temperature and level can be maintained more precisely than in water tank 1. Temperature control for tank 2 is provided by the PHS. Vertical turbine pump 3, located in the tank 2 doghouse, constantly circulates water in a loop from tank 2, through the PHS, where it is filtered and heat can be added as needed, then back to tank 2. This ensures that water tank 2 is always close to an ideal temperature. Water is pumped out of tank 2 into the HPP where it is pressurized to about 1,000 PSI. From there it is sent to the MHP's.

Pumps are located as follows:

#### Tank 1

- Vertical Turbine pumps 1 and 2 (VT1, VT2)
- Transfer pumps 1 and 2 (TP1, TP2)

#### Tank 2

- VT3
- TP3
- Charge pumps 1-4 (CP1-4)

Figure 2.33 to Figure 2.36 show the plumbing diagrams for both water tanks. These diagrams are up to date and include modifications up to when drilling was completed in Dec 2010.

Click on the links below to play videos giving an overview of Water tanks 1 and 2.

[Water Tank 1 with Audio.mp4](#)

[Water Tank 2 with Audio.mp4](#)



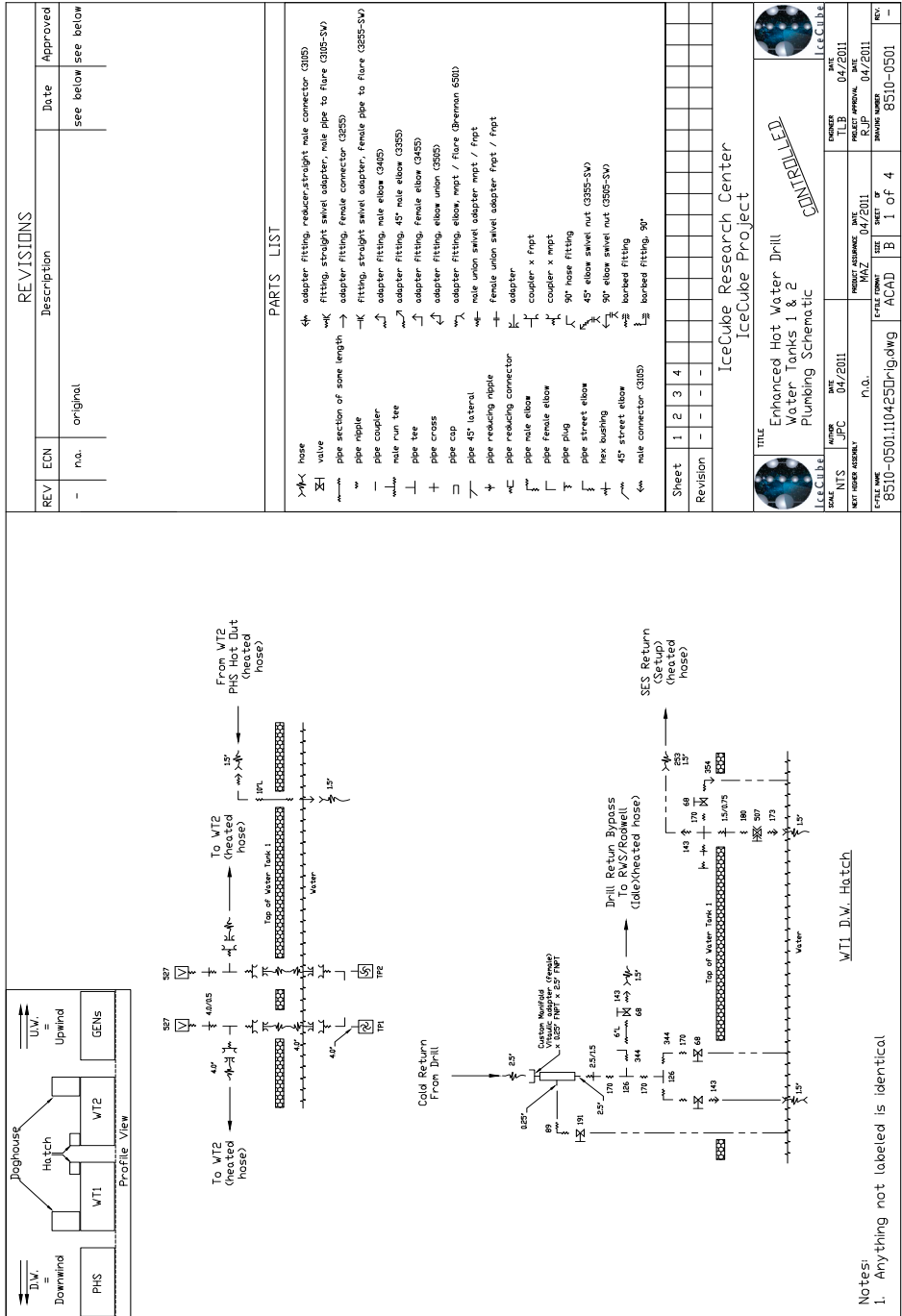
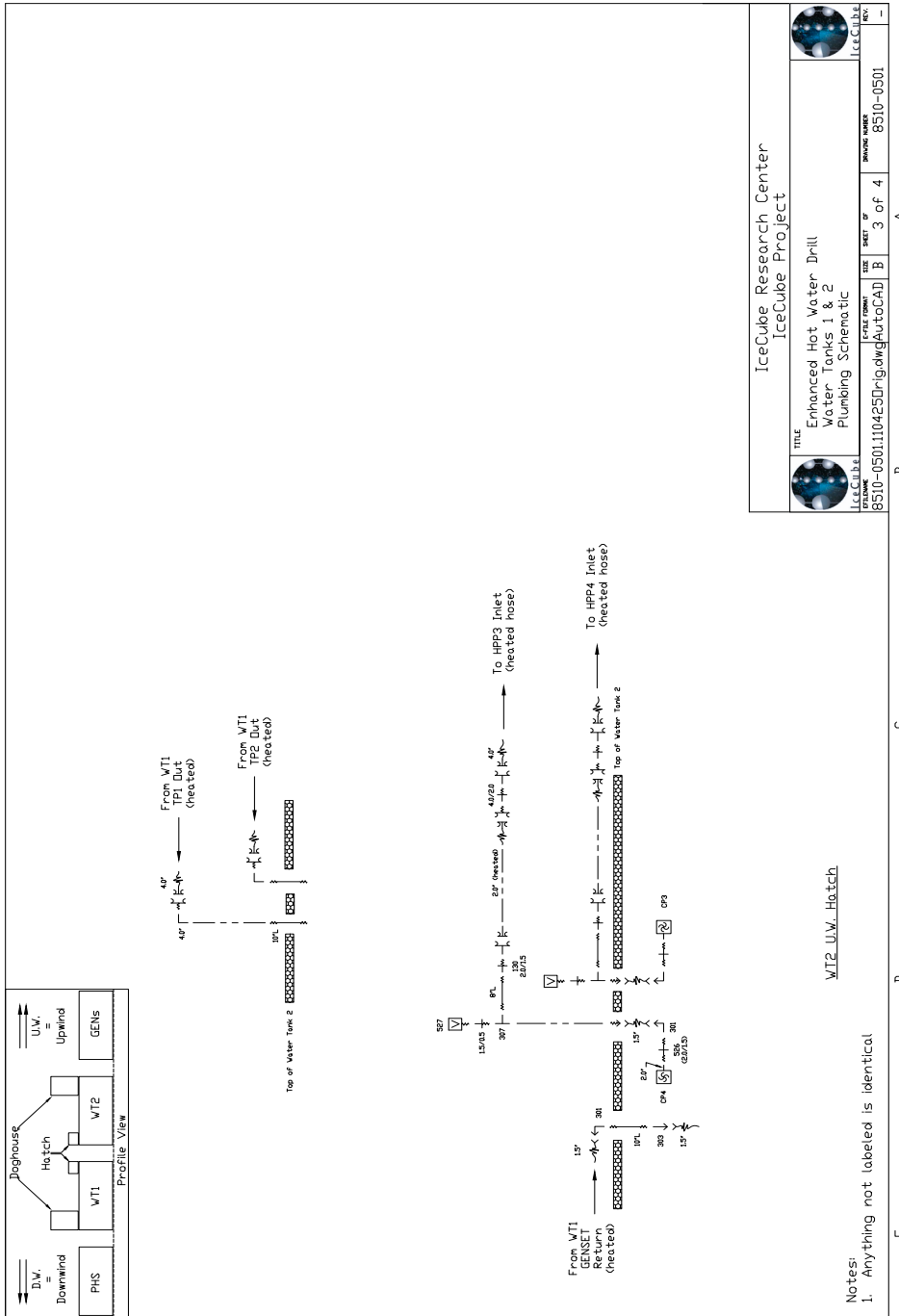


Figure 2.33 WT 1 Plumbing schematic sheet 1 of 2





**Figure 2.35** WT 2 plumbing schematic sheet 1 of 2

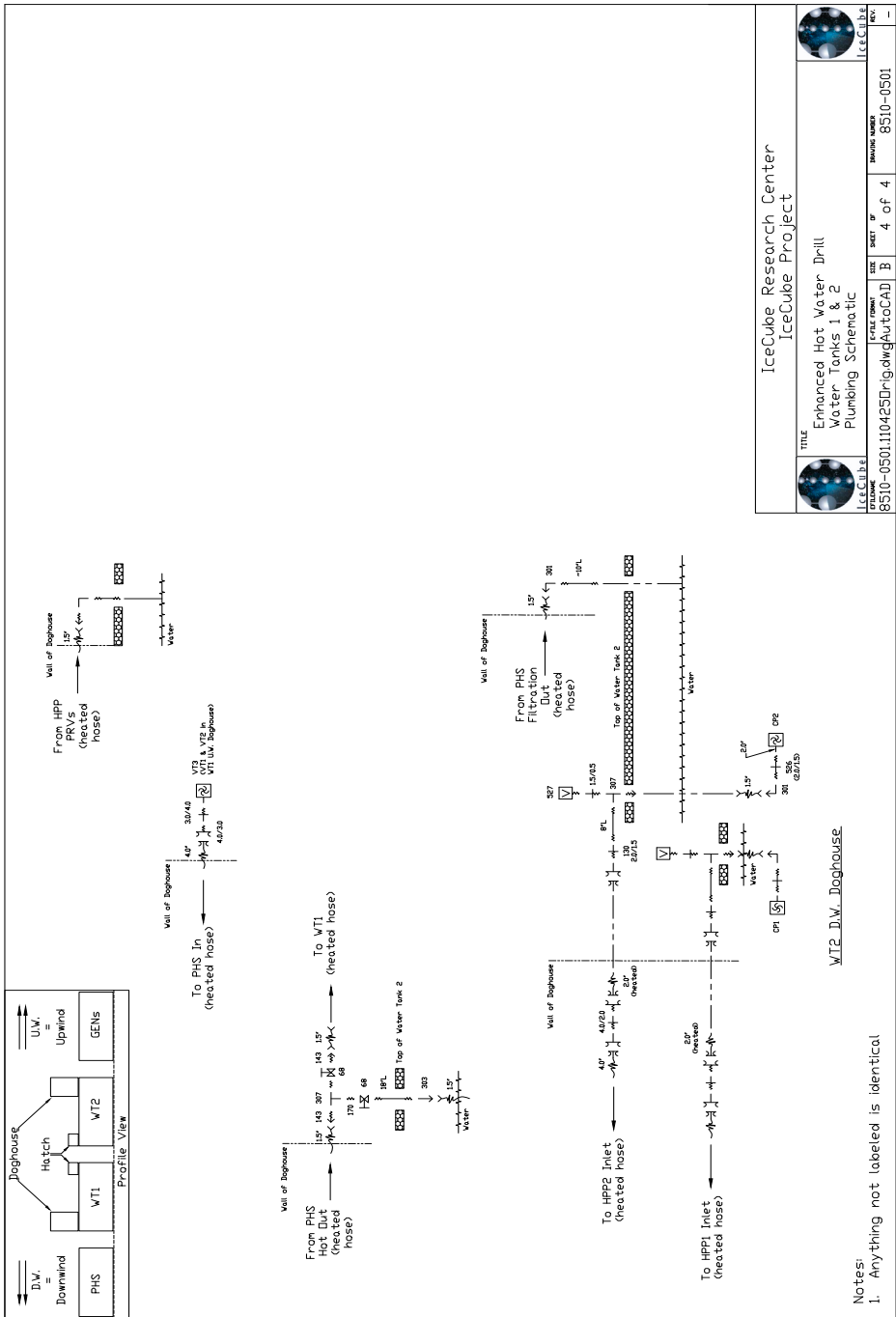


Figure 2.36 WT2 plumbing schematic sheet 2 of 2

## 2.4.5 Pre-Heat System (PHS)

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The PHS, shown Figure 2.37 is used to maintain the temperature of Tank 2. Vertical turbine pump 2 circulates a continuous flow of water between Tank 2 and the PHS that can be heated as needed. The circulating water is also filtered. The PHS is also home to the EHWD's condensate collection system, where condensate is collected, filtered, and injected into Tank 2. A booster pump has been installed in the PHS and can be utilized to increase the line pressure inside the building (which may be necessary to run the RO filter during drilling operations).



**Figure 2.37** PHS interior view

The PHS contains Three Whitco Model 75 heaters, as shown in Figure 2.38 and a prototype Sioux heater. Each has a 125 kW water heating capacity (@ approx. 90% efficiency). They are capable of heating 7 GPM of water at 125 psig from 20°C to 88°C. Heaters employ oil-fired Beckett SF burner units. Barometric dampers equalize building pressure and each heater is paired with

it's own 100 cfm makeup air fan to provide the burner inside the building with air for combustion.



**Figure 2.38** PHS heaters

The PHS is also the site of the main water filtration center for the SES as shown in Figure 2.39. A centrifugal filter removes any larger debris that is too heavy to remain in solution with the system water, while three bag filters, provide particulate filtration down to 25 microns. Condensate water from the MHP heaters is pumped to a central reservoir in the PHS where it is treated with soda ash (to raise the pH to a neutral value), filtered, and re-introduced into tank 2. An 80 gallon barrel acts as the condensate collection vessel.



**Figure 2.39** Condensate collection and filtration system inside PHS.

The PHS houses the Reserve Osmosis (R/O) filter, which is used exclusively to supply Ice Top tanks with ultra pure water. This is accomplished by forcing water at 125psi through an extremely fine, micro-membrane.

PHS plumbing is rated to 150psi and is instrumented with flow, temperature and pressure sensors. There are also redundant flow and temperature safeties on each of the building's four heaters.

In the electrical closet are located the Unico vector motor drives. One @ 10hp; 3 @ 3hp. The PDM supplies 100A electrical service.

The PHS contains a number of safety and environmental controls. These include smoke, CO, and water alarms. A passive barometric damper maintains a constant atmospheric pressure inside the module, and four 100 cfm air intake fans provide the four water heaters with air for combustion.

Fuel to the PHS is supplied by a positive pressure gravity feed from the day tank.

An oil-fired furnace controlled by an analog thermostat provides primary heat for

the building. An over temperature fan with an analog thermostat can cool the building if necessary.

Figure 2.40 and Figure 2.41 are the electrical schematics for the PHS, while Figure 2.42 to Figure 2.44 are the water plumbing schematics and Figure 2.45 is the fuel plumbing schematic. These schematics have been updated and should accurately reflect the final electrical and plumbing arrangement of the PHS at the completion of drilling in December 2010.

Click on the video link below to play a video giving an overview of the PHS.

PHS wt Audio .mp4

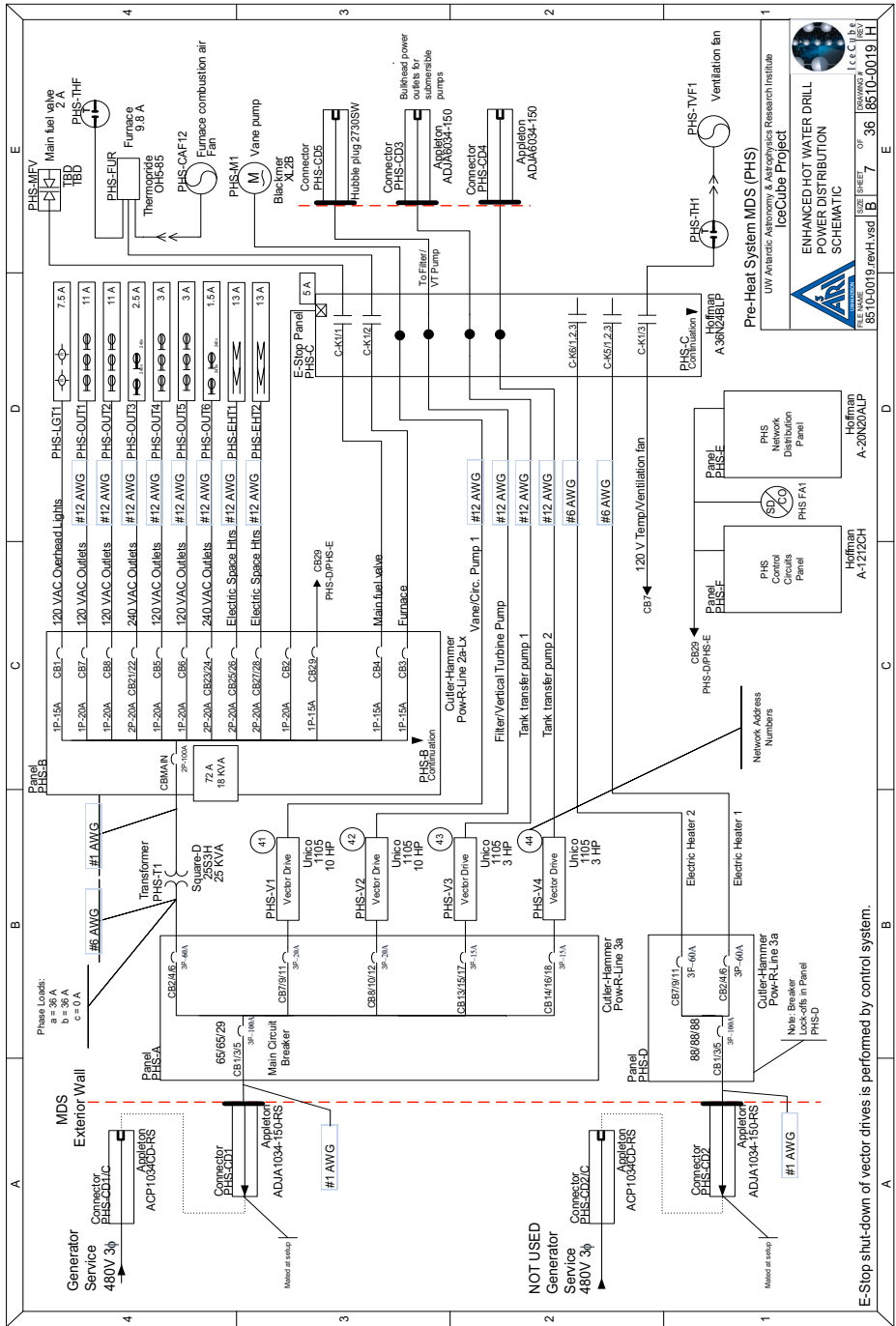


Figure 2.40 PHS electrical schematic, sheet 1 of 2







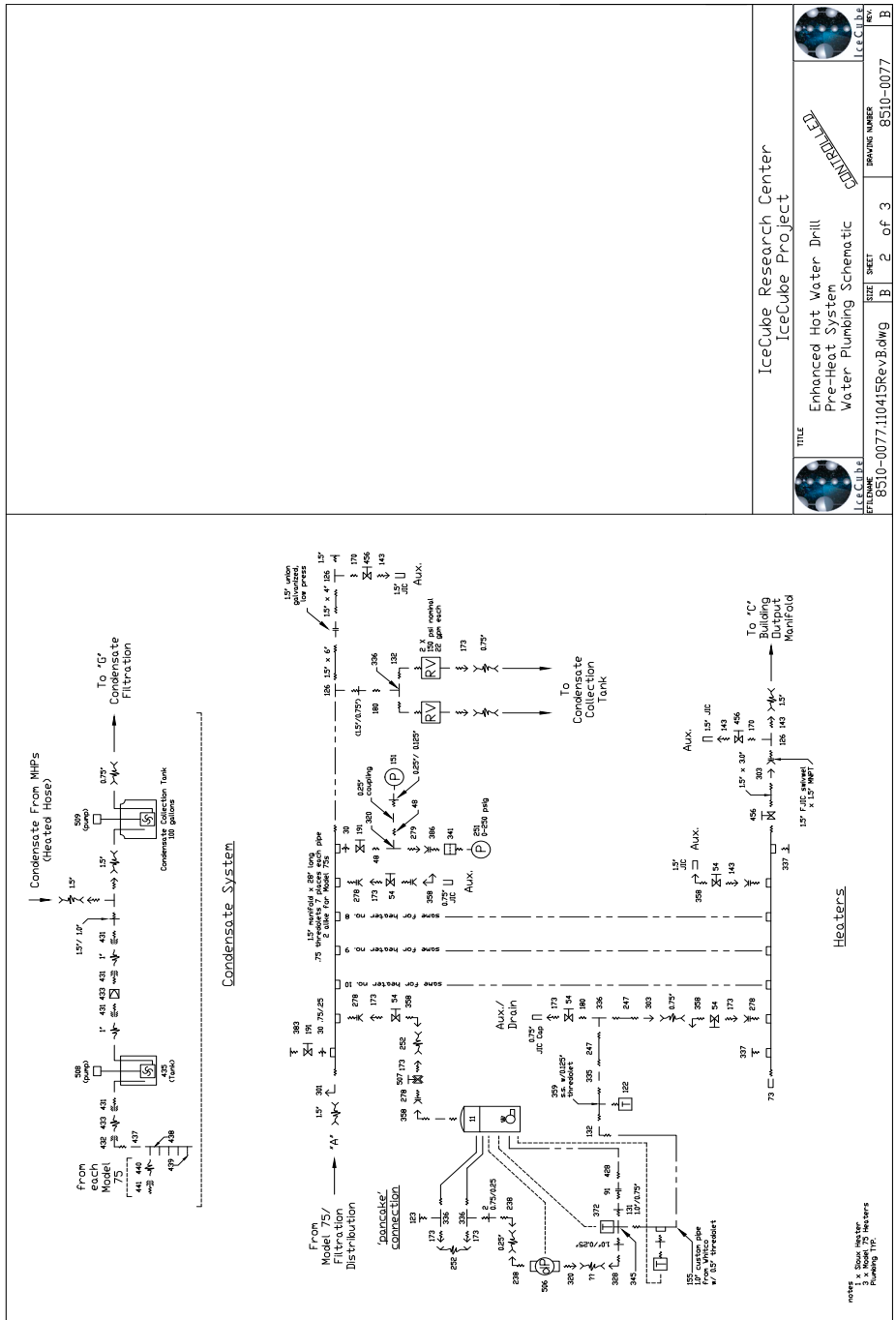


Figure 2.43 PHS plumbing schematic, sheet 2 of 3

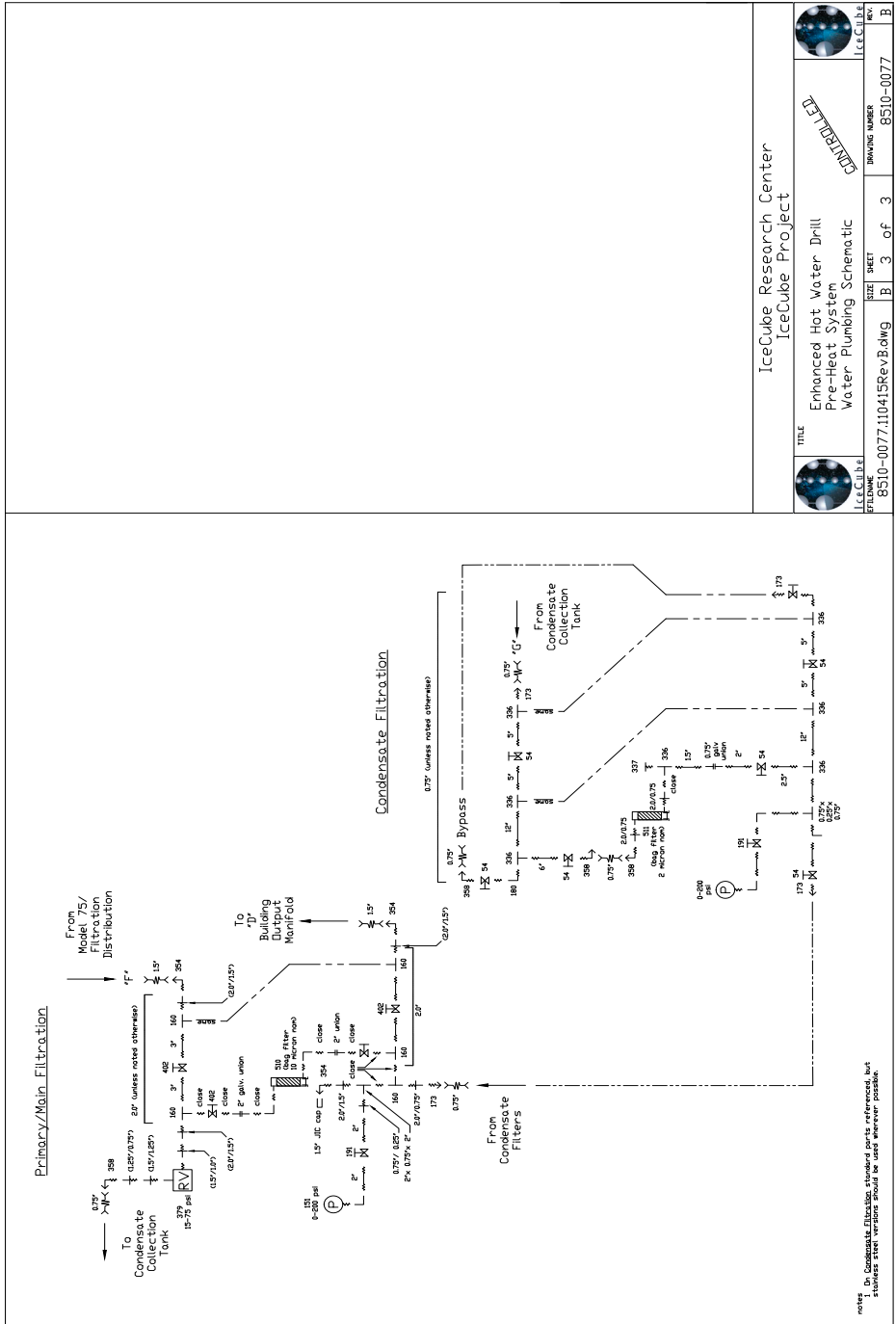
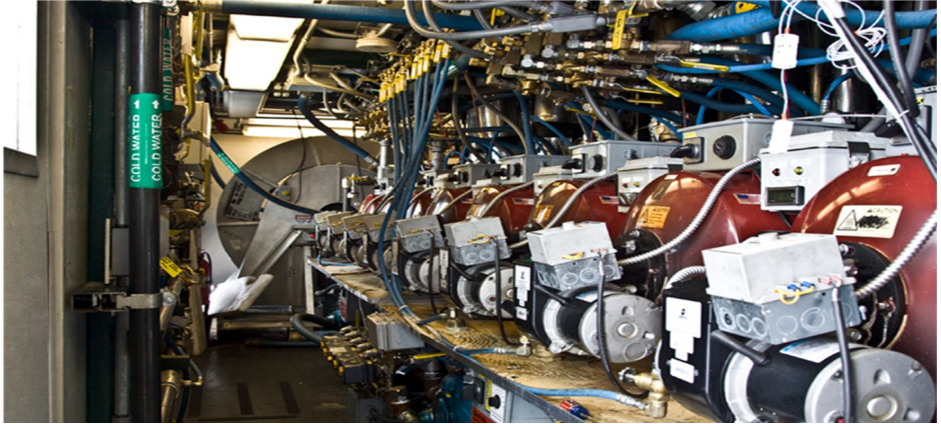


Figure 2.44 PHS plumbing schematic, sheet 3 of 3

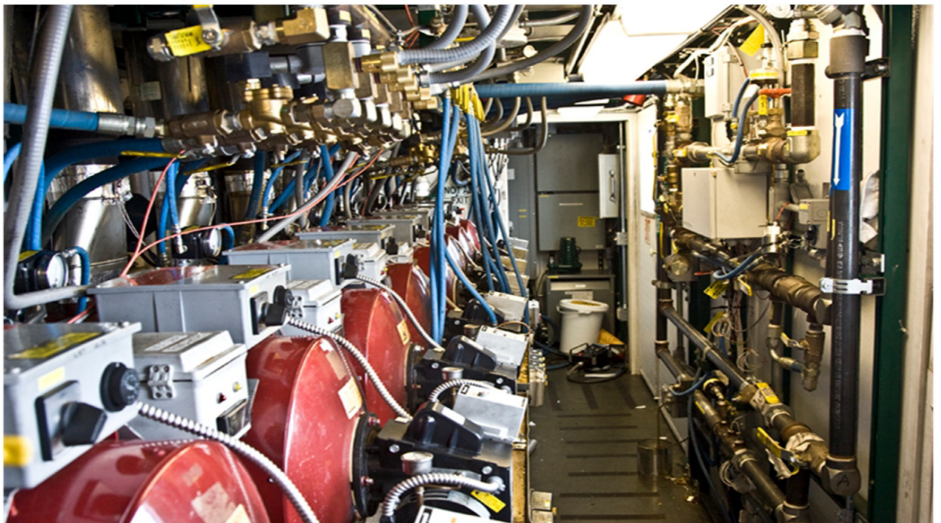


## 2.4.6 Rod Well System (RWS) MDS

The RWS building, shown in Figure 2.46 and Figure 2.47, is responsible for maintaining the Rodriguez Well, or Rod Well, controlling level and temperature of Water Tank 1, and providing the generators with a heat recovery cooling loop. The building houses 9 Stinger Heaters, a 2-pass parallel hose reel, instrumentation and control plumbing, and motor controls for the reels and a number of pumps.



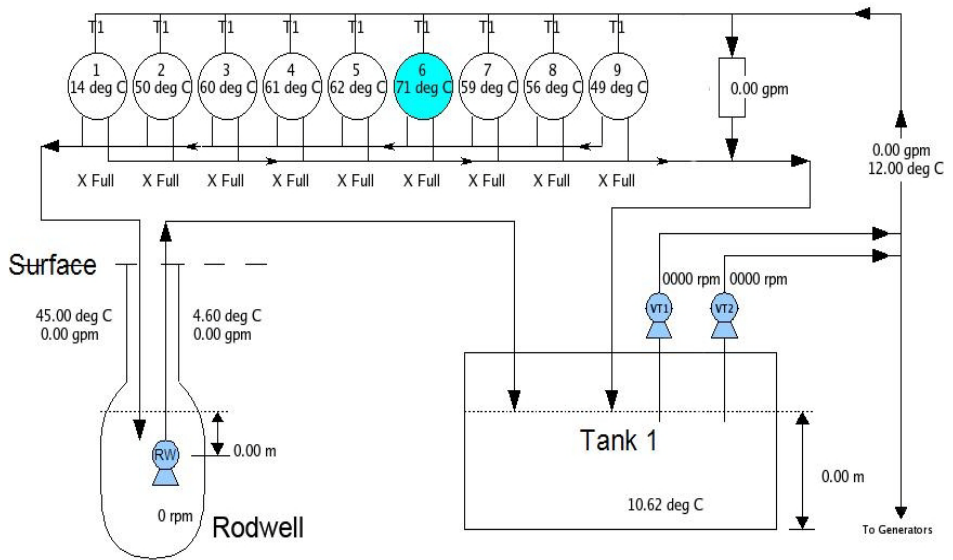
**Figure 2.46** Inside the RWS, looking towards the hose reel



**Figure 2.47** RWS looking towards electrical closet. Pumping/ instrumentation wall to the right.

The RWS plumbing, shown in Figure 2.48, is the single most complicated of all the buildings. The system has been extensively simplified from the original

design - much of the old plumbing remains in place, making the building look more complicated than it actually is - but it still takes some time to become familiar with how the water flows through the various loops in the building.



**Figure 2.48** RWS plumbing diagram

There are three pumps controlled from the RWS. Two vertical turbine pumps on top of Water Tank 1 operate in parallel, taking water from Water Tank 1 and providing flow to both the generator cooling loop and the RWS. The third pump is a submersible pump that resides in the Rod Well, pumping cold water back up to the surface, through the RWS, and back to Water Tank 1.

The building can be broken up into five sections:

- 1 Heaters
- 2 Plumbing/instrumentation wall (across the aisle from the heaters)
- 3 Hose reel
- 4 Backup pumps (obsolete, left over from previous configuration)
- 5 Electrical closet.

### Water Tank 1 Loop

Water is delivered to the RWS from the two vertical turbine pumps and fed through the heaters. The heaters can be turned on or off to deliver a discrete amount of heat to this loop. The heated water returns to Water Tank 1. This is one way to control Water Tank 1 temperature.

### Rod Well Loop

Water is delivered to the RWS from the two vertical turbine pumps and fed through the heaters. The heaters can be turned on or off to deliver a discrete amount of heat to this loop. The heated water is sent to the hose reel and delivered to the Rodwell. The submersible pump in the Rodwell then closes the loop by circulating cold melt water from the Rod Well back to Water Tank 1 (via the RWS - this return loop simply feeds through the building, allowing it to be instrumented).

Heaters can be assigned to either loop by way of a computer-controlled 3-way valve on the outlet of each heater. The total combination of pump RPMs, heater throttling, heater on/off, and 3-way valve assignment allows wide flexibility for flow balancing and temperature control.

### Generator Heat Recovery Loop

Flow splits at the outlet of the vertical turbine pumps. Part of the flow goes to the RWS as described above, the rest of it flows through heat exchangers in each generator to pick up waste heat, and is returned to Water Tank 1, where it splits again and can be divided between Water Tanks 1 and 2. Splitting of warm generator return water between the tanks is a valuable method of stabilizing tank temperatures.

### Idle Bypass Loop

During SES idle (between holes), supply to the TOS is looped through the main reels and returned to the SES at Water Tank 1. A few of the main heaters in the MHPs are typically running, and if the warm idle water were allowed to be dumped back into Water Tank 1, the overall system water temperature would continually rise, creating an unstable system and making for difficult time during the next hole startup. To get around this, a bypass from the TOS return on top of Water Tank 1 routes the idle water into the RWS and down to the Rodwell. This allows the heat added during idle to be used for maintaining the Rodwell, and means the full idle loop incorporates every major component of the system, including the Rodwell. This idle bypass loop is also valuable during Rodwell development in the beginning of the season because much more heat can be utilized with the help of the MHP heaters.

There are "low" pressure components integrated into the RWS plumbing system. Protection, especially when fed by the HPP in the idle bypass loop configuration, is provided by a single pressure relief valve located at the idle bypass loop input.

The original RWS configuration used floor mounted vane pumps for water supply. The vertical turbine pumps on Water Tank 1 replace these, but they've

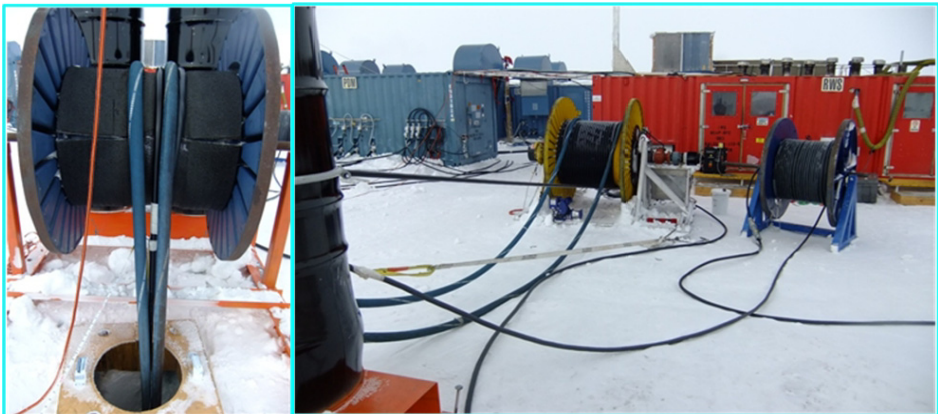


been left in place with their plumbing to act as a backup if needed. The wiring for these pumps is still in place, but disconnected.

The hose reel is a single split reel with two parallel hose runs spooled on it, one for Rodwell supply and one for return. Each hose section is approximately 277 feet, but the reel has a capacity for 2 x 300 feet. The hose is combined with a support/electrical/instrumentation combo cable from a reel external to the RWS building. Both reels are controlled from the RWS with pendants.

To provide combustion air to the building's heaters, makeup air fans are installed in the window openings, each rated at 100 cfm. There is one fan for each heater, and turn on automatically when a heater is activated. A passive airflow damper is also installed to equalize building pressure with ambient.

Figure 2.49 shows the assembly of hoses and cables used to feed water down to the Rod Well and recover water from the well. Hoses feed off the hose reel inside the RWS building, through the RWS wall, over the combo cable reel (yellow) and down to the Rodwell over the “Pernicator” (support structure to help feed the hoses and cables down the hole). The combo cable also goes down, and the three are banded together just after the Pernicator. This picture shows an additional cable reel (blue) that is not typically used””.



**Figure 2.49** “Pernicator” reel (L) and hoses and combo cable (R)

Figure 2.50 and Figure 2.51 are the RWS electrical schematics, while Figure 2.52 to Figure 2.55 are the water plumbing schematics and Figure 2.56 is the RWS fuel plumbing schematic. These schematics should accurately reflect the final electrical and plumbing arrangement as of the end of drilling in Dec. 2010.

Click on the video link below to watch an overview of the RWS.

**RWS Overview.mp4**



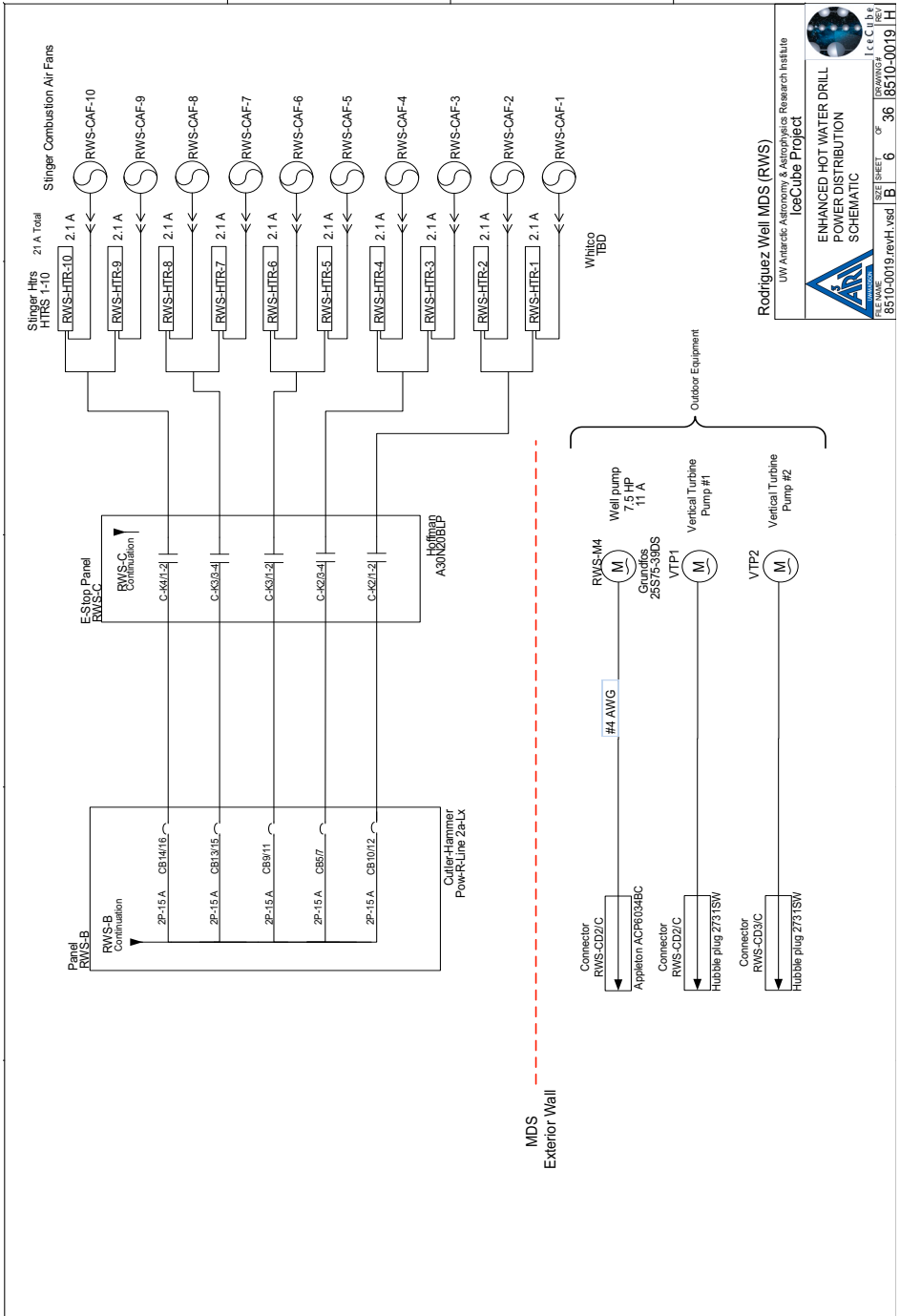


Figure 2.51 RWS electrical schematic, sheet 2 of 2



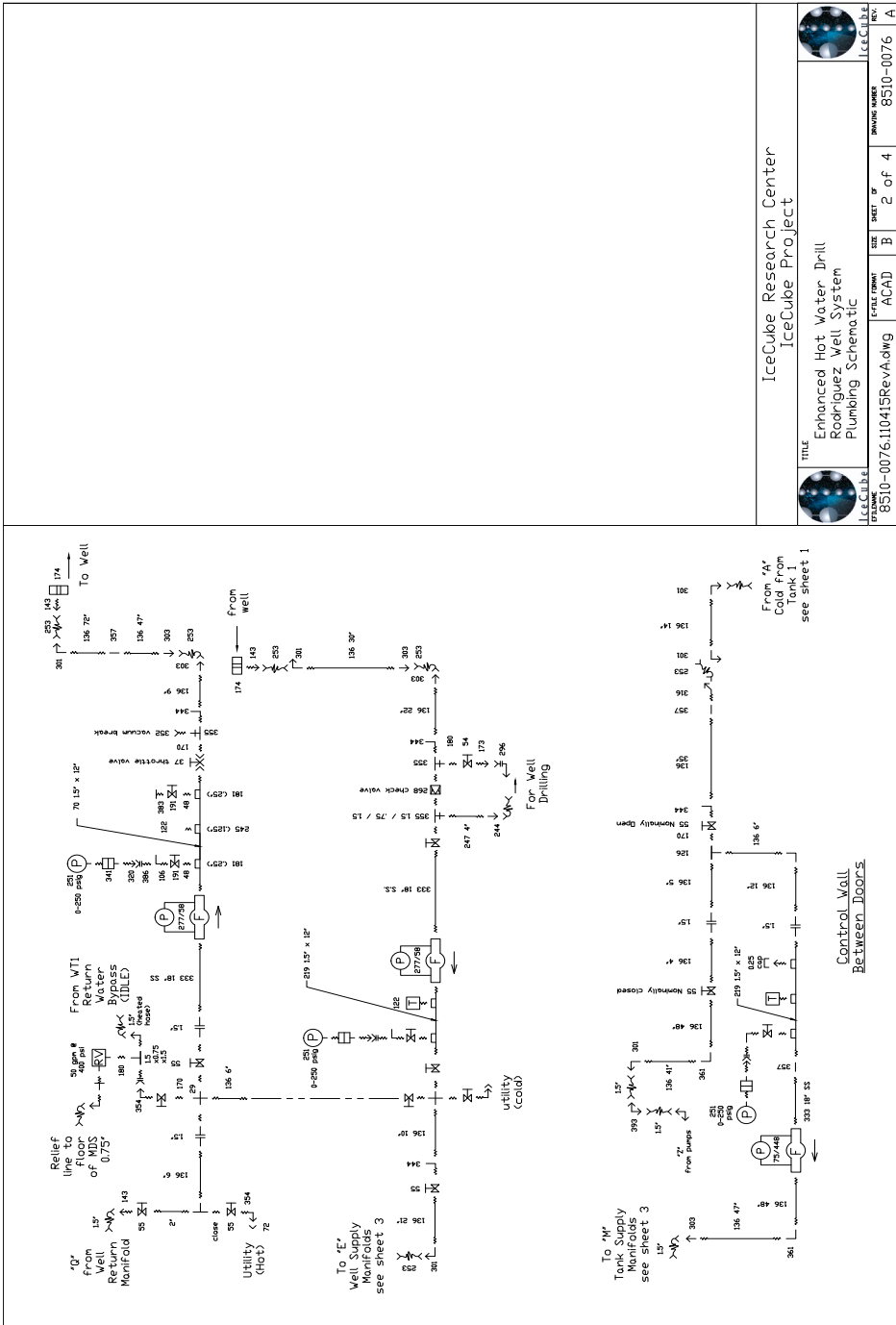


Figure 2.53 RWS plumbing schematic, sheet 2 of 4

IceCube Research Center  
IceCube Project

Enhanced Hot Water Drill  
Rodriguez Well System  
Plumbing Schematic



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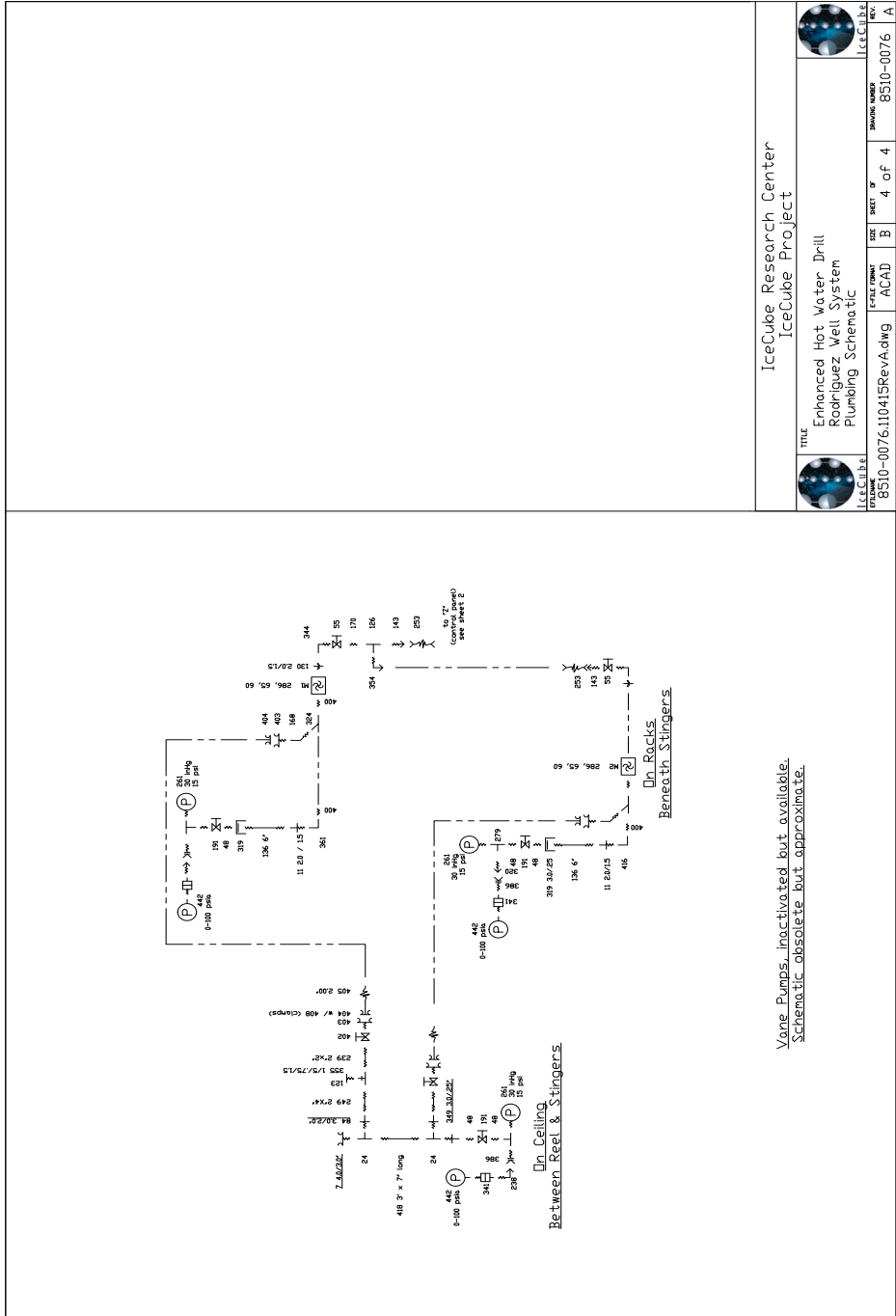




Figure 2.55 RWS plumbing schematic, sheet 4 of 4

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TITLE	Enhanced Hot Water Drill Rodriguez Well System Plumbing Schematic
ICECUBE	ICECUBE
FILE NAME	8510-0076.110415REVAdwg
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## 2.4.7 High Pressure Pump (HPP) Building

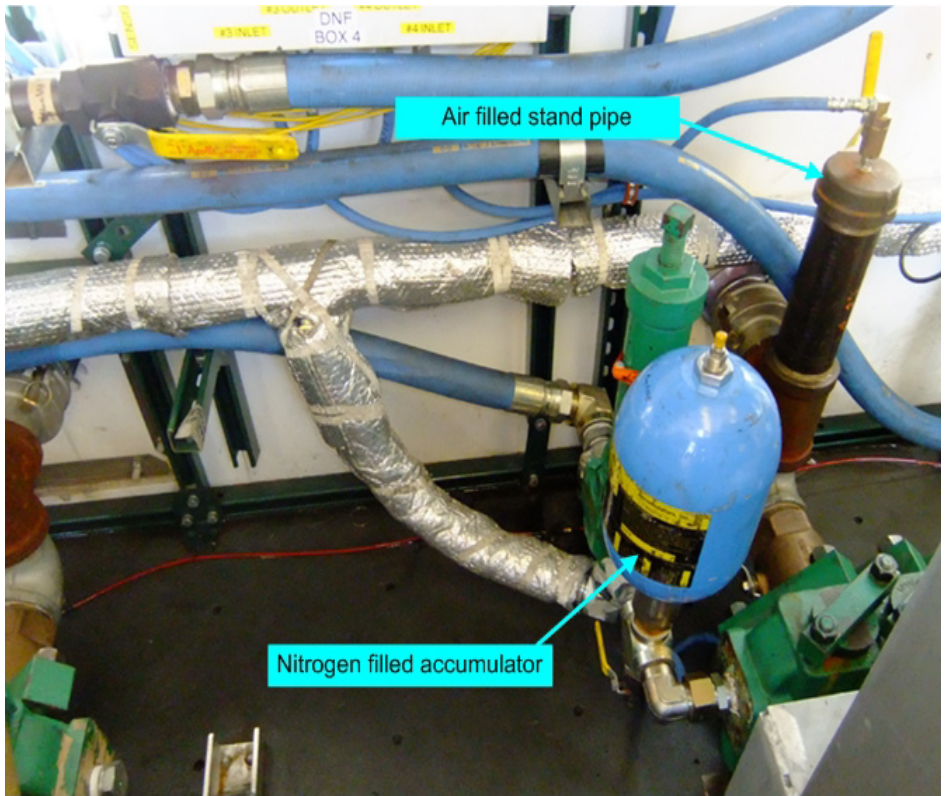
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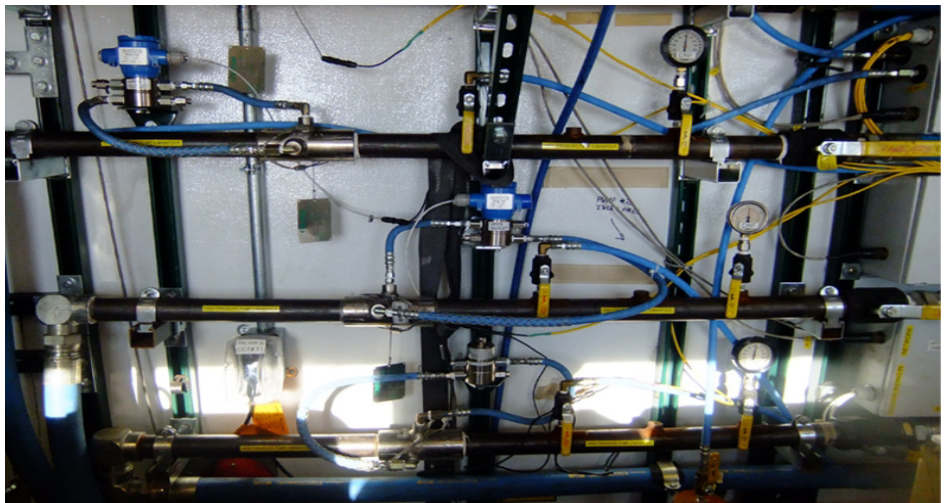
**Figure 2.57** Inside HPP building showing pump motors and plumbing wall

The High Pressure Pump (HPP) module houses 4 electrically-driven, Meyers Triplex positive displacement high pressure pumps, as shown in Figure 2.57, four 50 HP Unico vector motor drives, and 4 Telemecanique motor starters (for charge pumps). The Meyers pumps are powered by 50 HP Baldor induction motors with a toothed belt drive and are each capable of delivering 65 gpm of water at 1600 psig (50 gpm @ 1100 psi). Each pump employs an air filled stand pipe and a nitrogen filled accumulator for vibration dampening, as shown in Figure 2.58. Each pump also has a mechanical pressure relief valve calibrated to shunt water from the HPP output to tank 2 during an overpressure (greater than 1200 psi) event. This is a redundant safety. Overpressure protection is also provided by programmed torque limits on the Unico drives. (See Chapter 3).

All of the plumbing in the HPP is instrumented with digital flow, temperature, and pressure sensors that interface with the drill control software. Also all the plumbing in the HPP is equipped with analog pressure gauges, as shown in Figure 2.59.

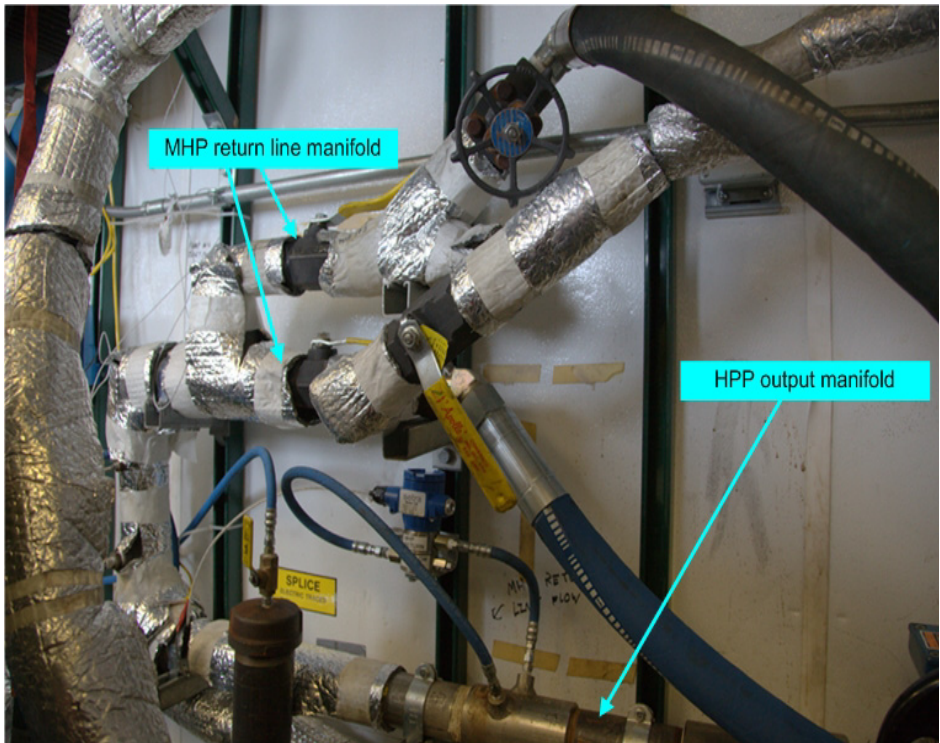


**Figure 2.58** HPP vibration dampening mechanisms

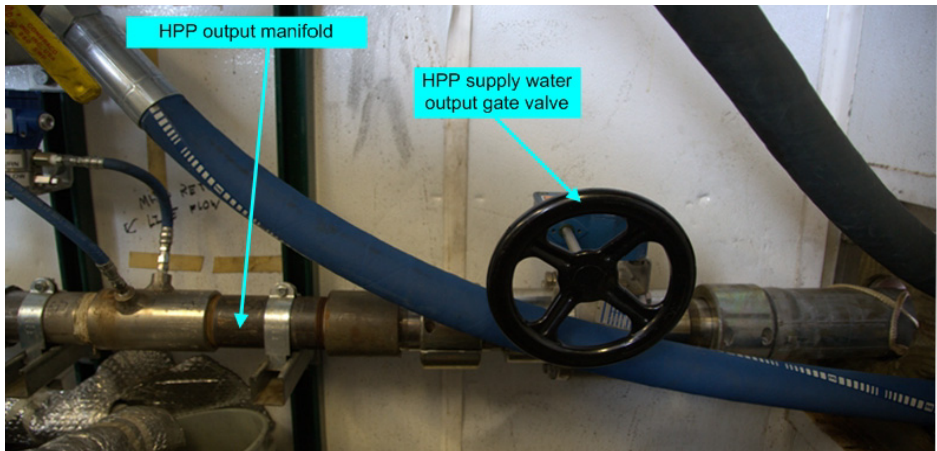


**Figure 2.59** HPP plumbing and instrumentation wall

The HPP's are fed with low pressure water from tank 2 by 4 Grundfos submersible centrifugal charge pumps (one charge pump for each HPP). These charge pumps maintain a positive pressure on the intake side of the HPPs which helps to prevent cavitation (the formation of air bubbles) which can damage a positive displacement pump. The plumbing from tank 2 that feeds the HPP is low pressure. All plumbing downstream of the HPP output is rated for 1400 psig. Pressurized water from each of the four HPP's is directed to the MHPs for heating via the HPP output manifold. This manifold combines the flows from all the HPPs before splitting the output into two parallel loops, one that circulates water through MHPs 1 and 3, and one through MHPs 2 and 4. After circulating through the heater buildings, the water returns to the HPP where the two parallel loops are rejoined at the MHP return line manifold as shown in Figure 2.60 and Figure 2.61. This manifold is instrumented to provide the last digital flow, temperature, and pressure values for the water as it leaves the SES headed for the TOS via the surface supply hose.



**Figure 2.60** MHP return line manifold inside HPP building



**Figure 2.61** HPP output manifold

The HPP module is provided with 480V, 3 phase power from the PDM. There are four 100-amp service feeds from the PDM to the HPP building to provide power for the pumps (one for each HPP), plus one 60-amp service for building power. The HPP also contains two 75 kVA transformers for phase balancing.

The HPP has 2 wall mounted 3 kW electric space heaters as well as a diesel fired furnace for primary building heat. A 1" flexible fuel line from the day tank provides the HPP building with a positive pressure gravity feed fuel to run the furnace. During normal drilling operations, the pump motors and Unico drives in the HPP building will generate enough waste heat to raise the building temperature to a level that exceeds the operational limitations of the equipment inside. For this reason the HPP module has been outfitted with an additional building temperature control system. This system includes a high temperature thermostat linked to the 50 HP Unico drive which drives HPP1. This drive controls a 1000 cfm intake fan (pulling in cold air from outside), and two 250 cfm exhaust fans. The HPP building also has a passive barometric damper to maintain a constant atmospheric pressure inside the module.

Figure 2.62 to Figure 2.64 are the HPP electrical schematic and Figure 2.65 to Figure 2.68 are the idle pump and charge pump schematics, while Figure 2.69 and Figure 2.70 are the water plumbing schematics and Figure 2.71 is the fuel plumbing schematic. These schematics should accurately reflect the final electrical and plumbing arrangement as of the end of drilling in Dec. 2010.

Click on the video link below to watch an overview of the HPP.

HPP wt audio.mp4



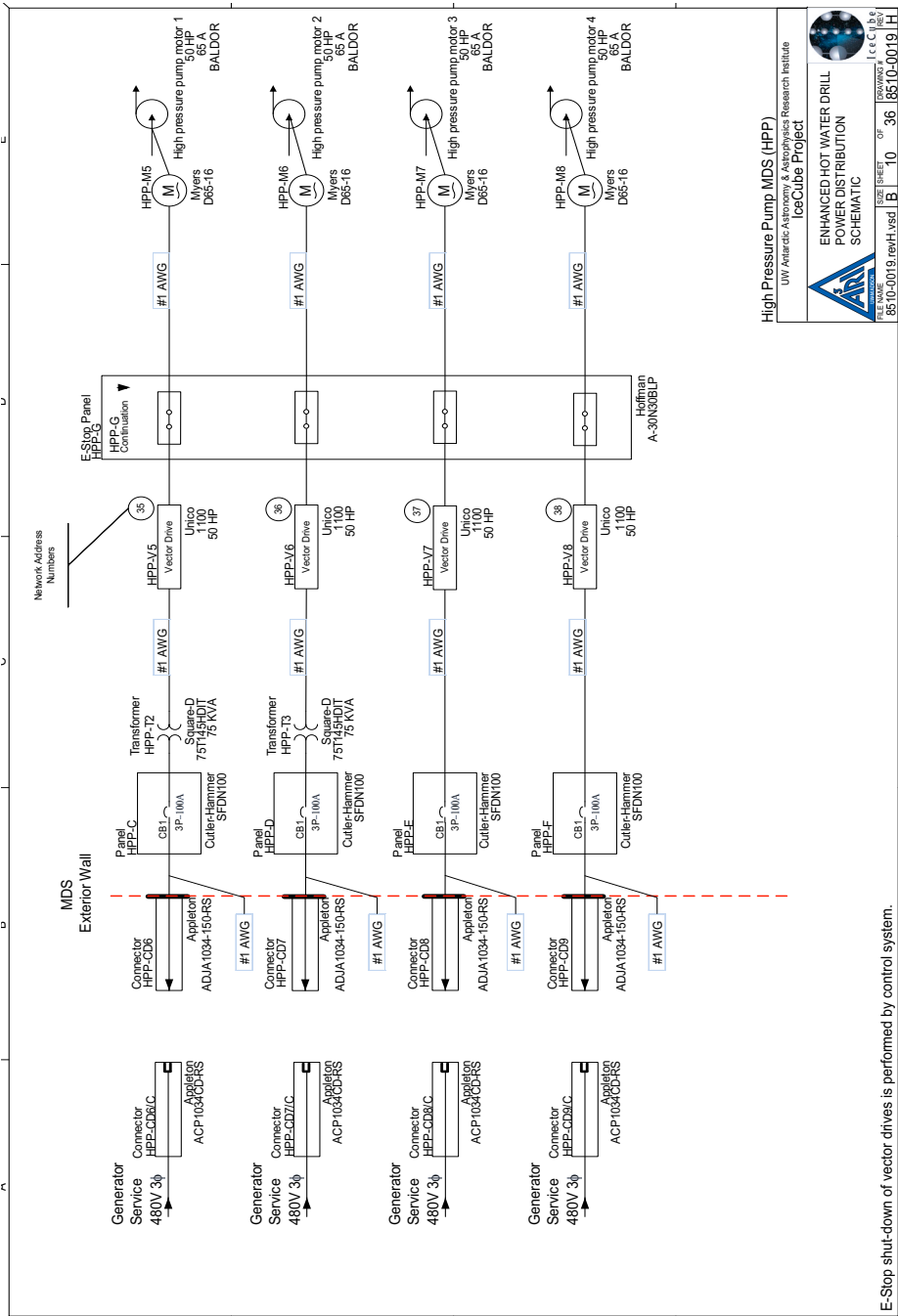


Figure 2.63 HPP electrical schematic, sheet 2 of 3

High Pressure Pump MDS (HPP)

UIW, Anaradi, Astronomy & Astrophysics Research Institute

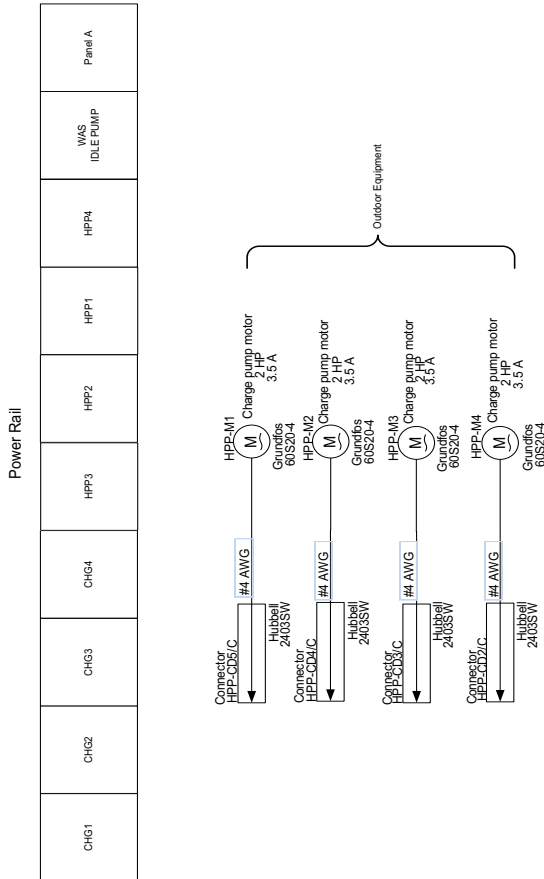


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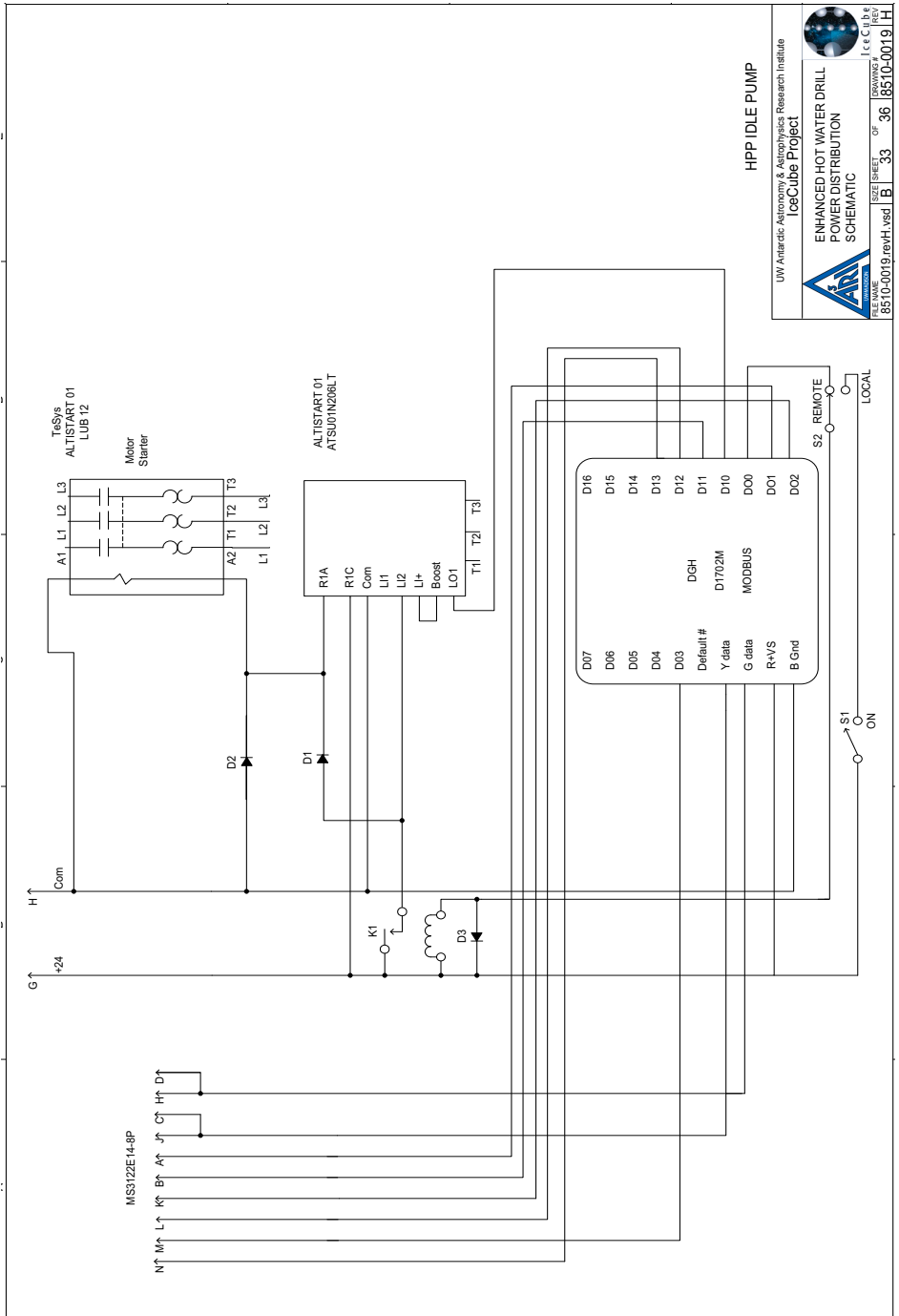


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E-Stop shut-down of vector drives is performed by control system.



**Figure 2.64** HPP electrical schematic, sheet 3 of 3



**HPP IDLE PUMP**

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POWER DISTRIBUTION  
SCHEMATIC**

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**Figure 2.65** HPP idle pump schematic



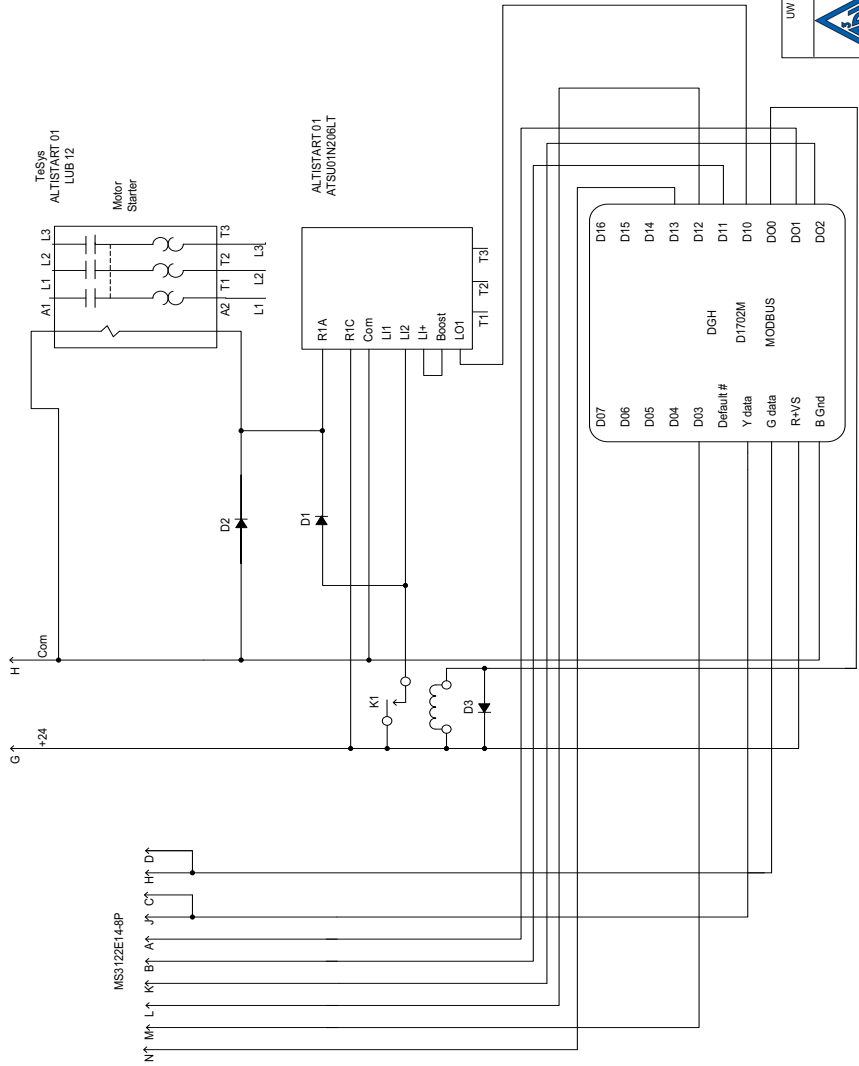


Figure 2.66 HPP charge pump 1 motor starter schematic

HPP #1 CHARGE PUMP  
MOTOR STARTER

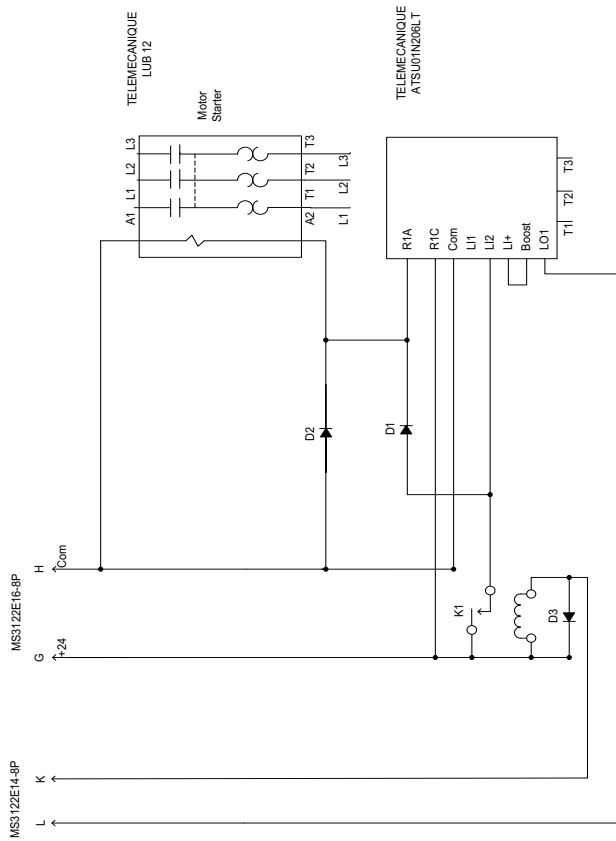
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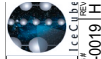
**Figure 2.67** HPP charge pump 3 motor starter schematic

HPP #3 CHARGE PUMP  
MOTOR STARTER

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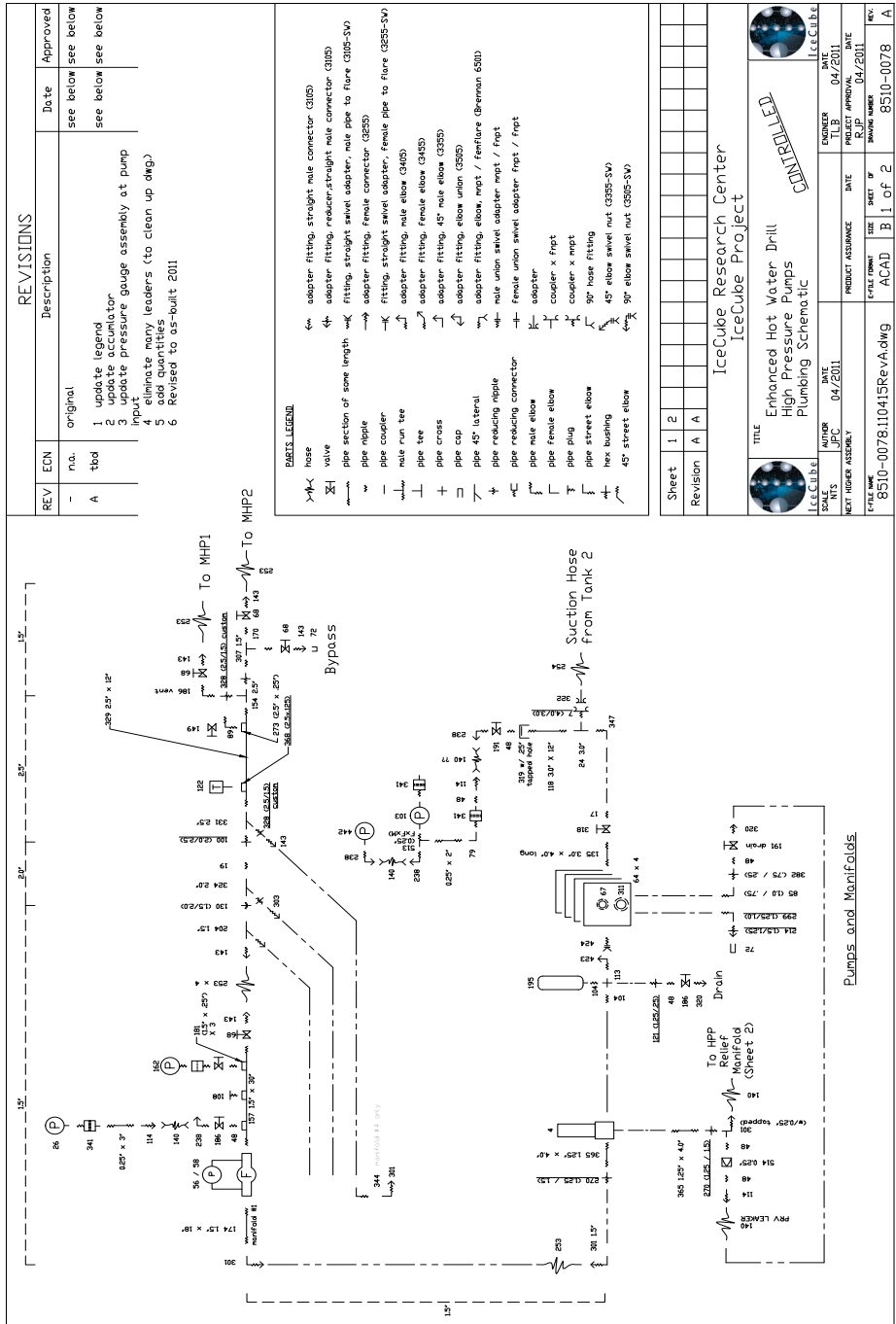


Figure 2.69 HPP plumbing schematic, sheet 1 of 2





## 2.4.8 Main Heating Plants (MHP's)

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The EHWD uses four Main Heating Plant (MHP) modules to add heat to the primary high pressure water loop for main drilling. Each of the four MHP modules contains 9 Whitco Model 75 heaters, except MHP 4, which only has 8, for a total of 35 heaters. Each Model 75 heater has a water heating capacity of 125 kW (125kW x 35 heaters = 4.375 megawatt total output capacity). In operation each heater is designed to heat a constant flow of 7gpm of water at a pressure of 1000psig from 20 C to 88 C, and requires the combustion of 3.5 gallons per hour of AN8 (diesel fuel) to accomplish this.

During normal drilling operations the MHP modules are supplied with high pressure water by two parallel loops from the HPP (MHPs 1 and 3 fed in separate loop from MHPs 2 and 4. See section 2.4.7 for more information). Because the MHPs are located downstream from the HPP, all of the plumbing in the MHPs is rated for 1400 psig. The 8 to 9 Model 75 heaters in each MHP are also plumbed in parallel, with the cold water supply for all the heaters coming off a central supply manifold located near the building's ceiling, and the hot water return to the HPP exiting the building via a central manifold near the floor. Each heater is instrumented with digital flow and temperature sensors that interface with the drill control software. This allows for redundant computer controlled safety shutoffs for low flow and high temperature in addition to the analog safeties built into each heater (thermostat and differential pressure switch. See section 2.7.3). Analog pressure gauges can also be found in all of the MHPs.

Every MHP is also equipped to collect the condensate produced by its Model 75 heaters (see section 2.7) in a central reservoir (located behind heaters 1 and 2). When the reservoir is filled, its contents are pumped to the PHS for filtration, neutralization, and reintroduction to the drilling water.

MHPs 1 and 2 receive electrical power via 100 amp service from the PDM. MHPs 1 and 2 also have 60 amp output feeds. These outputs provide power to MHPs 3 and 4, which both have 60 amp service. MHP 1 feeds MHP 4. MHP 2 feeds MHP 3.

All the MHP modules receive fuel for their Model 75 heaters via a 1" fuel line from the day tank. Fuel is gravity fed to the building at a positive pressure of 2-3 psi, and is filtered in each MHP by two Racor filters prior to distribution to the individual heaters. The main fuel line inside each MHP also has a fuel solenoid valve installed that is connected to the drill's e-stop system. This allows fuel flow to these buildings to be terminated remotely in the event of an emergency.

All the MHP modules are heated by a diesel fired furnace with local thermostat control. Each MHP module is equipped with smoke, carbon monoxide, and water, building environmental sensors, as well as a manually operated CO2 fire suppression system. The MHP modules have also been fitted with one 100 cfm air intake fan for each Model 75 heater in the building. This fan provides air for combustion for the running heater. Each module also has a 100 cfm over-temperature fan controlled by an analog thermostat, and a separate passive barometric damper to maintain a constant atmospheric pressure inside the building.

Figure 2.72 to Figure 2.75 are the electrical schematics for MHP's 1-4 respectively, while Figure 2.76 to Figure 2.79 show the plumbing schematics for the 4 MHP's and Figure 2.80 to Figure 2.83 show the fuel plumbing schematics for the buildings.

The electrical, plumbing and fuel schematics are very similar for each building. However there are some minor variations, so the schematics for each building are shown for completeness.

Click on the video link below to watch an overview of the heaters in the MHP buildings.

[Heaters, full film.mp4](#)



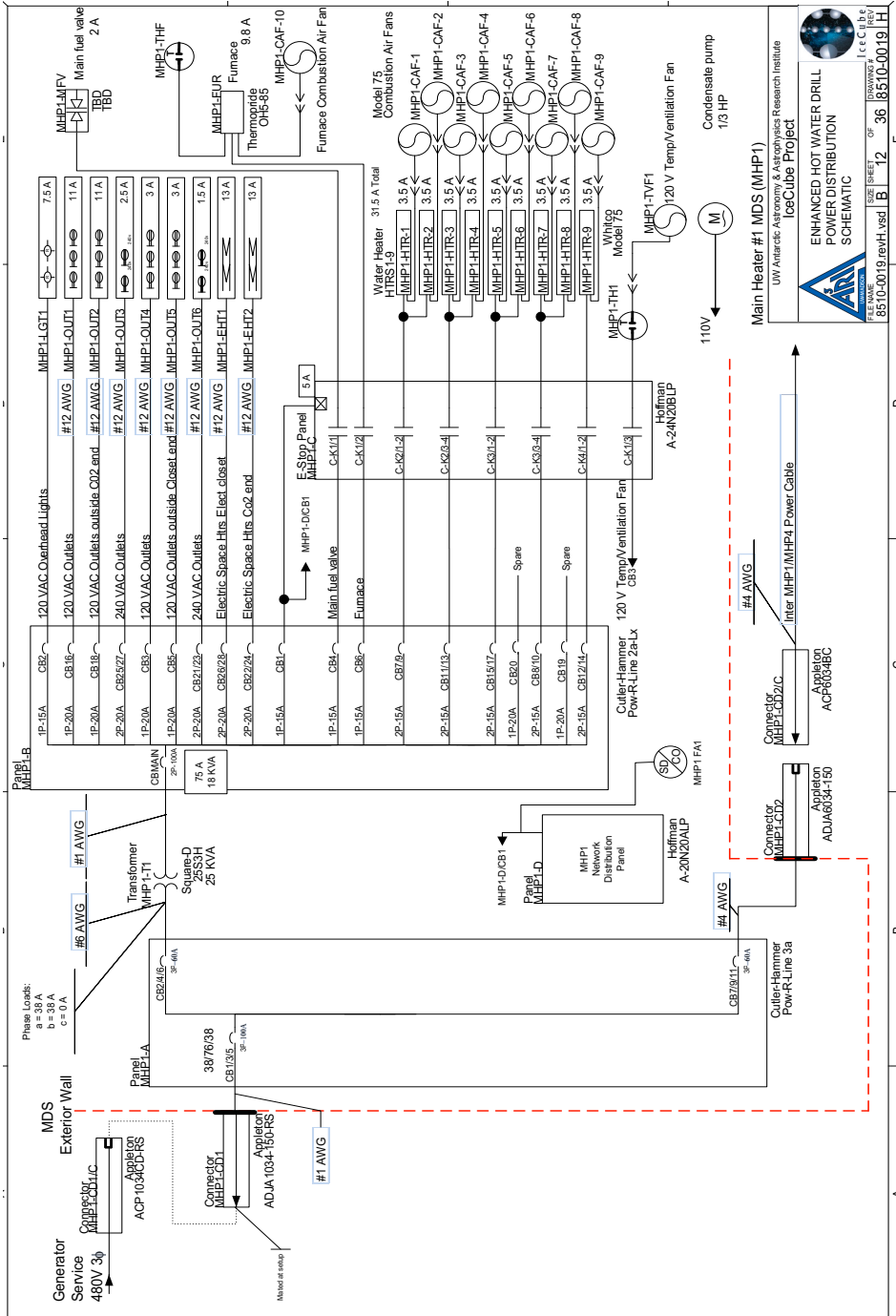


Figure 2.72 MHP1 electrical schematic

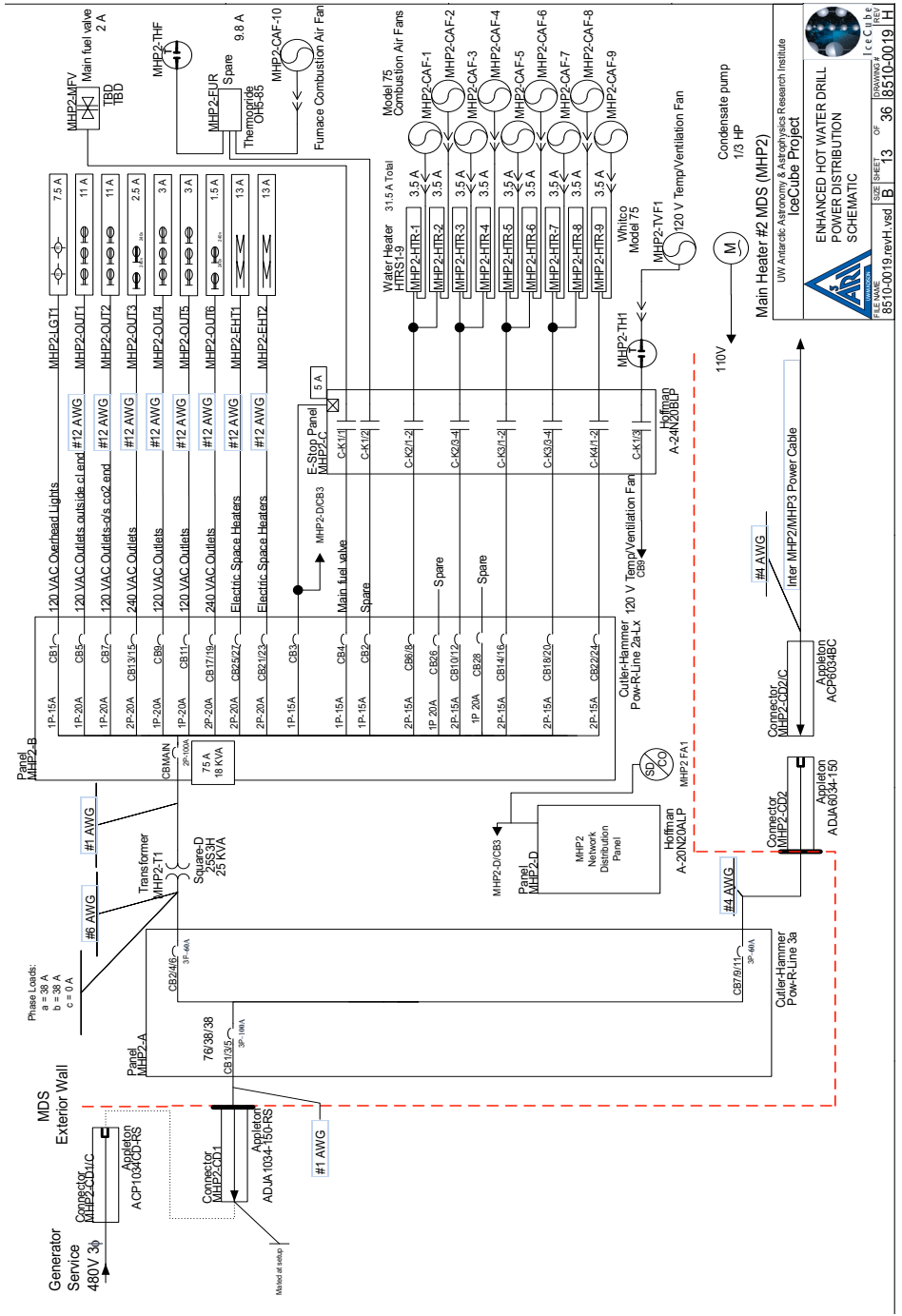


Figure 2.73 MHP2 electrical schematic

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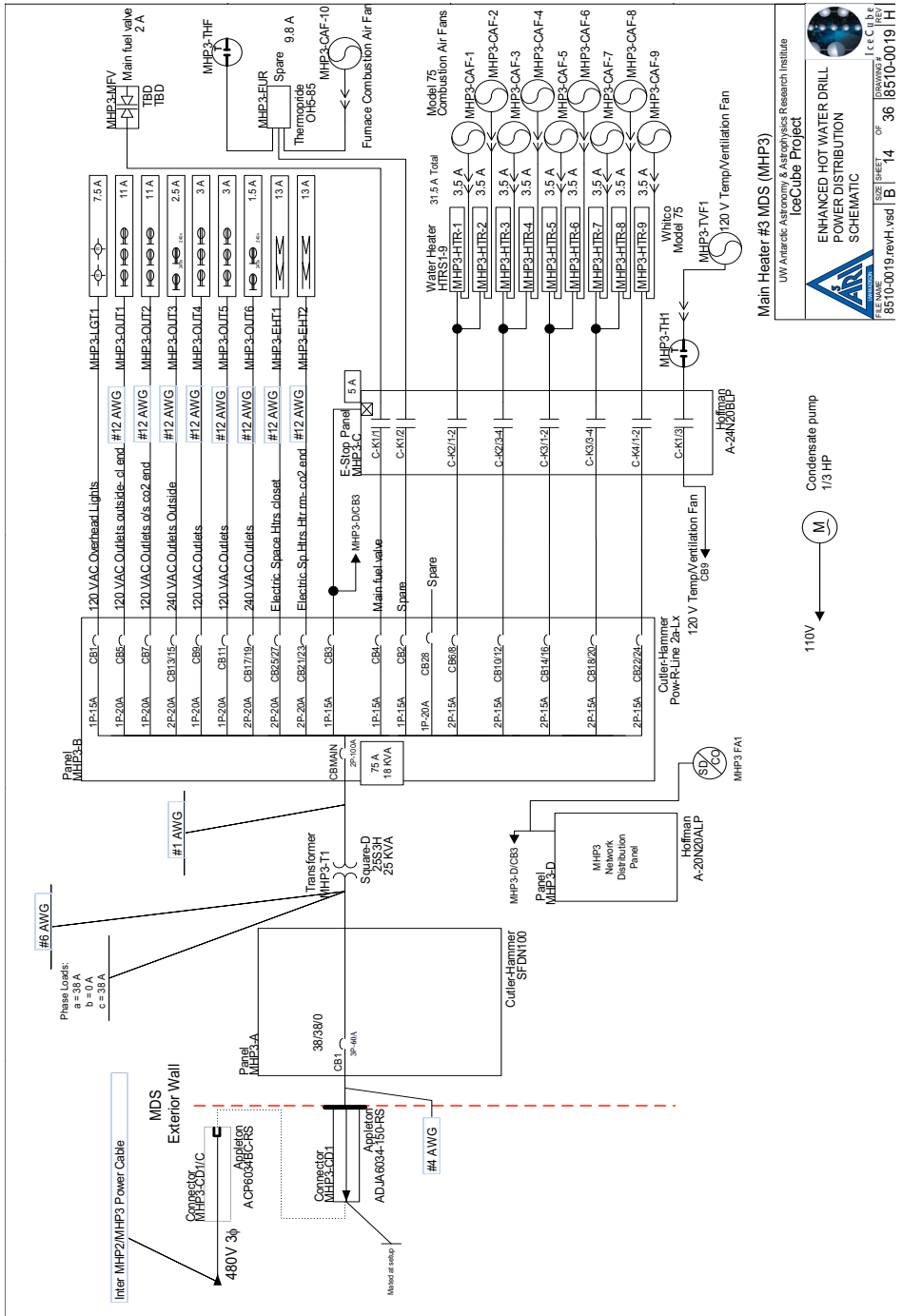


Figure 2.74 MHP3 electrical schematic

Main Heater #3 MDS (MHP3)  
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110V



MHP3 FA1



Hoffman  
A-20N20ALP



Hoffman  
A-20N20BTP



C-610



C-610



C-610



C-610



C-610



C-610



C-610

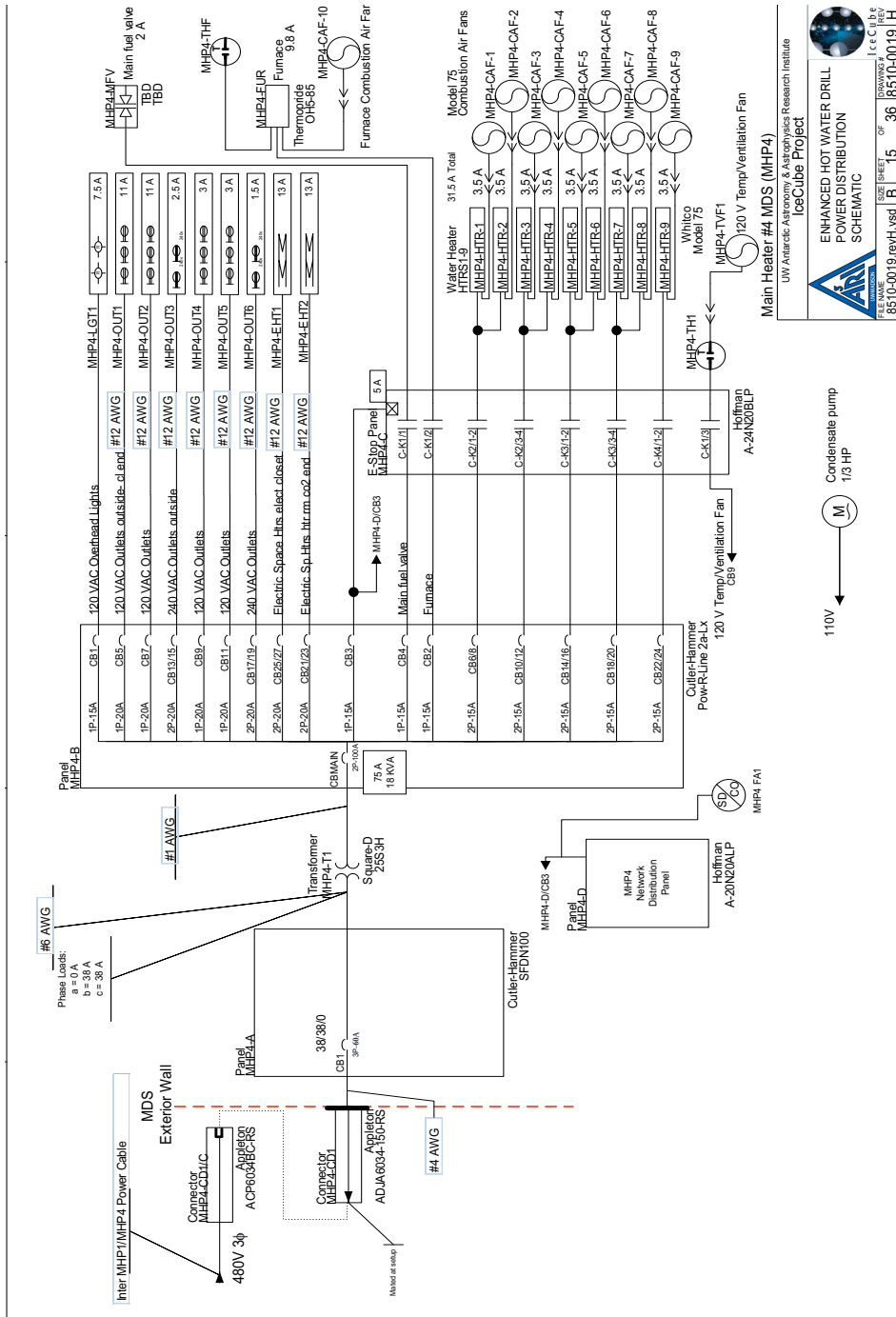


Figure 2.75 MHP4 electrical schematic

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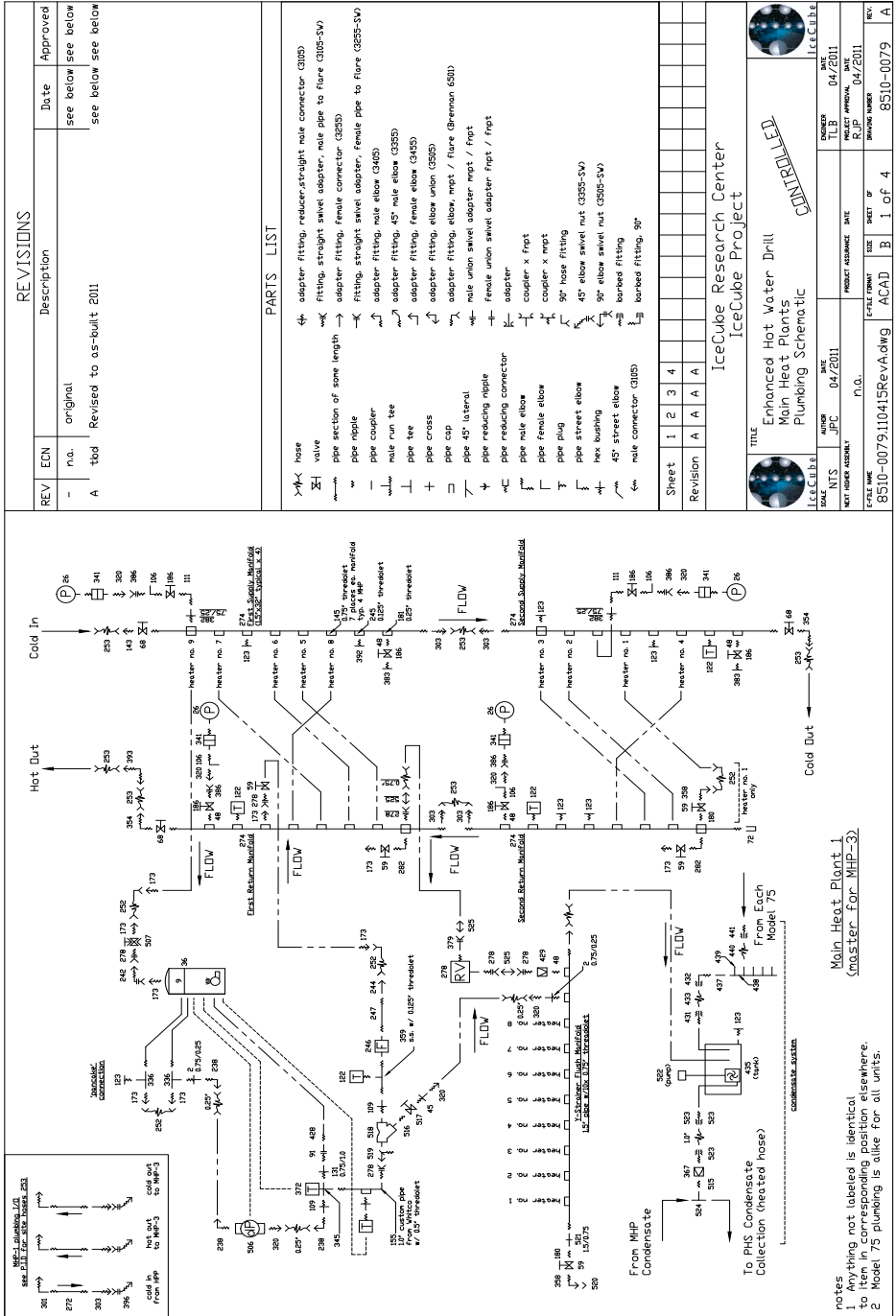


Figure 2.76 MHP1 plumbing schematic



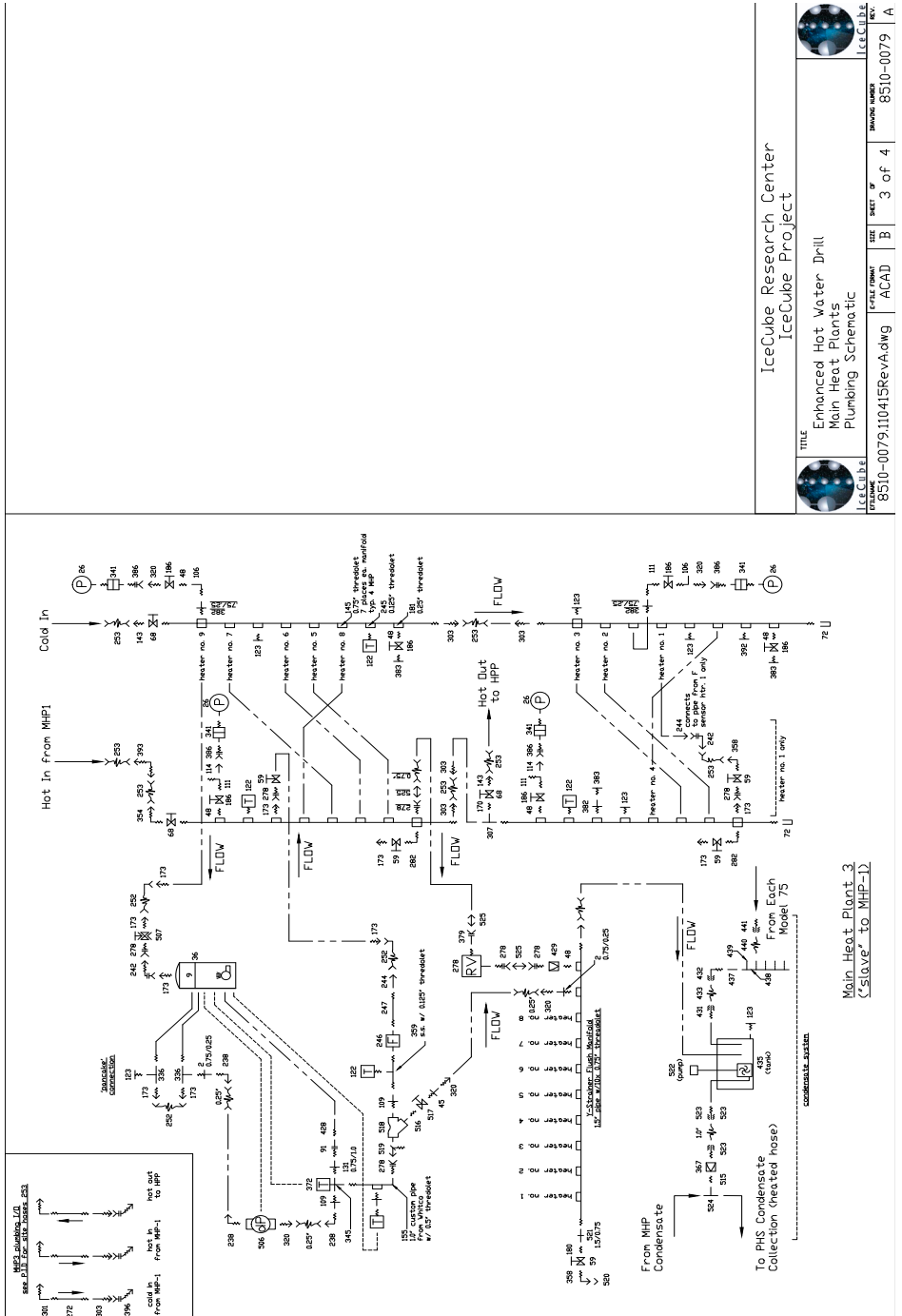


Figure 2.78 MHP3 plumbing schematic

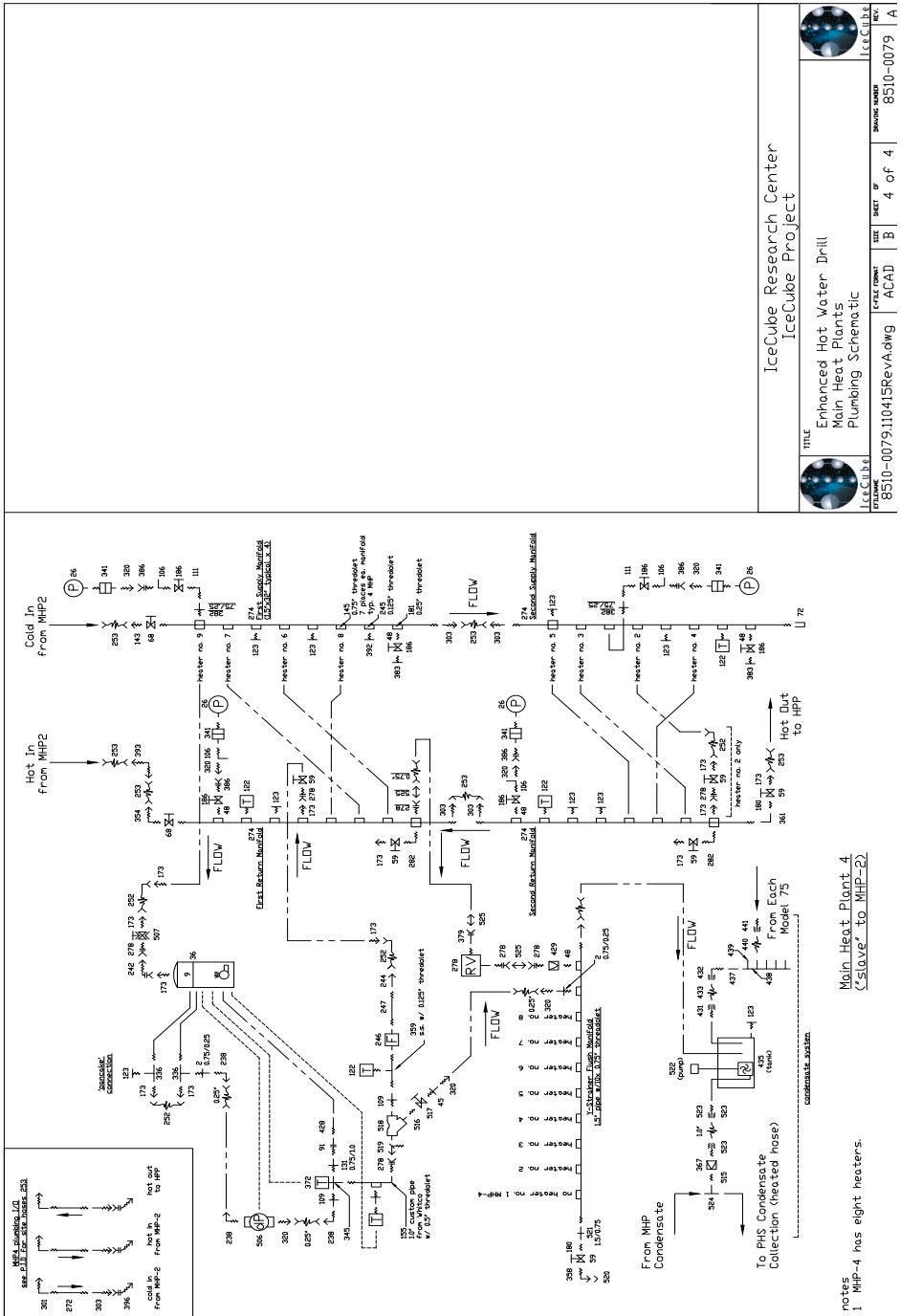


Figure 2.79 MHP4 plumbing schematic





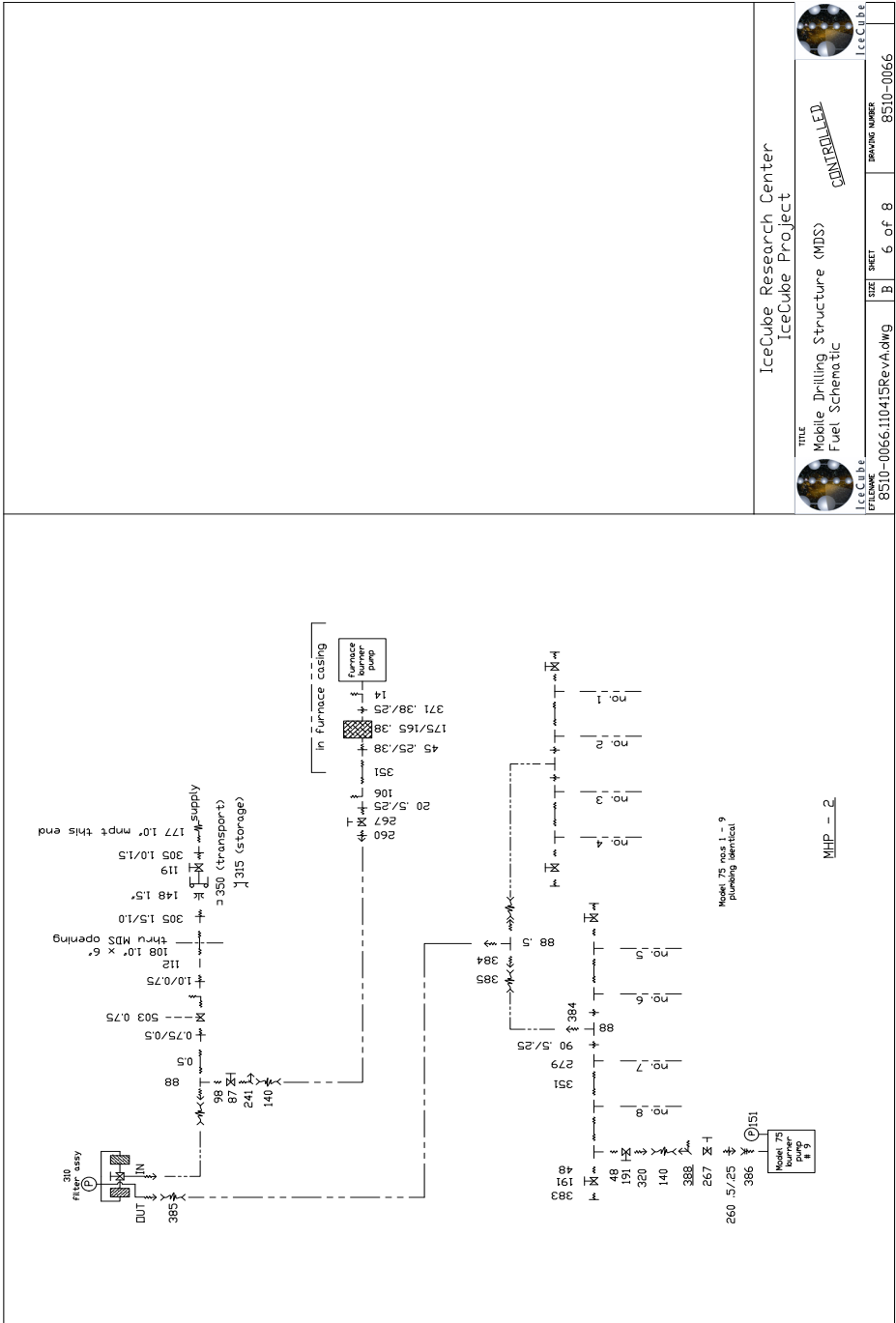


Figure 2.81 MHP2 fuel plumbing schematic

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TITLE  
 Mobile Drilling Structure (MDS)  
 Fuel Schematic

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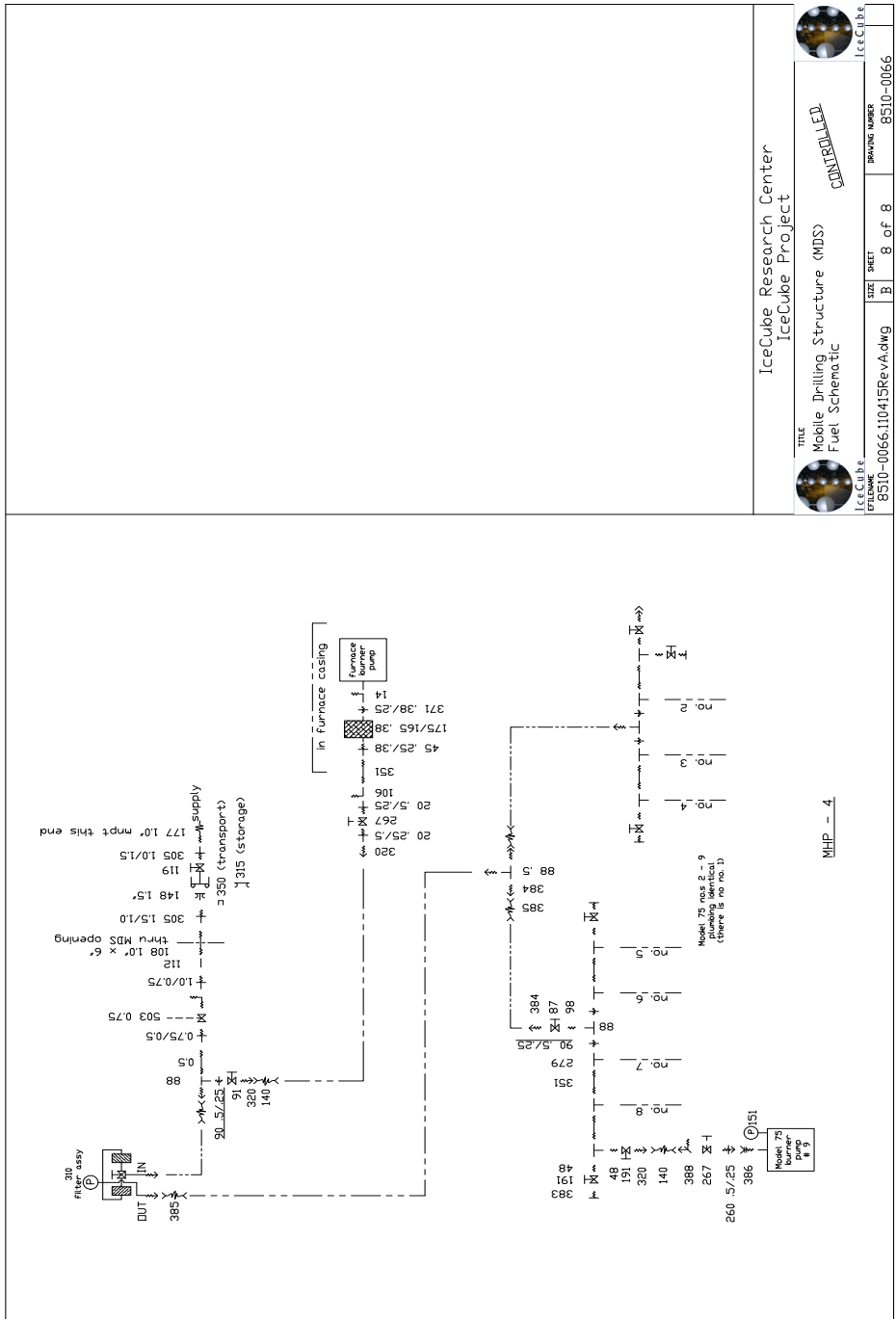
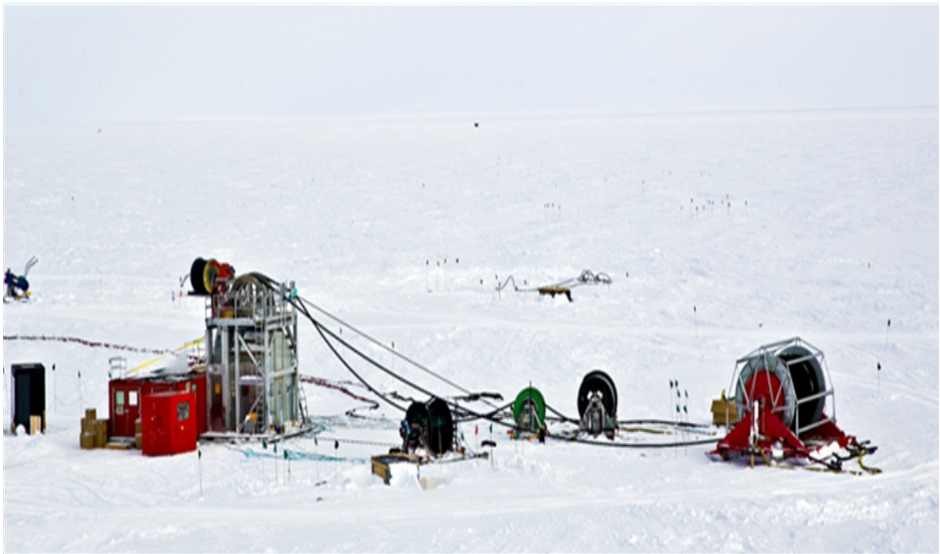


Figure 2.83 MHP4 fuel plumbing schematic

## 2.4.9 Tower Operations Site (TOS)

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The TOS acronym is a little confusing. It stands for Tower Operations Structure and Tower Operations Site. The Tower Operations Structure is composed of two joined ISO units and an adjoining tower. The two ISO's form an enclosed double-wide unit divided into designated work spaces. It contains an electrical components closet, a computer room and a workspace for storing and preparing DOMs for deployment. The other distinct section of the TOS is The Drill Tower. The tower is essential in providing space for placement and extraction of the EHWD and the submersible pump as well as providing an area in which to properly deploy the DOM's into the ice. All hole drilling activities and deployment of in-ice instrumentation are monitored, controlled, and performed from the computer room. The Tower Operations Site is composed of the Tower structure and containers, as well as the reels, as shown in Figure 2.84.



**Figure 2.84** Tower Operations Site and reels

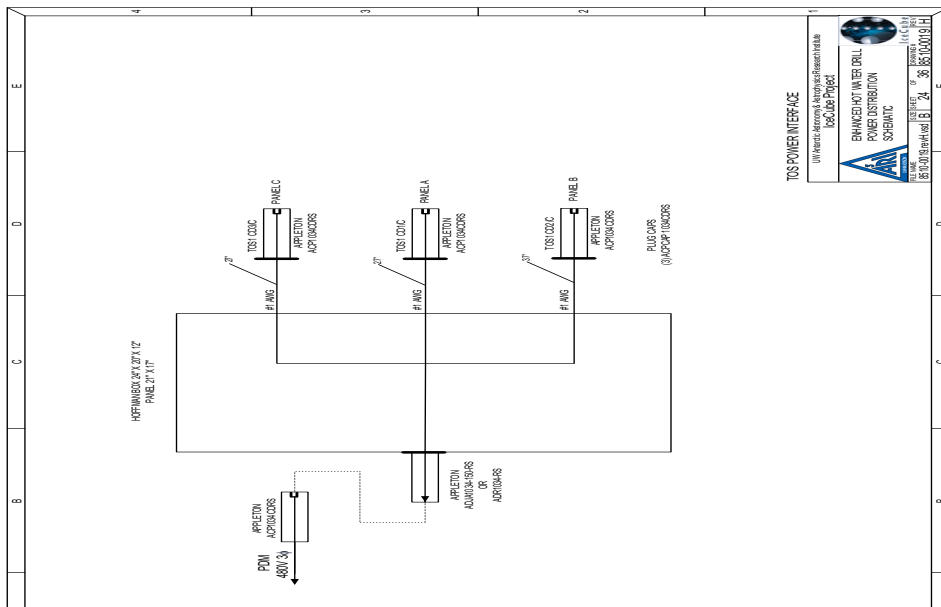
The TOS is mated to the tower prior to the commencement of drilling operations. The two components are assembled directly atop the predrilled firm hole. This is done with the aid of heavy equipment, such as a D-7 or D-8 dozer. The combined weight of the dual module assembly is 35,000lbs. The TOS is positioned first at an established hole location in a predetermined orientation. The tower is then moved into place against the TOS and the two structures are mated with large ratchet straps. Once the TOS has been mated to the tower the more sensitive electrical connections can be made. Among the connections are load cells, payout encoders and the E-stop cabling. A 100A power feed from the PDM provides the TOS with 480V three phase electrical power. A portable

fuel tank positioned outside the TOS provides fuel for the furnace, which provides the structure's primary heat. Four - 4kW electric heaters also help warm the TOS. Communications cables are run from the DCC.

The electrical closet is where the Unico motor drives are located. They are 1@50hp, 2@20hp, 2@10hp and 3@3hp. Dynamic braking resistors, also located in the electrical closet, help release energy accumulated by the reels in the form of heat.

Figure 2.85 is a schematic of the TOS power interface panel. The original TOS design had 3 feeder cables feeding 3 separate circuits in each TOS. In the field, it was determined that one cable is able to supply all the power requirements for each TOS. The power interface panel was therefore required to feed all three circuits in the TOS from the one feeder cable.

Figure 2.86 to Figure 2.89 are the electrical schematics for TOS1, while Figure 2.90 to Figure 2.93 are the electrical schematics for TOS2. The schematics for each TOS should be very similar, however the complete set of diagrams are shown for completeness.



**Figure 2.85** TOS power interface panel

Click on the video link below to watch an overview of the Tower Operations Site.

[Tower and Tos Overview with Audio.mp4](#)

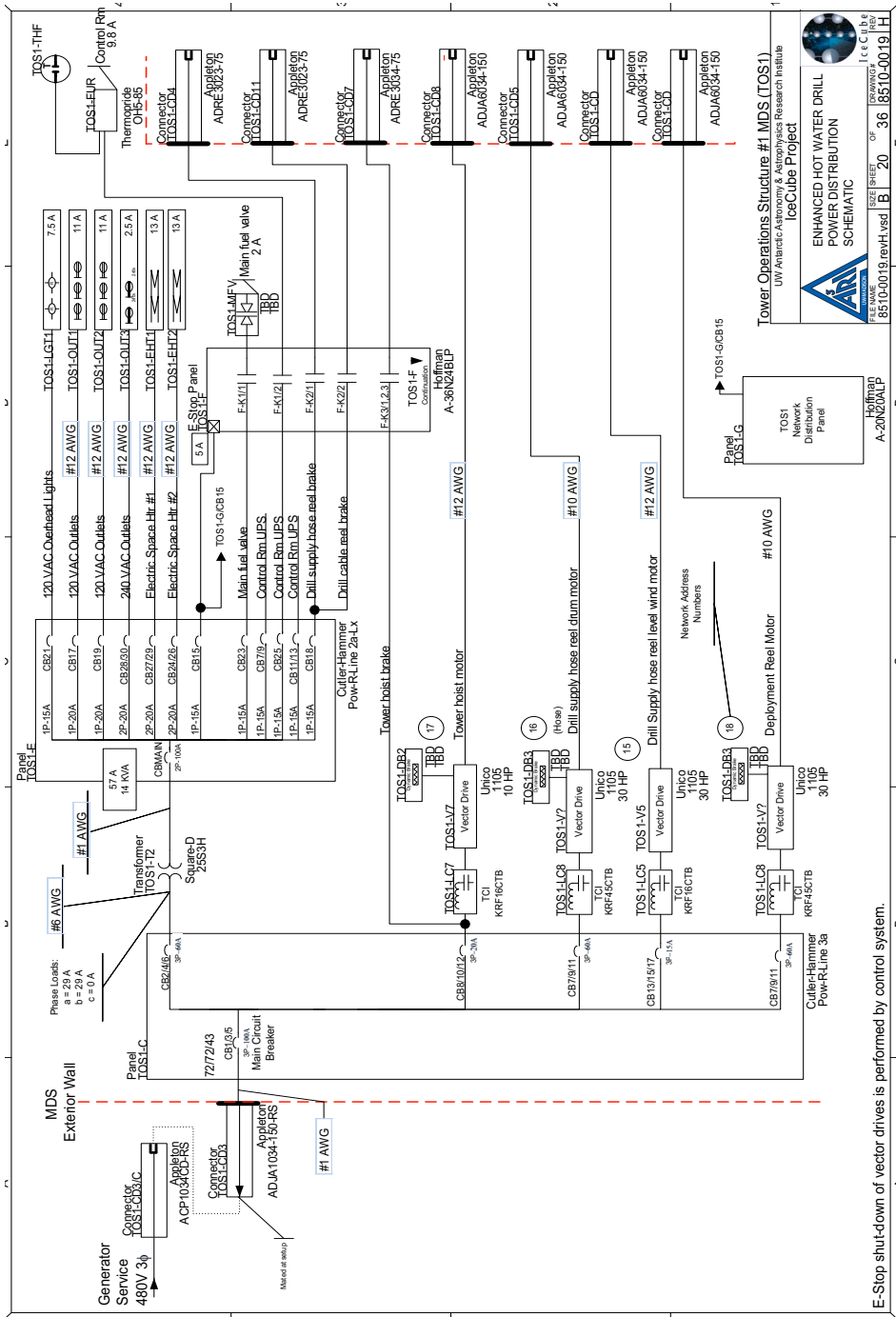


Figure 2.86 TOS1 electrical schematic, sheet 1 of 4







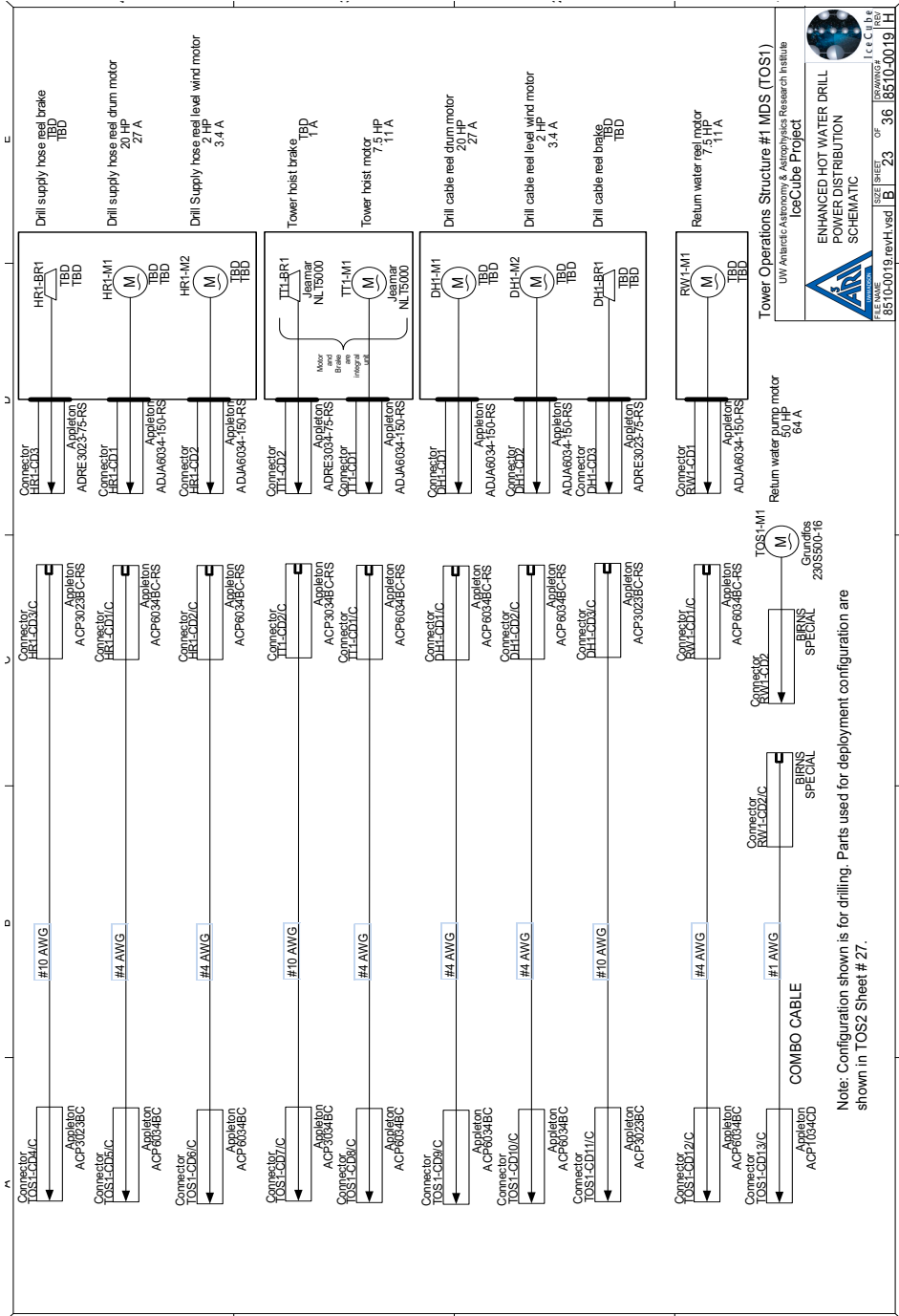

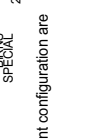


Figure 2.89 TOS1 electrical schematic, sheet 4 of 4


  
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 OF: 36
   
 DRAWING: 8510-0019
   
 DATE: 18510-0019

Tower Operations Structure #1 MDS (TOS1)
   
 UW Antarctic Astronomy & Astrophysics Research Institute
   
 iceCube Project
   
 ENHANCED HOT WATER DRILL
   
 POWER DISTRIBUTION
   
 SCHEMATIC



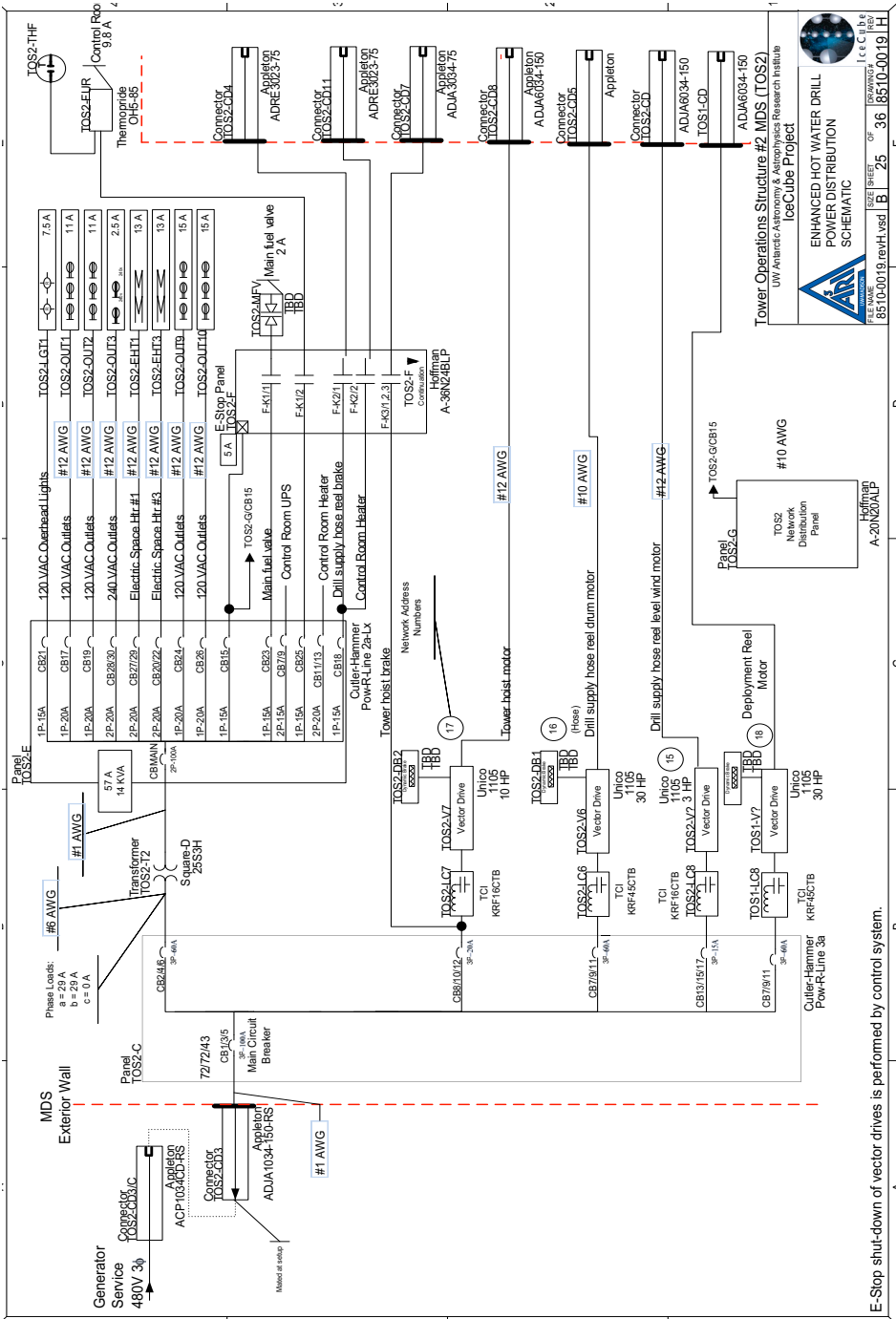


Figure 2.90 TOS2 electrical schematic, sheet 1 of 4





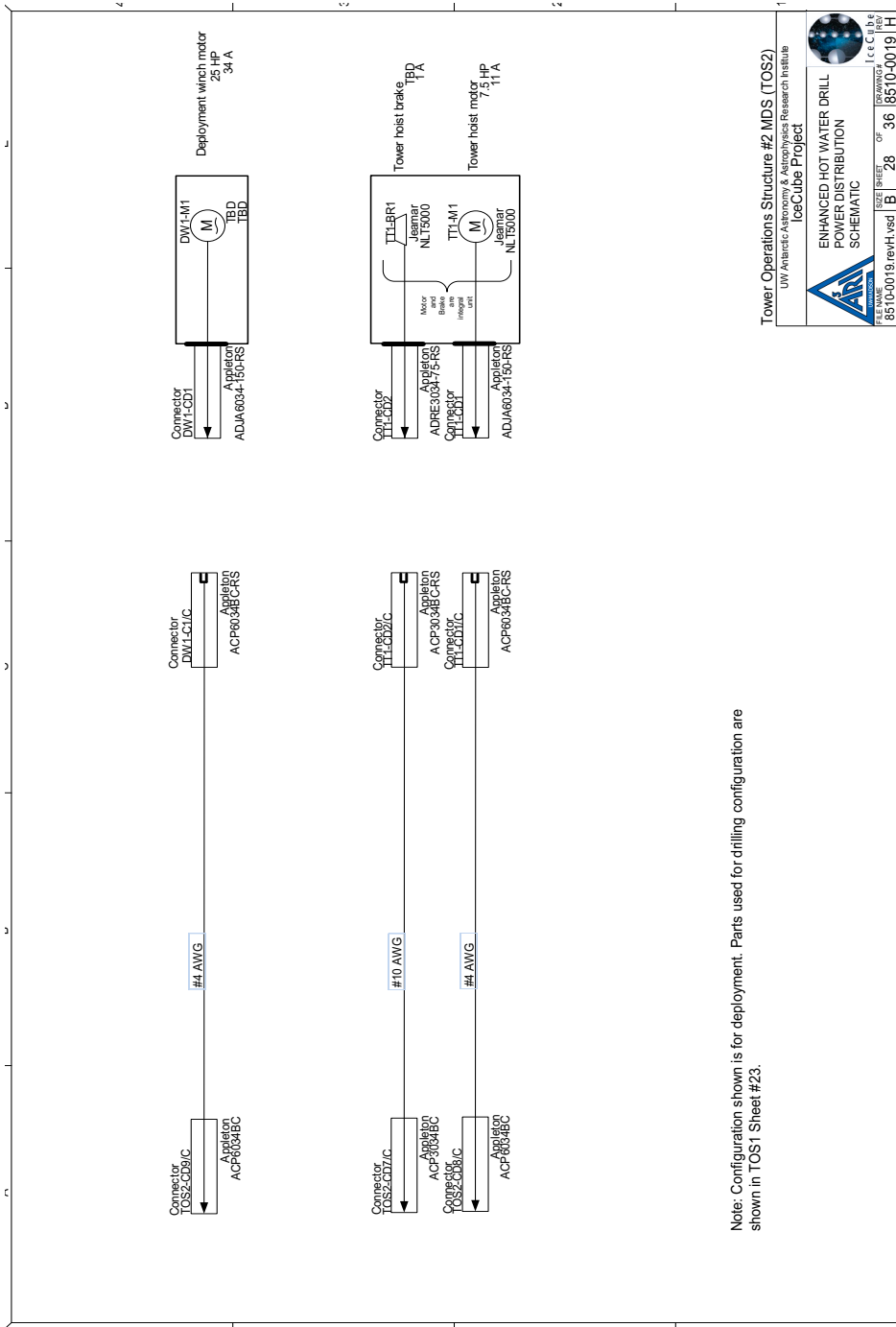


Figure 2.93 TOS2 electrical schematic, sheet 4 of 4

Note: Configuration shown is for deployment. Parts used for drilling configuration are shown in TOS1 Sheet #23.

Tower Operations Structure #2 MDS (TOS2)  
 UW Antarctic Astronomy & Astrophysics Research Institute  
 IceCube Project

ENHANCED HOT WATER DRILL  
 POWER DISTRIBUTION  
 SCHEMATIC

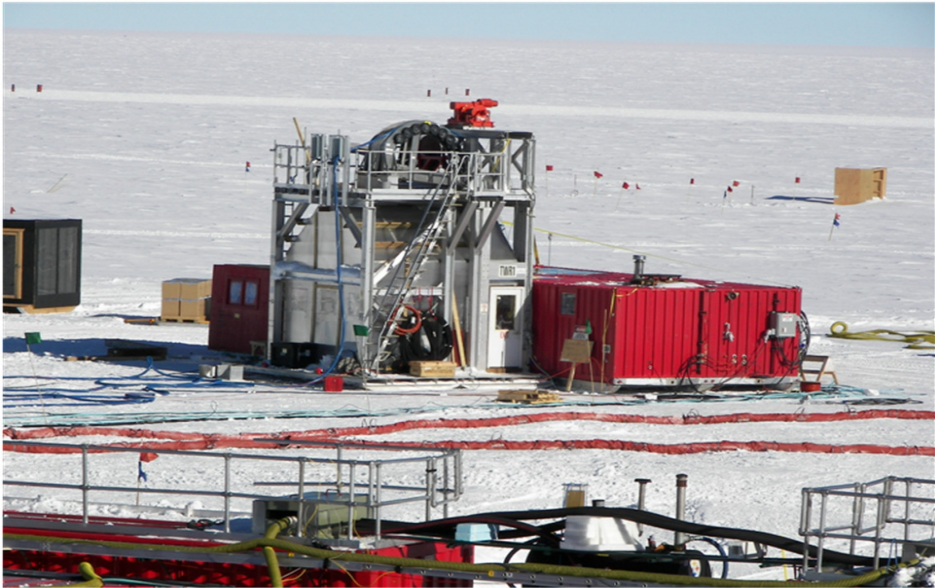


FILE NAME: 8510-0019.revH.vxstd | DRAWING: 36.18510-0019 | 1 of 1  
 SIZE: SHEET: 28

## 2.4.10 The Drill Tower

---

The drill tower, shown in Figure 2.94, is the structure within which the hot water drilling occurs. It is directly connected to the TOS and is integral with the TOS infrastructure. Its purpose is to provide a sheltered platform for the entire drilling process as well as the deployment sequence.



**Figure 2.94** Tower (crystal palace) and TOS

The tower is a two-story aluminum frame sided with transparent panels. It is mounted on skis for convenient moving. Black plywood 'tool boards' line the inside walls to absorb solar heat. A 5000lb capacity overhead tower hoist assists in drill and deployment operations. Mounted on the ceiling is an overhead bridge chain hoist useful in many applications. Engineered anchor points are located on the floor and ceiling. In the floor is an opening conforming roughly to the size of a predrilled firm hole. The floor penetration is protected by a kick-plate and cover. An electrically powered capstan winch is mounted to the exterior deck to aid in pulling cable and hose over the sheave.

The top deck of the tower is accessed via Lapeyre style stairs. Safety features of the tower include railings and toe-boards. The upper deck provides access to the hose crescents (both main and return water hoses) and the main cable sheaves. The primary crescent is designed to conduct 3.7"O.D. hose without jeopardizing the bend radius. The secondary crescent routes the return water pump combo cable. The load cell and payout encoders are mounted here.

E-stop/Reel stop switches are positioned at various locations inside, outside and on top of the tower.

## 2.4.11 Fuel tower

---

The fuel tower/day tank, shown in Figure 2.95, is a 300 gallon; single wall stainless steel tank built to NFPA 30 and UL 142 specifications. The tank has a fuel level sight gauge, and manual filler cap. The tower and tank incorporate a containment basin with adequate capacity for containing fuel leaks. The day tank is a bottom feed, tank mounted on an adjustable height tower, allowing the ability to maintain optimum head pressure.



**Figure 2.95** Fuel tower/ day tank

**Warning:** **Fuel manifold pressure should never exceed 2 psi**

The tank has two feed manifolds, shown in Figure 2.96, with eight 1 inch ports with ball valves and 2 gauge ports with ball valves. One return line manifold, and two electric motor driven vane pumps for filling the day tank from an external fuel source with an analog fuel meter for recording fuel usage.



**Figure 2.96** Fuel tower feed manifolds

The Fuel Tower Control is split in three sections.

### 1 Fuel Tank

An enclosure, shown in Figure 2.97, mounted to the end of the fuel tower provides a tie point for sensor wiring, the interface cable connecting the fuel



tank back to the DCC and a pushbutton for manual fill of equipment. Sensor cables connect to the bottom of the fuel tank control enclosure.



**Figure 2.97** Control box at end of fuel tower

## **2** Between Fuel Tank & DCC

Two 480v power cables connect the motors on the fuel transfer pumps back to the Appleton power outlets on the power rail of the DCC. An interface cable connects the fuel tank enclosure with the Network distribution box in the DCC

## **3** Utility Closet of DCC

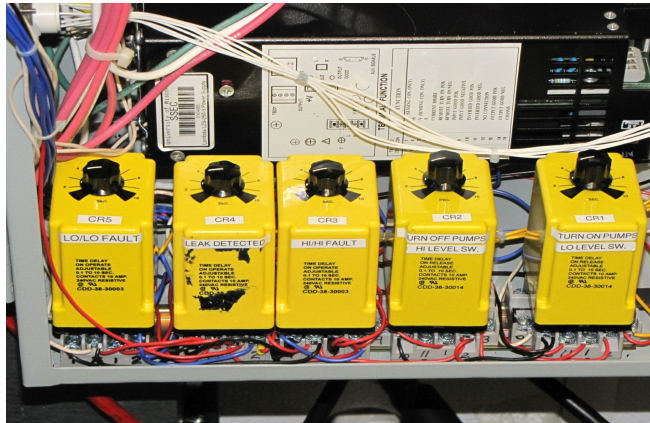
Motor starters for the pumps are in the E-stop enclosure in the utility closet of the DCC, shown in Figure 2.98. Five control relays, shown in Figure 2.99 are mounted inside the Network distribution box in the utility closet of the DCC. Lights, pushbuttons, a fault alarm and a selector switch are mounted on the cover of the Network distribution box.



**Figure 2.98** Fuel tank controls mounted on network panel inside DCC

Click on the video link below to watch an overview of the fuel tower.

Day Tank wt Audio.mp4



**Figure 2.99** Fuel fill control relays inside DCC network panel

The DCC drill computer displays fuel tank information but does not control the fuel fill process. This is controlled by the fuel tower controls. These controls have two modes of operation; Automatic and manual mode.

**Automatic operation:**

- Choose pump 1 or 2 in DCC utility closet
- Make sure breaker is "on" for selected pump motor
- You are done!!
- If Fuel level switch is calling for fuel, the selected pump will energize and fill the tank until the Hi level switch is hit, then pump will turn-off.
- Pump will remain off until fuel level drops below the Lo level switch, at which time the pump will turn on.
- This sequence will repeat all season.

**Manual operation**

Manual fill is used when for some reason teh automatic fill system isn't working, or refueling of vehicles and other equipemn is required.

- Push "Manual Fill" button on black control box
- If tank is not full, the pump will start
- Fill the 287 or 953
- Stow manual fill spout and do nothing
- Fuel level in tank will rise to the "High" level and the pump will turn off.

## **Faults**

- Three sensors can cause faults in the fuel fill system
  - “Hi/Hi” Level Switch
  - “Leak Detect” Switch in the Catch basin
  - “Lo/Lo” Level Switch
- In case of a fault
  - Any fuel pump energized turns off
  - An audible alarm in the DCC utility closet sounds
  - The computer display indicates a problem

## **Fault Recovery**

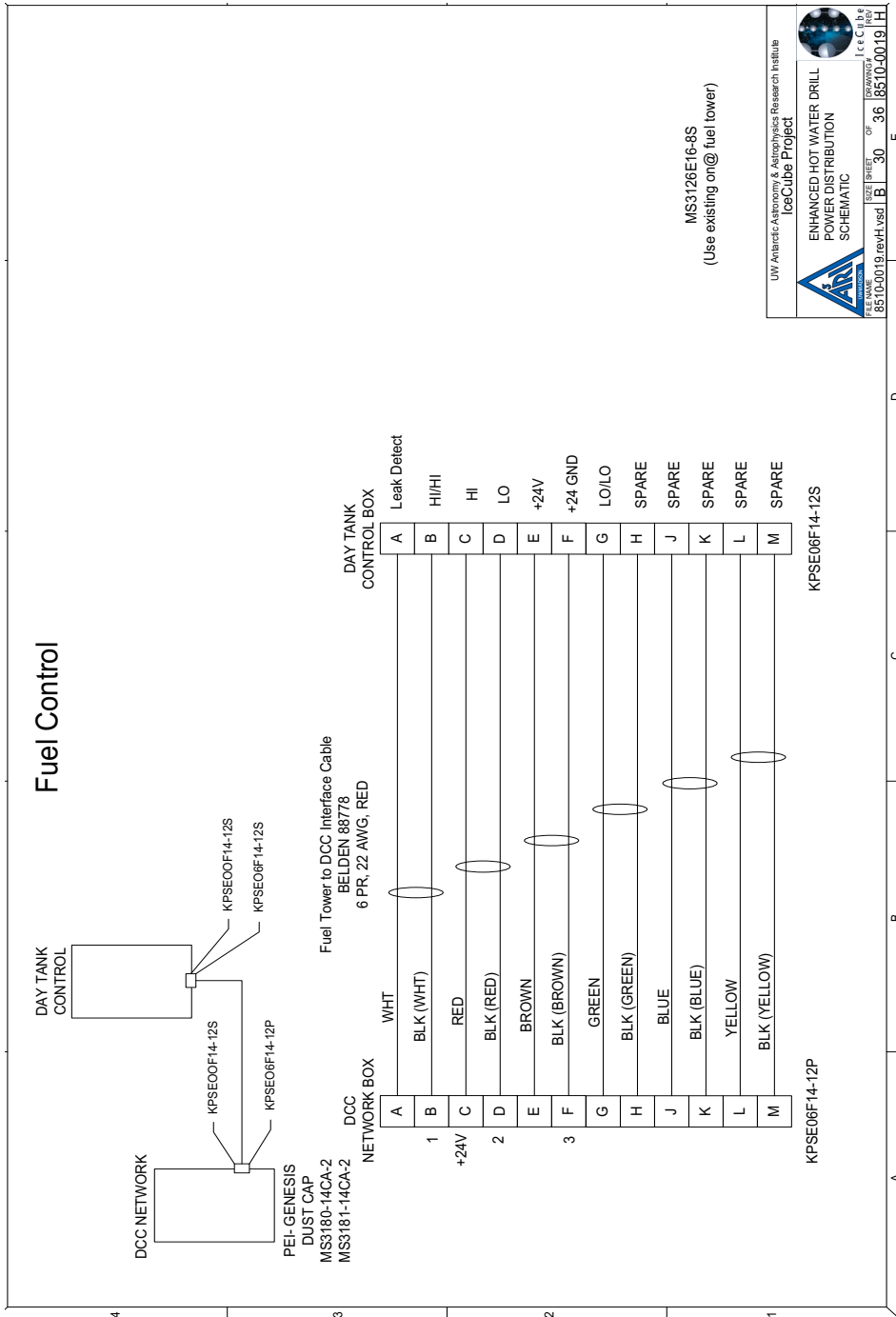
- Determine what caused the fault by looking in the catch basin and at the visual fuel level
- Throw the switch on the fuel control to silence the alarm
- Clear the fault causing conditions
  - The control can't be reset until the fuel level falls below the Hi/Hi switch or the catch basin is emptied
- Reset the Control
  - Press yellow button on Network box in DCC utility closet for 2 seconds
  - Throw switch on network box door to enable alarm

Click on the video link below to watch an overview of the fuel tower (day tank) controls and components.

Day Tank controls and components.mp4

Figure 2.100 and Figure 2.101 are the fuel tank tank electrical schematics, while Figure 2.102 is the fuel plumbing schematic.





UW Antarctic Astronomy & Astrophysics Research Institute  
**ICECube Project**

**ENHANCED HOT WATER DRILL  
POWER DISTRIBUTION  
SCHEMATIC**

DRAWING OF ICECube  
REV 85100079.rev1.vsd | B | 30 | 36 | 8510-9019 | H

**Figure 2.101** Fuel system electrical schematic, sheet 2 of 2

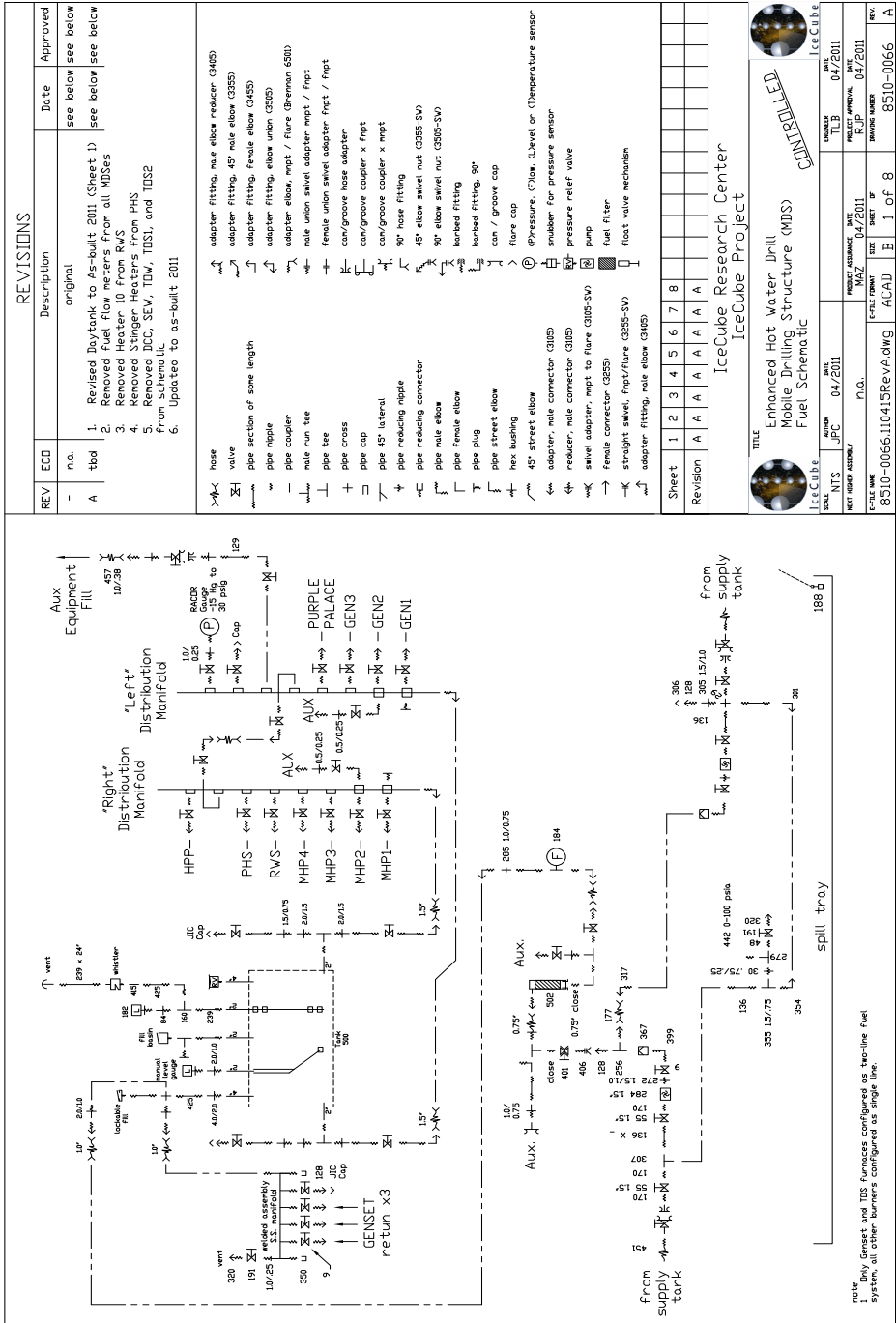


Figure 2.102 Fuel day tank fuel schematic

REVISIONS				
REV	ECO	Description	Date	Approved
-	na.	original.	see below	see below
A	tbd	<ol style="list-style-type: none"> <li>Revised Daytank to As-built 2011 (Sheet D)</li> <li>Removed Fuel Flow meters from all MIDSES</li> <li>Removed Heater ID From RWS</li> <li>Removed Heating Element From RWS</li> <li>Removed BCC, SEV, TDW, TDS, and TDS2 from schematic</li> <li>Updated to as-built 2011</li> </ol>	see below	see below

↗	hose	↗	adapter fitting, male elbow reducer (3MS)
↘	valve	↘	adapter fitting, 45° male elbow (3MS)
↖	pipe section of some length	↖	adapter fitting, female elbow (3MS)
↙	pipe nipple	↙	adapter fitting, elbow union (3MS)
↘	pipe coupler	↘	adapter elbow, mpt / flare (Brennan 650)
↖	male run tee	↖	male union sleeve adapter mpt / mpt
↙	pipe tee	↙	female union sleeve adapter mpt / mpt
+	pipe cross	+	can/groove hose adapter
≡	pipe cap	≡	can/groove coupler x mpt
↗	pipe 45° lateral	↗	can/groove coupler x mpt
↘	pipe reducing nipple	↘	90° hose fitting
↖	pipe reducing connector	↖	45° elbow sleeve nut (3MS-SV)
↙	pipe male elbow	↙	90° elbow sleeve nut (3MS-SV)
↘	pipe female elbow	↘	barbed fitting, 90°
+	pipe plug	+	barbed fitting, 90°
↗	pipe street elbow	↗	can / groove cap
↘	hex bushing	↘	flare cap
↖	45° street elbow	↖	⊙ (Pressure, Flow, Level or Temperature sensor)
↙	reducer, male connector (3MS)	↙	sluider for pressure sensor
↘	reducer, male connector (3MS)	↘	pressure relief valve
↖	sleeve adapter, mpt to flare (3MS-SV)	↖	pump
↙	female connector (3MS)	↙	fuel filter
+	straight sleeve, mpt/flare (3MS-SV)	+	float valve mechanism
↗	adapter fitting, male elbow (3MS)	↗	

Sheet	1	2	3	4	5	6	7	8											
Revision	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

IceCube Research Center  
IceCube Project

SCALE	AUTHOR	DATE	ISSUE ASSIGNED	DATE	ISSUE APPROVAL
NTS	JPC	04/2011	N/A	04/2011	04/2011

FILE NAME	FILE EXT	SIZE	REV
8510-0066.110415RevAdwg	ACAD	B	1 of 8

8510-0066  
ICECUBE

## 2.4.12 Drill supply hose reel (DSHR)

---

The DSHR, shown in Figure 2.103, is a large sled mounted reel capable of storing 8800 feet of hose that, once attached to the EHWD allows for uninterrupted deep drilling. The reel is stocked with 2.5" I.D. 3.7" O.D. IVG hose. Once the SES has heated water to the appropriate temperature it is delivered to the hose reel and from there to the hole.

Hot, high pressure water is sent from the SES to the DSHR via the surface supply hose. From there the hose on the DSHR is led over the tower crescent and down to the drill head. By changing the plumbing arrangement around the drill hose, the drill can be placed in various modes to allow water circulation to continue in the system when drilling is not taking place. See the “Main Hole Drilling” chapter for further explanation.



**Figure 2.103** Main supply hose reel to the right. Return water hose reel is to the left

The DSHR gets its power from three electrical feeds at the TOS. The reel drive, level wind motors, and the brake are powered by independent electrical circuits and each motor has it's own dedicated power cable.

The massive reel has a dry weight of 35 tons. It is equipped with a large disc brake plus an E-stop system. The main drum is powered by a 20HP Unico synchronous motor (drive ratio 1023:1) gearbox & chain. The reel sports a hydraulic rotary union and inlet water manifold with pressure relief valve, burst disc and reel bypass port. Mounted in front of the drum is a Unico driven level wind, shown in Figure 2.104, synched with the drum speed and drum diameter. Since the hose overlaps multiple times, limit switches are positioned to control

the level wind. A side-mounted 'doghouse' encloses and protects the reel's external plumbing connections and valving.



**Figure 2.104** DSHR level wind system

Click on the video link below to watch an overview of the drill supply hose reel.

## Drill Supply Hose Reel.mp4

### 2.4.13 Drill cable reel

---

The drill cable on the drill cable reel, shown in Figure 2.105, supports both the down-hole load of the drill and hose, and provides power and a communications link with the drill head.



**Figure 2.105** Drill Cable reel (DCR)



The reel, with cable, weighs approximately 4 tons. It boasts a large disk brake and releasable 1-way clutch. It is equipped with E-stop buttons, pull-cords, and hard-limit level wind switches. The level wind, shown in Figure 2.106, is synced with drum speed and diameter via Unico drive logic.

The main drum is driven by 20 HP fully enclosed Unico synchronous motor, final drive ratio 552:1 (gearbox). The reel currently holds 3300 meters of Cortland cable. A slip ring keeps electrical connections from rotating inside the drum axle.



**Figure 2.106** DCR level wind and safety E-stop trigger wire

Click on the video link below to watch an overview of the drill cable reel.

## Drill Cable Reel.mp4

### **2.4.14 Return water hose reel**

---

The return water hose reel, shown in Figure 2.107, holds the hose that transports water from the return water pump to the surface.

Its approximate weight is 9280lbs. It has a disc brake and releasable 1-way clutch. The reel currently holds 400 ft of IVG Main Drill Hose. The main drum is driven by a 7.5 HP Powertec synchronous motor. The reel has a hydraulic rotary union and outlet water manifold with reel bypass port to allow replumbing and valving to place the system in bypass mode. This maintains water circulation in the hose system when there is no drilling taking place. See the “Main Hole Drilling” chapter.



**Figure 2.107** Return Water Hose Reel

## **2.4.15 Return water cable reel**

---

The return water cable reel, shown in Figure 2.108, supports the weight of and supplies power and a communications link to the return water pump.



**Figure 2.108** RReturn water cable reel

The reel and cable weighs approximately 3 tons. It sports a disc brake and releasable 1-way clutch.

The reel is currently holding approximately 400 ft of Birns combo cable. The main drum is driven by a 2 HP Powertec synchronous motor, final drive ratio 14:1 with a selectable 1:1 or 3:1 gearbox. It is also equipped with an electrical slip ring, providing connections for low voltage signal and 480 VAC 3-phase power. The slip ring is not shown in this photo, but normally attached where the connector exits the drum axle.

## **2.4.16 Rodwell hose reel**

---

Rodwell Hose reel is a split drum hose reel located in the end of the RWS building. The Rodwell hose reel carries the hoses that supplies water to the Rodwell and carries the feed hose from the Rodwell pump. The reel has enough capacity for two, 1-1/2 inch ID hose by 350 ft in length. Water is fed in through two rotary unions feeding in on each end of the reels axle. The reel is chain driven through a reduction gearbox with a 460 volt AC electric motor, controlled by a Unico brand high frequency motor controller located in the RWS utility closet. Operation is achieved through a hand held pendant also located in the RWS utility closet. Braking is accomplished by a spring disc brake, hydraulic controlled with resettable reel stops located at the reel and the pendant.

## **2.4.17 Rodwell Cable Reel**

---

Rodwell cable reel is a skid mounted reel that carries the combo cable. The cable that carries power to the Rodwell pump, carries the signal for instrumentation in the Rodwell, and carries the down hole weight load. The Rodwell reel is staged on the outside of the RWS building and secured to the RWS building with chains to stop unintended movement of the reel. The RWS cable reels have enough capacity to carry well more than the 350 feet of cable we need for operating a Rodwell. There is a slip ring on the axle side to allow operation of reel without disconnecting the combo cable. The reel is powered by a 460 volt 3ph electric motor, gear reduction, and controlled by a Unico brand high frequency motor controller located in the RWS utility closet. Controls and brakes are the same as the Rodwell hose reel. The Rod Well Cable reel is identical to the Return Water Cable Reel shown in Figure 2.108.

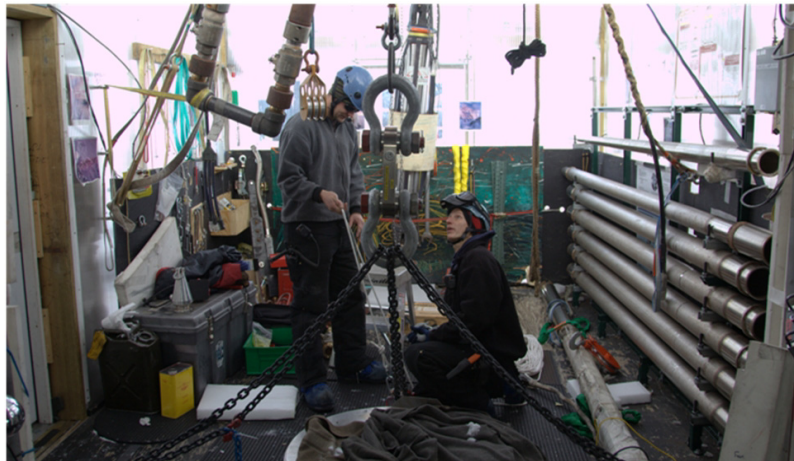
## 2.4.18 Weight stack

---

The weight stack serves a couple of purposes. One is to add extra vertical weight to the drill head in order to straighten the hose out and guide it as straight as possible in the hole during drilling. The other is to add distance between the drill head and nozzle in order to deposit the hot water far enough ahead of the drill head, that the hole has had a chance to expand to a wide enough diameter that the drill head can pass through the hole (see chapter 1 for further explanation).

The weight stack is made of stainless steel with an insulating hollow nylon inner core in order to insulate the water from the outer steel wall and therefore the cold water in the drill hole.

When fully assembled and mounted beneath the drill head, it is about 75 ft in length and weighs about 900lbs. It is composed of 6 flanged sections joined by mechanical 'clam shell' couplings and must be assembled and disassembled at the beginning and end of each hole. The bottom-most section is tapered, reducing the 5" OD of the stack to about a 2" OD at the nozzle, which has a .75" aperture. It is normally stored on specially designed racks in the tower, as shown in Figure 2.109. See "Main Hole Drilling" Chapter for further details.



**Figure 2.109** Weight stack on storage rack to right of photo

Click on the video link below to watch an video detailing the weight stack assembly procedure.

[Installing the weight stack.mp4](#)

## 2.4.19 E-stop/ Reel stop system

---

### 2.4.19.1 E-Stop System

The E-stop system, a safety system that when activated will do the following:

- Halt all equipment motion
- Removes drive power from all winches, reels, and hoists
- Applies brakes
- Stops the High Pressure Pumps
- Halts flow of fuel to burners and furnaces

The E-stop/ Reel stop system does not stop the generators or the charge pumps that supply the high pressure pumps. This is to allow low pressure water to continue flowing through the system to cool down the heaters and prevent any possible overheating condition from developing as a result of hot water remaining stagnant inside the heater coils.

The E-stop system consists of red slap buttons located throughout the SES and TOS. This system has two operating modes, global and local. Giving the E-stop system the ability to be tied to all components of the EHWD (global mode) or being able to operate the SES and TOS's separate (Local mode). The reset stations are in the DCC and TOS's. Reset consists of finding the red slap button that was tripped and resetting it, then resetting one of the control boxes.

### 2.4.19.2 Reel Stop System

The reel stop system is used to stop reel movement and apply the reel brakes at a local level, in case of emergency, requiring quick stopping of a reel. For example: at the drill tower, a reel stop will stop all reels around the tower but not affect a reel at the RWS.

Reel stops are accomplished with yellow slap buttons located around the reels and towers, by one of the reels safety micro switches, or by the computer registering a fault through the load cells. The reel stop is reset by first clearing the fault or resetting the reel stop slap switch. When the fault is cleared, resetting the reel stop panel on in the TOS/or pendant at RWS will allow the reels to operate again. After the Reel stop panel is reset all brakes on effected reels can be pumped up until they release, then normal operation can begin.

Click on the video link below to watch an overview of the E-Stop ssystem.

[E-Stop Overview.mp4](#)

Figure 2.110 to Figure 2.114 detail the E-stop system block diagram and give an overview of the E-stop block diagram and schematics for the E-stop system in the MDS' at the seasonal equipment site.

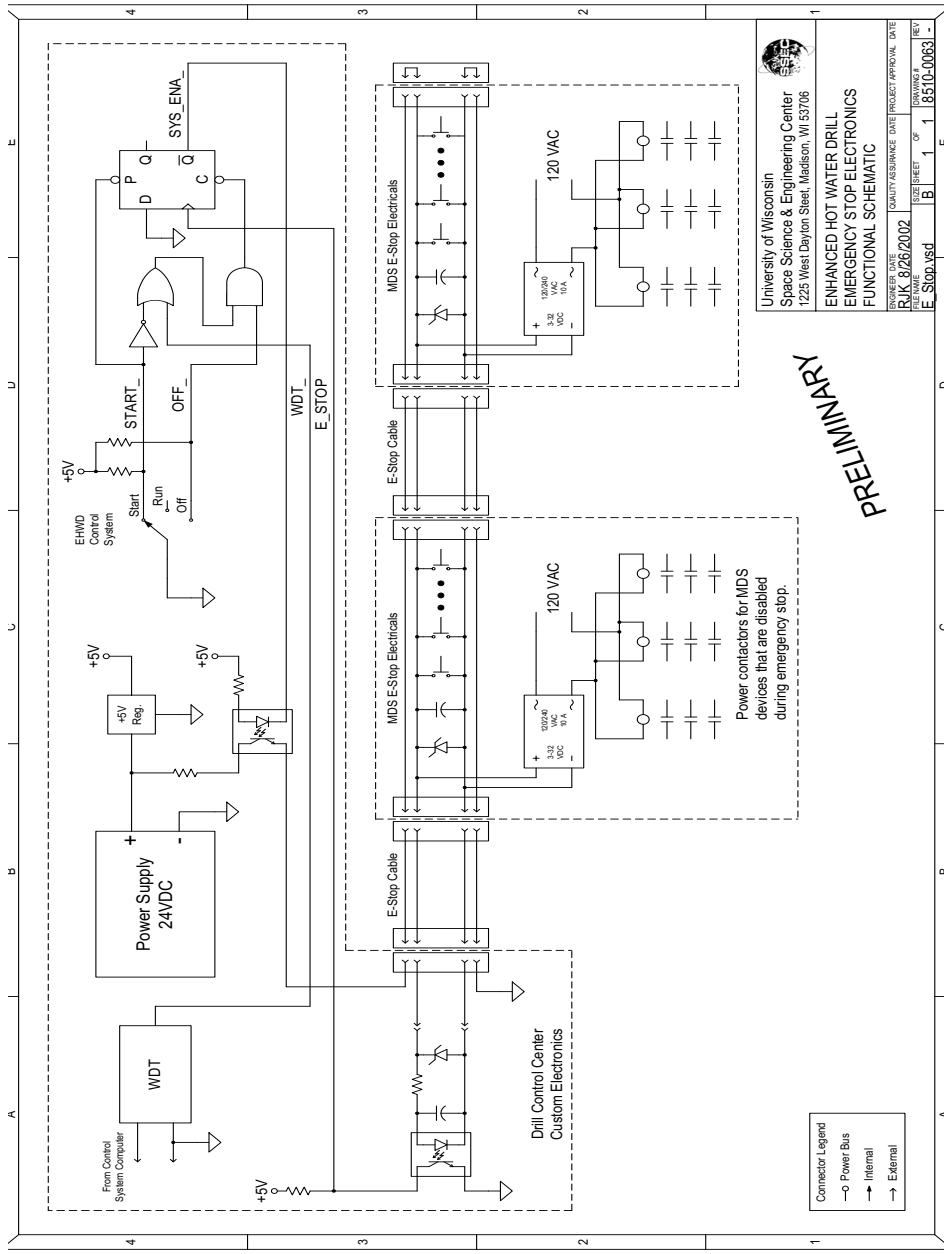
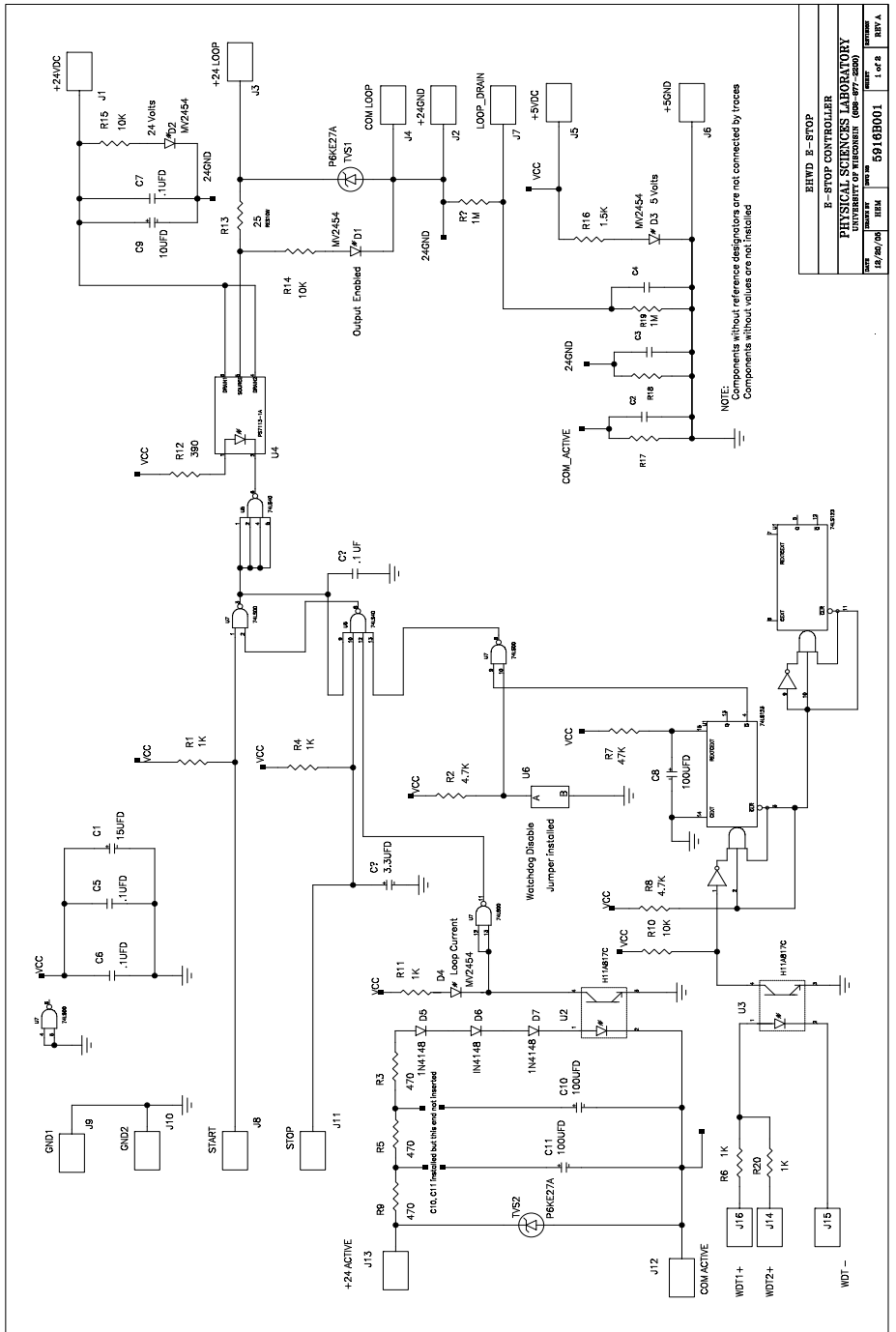


Figure 2.110 E-Stop/ Reel Stop system functional block diagram



REVISION		1 of 2	REV A
DATE		12/20/05	ITEM
PART NUMBER		5914B001	
E-STOP CONTROLLER			
PHYSICAL SCIENCES LABORATORY			
UNIVERSITY OF MISSOURI (606-497-2650)			

Figure 2.111 E-Stop controller schematic sheet 1 of 2

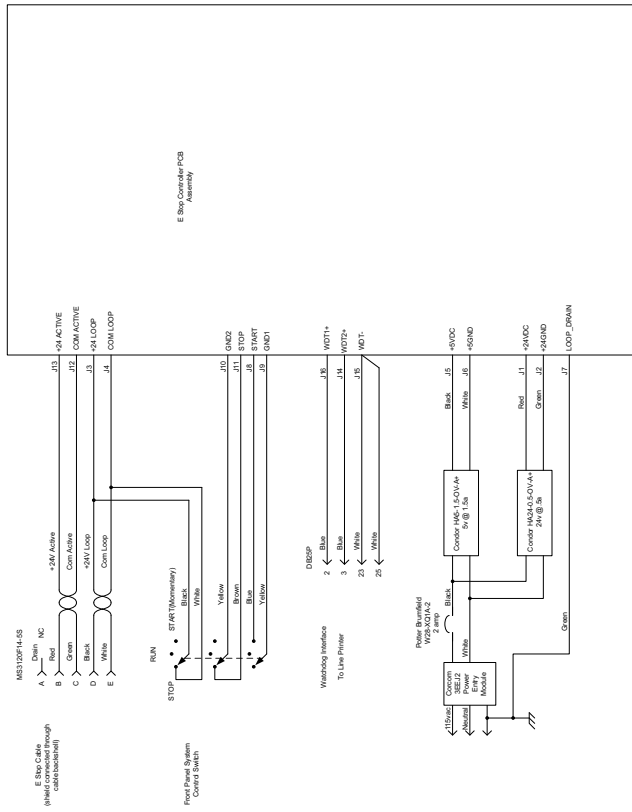


Figure 2.112 E-Stop controller schematic, sheet 2 of 2





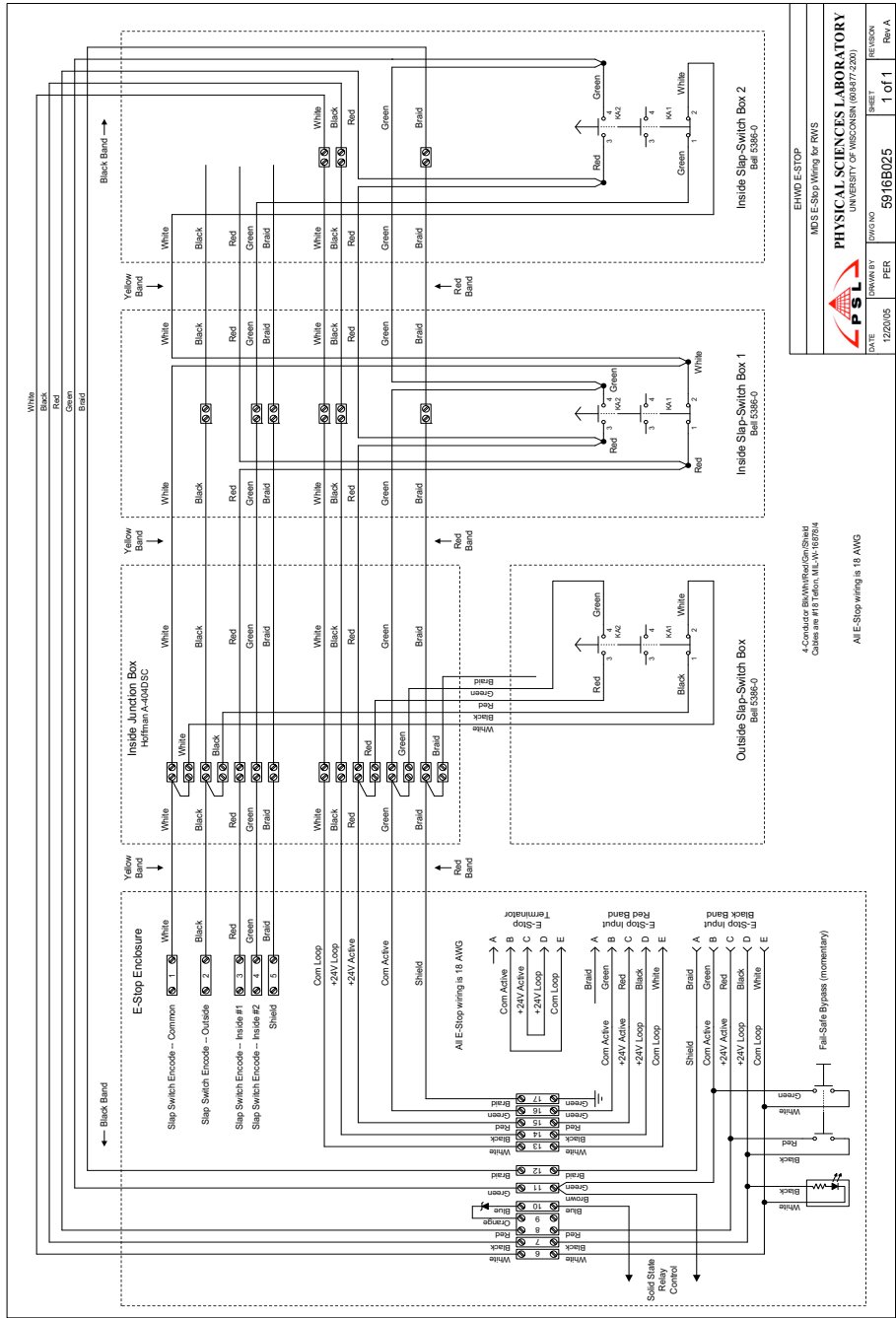


Figure 2.114 MDS E-Stop wiring for RWS

EHWD E-STOP		REVISION	Rev A
MDS E-Stop Wiring for RWS		DRAWN BY	5916B025
PHYSICAL SCIENCES LABORATORY UNIVERSITY OF WISCONSIN (608.877.2200)		PER	1 of 1
DATE	12/20/05	SHEET	1 of 1

4 Conductor Braid/White/Green/Black  
Cables are #18 (also, ILL. W-152934)

AE-Stop wiring is 18 AWG

## 2.4.20 Main drill hose

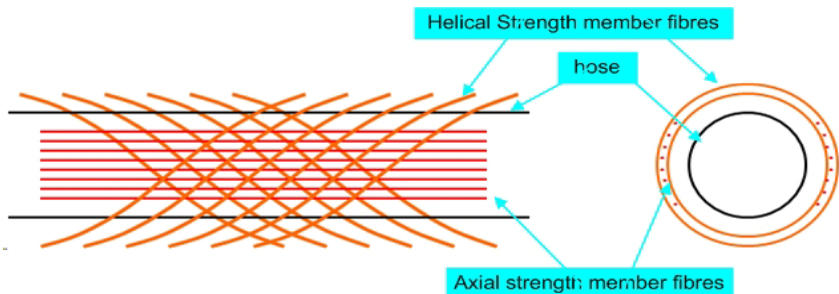
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The Main Drill Hose is the vessel by which the SES prepared hot pressurized water is delivered to the hole. It is custom designed for deep drilling operations and supplied by IVG, Italy. Hose specifications are as follows:

- ID = 2.5 inches, OD = 3.7 inches
- Each section 400 foot length
- Rated for simultaneous pressure, high temperature, tension, and bending
  - Pressure: 1000 psig
  - Temperature Range: 0-90C
  - Axial Tension: 1500 lb
  - Minimum Bend Radius: 42 inches
- EPDM rubber with Aramid fiber reinforcement (helical windings, bootstraps, and end reinforcement)
- YLW hose is made with low density EPDM (specific gravity < 1), GRN hose is a standard EPDM
- Swaged-on Victualic fittings

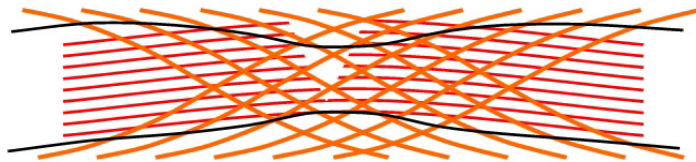
Each section is 400' long and is rated at 1000psi. There are 33 sections on the main hose reel. Victualic couplings are used to join hose sections. Strain reliefs installed at each coupling on the main hose protect the hose at these joints as the hose passes over any sort of bend, such as the crescent on the tower, or when wrapping onto the hose reel.

The hose is constructed of an EPDM inner tube and matrix wrapped around the fibre. A Kevlar or Aramid fibre is wrapped in helical layers around the hose, as shown in Figure 2.115, to carry the pressure load. Axial fibres running along each side of the hose, also shown in Figure 2.115, are designed to carry excess tension.



**Figure 2.115** Main drill hose construction

The specifications given above for pressure, axial tension and bend radius are numbers arrived at during testing, in order to minimise damage to the hose. The hose is rated for higher pressure, axial tension and smaller bend radius, **but not all at the same time**. It was found during testing that if these parameters were exceeded simultaneously and while the hose was hot, load is distributed unevenly across the axial fibres, causing them to break, as shown in Figure 2.116.



**Figure 2.116** Axial fibres breaking under excess load, resulting in hose necking

Once the axial fibres break, tension is transferred to the helical fibres, which contract like chinese fingers, causing the hose to neck, as shown in Figure 2.116.

This happens most often around the hose end fittings. The fittings cause the hose to bend at a higher bend radius than it was designed for, resulting in higher axial load. Coupled with the excess tension and heat, the axial fibres fail most often at this point. It is therefore important that the above specifications are not exceeded for the hose. To further aid in mitigating this problem, strain relief

fittings were designed to fit at the ends of these fittings to help minimise hose bending at these points.

Three different hoses are deployed during the season and are designated by their colors. Red indicates the first generation hose. Green signifies structural improvements that reduce necking. Yellow hose has the same structure as green but the hose has less density and is therefore more buoyant in water. Green and yellow hose lengths are used on the high pressure supply side of the drill (surface supply line and supply hose reel). The red IVG hose is used on the low pressure return.

## 2.4.21 System Safeties

---

The EHWD system safeties consist of electrical, computer, and mechanical safety systems.

### Electrical safeties

The electrical parts of the safety systems consist of three parts.

- 1 The utility wiring of the EHWD, meaning that all Utility wiring and appliances (for example GFCI outlets) are installed according to National Electrical Code.
- 2 The E-stop system, a safety system that when activated will shut down, mainly, high pressure pumps, heaters and environment furnaces and fuel flow to the SES building. The E-stop system consists of red slap buttons located throughout the SES and TOS. This system has two parts, global and local. Giving the E-stop system the ability to be tied to all components of the EHWD or being able to operate the SES and TOS's separate in a local mode. The reset stations are in the DCC and TOS's. Reset consists of finding the red slap button that was tripped and resetting, then resetting in one of the control boxes.
- 3 Reel stop, as the name implies the reel stops are used to stop reel movement and apply the reel brakes at a local level in case of emergency requiring quick stopping of a reel, for example at the drill tower a reel stop will stop all reels at around the tower but not affect a reel at the RWS. Reel stops are accomplished with yellow slap buttons located around the reels and towers, by one of the reels safety micro switches, or by the computer registering a fault through the load cells. The reel stop is reset by first clearing the fault or resetting the reel stop slap switch then when fault is cleared then resetting the reel stop panel on in the TOS/or pendant at RWS. After Reel stop panel is reset all brakes on effected reels can be pumped up until they release then normal operation can begin.

## **Mechanical safeties**

Mechanical safeties exist primarily on the water side of the EHWD for preventing over pressuring and fire suppression for the different systems. The mechanical safeties are of three types:

### Pressure relief valves:

These type of safety valves are the most common safety valves in the EHWD. They are used in both high and low pressure systems. The pressure relief valves are located in the following systems:

- 1** HPP, uses high pressure relief valves to protect from over pressuring high pressure pumps and plumbing.
- 2** MHP's, use High pressure relief valves to protect MHP high pressure plumbing.
- 3** RWS, uses low pressure relief valves to protect RWS plumbing.
- 4** PHS, use low pressure relief valves to protect PHS plumbing.
- 5** Generator three contains a low pressure relief valve for protection of the waste heat recovery system.

### Rupture Disk:

The plumbing manifold, contains a high pressure relief valve and a rupture disk for protecting from over pressuring the surface and drill hose. This provides a needed safety at the reel. Without this feature, it is hard for the pressure reliefs in the HPP and MDS's to react in time to an overpressure at the main hose reel.

### Carbon Dioxide fire suppression system:

Used in the MHP's, PHS, RWS, gen sets, and PDM.

## **Computer Safeties**

Computer safeties, provide safeties at many levels, including everything from environmental in the different MDS's to the load cell reading at the drill tower. So this is just a quick over view of safeties since the computer system is extensive, more detail can be found in the separate sections that cover Unico motor drives, the drill computers and heater section.

## 2.5 Heaters

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The main heaters in the EHWD are the primary thermal power source for drilling, providing 3.6 MW, or 77%, of the total thermal energy delivered to the drilling water. The main heaters are referred to as Model75s. Their design is of a large oil-fired heater commonly utilized in the high-pressure washing industry, such as carwashes, and has been modified to improve fuel efficiency, safety, and usability for application in the EHWD.

Some nominal operating specifications of the Model75 are shown in Figure 2.117 below:

Heat Delivered to Water	125 kW
Water Flow	7 gpm
Water Pressure	1000 psig
Delta Water Temp	67°C
Fuel Consumption	3.5 gph
Fuel Efficiency (HHV)	92 %
Dimensions	31" x 31" x 74"
Weight (dry)	1200 lb
Operating Supply Voltage	240 VAC 1-phase

**Figure 2.117** “Model 75” Heater specifications

### 2.5.1 Heater construction

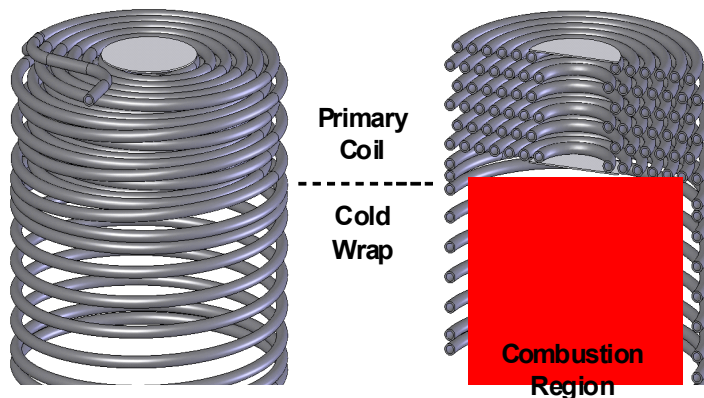
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Pumping options are very limited when the fluid is first heated to temperatures near the boiling point of water, and the options that are available are extremely expensive. This equipment issue essentially forces the pumping to occur first. Because the water is pumped to system pressure upstream of the MHPs, the heaters need to be designed for high pressure application. The hot water drill used in AMANDA addressed this problem by turning to the high-pressure cleaning industry. Whitco, a small family-owned business based out of Arkansas, had decades of practical experience in making high-pressure cleaning systems. Included in Whitco's arsenal of high pressure water heaters was the original diesel-powered Model75. Capable of about 100 kW, the original

Model75 was not only able to produce enough power for the AMANDA drill in limited numbers, but also maintained the simplicity, ruggedness, and dependability essential to easy maintenance and operation in an environment as demanding as the South Pole.

The original Model75, shown in Figure 2.118, is basically a spiraled steel coil with a central void in the lower half where combustion occurs. Water flows through coils that are heated both by radiation from combustion and convection from the combustion gases traveling through the coil array. The top of the coil consists of six spiraled layers constructed two at a time in the form of a "pancake" (spiraled out for one layer and then back in for the next). The bottom of the coil, referred to as the cold wrap, is simply a helix that both supports the weight of the upper primary coil section and absorbs heat from combustion occurring within its confines. The entire coil is surrounded by insulation and an outer painted steel shell. Combustion is made possible by a commercial-grade Beckett SF burner assembly that includes a fuel pump, blower, ignition coil, air tube and fuel nozzle. JP-8 jet fuel is consumed at a rate of about 3.5 gph.

### ORIGINAL MODEL75 HEAT EXCHANGER COIL



**Figure 2.118** Original Model 75 heat exchanger coil

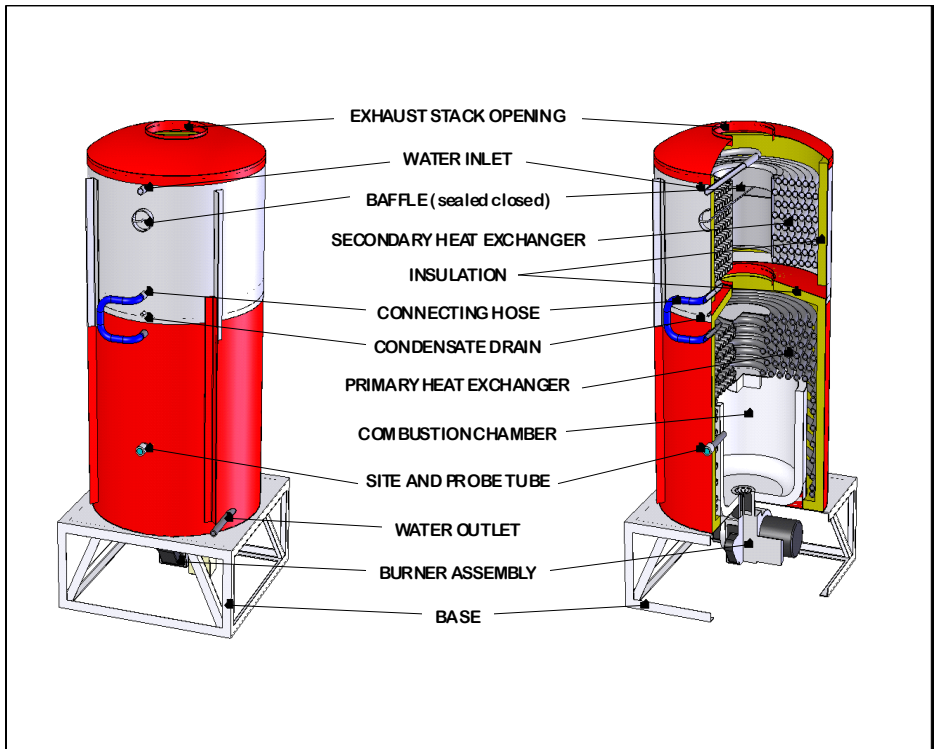
The original Model75 would also meet the power requirements and robustness of the EHWD in acceptable quantities, but at 77%, its fuel efficiency was still disappointing (using the lower heating value). The original Model75 underwent extensive modifications to improve its fuel efficiency.

Two major additions were made. The first was a combustion liner. This liner consists of a refractory combustion chamber surrounded by a stainless



steel shell and a refractory disk that is centralized directly above the combustion chamber. This combustion liner reflects radiant heat energy back into the combustion flame while at the same time insulating the combustion region, resulting in increased combustion temperatures and cleaner, more complete combustion.

The second was the addition of another complete coil assembly that absorbs much of the energy remaining in the exhaust gases by additional convection and condensing the moisture out of them. This condenser coil, or secondary coil, is constructed much the same way as the Primary coil in the original Model75 except that it is made of stainless steel to inhibit corrosion caused from being in contact with the condensate. Condensate, generated at a rate of over 2 gph, is collected on the top of what is the original Model75 shell and removed via a drain (there is a subsystem centralized in the PHS that is devoted to neutralizing and filtering the collected condensate from all the heaters and injecting it back into the main system). The coil is surrounded by insulation and a stainless steel shell. Figure 2.119 outlines much of the modified Model75's construction.



**Figure 2.119** Major components of the modified Model 75 heater used in the EHWD

The addition of the secondary condensing coil helps drop the exhaust gases from a combustion chamber temperature of 1114°C to a near-room-temperature

of 46°C, and the addition of both the coil and combustion chamber improve the heater's fuel efficiency to about 92% (using the higher heating value). Exhaust quality is also improved.

Some other additions include a site tube, or viewport, that allows for visual confirmation of a combustion flame (also doubles as an access port for measuring combustion chamber temperature) and a baffle that can be opened to bypass the combustion gases through the Secondary coil section. The baffles have since been sealed shut on all modified Model75s in the system to meet Code issues surrounding the maximum allowable gas temperature through the exhaust stacks.

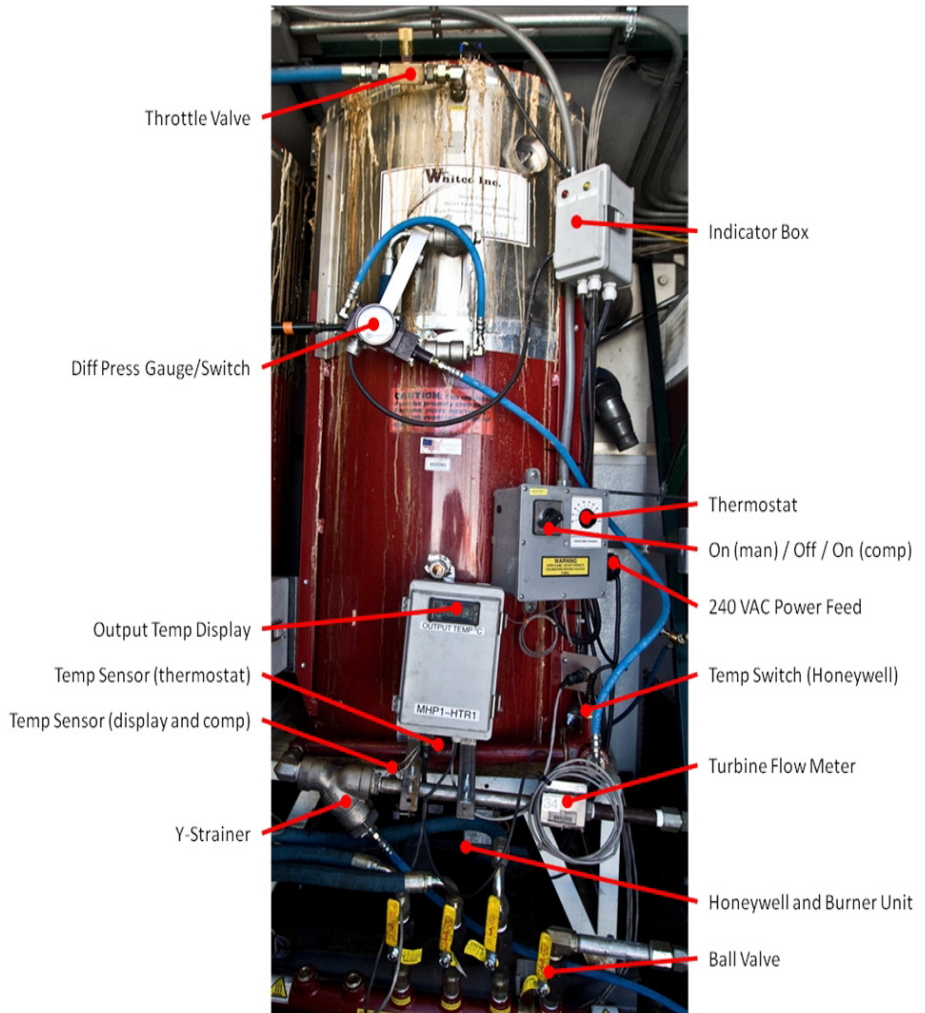
**Note:** For every gallon of fuel burned, 1.03 gallons of liquid water is produced in the form of water vapor. 37% of this water is condensed out in the Secondary section, at a rate of 2.3 gph.

## **2.5.2 Heater controls and safety systems**

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The control and safety systems of the Model75 are shown in Figure 2.120 and consists of manual valves, redundant temperature and flow sensors, a thermostat, and the EHWD computer control system. There is a temperature and flow sensor local to the heater controls, then another set of temperature and flow sensors that provide feedback to the EHWD control system and operator. The burner unit also has a temperature switch, flame eye, and Honeywell burner control. Due to the large amounts of stored energy during operation in the form of heat and pressure, it is essential to verify all aspects of the controls and safeties are operating properly during seasonal commissioning of the EHWD, and periodically throughout the season.

On the front of every Model75 is an on/off switch that has three positions. The center position is "OFF". Position "1" is manual control mode and will turn the heater on without a command from the EHWD computer control system. This mode should only be used for maintenance and troubleshooting and in the presence of the technician. If left in position "1" the computer control system has no control over the heater and neither it nor the DCC operator can shut it down in the event it overheats. Position "2" is computer control mode. In this mode control is relinquished to the computer control system and operator. On-line heaters should be left in position "2". Off-line heaters should be left in the "OFF" position.



**Figure 2.120** Location of Model 75 heater controls

Each Model75 has its own inlet and outlet water valves. At the inlet is a needle valve used to control the amount of water flowing through the heater, and at the outlet is a standard on/off ball valve. The throttling needle valve is used to control the output temperature of the heater, recalling that a given flow provides a given output temperature since the Model75 provides constant heat output. This valve is constructed of brass and has color and number coding on the knob for reference. One important thing to remember about these valves is not to turn the valve out past the purple band, because beyond this point further opening begins to pull the packing out of the valve and destroys it. These valves are seldom repaired in the field and so a failed valve usually means

replacement with a new one. The needle valve can also be closed all the way down to close off the inlet flow. Closing the outlet ball valve is the standard method of stopping flow, however. This ball valve should not be used in an intermediate position to throttle flow because it will wear very quickly.

**IMPORTANT!** **Both valves can be closed to perform maintenance on a heater, however it is of paramount importance to make sure the heater switch is in the "OFF" position before both valves are closed, and remain in the "OFF" position until at least one valve is opened. In a case where the safety systems are not in proper working order, and the heater is allowed to burn with both inlet and outlet valves closed, the trapped water has nowhere to expand and the heater becomes a "bomb". If the technician must leave site of a heater with both valves closed, then that heater should be locked out according to standard lockout/tagout procedures.**

Temperature and flow safeties local to the heater control logic is made up of a temperature sensor paired with an electronic thermostat and a differential pressure sensor.

The electronic thermostat and associated temperature sensor turns the heater off when the outlet water temperature reaches the set point. Once the temperature drops low enough to overcome hysteresis and reset the thermostat, the heater will fire back up. Heater cycling can be reduced by maintaining sufficient flow so that the outlet temperature stays consistently near but not above the thermostat set point. Nominal set point is 95°C. Sometimes the set point and displayed outlet temperature do not agree and the thermostat needs to be turned up to prevent premature shut-off, which is an indication of a faulty thermostat or improper installation of the thermostat knob, and necessitates immediate replacement. Generally, operating with a thermostat setting much above 95°C is bad practice.

The differential pressure sensor, shown in Figure 2.121, measures the pressure drop over the primary (bottom) coil, and has a range of 0-30 psid. At zero flow there will be zero pressure drop, and pressure drop increases with the square of flow. The sensor has a needle display for immediate visual feedback, and two internal reed switches with adjustable switch points. For the Model75s, only one reed switch is used, and must be closed (differential pressure above the set point) in order for the heater to fire. To set the differential pressure switch, the technician can test continuity across the switch while adjusting flow with the needle valve and monitoring actual flow values via the DCC. The set point should correspond to a flow no lower than 5 gpm. Sometimes the diaphragms internal to the differential pressure sensors become damaged, and would be indicated by a needle that does not respond or one that is permanently pegged at max differential. The differential sensors are field repairable with the proper diaphragm and seal kit.



**Figure 2.121** Differential pressure gauge and switch

The indicator box, pointed out in Figure 2.120, has two LEDs, one yellow and one red, and is used to determine why a heater is not firing. The yellow LED indicates there is insufficient flow, i.e. the differential pressure reed switch is not satisfied. The red LED indicates the outlet temperature has exceeded the thermostat set point. If neither LED is lit then both of these sensors are satisfied and the problem is elsewhere.

Temperature and flow safeties tied into the computer control system consist of a temperature sensor and turbine flow meter on the heater outlet.

The temperature sensor supplies feedback to the computer control system and also reads out to the display in front of the heater. An upper temperature limit is set in the computer control system and the control system will automatically shut down the heater if this is exceeded. If this happens, the DCC operator must restart the heater in the software, it will not restart on its own.

The turbine flow meter is located on the heater outlet manifold, as shown in Figure 2.120, and also provides feedback to the control system (there is no visual readout at the heater for this sensor). A lower flow limit is set in the computer control system and the control system will automatically shut down the heater if flow drops below this limit. If this happens, the DCC operator must restart the heater in the software, it will not restart on its own. Note that the turbine flow meter requires a straight length of pipe 10x the ID in length upstream and 5x the ID in length downstream to ensure accurate measurement. Stainless pipe is used because it provides a better medium for clamp-on

ultrasonic flow meters that are sometimes paired with a turbine meter for calibration.

The temperature sensor and turbine flow meter communicate their data over the network via DGHs. See the software section for more information on network and DGHs.

The turbine flow meter is susceptible to buildup of iron deposits and foreign particles like Teflon pipe tape and metal shavings. A Y-strainer, shown in Figure 2.120, is located just upstream of each turbine flow meter to protect it from these things. Recommended size for the screen is 60 mesh. Methods on flushing and cleaning the Y-strainer are discussed below.

**Important:** **It is important to note that the pairing of working temperature and flow sensors is essential to safe heater operating and proper feedback. Output temperature is the primary measure, but since the temperature sensors are located outside the heater on the outlet manifold, positive flow is required to assure the heated water is transported past the temperature sensors. Therefore, a reliable temperature sensor must be paired with a working flow sensor.**

The following list summarizes the temperature and flow safeties:

- 5 Safeties
- 3 (redundant) temperature safeties
- 3 (redundant) flow safeties
- Temperature safeties
  - Thermostat (local to heater logic)
  - Temp sensor reading to local display and computer (software can only control heater via this sensor in Computer Control Mode, switch position "2")
  - Temperature switch (local to heater logic)
- Flow safeties
  - Differential pressure switch (local to heater logic)
  - Turbine flow meter reading to computer (software can only control heater via this sensor in Computer Control Mode, switch position "2")

**Note:** **Satisfied flow safeties assure the temperature safeties are accurate. Both flow AND temperature are needed!**

The burner unit has its own Honeywell control box, as shown in Figure 2.122. This control box interfaces with a temperature switch and flame eye for feedback, and controls the motor for the blower and fuel pump, fuel solenoid, and ignition coil. If the output temperature exceeds the setting of the temperature switch, or if the flame eye does not see flame while the controller is calling for flame (after a delay), the Honeywell will trip into a disable state. In this state, the blower and fuel pump continue to run, but the fuel solenoid closes and ignition spark stops. The red reset button will pop out, and the controller can be reset by holding in the red button for approximately 2 seconds.



**Figure 2.122** Model 75 burner unit and Honeywell controller

The burner unit also has a fire safety valve on the fuel inlet line that closes in the event of a fire, and a pressure gauge reading fuel pressure. More information on the burner unit is available in the video sequence below, in the Appendix E which is a copy of the Beckett burner field manual.

Click on the video link below to play a video giving an overview of the “Model 75” heater operation, the burner system and the safety features of the heater.

Heaters, full film.mp4

The wiring diagram for heater controls and safeties is shown in Figure 2.123.

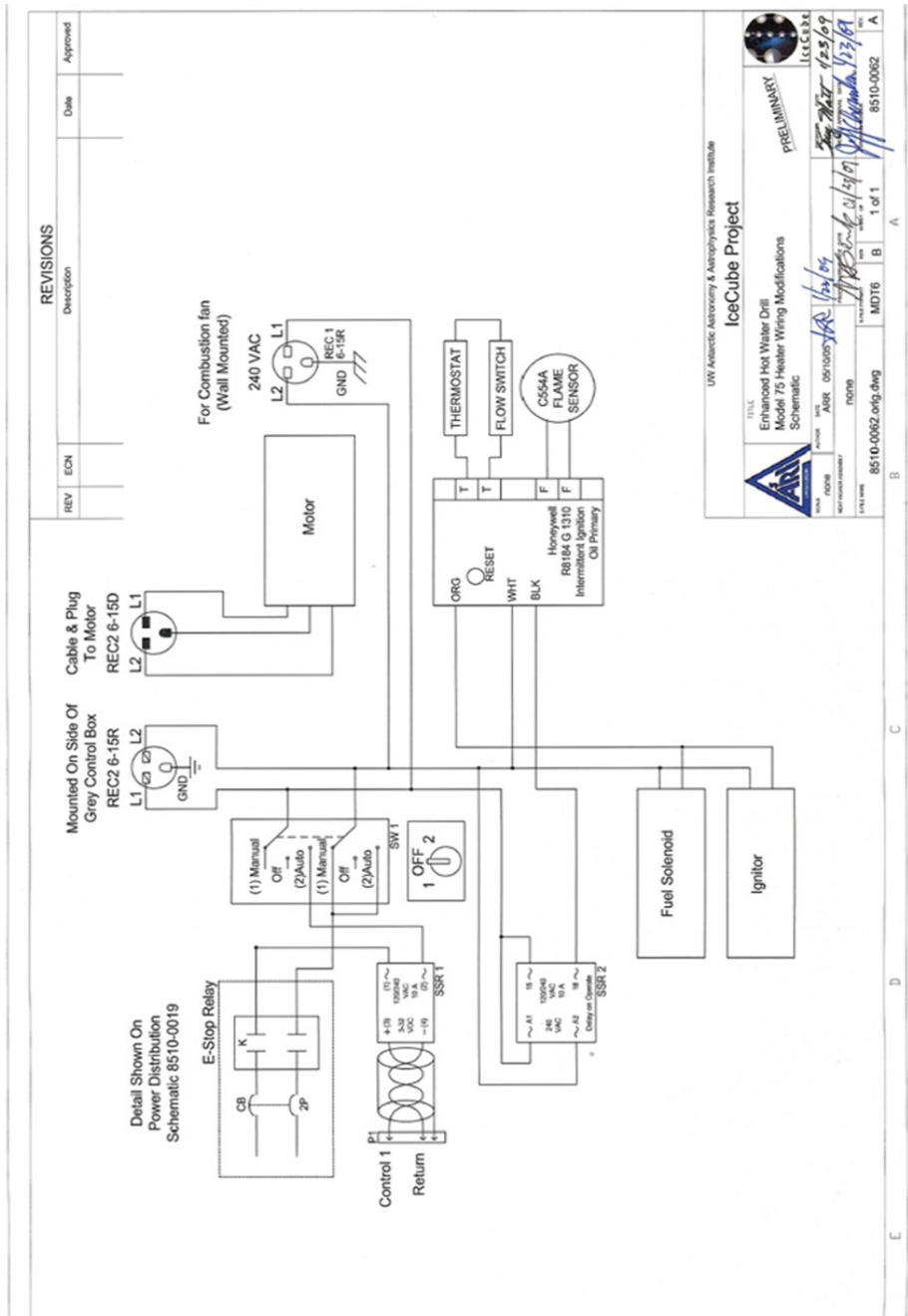


Figure 2.123 Heater control wiring diagram



## 2.5.3 Heater operations

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### **Balancing heaters:**

Water flow through a heater is controlled by the inlet throttling valve. All main heaters in the MHPs are plumbed in parallel, so adjusting flow of one heater affects all others. Flow adjustments are made to tweak output temperature, and should be made in small increments. Adjustments should first be made to lower output temperatures of heaters running hot (by increasing flow). This also robs flow from other heaters, and cool heaters will heat up. Additionally, opening throttle valves reduces backpressure and therefore can help lower overall system operating pressures. For this same reason, before starting a new hole all throttle valves should be completely opened.

PDA's have been set up so heater technicians can take them with them and be provided with real-time temperature and flow data from the DCC. These greatly facilitate heater flow and temperature adjustments.

When making temperature adjustments, recall that total thermal output provided to the drill depends on both temperature and flow. At times, operators can get hung up on output temperature alone, and throttle heaters down to achieve the desired average temperature of 88°C, but at the same time increase system pressure enough to begin activating torque limits at the pumps. Torque limiting results in a drop in flow, and the overall outcome of this method is less thermal energy despite attaining desirable temperatures.

### **Condensate:**

Condensate is generated at surprising rates and must be managed. Occasionally, soot that collects within the condensate plugs up the fittings at the drain on the heater. The drain on a Model75 is plumbed with a cross fitting, shown to the left in Figure 2.124, so that a small screwdriver can be pushed in (either towards the heater or down into the drain tube) to unclog any buildup. The rest of the condensate collection system should also be periodically checked for clogging.

There is a triangular condensate collection tank, shown to the right in Figure 2.124, in each building that contains Model75 heaters. The condensate drains from each heater into the tank. Inside the tank is a submersible pump and float switch, and when the float reaches its set point the pump kicks on and sends the condensate to the PHS building where the condensate collection, filtering, and reinjection system is located (see PHS subsystem description).



**Figure 2.124** Condensate drain cross fitting and drain tubing on model 75 (left) and condensate tank with submersible pump (right). The blue hose entering the condensate tank comes from the Y-strainer manifold.

Caution: Condensate is extremely corrosive, so any replumbing jobs should utilize stainless or brass plumbing. Galvanized pipe does not cut it.

### **Y-strainer flushing:**

The advantage of Y-strainers is the ability to purge them of collected debris while still in operation. Each Y-strainer in the EHWD system has purge port, valve, and hose leading to a centralized manifold, shown in . From here the purged water/debris travels to the building's condensate collection tank and is expelled through a large diameter hose/fitting. During operation, purged water is under high pressure and is hot (1000 psi, 88°C) and can cause severe burns if not handled properly. The hard-plumbed design of the Y-strainer purging system eliminates the risk of coming into contact with any hot water jets. The large diameter expelling at the condensate tank acts to diffuse the pressure and any resulting high velocity jets.



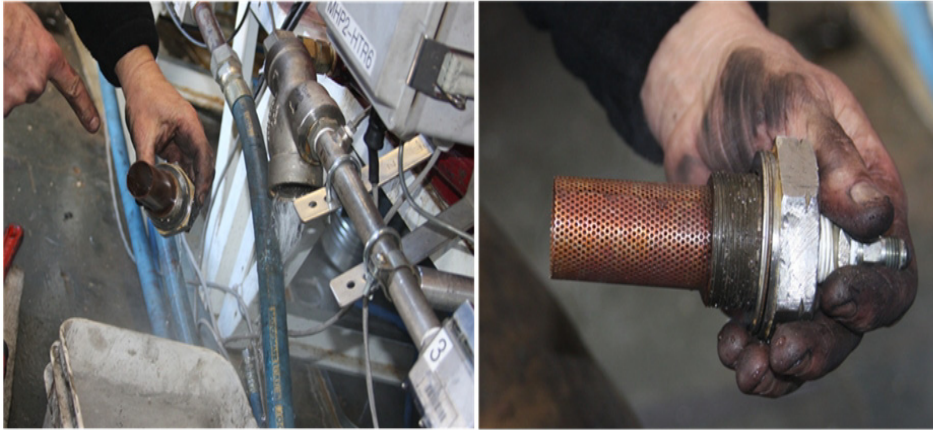
**Figure 2.125** Y-strainer centralised manifold on ceiling of MHP building

When purging, the valve should be opened for duration on the order of 20 seconds to assure the screens are thoroughly rinsed and any debris is pushed into the larger sized plumbing. If the small plumbing lines are not cleared they clog easily and the ability to purge is lost. A proper purge will affect measured heater temperature and flow, and will likely cause the heater to be shut down on a low flow condition (since the turbine flow meter is located downstream of where flow is being bled off during a purge). A quick call to the DCC to restart the heater will have it running again. System pressure dips will also be observed during a purging process.

Purging during drilling is only needed when online heaters become clogged enough to affect performance. This is indicated by a hot-running heater (flow too low) even though the throttle valve may be completely open. Purging and screen cleaning occurs often early in the drilling season when debris that has collected during storage is being flushed out of the system. After a couple holes, a purge cycle or two on each y-strainer between holes is typically sufficient to keep things clear during drilling.

To achieve a more thorough cleaning, the screen should be removed and cleaned by hand, as shown in Figure 2.126. To do this, make sure water flow is shut off and there is no stored pressure, unhook the purge hose, and unthread the y-strainer cap. The screen can then be removed and cleaned, or replaced with a new one. When reinstalling the screen, a new compression sealing ring should

be used (seals between cap and y-strainer housing), and the threads should be redressed with anti-seize to prevent stainless-stainless galling. Do not over-tighten the cap.



**Figure 2.126** Removing Y-strainer cap to manually clean screen

Click on the video link below to see a video description of the Y-strainer system.

Model 75 Y strainers.mp4

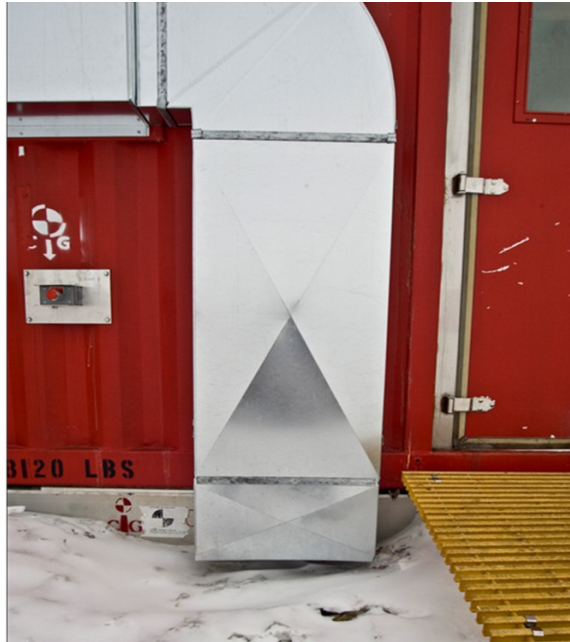
### **Intake Fans:**

Each heater has a dedicated building make-up air intake fan. These fans are mounted in foam cutouts that fit into the windows of the building. Each fan plugs into a circuit that is controlled in parallel with its respective heater, so both turn on/off at the same time. There is also a fan for furnace make-up air and an overtemp fan that turns on if building temperature becomes too high, as dictated by a separate thermostat.

On the outside, the intake air for a window's worth of fans is routed through ducting, as shown in Figure 2.127, with its opening near the ground. This limits the amount of exhaust being sucked in from adjacent buildings upwind. After windy days, drifts can form around the intakes of the ductwork and must be cleared.

There is also a passive building pressure damper in each building. In the case of the MHPs, these are mounted in the electrical closet wall, and so the pocket doors of the MHP electrical closets should remain open.

The fans in conjunction with the pressure dampers equalize the inside building pressure with ambient. If the building goes into vacuum, cold air from outside is drawn in through heaters that are not running and freeze the water in their coils. Additionally, immediately after shutting down a heater, the hot combustion gases can be drawn back into the building through the burner unit, melting the plastic shaft coupling between the motor and fuel pump.



**Figure 2.127** Intake fan ducting, with snow sufficiently cleared around bottom opening

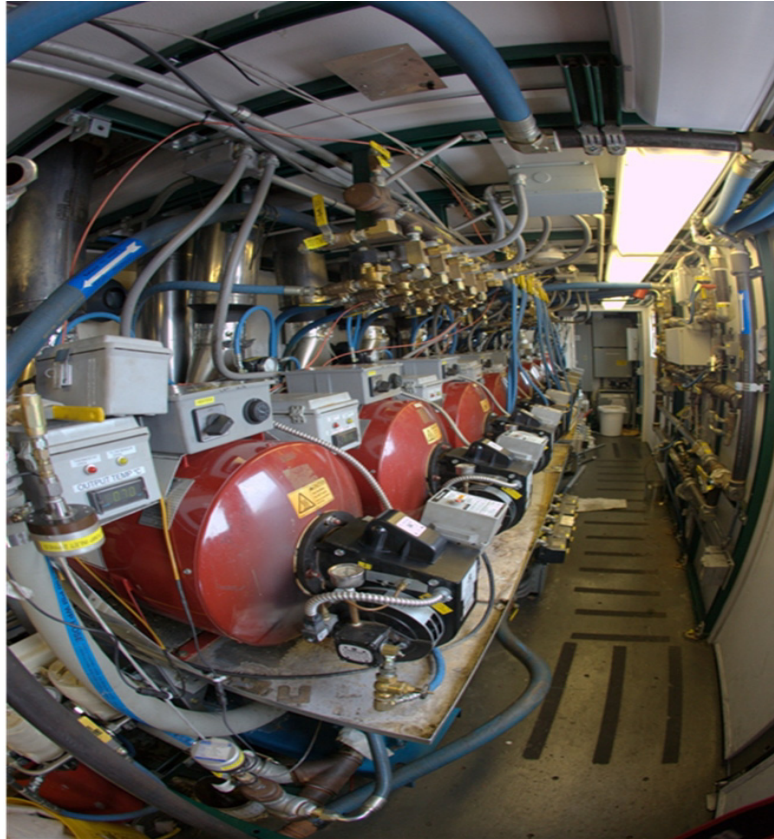
### **Maintenance, Troubleshooting, and Tuning**

For information on heater maintenance, troubleshooting, and tuning please see Appendix E.

### **2.5.4 Stinger Heater**

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Another type of heater in the EHWD system is the Stinger heater. This is a smaller heater capable of approximately 50 kW of heating capacity. Like the Model75, it is constructed for high pressure operation and utilizes Becket oil-fired burner units. Unlike the Model75, there is no combustion liner or condensing heat exchanger, and it is oriented horizontally. There are 9 of these in operation in the RWS building as shown in Figure 2.128, where less heat output but finer temperature control is desired.



**Figure 2.128** Stinger heaters inside RWS building

Much of the controls and safeties are identical to a Model75, with the exception of flow indication. The Stinger heaters do not use a turbine flow meter, but instead take advantage of the second reed switch internal to the differential pressure sensor. The differential pressure sensor reads the differential pressure over the entire heater coil and has a smaller range than the sensors used on the Model75s (0-15 psid). One reed switch is hooked up locally to the heater logic, like with the Model75, and the second reed switch is hooked into the control system. On the screen in the DCC, either a LOW or FULL flow state is indicated, as dictated by the differential pressure switch set point. The control system will not allow the heater to fire when flow is LOW, and will allow it to fire when FULL. Both switch set points should correspond to a flow no lower than 2 gpm.

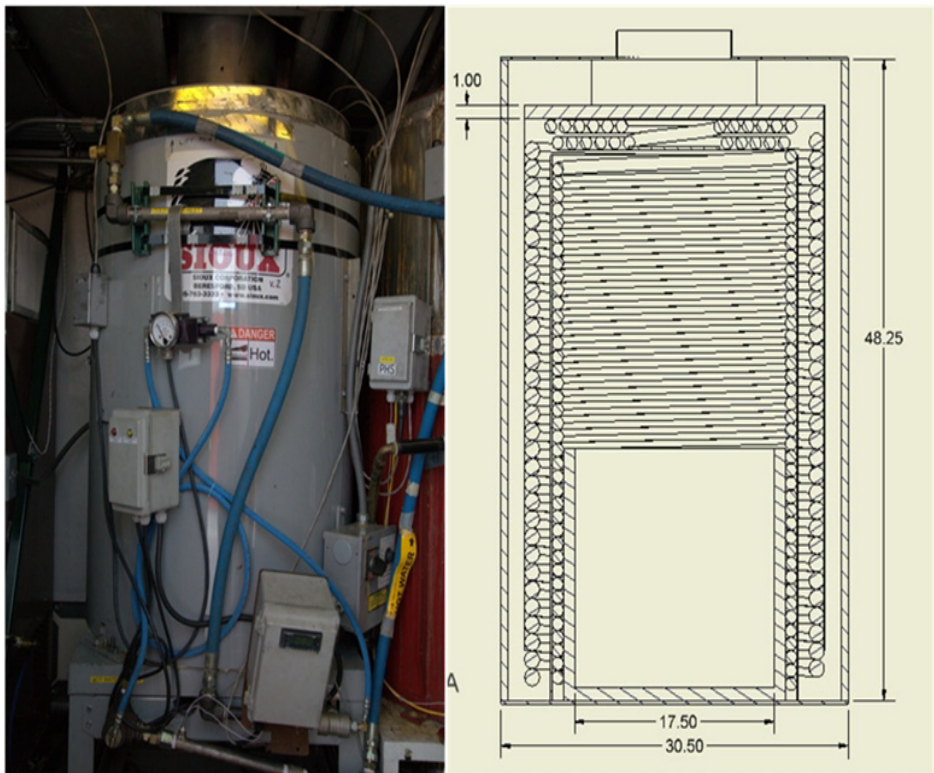
The Stinger heaters in the RWS are also equipped with an on/off solenoid on the water intake, controlled from the DCC. Note that these valves fail in the

OPEN position. Leading cause of malfunction is small pieces of debris that clogs the pilot ports internal to the valve.

**Note:** Some condensate is produced in the Stinger heaters when starting up, and there is a small drain hole in each shell from which condensate drips are expected. Also, Stinger heaters are less efficient (~70%) resulting in hot exhaust temperatures. Additional caution should be used when working around the Stinger exhaust stacks, and insulated stacks need to be in place (to adhere to Code for passing stack through ceiling).

## 2.5.5 Sioux Heater

The Sioux Heater, shown in Figure 2.129, was developed as a prototype replacement for the Model75. It is of a very different construction internally, with a large and open combustion region and a 3-pass gas flow path. The goal was to fit a heater that has 1.5x the output of a Model75 into the same footprint and at comparable fuel efficiency. The end result was a heater that could attain greater outputs but at relatively poor efficiency.



**Figure 2.129** Sioux heater in PHS and schematic profile of heater internal makeup

The combustion is not contained and controlled like with the Model75. The combustion region is bigger and more open, allowing for larger flames and increased burn rates (leading to higher heating output), but heat is quickly radiated to the upper section of coil rather than being reflected back, so complete and clean combustion requires more combustion air and combustion temperatures are lower.

Furthermore, the gas path leads to heat transfer characteristics that are fundamentally different than the Model75, and less efficient at high altitudes like the South Pole. Looking at the Model75, the gas path is very tortuous, as it is pushed through a tight array of coil. With the Sioux heater, however, the combustion gases travel up the center of the heater, then down between the inner and outer coils, then finally up on the outside of the outer coil and through the stack. Compared to the Model75, this flow path is very non-tortuous.

At higher altitudes, more volumetric flow of air is required to assure good fuel/air mixtures and proper tuning. This results in higher gas velocities through the heater. Greater turbulence improves gas-to-surface heat transfer, and so the Model75 benefits from more air flow at altitude due to its tortuous gas path. In contrast, heat transfer in the Sioux heater would benefit from longer contact time between the gas and the coil, so at altitude and greater required air flow rates efficiency is hindered.

However, the Sioux heater does run dependably, and serves as a good backup heater. In 2010 it was installed in the PHS, retrofitted with the standard Model75 Beckett burner unit, and tuned to match the output of a Model75.

Like with the Stinger heaters, the Sioux heater is less efficient and requires the use of an insulated exhaust stack.

**Caution: Care should be used when working around the stack and/or hot exhaust gases.**



## 2.6 Drill Head

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### 2.6.1 Introduction:

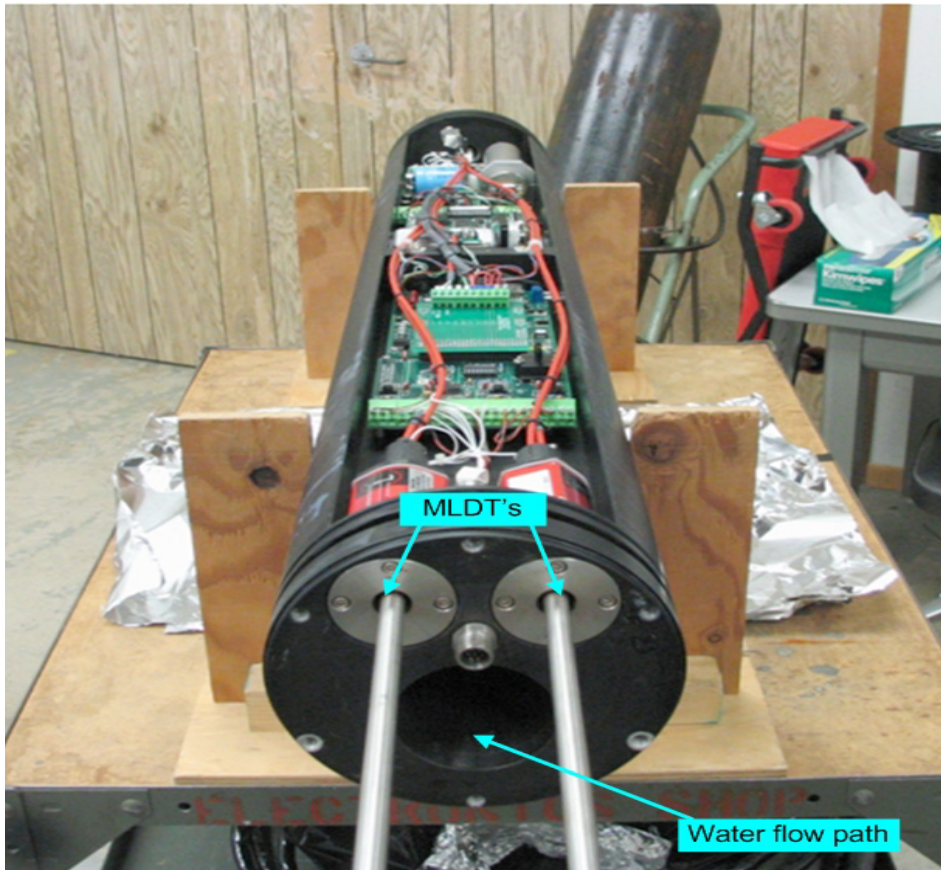
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**Figure 2.130** Drill head on test stand for testing and calibration

The drill head, shown on a test bed in Figure 2.130 above, consists of an electronics package sitting in a milled out steel housing. A hole drilled through the housing, as shown in Figure 2.131, allows water to flow through it. The housing sits inside a pressure rated tube with sealed end caps at either end to provide a pressurised housing for the electronics package. One end of the pressure housing connects to the drill hose and support and communications

cable via the drill head hanger, while the other end attaches to the weight stack via a drill head to weight stack adaptor. The drill head body incorporates caliper arms to provide borehole diameter information. Drill Head Mechanical Design.



**Figure 2.131** Drill head electronics housing showing water flow path through housing

The drill head provides the following mechanical and electrical functions:

Mechanically;

- The Drill Head and Weight Stack provide self centering in the drill hole and, with the aid of the drill head hanger, allows the weight stack to hang vertically to provide a vertical hole (within 2m of vertical from top of hole to bottom of hole).
- The drill head is a Conduit for Hot Water Flow by allowing hot water to enter the Drill Head from the hose coupled to top of drill head, which then flows

through the drill head to the weight stack adaptor and through the weight stack to the nozzle.

- The calipers, combined with the Magnetostrictive Linear Displacement Transducers (MLDT's) provide an electromechanical technique for measuring Drill Hole Diameter.

Electrically;

- The drill head allows the drill hole to be logged via a navigation package which measures:
  - X and Y tilt with respect to vertical
  - X , Y and Z components of the earths magnetic field, thereby providing drill head heading and therefore direction of tilt.
- The drill head provides drilling performance parameters such as:
  - Drill hole water and hose water temperatures via thermistors.
  - Drill hole water pressure via pressure sensors
  - The weight on the support cable via a load cell at the top of the drill head.
  - Drill hole diameter via the calipers and MLDT.
  - Acceleration via accelerometers in the drill head
- The drill head provides drill head operation parameters such as;
  - Power supply board DC to DC converter heat sink temperature.
  - Drill head cavity air pressure sensor.
  - End cap “T seal” pressure sensor to detect the start of pressure seal leaks.
  - Input voltage and DC to DC converter output voltage sensors.

### **Drill Heads History**

Two Drill Heads were built for PICO-Nebraska in 1995 for the Amanda Project. These were used successfully in FY96, FY97 and FY98 and again in FY00 after refurbishment. One refurbished drill head was lost in FY00 and one remains.

The remaining drill head has been refurbished and modified twice (in 2004 and 2005) for use in ICECUBE Project.

Two new EHWD drill heads were constructed for the ICECUBE Project (designated drill heads “X” and “Y”). These new EHWD drill heads are improved versions of the Amanda drill heads.





77	6	SHSETSS	3/8-16 NC x 3/4 LONG	57	16	AFHCAPSS	1/4-20 NC x 1 1/2 LONG
76	6	SHCAPSS	5/16-18 NC x 1" LONG	56	1	18-8 ST STL	1/2-20 NF x 1 1/4 LG THD ROD
75	2	SHSETSS	3/8-24 NF x 5/8 LONG	55	1	SHCAPSS	1/2-20 NF x 1" LONG
74	1	5377EXXX	EHWD NOZZLE END ASSEMBLY	54	1 pr.	5377C112	UNION PLATE
73	1	5377B129	PRESSURE TRANSDUCER PLUG	53	1	5377D101	LOWER MODULE - REV. A
72	1	'PAROSCIENT.'	#9000-6K-101 PRESSURE SENSOR	52	1	5377B022	TRANSDUCER WELL CAP-TYPE I
71	2	'INVENSYS'	#13C5000PA4K PRESSURE SENSOR	51	1	5377A034	THERMISTER SLEEVE
70	2	'McMASTER'	SIZE -166 BUNA-N O-RING	50	1	'IMPULSE'	MKS(W)-307-CCP TO MKS(W)-
69	2	'McMASTER'	SIZE -363 BUNA-N O-RING				307-CCP x 28" LONG CABLE
68	1	5377C135	TOP CAP PLATE	49	1	5587C343	HOSE CONNECTION
67	1	5377C116	CLEVIS PIN	48	2	SHCAPSS	8-32 NC x 1" LONG
66	3	ST STL	1/2-13 NC HEX LOCK NUT	47	14	SHCAPSS	8-32 NC x 1/2 LONG
65	3	SHCAPSS	1/2-13 NC x 5" LONG	46	1	5377A024	THERMISTER SLEEVE CLAMP
64	6	SHCAPSS	1/2-13 NC x 2" LONG	45	4	'IMPULSE'	MKS(W)-307-BCR CONNECTOR
63	1	5377C130	LOWER CAP PLATE	44	6	SHCAPSS	5/16-18 NC x 2" LONG
62	2	SHCAPSS	1/4-20 NC x 3/4 LONG	43	6	'PARKER'	SIZE -029 BUNA-N O-RING
61	1	5377C064	CABLE RETAINING PLATE	42	6	SHCAPSS	5/16-18 NC x 2 3/4 LONG
60	1	5377C113	LONG UNION BLOCK	41	2	5377D018	TYPE III - SPRING MOUNT RING
59	1	AEROQUIP	#2045-24-24 SWIVEL ADAPTER	40	2	5377B017	MLDT MAGNET SLEEVE
58	1	5377C010	MECHANICAL CALIPER HUB	39	1	5377D134	MECHANICAL CALIPER GUIDE
				38	1	'McMASTER'	#92384A076 ø3/8x2"POS. LK PIN
				37	2	'PARKER'	TP015 'T'-SEAL
				36	2	5377B016	MLDT ADAPTER
				35	2	'MTS'	MLDT - 8" RANGE - 10 KSI
				34	1	5377E111	INSTRUMENT/NAV PKG MOUNT
				33	1	5377C013	HOUSING
				32	2	'PARKER'	TP060 'T'-SEAL
				31	8	5377B020	CALIPER SPRING
				30	16	BERG/303 SS	#S4-22 ø.249x2.25 DOWEL PIN
				29	104	ABHCAPSS	6-32 NC x 1/2 LONG
				28	16	5377A014	SPRING MOUNT
				27	8	AFHCAPSS	5/16-18 NC x 1 1/2 LONG
				26	1	5377C012	TYPE II - SPRING MOUNT RING
				25	1	5377C011	TYPE I - SPRING MOUNT RING
				24	1	'IMPULSE'	MSSL-CCP MSSL-BCR CONNECTOR
				23	6	SHCAPSS	5/16-18 NC x 5" LONG
				22	1	5377C136	ADAPTER RING
				21	2	5377C133	BUMPER RING - REV. A
				20	6	SHCAPSS	5/16-18 NC x 3" LONG
				19	1	5377C131	HOT WATER TUBE
				18	1	'IMPULSE'	MKS(W)-307-CCP TO MKS(W)-
							307-CCP x 40" LONG CABLE
				17	1	5377D125	UPPER MODULE - REV. C
				16	6	'SPRAY SYS'	WIDE ANGLE 1/8 NPT SPRAY NOZ
				15	2	'McMASTER'	#90298A712 1/2x1" SHLDR SCR
				14	4	5377A033	PIN
				13	1	'TRANS TECH'	TLL-3K LOAD CELL
				12	1	5377D005	LOADPIN HOUSING
				11	3	'PARKER'	TP026 'T'-SEAL
				10	1	5377A004	PLUG
				9	2	'McMASTER'	#98401A493 ø5/32 COTTER PIN
				8	6	SHCAPSS	5/16-18 NC x 1 1/4 LONG
				7	1	5377B003	BRACKET - REV. A
				6	2	5377A006	PIN
				5	2	SHSETSS	3/8-24 NF x 1 1/4 LONG
				4	4	SHSETSS	1/4-20 x3/8 LONG w/BRASS TIP
				3	1	5377C002	YOKE
				2	1	5377A114	HANGER BAR
				1	1	'McMASTER'	#54685K215 TFLON HOSE x 36"

I	GMG	LSG	9-15-05	REVISED & REDRAWN 2005-06 REFURB.
H	GMG	LSG	9-15-05	REVISED & REDRAWN
G	GMG	JA	4-20-05	CHANGED SHRINK WRAP
F	GMG	JA	6-30-04	ADDED "Y" SHRINK WRAP
E	GMG	JA	5-25-04	CHANGED SUPPORT CABLE DETAIL
D	GMG	LSG	3-16-04	REVISED & REDRAWN
C	GMG	JH	3-26-03	SUPPORT CABLE & TEFLON HOSE UPDATED
B	GMG	JH	2-10-03	DRILL SUPPORT CABLE DETAILS ADDED
A	GMG	LG	8-29-02	REVISED & REDRAWN

**Figure 2.134** Drill head mechanical parts description and list

Figure 2.132 above shows the drill head hanger block section, while Figure 2.133 is a schematic of the drill head main body section and Figure 2.134 is a list of drill head parts referenced by the numbers in Figure 2.132 and Figure 2.133.

The drill head hanger block section interfaces the main drill hose, the drill cable load bearing member and electrical connections to the drill head main body. The drill head hanger block also allows the drill head and weight stack to hang vertically in the hole and is designed such that tension on the hose will not change the drill attitude in the hole.

The drill head main body section contains the drill head electronics and sensors, the calipers for measuring borehole diameter and provides a conduit for the water to flow from the drill hose to the weight stack and out to the nozzle.

### **Drill Head mechanical Specifications:**

#### **Pressure drops at 200 gpm**

Pressure drop through transitional hose, drill head, weights and nozzle is  
 $15 \text{ psi} + 10 \text{ psi} + 15 \text{ psi} + 50 \text{ psi} = 90 \text{ psi} \text{ (621 kPa)}$

#### **Drill Head Weight**

Weight of drill head without weight stack is ~ 500 lb (227 kg)

Weight stack, adapter, and nozzle weight ~ 1250 lb (567 kg)

Total weight of drill is 1750 lb. (795 kg)

Total weight of drill in water is 1150 lb (522 kg)

## 2.6.3 Drill Head Electrical Design

### 2.6.3.1 Drill Heads block diagram and sensor list

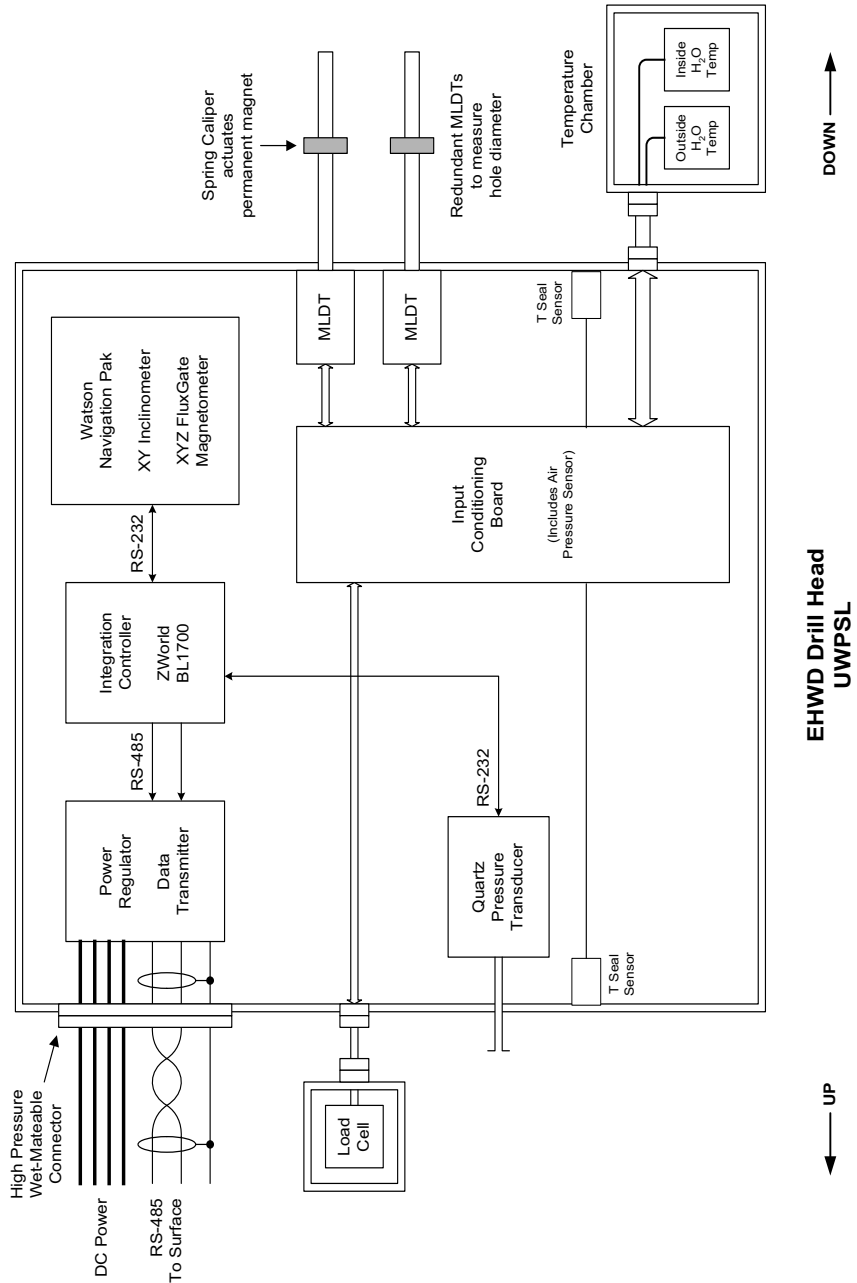


Figure 2.135 New Drill Head X and Y block diagram



Figure 2.135 above is a block diagram of the new X and Y drill heads. The refurbished drill head was modified to have similar functionality and specifications as the new drill heads. The sensors included in each drill head are listed in Figure 2.136 below while Figure 2.137 lists the sensor manufacturer, sensor type and power and output information.

*PICO/AMANDA Drill, Refurbished  
Amanda Drill, and EHWD Sensors*

Sensor	AMANDA	Refurbished (2004)	Refurbished (2005)	EHWD	Notes
Load Cell	✓	✓	✓	✓	Analog Output
Drill Hole Water Temperature Sensor	✓	✓	✓	✓	Analog Output
Hose Water Temperature Sensor	✓	✓	✓	✓	Analog Output
Drill Hole Water Pressure Sensor	✓	✓	✓	✓	AMANDA: Analog EHWD and Refurbished: Digital
Hose Water Pressure Sensor	✓	—	✓	—	Analog Output
Heat Sink Temperature Sensor	✓	✓	✓	✓	Analog Output
Regulator Input Voltage	✓	✓	✓	✓	Analog Output
Regulator Output Voltage	✓	✓	✓	✓	Analog Output
Watson Navigation Pack	✓	✓	✓	✓	Digital Output (RS232)
Drill Hole Diameter Sensor (MLDT #1)	✓	✓	✓	✓	Analog Output
Drill Hole Diameter Sensor (MLDT #2)	—	—	—	✓	Analog Output
Cavity Air Pressure Sensor	—	✓	✓	✓	Analog Output
T Seal Pressure Sensor #1	—	✓	✓	✓	Analog Output
T Seal Pressure Sensor #2	—	✓	✓	✓	Analog Output
Accelerometer #1	—	—	✓	—	Analog Output
Accelerometer #2	—	—	✓	—	Analog Output

Number of Analog and Digital Sensors for each drill:

1. The AMANDA drill had 9 sensors with analog and 1 with digital outputs
2. The Refurbished AMANDA Drill in 2004 had 10 sensors with analog outputs and two with digital outputs.
3. The EHWD has 11 sensors with analog outputs and two with digital outputs.

Other Issues:

1. The Z World controller card is same as used for Amanda.
2. The BL1700 has 10 analog inputs – not enough for the EHWD. A multiplexer was added to the ICB to expand the number of analog inputs that can be read. For the 2005 Refurbished Amanda Drill Head a daughter board with another multiplexer was added to accommodate the three additional sensors and provide some extra channels for future expansion

**Figure 2.136** Drill head sensor list and Amanda refurbished head history. The “EHWD” column refers to the new “X” and “Y” drill heads.

The difference between the new drill heads and the refurbished drill head is that the new drill heads have a second (redundant) Magnetic Linear Displacement Transducer (MLDT) while the refurbished drill head had accelerometers fitted in 2005.

## ICECUBE EHWD Sensors

Sensor	Mfg	Part Number	Notes
Load Cell	Transducer Techniques	TLL-3K	<ol style="list-style-type: none"> <li>1. Analog Output: 2mv/V of excitation (power supply) at rated output</li> <li>2. Max Load (Rated Output) = 3000 lbs</li> <li>3. Power Supply: 10 Volts or less</li> </ol>
Drill Hole Water Temperature Sensor	Omega	44018	<ol style="list-style-type: none"> <li>1. Analog Output</li> <li>2. Dual Thermistor: 0 – 100 °C</li> <li>3. Linear Output when used with recommended external resistor network</li> <li>4. 2.5 Volt Reference used as Supply</li> </ol>
Hose Water Temperature Sensor	Omega	44018	Same as Drill Hole Water Temp Sensor
Heat Sink Temperature Sensor	Omega	44018	Same as Drill Hole Water Temp Sensor
Regulator Input Voltage	-	-	<ol style="list-style-type: none"> <li>1. Analog Output</li> <li>2. Resistive Divider</li> </ol>
Regulator Output Voltage	-	-	<ol style="list-style-type: none"> <li>1. Analog Output</li> <li>2. Resistive Divider</li> </ol>
Drill Hole Diameter Sensor (MLDT #1)	MTS Tempsonics	LHTRB00U00801AO	<ol style="list-style-type: none"> <li>1. Analog Output - 4-20 ma output</li> <li>2. 8.1 inch maximum displacement</li> <li>3. Power Supply = 24 VDC</li> </ol>
Drill Hole Diameter Sensor (MLDT #2)	MTS Tempsonics	LHTRB00U00801AO	Same as MLDT#1
Cavity Air Pressure Sensor	Omega	PX139-030A4V	<ol style="list-style-type: none"> <li>1. Analog Output: 0.25 Volts to 4.25 Volts</li> <li>2. 0 – 30 psia</li> <li>3. Power Supply = 5 VDC</li> </ol>
T Seal Pressure Sensor #1	Invensys (Sensym)	13C5000PA4K	<ol style="list-style-type: none"> <li>1. Analog Output: 0 to 150 mv full scale</li> <li>2. 0 – 5000 psia</li> <li>3. Power Supply = 10 Volts</li> </ol>
T Seal Pressure Sensor #2	Invensys (Sensym)	13C5000PA4K	Same as T Seal Pressure Sensor #1
Drill Hole Water Pressure Sensor	Paroscientific	9000-6K-101	<ol style="list-style-type: none"> <li>1. Digital Output (RS232)</li> <li>2. Power Supply = 6.4 Volts</li> </ol>
Watson Navigation Pack	Watson Industries	Watson Nav Pack (Special)	<ol style="list-style-type: none"> <li>1. Digital Output (RS232)</li> <li>2. Two Axis Tilt; Three Axis Magnetic Field; Heading</li> <li>3. Power Supply = 24 VDC</li> </ol>
Accelerometer #1	Honeywell Sensotek	MA321	<ol style="list-style-type: none"> <li>1. ±2g; DC to 250 Hz; 10-30V; 4-20ma out</li> </ol>
Accelerometer #2	Kistler	8305A2	<ol style="list-style-type: none"> <li>1. ±2g; DC to 250 Hz; 7-16V; 1.5 to 3.5 V output</li> </ol>
Hose Water Pressure Sensor	Entran	EPXM-X33-5KP	<ol style="list-style-type: none"> <li>1. 0-5000 PSI; 24-32 V; 5 V FSO</li> </ol>

**Figure 2.137** Drill head sensor manufacturer and specifications

### 2.6.3.2 Drill head block wiring diagram

The following section details the block wiring diagram for the 3 drill heads, Drill head “X”, “Y” and the Amanda refurbished drill head.

As can be seen from the diagrams in Figure 2.138 to Figure 2.147, drill heads “X” and “Y” are functionally identical but have some minor wiring differences, while the refurbished drill head does not include a second MLDT, but includes accelerometers via a daughter board added in 2005.





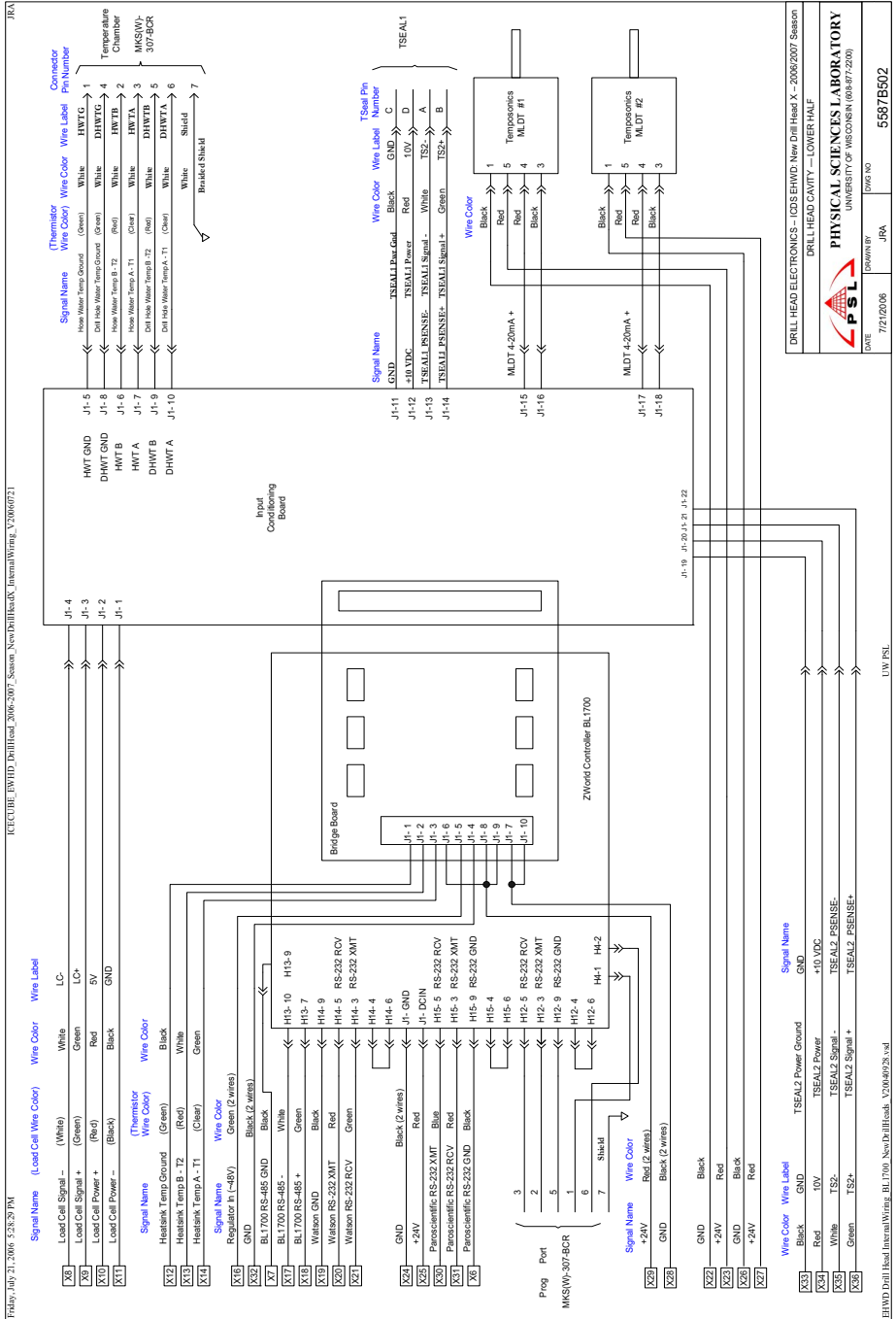


Figure 2.140 Drill head “X” cavity lower half wiring diagram



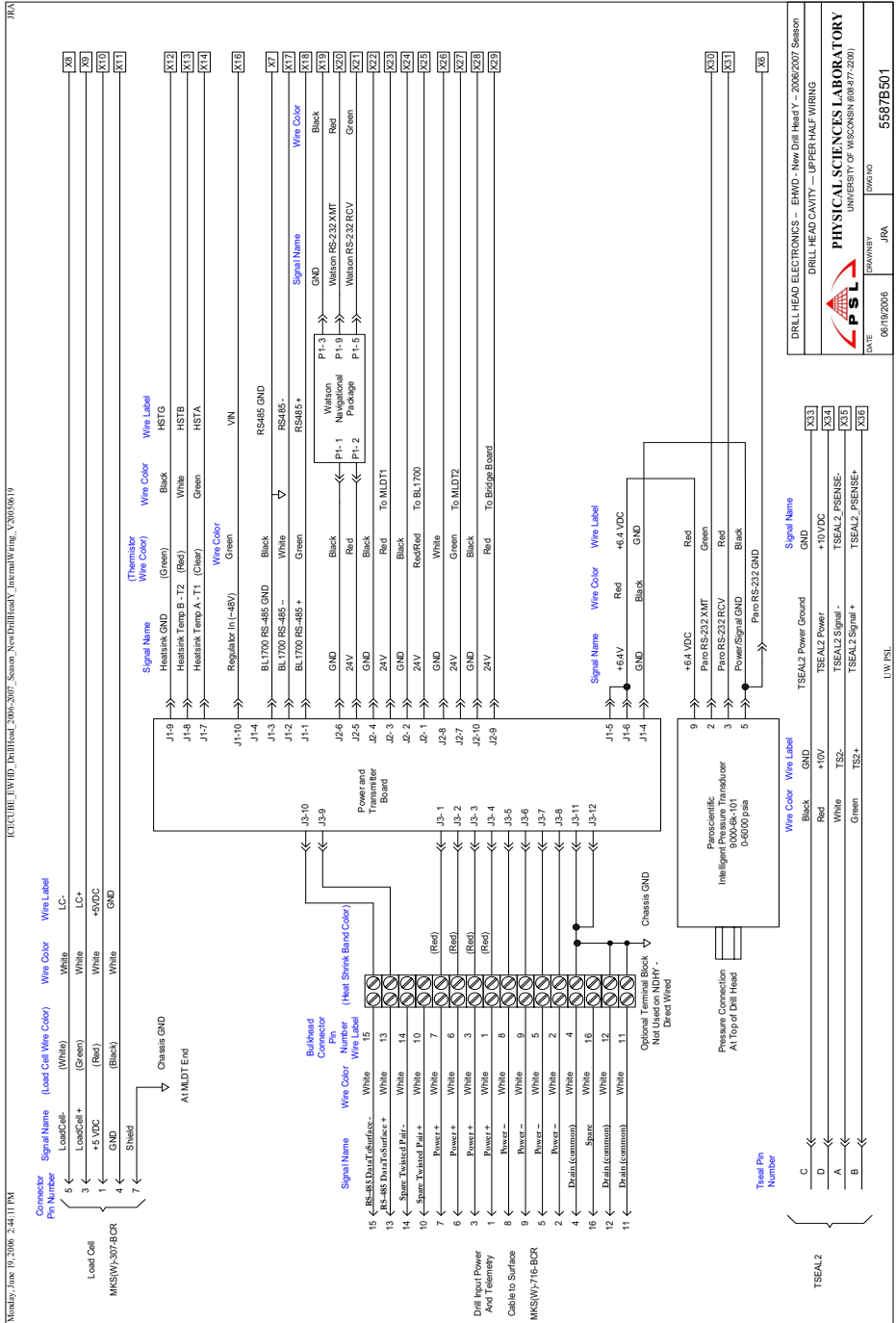


Figure 2.142 Drill head “Y” cavity upper half wiring diagram





# Refurbished drill head

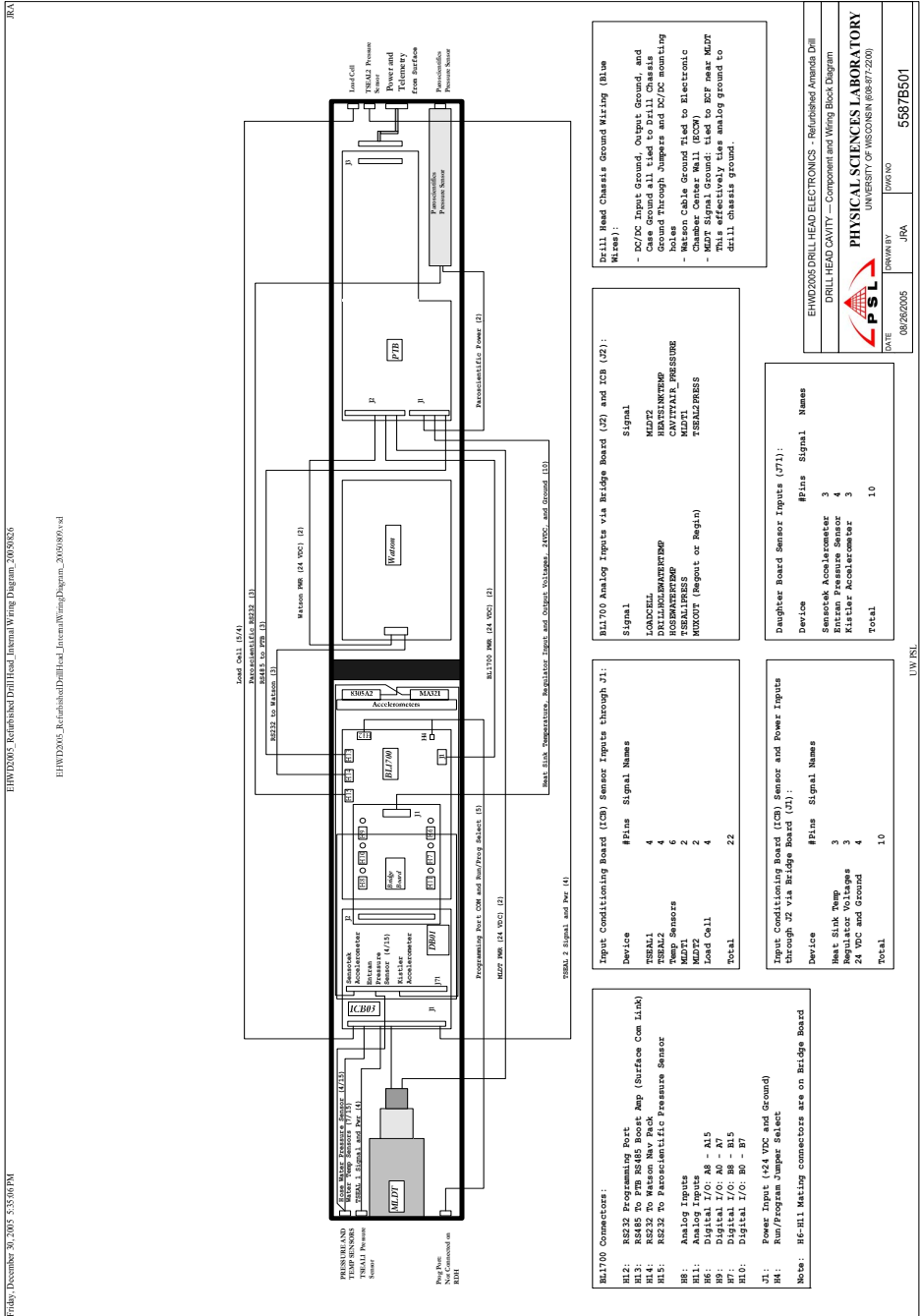
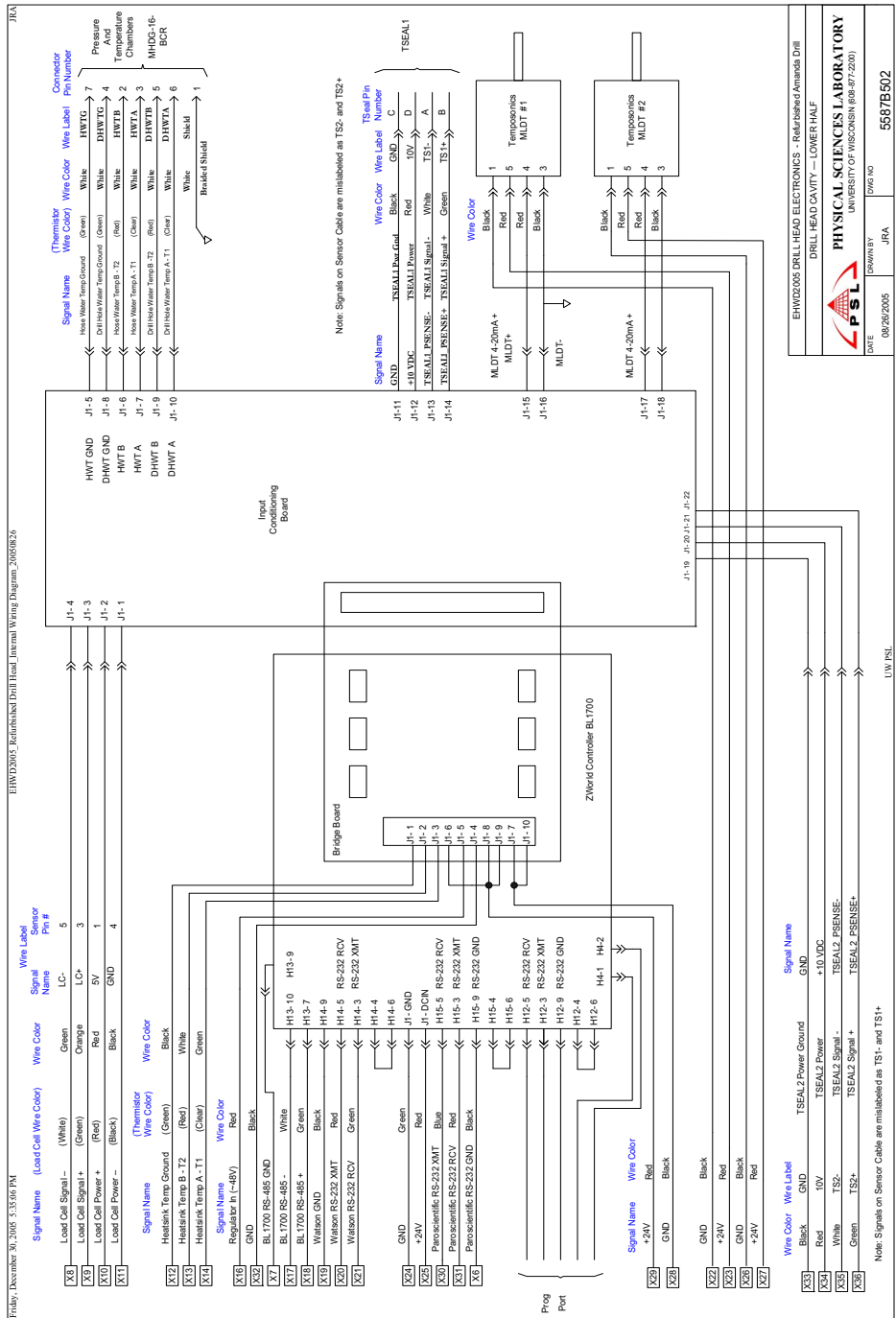
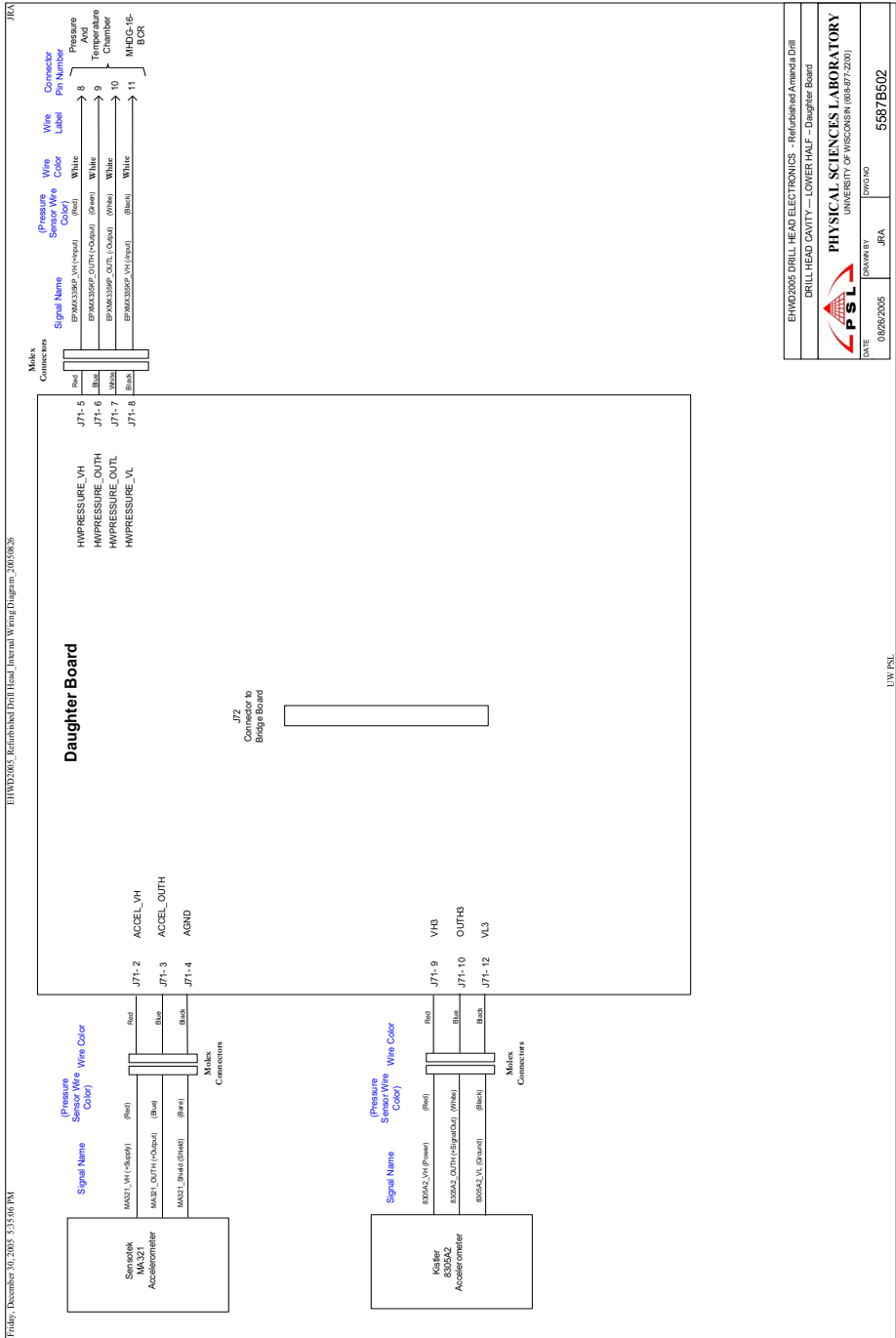


Figure 2.144 Refurbished drill head cavity component and block wiring diagram







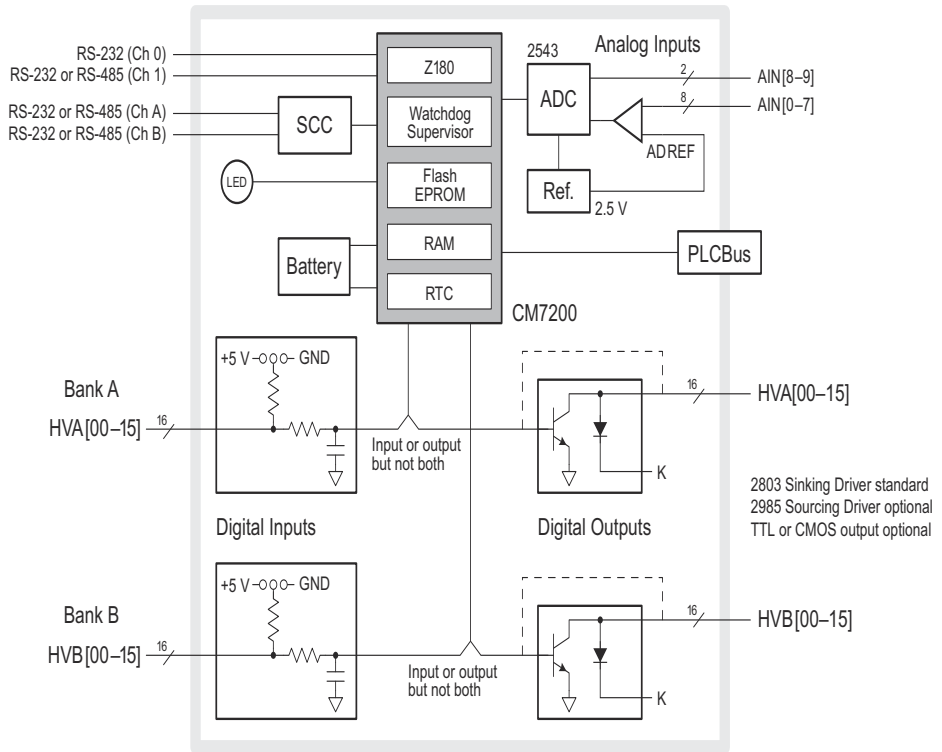
**Figure 2.147** Refurbished drill head cavity lower half daughter board

### 2.6.3.3 Drill head boards and sensors description

The drill head electronics consists of a combination of complete off the shelf computer board and sensor modules as well as in house built circuit boards to provide power and signal conditioning to the various sensors and to interface these sensors to the computer board.

#### 2.6.3.3.1 BL1700 Controller board

The heart of the system is a Z-World BL1700 C-programmable controller board. A block diagram of this board is shown in Figure 2.148.



**Figure 2.148** BL1700 computer board block diagram

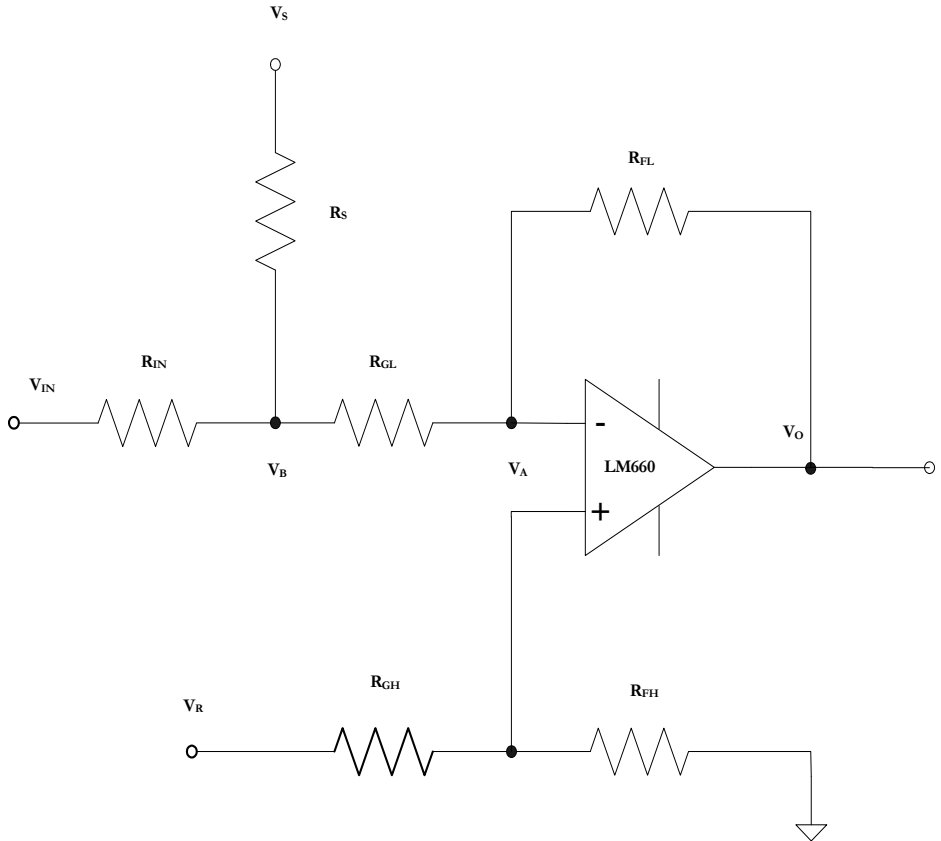
The BL1700 is a controller with modular digital and analog I/O that allows for easy custom modification. The board is programmed using Dynamic C, Z-world's version of the C programming language designed for embedded control.

As shown in Figure 2.148, the BL1700 is comprised of several subsystems, including a microprocessor core module, four serial communications channels, up to 32 protected digital inputs, up to 32 high voltage and high current digital

outputs, eight conditioned analog inputs, two unconditioned analog inputs and a PLCBus expansion port.

### BL1700 analog input circuit

Analog signals from various sensors are fed to the BL1700 conditioned analog inputs. The conditioned analog circuit equivalent is shown in Figure 2.149.



**Figure 2.149** B11700 Analog input buffer amplifier with non zero source impedance and source bias

A general analysis of this circuit with no source bias ( $R_S = \infty$ ) and zero source resistance ( $R_{in} = 0$ ) yields the following:

### Inverting Branch Analysis

$$\frac{V_O - V_A}{R_{FL}} = \frac{V_A - V_{IN}}{R_{GL}}$$

$$\frac{V_O}{R_{FL}} = \left( \frac{1}{R_{FL}} + \frac{1}{R_{GL}} \right) V_A - \frac{V_{IN}}{R_{GL}}$$

$$V_O = \left( 1 + \frac{R_{FL}}{R_{GL}} \right) V_A - \frac{R_{FL}}{R_{GL}} V_{IN}$$

$$\text{Let } G_L = \frac{R_{FL}}{R_{GL}}$$

$$V_O = (1 + G_L) V_A - G_L V_{IN}$$

### Non inverting branch analysis

$$\frac{V_R - V_A}{R_{GH}} = \frac{V_A}{R_{FH}}$$

$$\frac{V_R}{R_{GH}} = \left( \frac{1}{R_{FH}} + \frac{1}{R_{GH}} \right) V_A$$

$$\frac{V_R}{R_{GH}} = \left( \frac{R_{FH} + R_{GH}}{R_{FH} R_{GH}} \right) V_A$$

$$V_A = \left( \frac{R_{FH} R_{GH}}{R_{FH} + R_{GH}} \right) \frac{V_R}{R_{GH}}$$

$$V_A = \left( \frac{R_{FH}}{R_{FH} + R_{GH}} \right) V_R$$

$$V_A = \left( \frac{\frac{R_{FH}}{R_{GH}}}{1 + \frac{R_{FH}}{R_{GH}}} \right) V_R$$

$$\text{Let } G_H = \frac{R_{FH}}{R_{GH}}$$

$$V_A = \left( \frac{G_H}{1 + G_H} \right) V_R$$

$$V_O = (1 + G_L) V_A - G_L V_{IN}$$

Combined analysis:

$$V_A = \left( \frac{G_H}{1 + G_H} \right) V_R$$

$$V_O = (1 + G_L) V_A - G_L V_{IN}$$

$$V_O = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN} \quad \text{Equation 1}$$

If  $G_H = G_L$  Then

$$V_O = G(V_R - V_{IN})$$

$$\text{If } V_{IN} = 0 \quad V_O = G V_R = V_{Omax}$$

$$\text{If } V_{IN} = V_R \quad V_O = 0 = V_{Omin}$$

### Gain Selection based on Input Voltage and Output Voltage Ranges:

*For the case of no source bias ( $R_s = \infty$ ) and zero source resistance ( $R_{in} = 0$ ):*

Determination of the Gains ( $G_L$  and  $G_H$ ) is based on equation 1 above and knowledge of the input and output voltage ranges. For the analysis below, the input range is restricted to unipolar inputs with the minimum  $V_{in} = 0$  volts.

First determine the value of  $G_L$ :

$$V_O = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN}$$

Let the range of  $V_{IN}$  be:  $V_{INMIN} \leq V_{IN} \leq V_{INMAX}$  where  $V_{INMIN} = 0$

Let the range of  $V_O$  be:  $V_{OL} \leq V_O \leq V_{OH}$

Because the amplifier is an inverting amplifier,  $V_{OH}$  will occur when  $V_{IN} = 0$

Case 1:  $V_{IN} = V_{INMIN} = 0$

$$V_{OH} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R \quad \Rightarrow \quad \frac{V_{OH}}{V_R} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H$$

Case 2:  $V_{IN} = V_{INMAX}$

$$V_{OL} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{INMAX} \quad \text{then substituting } \frac{V_{OH}}{V_R} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H$$

$$V_{OL} = \frac{V_{OH}}{V_R} V_R - G_L V_{INMAX} = V_{OH} - G_L V_{INMAX}$$

$$G_L = \frac{V_{OH} - V_{OL}}{V_{INMAX}} \quad \text{Equation 2}$$



Next use  $G_L$  to determine the value of  $G_H$ :

$$\text{From above : } G_L = \frac{V_{OH} - V_{OL}}{V_{INMAX}} \quad \text{and} \quad V_{OH} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R$$

Substituting for  $G_L$  :

$$V_{OH} = \left( \frac{1 + \frac{V_{OH} - V_{OL}}{V_{INMAX}}}{1 + G_H} \right) G_H V_R$$

$$(1 + G_H) \frac{V_{OH}}{V_R} = \left( 1 + \frac{V_{OH} - V_{OL}}{V_{INMAX}} \right) G_H$$

$$\frac{V_{OH}}{V_R} = \left( 1 + \frac{V_{OH} - V_{OL}}{V_{INMAX}} - \frac{V_{OH}}{V_R} \right) G_H$$

$$\frac{1}{G_H} = \left( \frac{1 + \frac{V_{OH} - V_{OL}}{V_{INMAX}} - \frac{V_{OH}}{V_R}}{\frac{V_{OH}}{V_R}} \right) = \frac{V_R}{V_{OH}} + \frac{V_R}{V_{OH}} \left( \frac{V_{OH} - V_{OL}}{V_{INMAX}} \right) - 1 \quad \text{Equation 3}$$

If  $V_R = V_{OH}$  and  $V_{OL} = 0$  then  $\frac{1}{G_H} = \frac{V_{OH}}{V_{INMAX}}$  and the gain equations are :

$$G_H = \frac{V_{INMAX}}{V_{OH}} \quad \text{and} \quad G_L = \frac{V_{OH}}{V_{INMAX}} = \frac{1}{G_H} \quad \text{Equations 4 and 5}$$

For the more general case of unipolar inputs with non zero minimum input ( $V_{in} > 0$  volts):

$$V_O = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN}$$

Let the range of  $V_{IN}$  be :  $V_{INMIN} \leq V_{IN} \leq V_{INMAX}$

Let the range of  $V_O$  be :  $V_{OL} \leq V_O \leq V_{OH}$

Because the amplifier is an inverting amplifier,  $V_H$  will occur when  $V_{IN} = 0$

Case 1:  $V_{IN} = V_{INMIN}$

$$V_{OH} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{INMIN} \Rightarrow \frac{V_{OH}}{V_R} + G_L V_{INMIN} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H$$

Case 2:  $V_{IN} = V_{INMAX}$

$$V_{OL} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{INMAX} \quad \text{then substituting } \frac{V_{OH}}{V_R} + G_L V_{INMIN} = \left( \frac{1 + G_L}{1 + G_H} \right) G_H$$

$$V_{OL} = \left( \frac{V_{OH}}{V_R} + G_L V_{INMIN} \right) V_R - G_L V_{INMAX} = V_{OH} + G_L V_{INMIN} - G_L V_{INMAX}$$

$$G_L = \frac{V_{OH} - V_{OL}}{V_{INMAX} - V_{INMIN}} \quad \text{Equation 2g}$$

**Analysis with source bias ( $R_s$  finite,  $V_s$  non zero) and non zero input resistance ( $R_{IN}$ ):**

Non Inverting Branch Analysis:

$$\frac{V_R - V_A}{R_{GH}} = \frac{V_A}{R_{FH}}$$

$$\frac{V_R}{R_{GH}} = \left( \frac{1}{R_{FH}} + \frac{1}{R_{GH}} \right) V_A$$

$$\frac{V_R}{R_{GH}} = \left( \frac{R_{FH} + R_{GH}}{R_{FH} R_{GH}} \right) V_A$$

$$V_A = \left( \frac{R_{FH} R_{GH}}{R_{FH} + R_{GH}} \right) \frac{V_R}{R_{GH}}$$

$$V_A = \left( \frac{R_{FH}}{R_{FH} + R_{GH}} \right) V_R$$

$$V_A = \left( \frac{\frac{R_{FH}}{R_{GH}}}{1 + \frac{R_{FH}}{R_{GH}}} \right) V_R$$

$$\text{Let } G_H = \frac{R_{FH}}{R_{GH}}$$

$$V_A = \left( \frac{G_H}{1 + G_H} \right) V_R$$

Inverting Branch Analysis:

$$\frac{V_O - V_A}{R_{FL}} = \frac{V_A - V_{IN}}{R_{GL}}$$

$$\frac{V_O}{R_{FL}} = \left( \frac{1}{R_{FL}} + \frac{1}{R_{GL}} \right) V_A - \frac{V_{IN}}{R_{GL}}$$

$$V_O = \left( 1 + \frac{R_{FL}}{R_{GL}} \right) V_A - \frac{R_{FL}}{R_{GL}} V_{IN}$$

$$\text{Let } G_L = \frac{R_{FL}}{R_{GL}}$$

$$V_O = (1 + G_L) V_A - G_L V_{IN}$$

$$\frac{V_A - V_B}{R_{GL}} = \frac{V_B - V_s}{R_s} + \frac{V_B - V_{IN}}{R_{IN}}$$

$$\frac{V_A}{R_{GL}} = \frac{V_B}{R_{GL}} + \frac{V_B}{R_s} + \frac{V_B}{R_{IN}} - \frac{V_s}{R_s} - \frac{V_{IN}}{R_{IN}}$$

$$\frac{V_A}{R_{GL}} + \frac{V_s}{R_s} + \frac{V_{IN}}{R_{IN}} = \left( \frac{1}{R_{GL}} + \frac{1}{R_s} + \frac{1}{R_{IN}} \right) V_B$$

$$V_B = \frac{\frac{V_A}{R_{GL}} + \frac{V_s}{R_s} + \frac{V_{IN}}{R_{IN}}}{\left( \frac{1}{R_{GL}} + \frac{1}{R_s} + \frac{1}{R_{IN}} \right)}$$

$$V_B = \frac{\frac{V_A}{R_{GL}} + \frac{V_s}{R_s} + \frac{V_{IN}}{R_{IN}}}{\left( \frac{1}{R_{GL}} + \frac{1}{R_s} + \frac{1}{R_{IN}} \right)}$$

$$V_o = (1 + G_L) V_A - G_L V_B$$

$$V_o = (1 + G_L) V_A - G_L \left[ \frac{\frac{V_A}{R_{GL}} + \frac{V_s}{R_s} + \frac{V_{IN}}{R_{IN}}}{\frac{1}{R_{GL}} + \frac{1}{R_s} + \frac{1}{R_{IN}}} \right]$$

$$V_o = V_A + G_L \left[ \frac{\frac{R_{GL}}{R_s} + \frac{R_{GL}}{R_{IN}}}{1 + \frac{R_{GL}}{R_s} + \frac{R_{GL}}{R_{IN}}} \right] V_A - G_L \left[ \frac{1}{1 + \frac{R_s}{R_{GL}} + \frac{R_s}{R_{IN}}} \right] V_s - G_L \left[ \frac{1}{1 + \frac{R_{IN}}{R_{GL}} + \frac{R_{IN}}{R_s}} \right] V_{IN}$$

$$V_o = \frac{G_H}{1 + G_H} V_R + G_L \left[ \frac{\frac{R_{GL}}{R_s} + \frac{R_{GL}}{R_{IN}}}{1 + \frac{R_{GL}}{R_s} + \frac{R_{GL}}{R_{IN}}} \right] \frac{G_H}{1 + G_H} V_R - G_L \left[ \frac{1}{1 + \frac{R_s}{R_{GL}} + \frac{R_s}{R_{IN}}} \right] V_s - G_L \left[ \frac{1}{1 + \frac{R_{IN}}{R_{GL}} + \frac{R_{IN}}{R_s}} \right] V_{IN}$$

$$\text{Let } G_{sL} = \frac{R_s}{R_{GL}} \quad G_{sI} = \frac{R_s}{R_{IN}} \quad G_{IL} = \frac{R_{IN}}{R_{GL}} \quad G_{IS} = \frac{R_{IN}}{R_s} \quad G_{LS} = \frac{R_{GL}}{R_s} \quad G_{LI} = \frac{R_{GL}}{R_{IN}}$$

$$V_o = \frac{G_H}{1 + G_H} V_R + \left[ \frac{G_{LS} + G_{LI}}{1 + G_{LS} + G_{LI}} \right] \frac{G_L G_H}{1 + G_H} V_R - \left[ \frac{G_L}{1 + G_{sL} + G_{sI}} \right] V_s - \left[ \frac{G_L}{1 + G_{IL} + G_{IS}} \right] V_{IN}$$

$$V_o = \frac{G_H}{1+G_H} V_R + G_L \left[ \frac{\frac{R_{GL}}{R_S} + \frac{R_{GL}}{R_{IN}}}{1 + \frac{R_{GL}}{R_S} + \frac{R_{GL}}{R_{IN}}} \right] \frac{G_H}{1+G_H} V_R - G_L \left[ \frac{1}{1 + \frac{R_S}{R_{GL}} + \frac{R_S}{R_{IN}}} \right] V_s - G_L \left[ \frac{1}{1 + \frac{R_{IN}}{R_{GL}} + \frac{R_{IN}}{R_S}} \right] V_{IN}$$

$$\text{Let } G_{SL} = \frac{R_S}{R_{GL}} \quad G_{SI} = \frac{R_S}{R_{IN}} \quad G_{IL} = \frac{R_{IN}}{R_{GL}} \quad G_{IS} = \frac{R_{IN}}{R_S} \quad G_{LS} = \frac{R_{GL}}{R_S} \quad G_{LI} = \frac{R_{GL}}{R_{IN}}$$

$$V_o = \frac{G_H}{1+G_H} V_R + \left[ \frac{G_{LS} + G_{LI}}{1 + G_{LS} + G_{LI}} \right] \frac{G_L G_H}{1+G_H} V_R - \left[ \frac{G_L}{1 + G_{SL} + G_{SI}} \right] V_s - \left[ \frac{G_L}{1 + G_{IL} + G_{IS}} \right] V_{IN}$$

If  $R_S = \infty$   $R_{IN} = 0$   $R_{GL} = R_{GH} = R_G$   $R_{FL} = R_{FH} = R_F$  Then  $G_L = G_H = G$  and

$$G_{SL} = \frac{R_S}{R_{GL}} = \infty \quad G_{SI} = \frac{R_S}{R_{IN}} = \infty \quad G_{IL} = \frac{R_{IN}}{R_{GL}} = 0 \quad G_{IS} = \frac{R_{IN}}{R_S} = 0 \quad G_{LS} = \frac{R_{GL}}{R_S} = 0 \quad G_{LI} = \frac{R_{GL}}{R_{IN}} = \infty$$

$$V_o = \frac{G_H}{1+G_H} V_R + \left[ \frac{G_{LS} + G_{LI}}{1 + G_{LS} + G_{LI}} \right] \frac{G_L G_H}{1+G_H} V_R - \left[ \frac{G_L}{1 + G_{SL} + G_{SI}} \right] V_s - \left[ \frac{G_L}{1 + G_{IL} + G_{IS}} \right] V_{IN}$$

$$V_o = \frac{G}{1+G} V_R + \frac{G^2}{1+G} V_R - 0 - G V_{IN}$$

$$V_o = \frac{G}{1+G} (1+G) V_R - G V_{IN} = G (V_R - V_{IN})$$

Alternate Let  $R_S = \infty$   $R_{IN} = 0$   $R_{GL} = R_{GH} = R_G$

$$G_{SL} = \frac{R_S}{R_{GL}} = \infty \quad G_{SI} = \frac{R_S}{R_{IN}} = \infty \quad G_{IL} = \frac{R_{IN}}{R_{GL}} = 0 \quad G_{IS} = \frac{R_{IN}}{R_S} = 0 \quad G_{LS} = \frac{R_{GL}}{R_S} = 0 \quad G_{LI} = \frac{R_{GL}}{R_{IN}} = \infty$$

$$V_o = \frac{G_H}{1+G_H} V_R + \left[ \frac{G_{LS} + G_{LI}}{1 + G_{LS} + G_{LI}} \right] \frac{G_L G_H}{1+G_H} V_R - \left[ \frac{G_L}{1 + G_{SL} + G_{SI}} \right] V_s - \left[ \frac{G_L}{1 + G_{IL} + G_{IS}} \right] V_{IN}$$

$$V_o = \frac{G_H}{1+G_H} V_R + \frac{G_L G_H}{1+G_H} V_R - G_L V_{IN} = \frac{1+G_L}{1+G_H} G_H V_R - G_L V_{IN}$$

These derived formulas will be used to calculate the gain resistors and output ranges for each of the sensors in the drill head.

Two sensors, the Watson navigation pack and the Paroscientific pressure transducer, connect directly to the BL1700 board via the onboard RS232 ports,

while the rest of the sensors in the drill head connect to this board via the signal conditioning board.

Figure 2.150 below is a table of the board's mechanical and electrical properties. For further information on the board, see the BL1700 C-Programmable Controller User's Manual, P/No: 019-0048.020415-G.

Parameter	Specification
Board Size	4.20" × 6.25" × 0.85" (107 mm × 159 mm × 21.6 mm)
Operating Temperature	-40°C to 70°C
Humidity	5% to 95%, noncondensing
Power	15 V DC to 30 V DC, 140 mA
Digital Inputs	16 standard, up to 32 possible at expense of outputs
Digital Outputs	16 standard, up to 32 possible at expense of inputs
Analog Inputs	Ten 12-bit channels: <ul style="list-style-type: none"> <li>• 8 conditioned, factory configured 0 V to 10 V</li> <li>• 2 unconditioned, 0 V to 2.5 V</li> </ul>
Analog Outputs	Pulse-width modulated, on digital output lines
Resistance Measurement Input	No
Processor	Z180
Clock	18.432 MHz standard
SRAM	32K standard, supports up to 512K
Flash EPROM	128K standard, supports up to 256K, up to 512K EPROM possible
Serial Ports	<ul style="list-style-type: none"> <li>• 1 full-duplex RS-232</li> <li>• 3 configurable as full-duplex RS-232 or as RS-485</li> </ul>
Serial Rate	Up to 57,600 bps
Watchdog	Yes
Time/Date Clock	Yes
Backup Battery	Panasonic BR2325-1HG 3 V DC lithium ion, rated life 190 mA·h

**Figure 2.150** BL1700 mechanical and electrical specifications

### **2.6.3.3.2 Input conditioning board (ICB)**

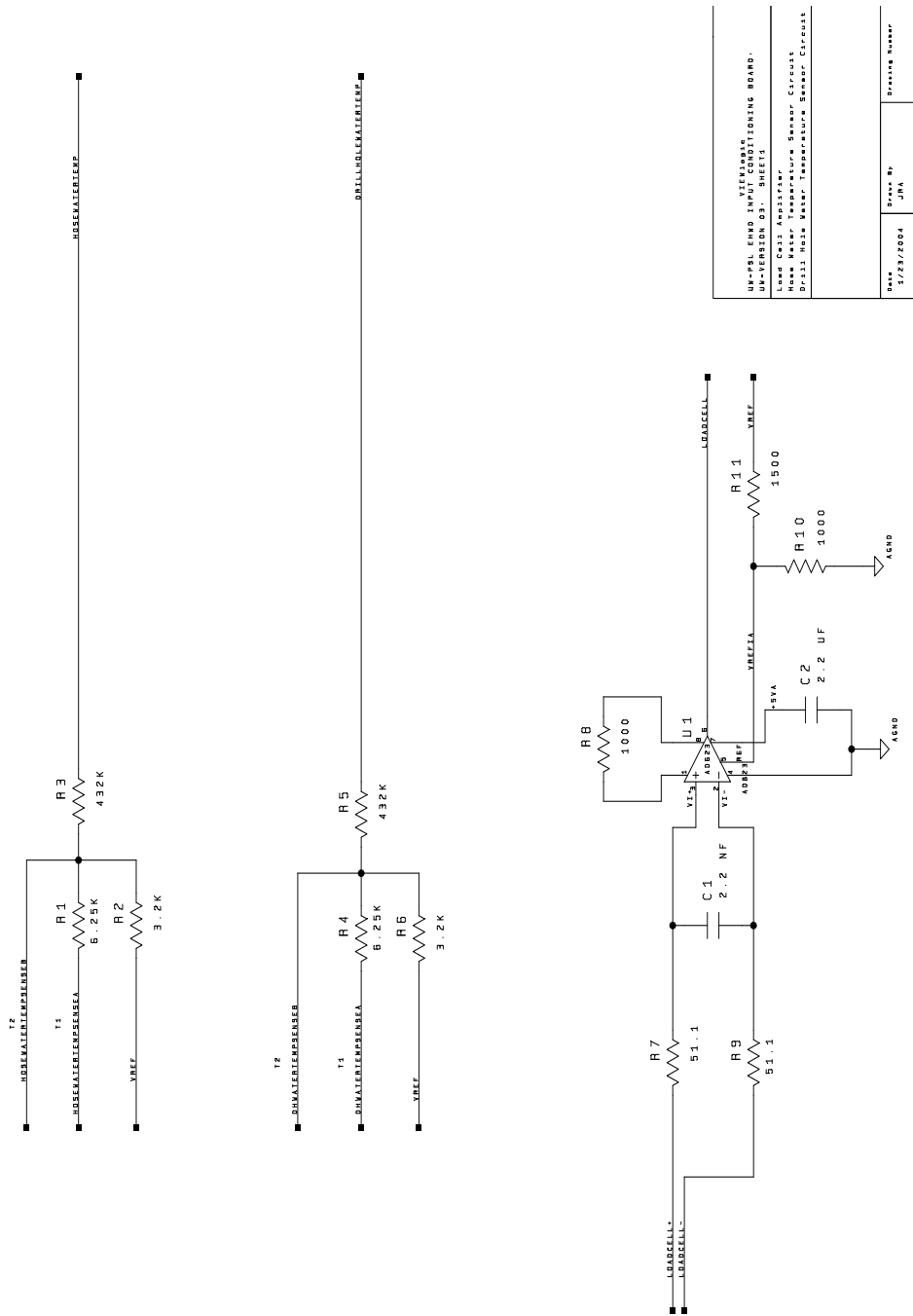
The input conditioning board (ICB) accepts input from, and provides signal conditioning for the following drill head sensors:

- Load cell amplifier
- Hose water temperature
- Drill hole water temperature
- Heat sink temperature
- Cavity air pressure sensor
- Regulator input and output voltages
- Tseal 1 and Tseal 2 pressure sensors

It also provides power to the 2 MLDT sensors as well as converting the 4-20mA output from these sensors to a voltage.

These conditioned sensors outputs are then fed to the analog inputs of the BL1700 computer board for scaling before being formatted into the correct strings output and transmitted to the surface control computer.

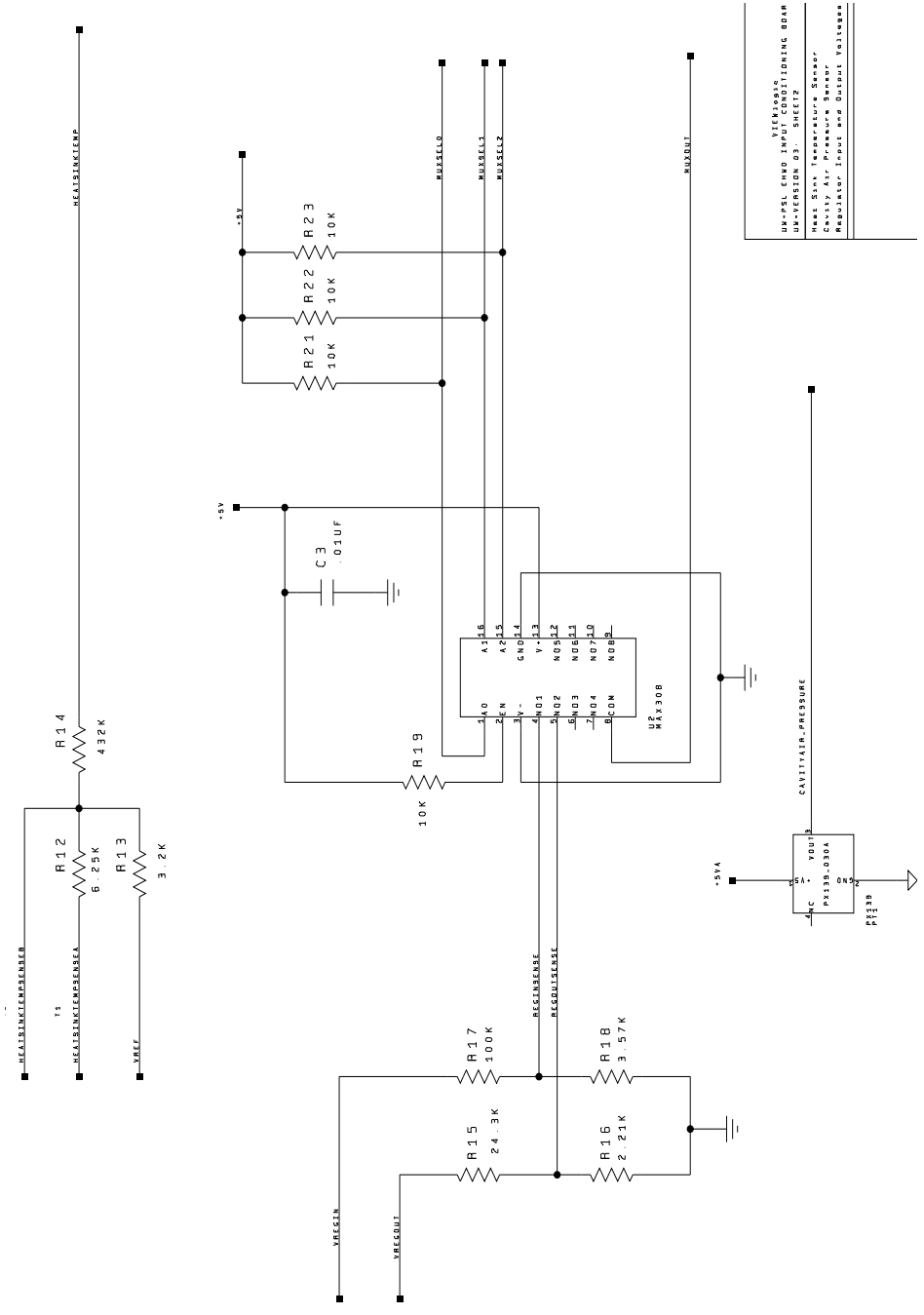
The following figures show the conditioning and scaling circuits for the various sensors. After the ICB circuit diagrams, an end to end circuit analysis of each sensor is presented.



TELERIS  
 UN-PSL EHWD IMPULS CONDITIONING BOARD.  
 UN-VERSION 03. SHEET1  
 Load Cell Amplifier  
 Hose Water Temperature Sensor Circuit  
 Drill Hole Water Temperature Sensor Circuit

Date: 1/23/2004  
 Drawn By: JPA  
 Drawing Number:

**Figure 2.151** ICB load cell amp, hose water and drill hole water temp sensor circuits

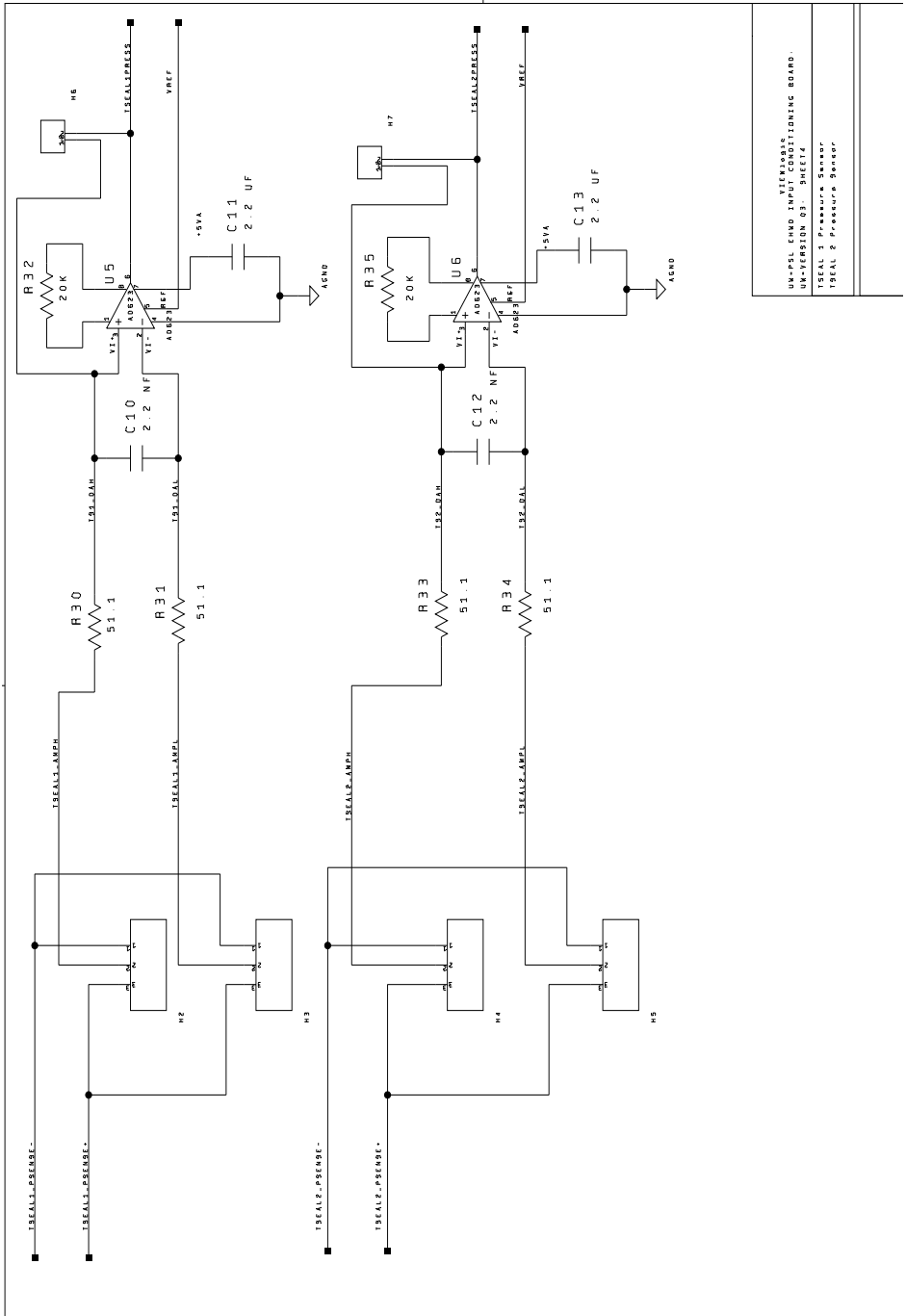


ICB308  
 HW/PSL EMD INPUT CONDITIONING BOARD  
 HW VERSION 03 - SHEET 2  
 Heat Sink Temperature Sensor  
 Cavity Air Pressure Sensor  
 Regulator Input and Output Voltages

**Figure 2.152** ICB heat sink temp sensor, cavity air pressure sensor and regulator voltage circuits







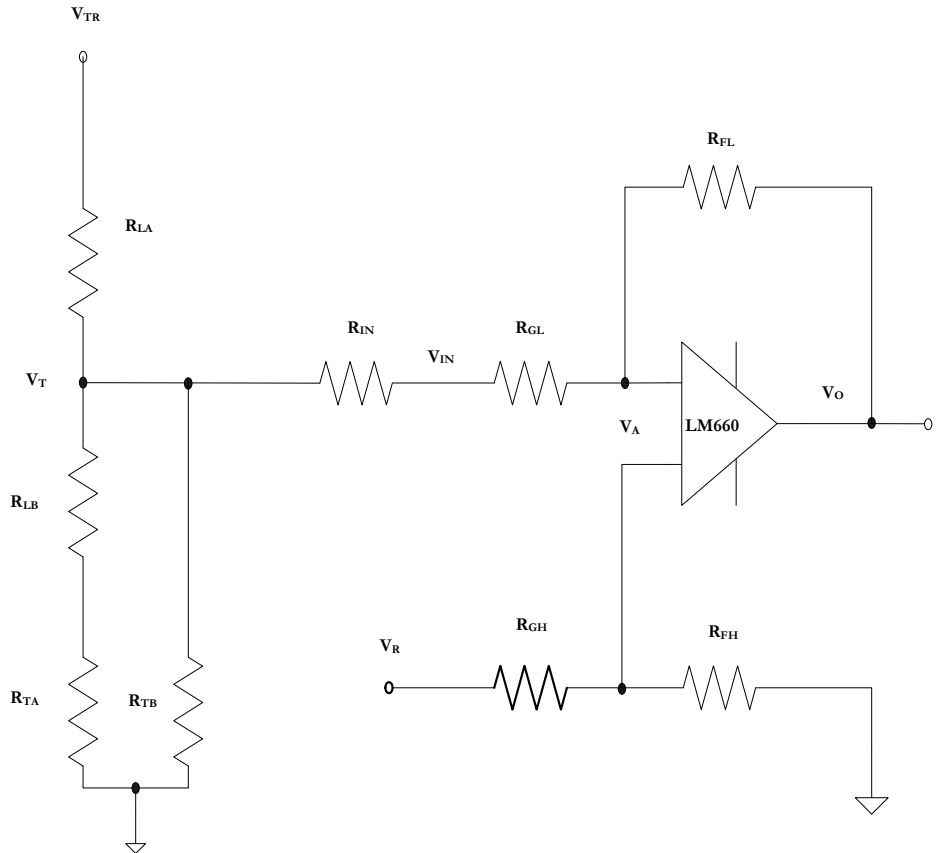
VIKING  
 UN-PSI EMD IMPROVEMENTS  
 UN-VERSION 03 - SHEET 4  
 TSEAL 1 Pressure Sensor  
 TSEAL 2 Pressure Sensor

**Figure 2.154** ICB Tseal 1 and Tseal 2 pressure sensor circuits



### ***Drill Hose Water Temperature Sensor circuit analysis:***

The drill head uses an Omega 44018 Thermistor to measure the hose water temperature. For the EHWD the Hose Water Temp Thermistor circuit output is applied to the BL1700 Analog Input (AIN) 6. The corresponding gain (RFL) and bias (RFH) resistors are R37 and R53. The thermistor-amplifier configuration is shown in Figure 2.156.



**Figure 2.156** EHWD Temperature sensors thermistor/ amplifier configuration

The resistor values used and corresponding output equations are given below. Because the Thevenin equivalent resistance of the thermistor and linearizing resistor network ( $R_{LA}$ ,  $R_{LB}$ ,  $R_{TA}$ , and  $R_{TB}$ ) is much smaller than the value of  $R_{IN}$  (432k), the thermistor-amplifier circuit can be approximated as a voltage source with zero source impedance as shown in Figure 2.149 (with  $R_s = \infty$  and  $R_{in} = 0$ ) with  $R_{GL}$  replaced with  $R_{GLI} = R_{GL} + R_{IN}$ .

$$\begin{aligned}
R_{FH} &= R_{51} \text{ (bias)} = 9090 \text{ ohms} \\
R_{FL} &= R_{36} \text{ (gain)} = 475000 \text{ ohms} \\
R_{GH} &= 10000 \text{ ohms} \\
R_{GLI} &= R_{GH} + R_{IN} = 10000 + 432000 = 442000 \\
G_H &= \frac{R_{FH}}{R_{GH}} = \frac{9090}{10000} = .909 \\
G_L &= \frac{R_{FL}}{R_{GLI}} = \frac{475000}{442000} = 1.07466 \approx 1.075 \\
V_O &= \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN} \\
V_O &= \left( \frac{2.1075}{1.909} \right) .909V_R - 1.075V_{IN} \\
V_O &= .987881884V_R - 1.075V_{IN}
\end{aligned}$$

The Hose Water Temperature Sensor amplifier output range is a function of the temperature range seen by the sensor and the general equation for the sensor network output voltage ( $V_T$  in Figure 2.156). The hose water temperature range will essentially be the same as the thermistor range: 32° F to 212° F. The sensor network used for all three thermistors (hose water temp, drill water temp, and heat sink temp) is the same network recommended by Omega for use with the 44018 thermistor. Omega provides an equation for the network output voltage  $V_T$ . This equation in combination with the amplifier output equation above and the hose water temperature range can be combined to determine the amplifier output range as shown below, with the complete temperature end to end circuit shown in Figure 2.157.

Amplifier output range :

$$\text{From above : } V_O = .987881884V_R - 1.075V_{IN}$$

The equation for the thermistor network output voltage  $V_T$  provided by Omega :

$$V_T = -0.00297127 V_{TR} T + 0.96015V_{TR} \quad \text{where } V_{TR} = \text{Thermistor excitation voltage}$$

Since  $V_{IN} = V_T$  Substituting gives :

$$V_O = .987881884V_R - 1.075(-0.00297127 V_{TR} T + 0.96015V_{TR})$$

$$V_O = .987881884V_R + 0.003194115V_{TR} T - 1.03216125 V_{TR} \quad \text{then substituting } V_R = 2.5$$

$$V_O = 2.4697 + 0.003194115V_{TR} T - 1.03216125 V_{TR}$$

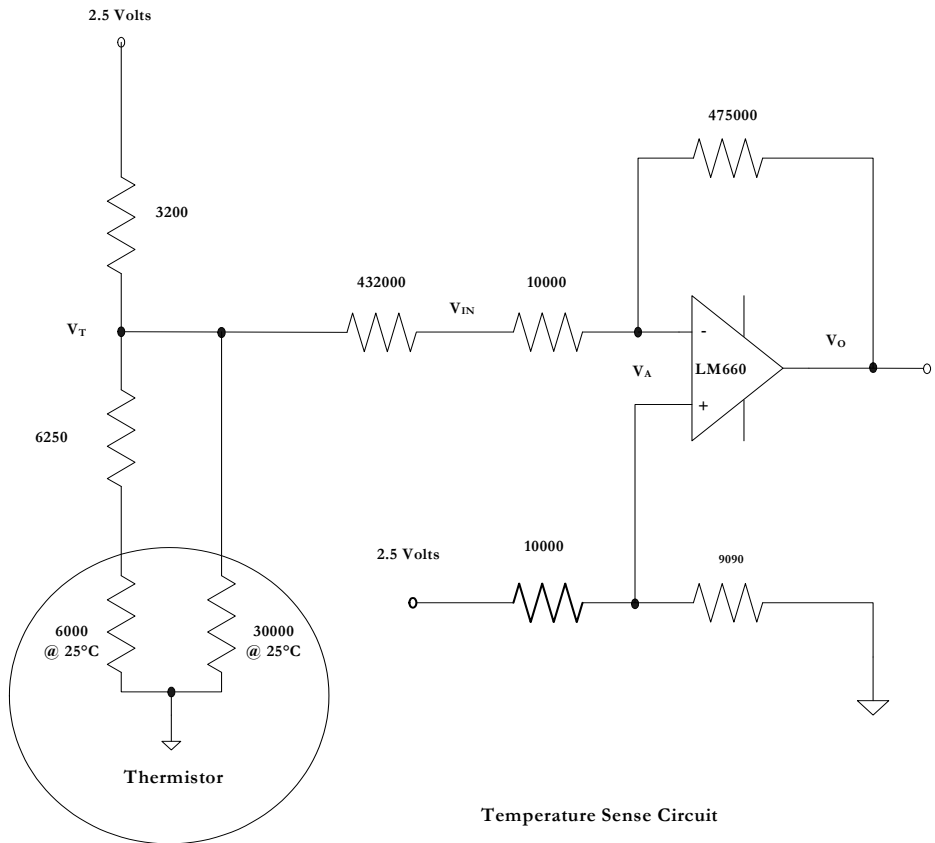
Then substituting  $V_{TR} = 2.5$  volts

$$V_O = 2.4697 + 0.007985288T - 2.580403125$$

$$V_O = -0.110698416 + 0.007985288T$$

$$\text{When } T = 32^\circ\text{F} \Rightarrow V_O = 0.145 \text{ Volts}$$

$$\text{When } T = 212^\circ\text{F} \Rightarrow V_O = 1.58 \text{ Volts}$$



**Figure 2.157** Temperature Sense circuit with input and gain resistors shown

***Drill Hole Water Temperature Sensor circuit analysis:***

The drill hole water temperature sensor is the same as for the hose water with the thermistor circuit output applied to AIN 5 on the BL1700 board, with the corresponding gain (RFL) and bias (RFH) resistors being R49 and R52.

The circuit is the same as for the hose water temperature thermistor circuit, shown in Figure 2.156 above and correspondingly, the same resistor values and output equations.

Because the circuit is the same as for the hose water temperature thermistor, the range equations will also be the same. However, the output range of the amplifier will differ because the drill hole water temperature will not be as high as the hose water temperature. Assuming a drill hole water maximum temperature of 50° F, the output amp range will be:

$$V_o = -0.110698416 + 0.007985288T$$

$$\text{When } T = 32^\circ\text{F} \Rightarrow V_o = 0.145 \text{ Volts}$$

$$\text{When } T = 50^\circ\text{F} \Rightarrow V_o = 1.58 \text{ Volts}$$

### ***Heat sink temperature sensor circuit analysis:***

The heat sink temperature sensor is the same as for the hose water with the thermistor circuit output applied to AIN 3 on the BL1700 board, with the corresponding gain (RFL) and bias (RFH) resistors being R35 and R18.

The circuit is the same as for the hose water temperature thermistor circuit, shown in Figure 2.156 above and correspondingly, the same resistor values and output equations.

Because the circuit is the same as for the hose water temperature thermistor, the range equations will also be the same. However, the output range of the amplifier will differ because the heat sink temperature will not be as high as the hose water temperature. Assuming the heat sink maximum temperature of 110°F, the output amp range will be:

$$V_o = -0.110698416 + 0.007985288T$$

$$\text{When } T = 32^\circ\text{F} \Rightarrow V_o = 0.145 \text{ Volts}$$

$$\text{When } T = 50^\circ\text{F} \Rightarrow V_o = 1.58 \text{ Volts}$$

### ***Load Cell circuit analysis:***

The Load Cell used on the drill is a Transducer Techniques TLL-3K tension only load cell with 3000 pound limit. The Load Cell Output is fed into an AD623 instrumentation amp and the output of the instrumentation amp is applied to Analog Input 4. The corresponding gain (RFL) and bias (RFH) resistors are R36 and R51. Because the output impedance of the instrumentation amp is essentially zero ohms, the circuit shown in Figure 2.149 (with  $R_s = \infty$  and  $R_{in} = 0$ ) applies. The resistor values used and the corresponding output equation are as follows:

$$R_{FH} = R50 \text{ (bias)} = 13000 \text{ ohms}$$

$$R_{FL} = R38 \text{ (gain)} = 22.1k \parallel 432k = 21024 \text{ ohms}$$

$$R_{GH} = 10000 \text{ ohms}$$

$$R_{GL} = 10000 \text{ ohms}$$

$$G_H = \frac{R_{FH}}{R_{GH}} = \frac{13000}{10000} = 1.3$$

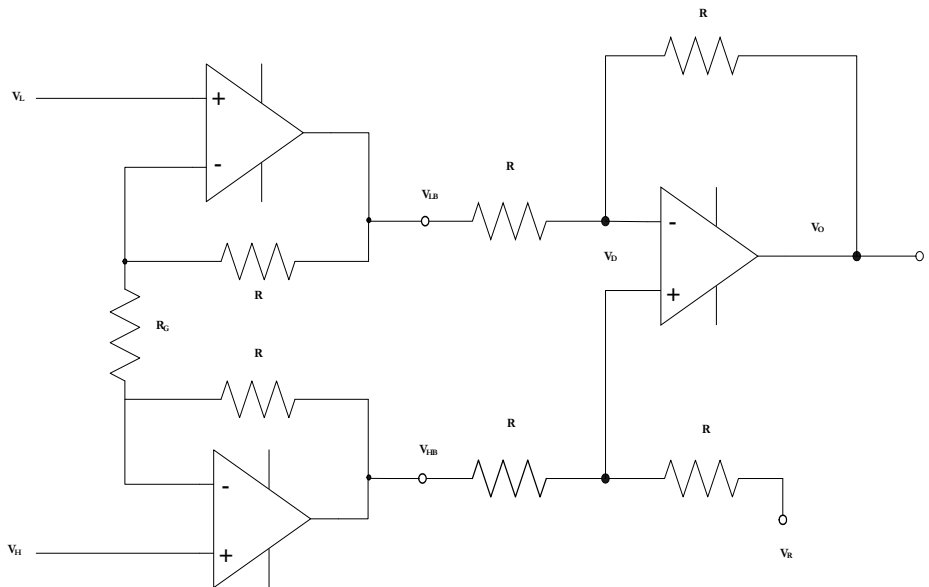
$$G_L = \frac{R_{FL}}{R_{GLI}} = \frac{21024}{10000} = 2.1024$$

$$V_O = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN}$$

$$V_O = \left( \frac{1 + 2.1024}{1 + 1.3} \right) 1.3V_R - 2.1024V_{IN}$$

$$V_O = 1.35V_R - 2.1024V_{IN} = 4.384 - 2.1024V_{IN}$$

The input into the BL1700 conditioning amp is the output of the Load Cell Instrumentation Amp (AD623). An internal schematic of this amplifier is shown in Figure 2.158 and its internal operation is analysed below.



**Figure 2.158** Load cell instrumentation amplifier (AD623) internal schematic

$$\frac{V_O - V_D}{R} = \frac{V_D - V_{LB}}{R} \Rightarrow \frac{V_O}{R} + \frac{V_{LB}}{R} = \frac{2V_D}{R} \Rightarrow V_O + V_{LB} = 2V_D$$

$$\frac{V_R - V_D}{R} = \frac{V_D - V_{HB}}{R} \Rightarrow \frac{V_R}{R} + \frac{V_{HB}}{R} = \frac{2V_D}{R} \Rightarrow V_R + V_{HB} = 2V_D$$

$$V_O - V_R = V_{HB} - V_{LB}$$



$$\frac{V_{LB} - V_L}{R} = \frac{V_L - V_H}{R_G} \Rightarrow \frac{V_{LB}}{R} + \frac{V_H}{R_G} = \left( \frac{1}{R} + \frac{1}{R_G} \right) V_L \Rightarrow$$

$$V_{LB} + \frac{R}{R_G} V_H = \left( 1 + \frac{R}{R_G} \right) V_L$$

$$\frac{V_{HB} - V_H}{R} = \frac{V_H - V_L}{R_G} \Rightarrow \frac{V_{HB}}{R} + \frac{V_L}{R_G} = \left( \frac{1}{R} + \frac{1}{R_G} \right) V_H \Rightarrow$$

$$V_{HB} + \frac{R}{R_G} V_L = \left( 1 + \frac{R}{R_G} \right) V_H$$

$$\text{Let } G = \frac{R}{R_G}$$

$$V_{HB} = (1 + G) V_H - G V_L \quad \text{and} \quad V_{LB} = (1 + G) V_L - G V_H \Rightarrow$$

$$V_{HB} - V_{LB} = V_O - V_R = (1 + G)(V_H - V_L) + G(V_H - V_L) \Rightarrow$$

$$V_O - V_R = (1 + 2G)(V_H - V_L) = (1 + 2G)V_{IN}$$

Equation B-1

$$\text{If } R = 50k \quad V_O - V_R = \left( 1 + \frac{100000}{R_G} \right) V_{IN}$$

The gain resistance used on the input conditioning board instrumentation amp was 1000 ohms and the reference voltage of 2.5 volts was divided down to 1 volt. Thus the load cell output equation is:

$$V_{IAO} - V_R = (1 + 2G)(V_H - V_L) = (1 + 2G)V_{IN} \quad \text{where } V_{IAO} = \text{Instrumentation Amp Output}$$

$$\text{If } R = 50k \quad V_{IAO} - V_R = \left( 1 + \frac{100000}{R_G} \right) V_{IN}$$

With  $V_R = 1$  Volt and  $R_G = 1000$  ohms :

$$V_{IAO} = 101V_{IN} + 1$$

On the PICO/Amanda Drill input conditioning board, the load cell was powered from the auxiliary +5Volt supply from the BL1700. With rated output of the load cell = 2 mv/V, the maximum output of the load cell (at 3000 pound load) would be 10 mv.

The maximum load will under normal operating conditions be 2000 pounds or less.

Thus the maximum output of the load cell with a 5 volt supply would be 6.7 mv or less.

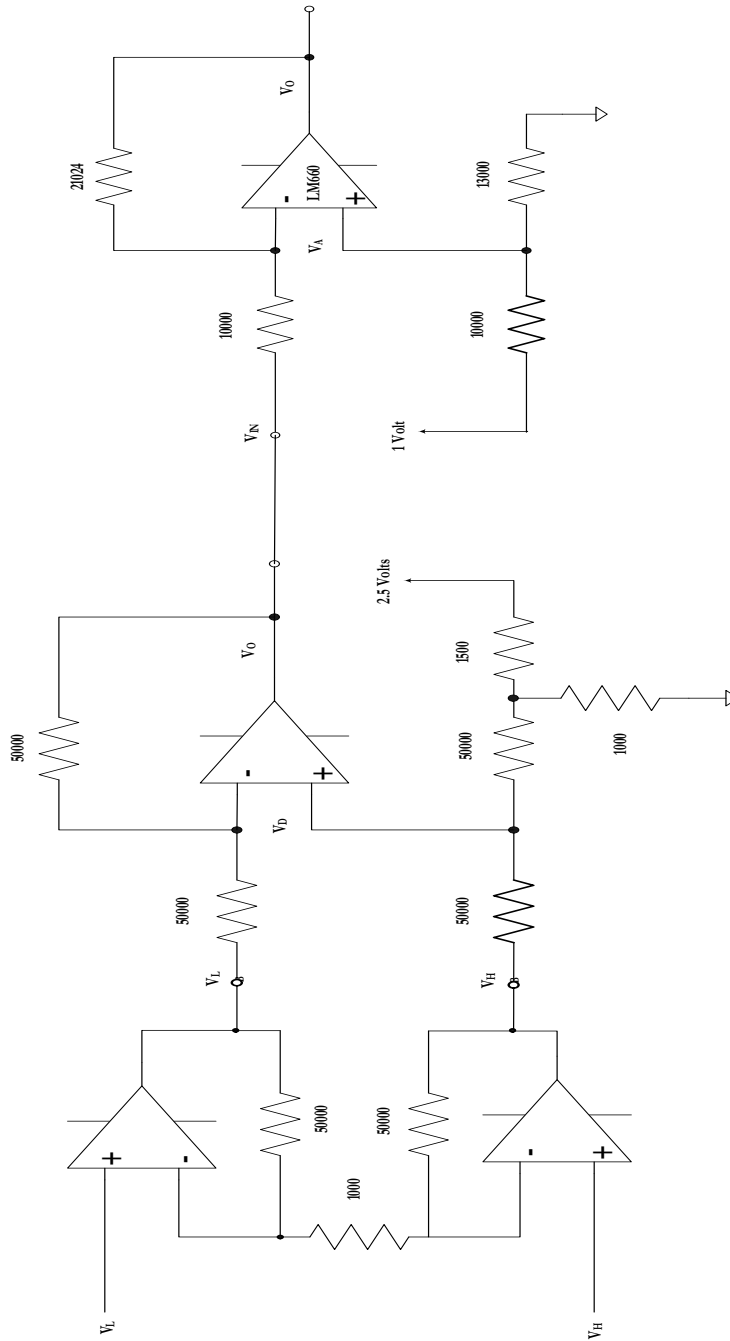
Assuming  $V_{OMAX} = 7$  mv, the BL1700 input amp output range from no load to slightly over 2000 pounds load will be :

$$V_O = 4.384 - 2.1024(101V_{IN} + 1) = 2.28 - 212.34V_{IN}$$

With No Load  $V_{IN} = 0$  and  $V_O = 2.28$  Volts

At Maximum Load  $V_{IN} = 0.007$  Volts and  $V_O = 2.28 - 1.4864 = 0.794$  Volts

The complete end to end circuit for the load cell amp, along with resistor values is shown in Figure 2.159.



**Figure 2.159** Load cell end to end circuit and resistor values

Load Cell BEL700 Analog Input Buffer Amplifier Setup

Load Cell AD623 Instrumentation Amplifier Setup  
 VH and VL connect to Load Cell Output (Bridge);  
 Load Cell is Powered from 5 Volt Supply

**MLDT1 circuit analysis:**

The MLDT used on the PICO/Amanda Drill is an MTS Temponics LHTRB00U00801AO 8.1 inch rod style position sensor. For the EHWD the MLDT 4 to 20 ma output is converted to a 484 mv to 2420 mv signal through a 121 ohm dropping resistor. This voltage is applied to AIN 1 on the BL1700 board. The corresponding gain (RFL) and bias (RFH) resistors are R34 and R19.

Because the input impedance of the BL1700 analog input amplifier circuit is over a factor of 50 larger than the 121 ohm dropping resistance, the circuit can be approximated as a voltage source with zero source impedance driving the basic amplifier shown in Figure 2.149 (with  $R_s = \infty$  and  $R_{in} = 0$ ). The resistor values used and corresponding output equation are as follows:

$$R_{FH} = R50 \text{ (bias)} = 10000 \text{ ohms}$$

$$R_{FL} = R38 \text{ (gain)} = 10000 \text{ ohms}$$

$$R_{GH} = 10000 \text{ ohms}$$

$$R_{GL} = 10000 \text{ ohms}$$

$$G_H = \frac{R_{FH}}{R_{GH}} = \frac{10000}{10000} = 1$$

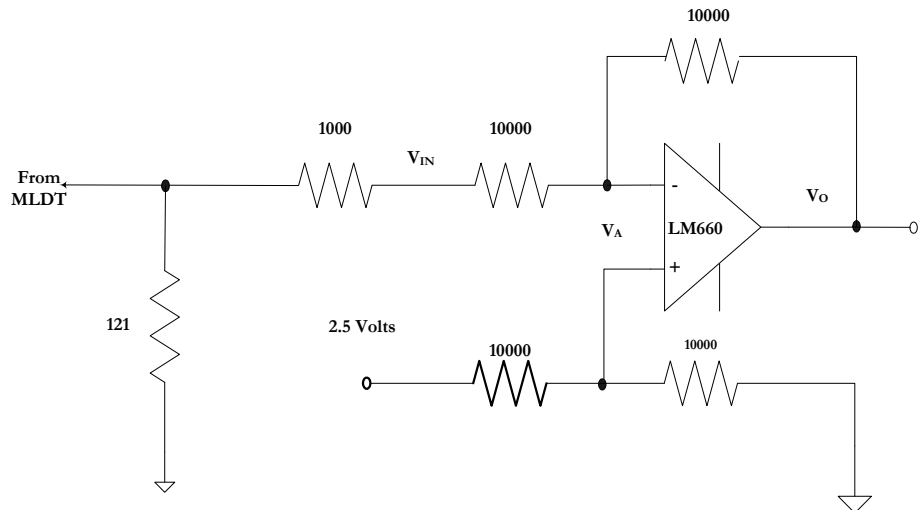
$$G_L = \frac{R_{FL}}{R_{GL}} = \frac{10000}{10000} = 1$$

$$V_o = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN}$$

$$V_o = V_R - V_{IN} = 2.5 - V_{IN}$$

When  $I = 4 \text{ ma}$   $V_{IN} = .484 \text{ volts} \Rightarrow V_o = 2.5 - .484 = 2.016 \text{ Volts}$

When  $I = 20 \text{ ma}$   $V_{IN} = 2.42 \text{ volts} \Rightarrow V_o = 2.5 - 2.42 = .08 \text{ Volts}$



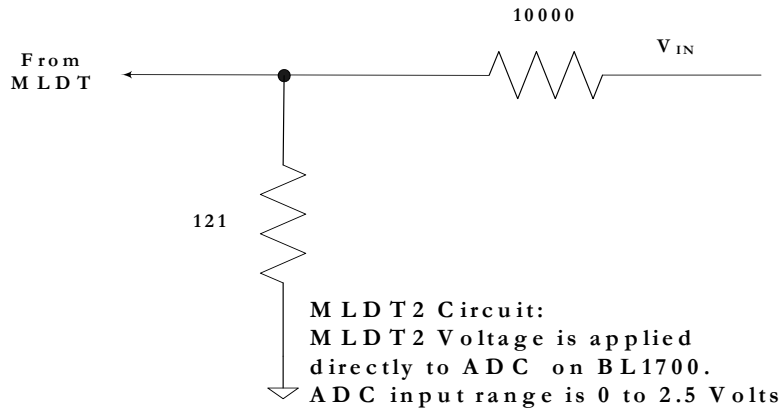
**Figure 2.160** MLDT1 circuit and resistor values

***MLDT2 circuit analysis:***

The second MLDT used on the EHWD is also an MTS Tempsonics LHTRB00U00801AO 8.1 inch rod style position sensor. The MLDT 4 to 20 ma output is converted to a 484 mv to 2420 mv signal through a 121 ohm dropping resistor. This voltage is applied to Analog Input 8, which is a direct input to the ADC.

When I = 4 ma  $V_{IN} = .484$  volts

When I = 20 ma  $V_{IN} = 2.42$  volts



**Figure 2.161** MLDT2 circuit and resistor values

***Parker T seal 1 and 2 pressure sensors circuit analysis:***

The sensors selected are an Invensys (Sensym ICT) 13C5000PA4K – a 5000 psia pressure sensor.

Because the sensor voltage is buffered by an AD623 instrumentation amp with a gain of 6 (the original design had a gain of 16.667, which caused the output of the AD623 to become non linear and eventually clip for maximum signal amplitudes of -150mV), the source impedance seen by the BL1700 amplifier is low and the circuit shown in Figure 2.149 (with  $R_s = \infty$  and  $R_{in} = 0$ ) applies. The output of the AD623 Instrumentation amp is fed to AIN7 for T seal 1 with gain (RFL) and bias (RFH) resistors being R38 and R50 and for Tseal 2, the output is fed to AIN0, with gain (RFL) and bias (RFH) resistors being R21 and R20. The gain resistor selection equations are derived as follows:

Instrument Amp Output :

$$V_{out} = 2.5 + 6V_{IN} \quad \text{where } -0.15 \leq V_{IN} \leq 0 \quad \text{and } R_g = 20000 \text{ ohms}$$

$$R_{GH} = 10000 \text{ ohms}$$

$$R_{GL} = 10000 \text{ ohms}$$

$$V_{OH} = V_R = 2.5 \text{ Volts when } V_{IN} = 0 \text{ Volts}$$

$$V_{OL} = 1.6 \text{ Volts when } V_{IN} = -.15 \text{ volts}$$

$$V_{INMAX} = 2.50 \text{ Volts}$$

These conditions can be used to determine the BL1700 gains :

$$G_H = \frac{V_{INMAX}}{V_{OH}} = \frac{2.5}{2.5} = 1 = \frac{R_{FH}}{R_{GH}} = \frac{R_{FH}}{10000} \Rightarrow R_{FH} = 10000 \text{ ohms}$$

$$G_L = \frac{1}{G_H} = 1 = \frac{R_{FL}}{R_{GL}} = \frac{R_{FL}}{10000} \Rightarrow R_{FL} = 10000 \text{ ohms}$$

$$V_O = \left( \frac{1+G_L}{1+G_H} \right) G_H V_R - G_L V_{IN}$$

$$V_O = 2.5 - V_{IN} = 2.5 - V_{IN}$$

$$\text{When } V_{IN} = 1.6 \quad V_O = .9 \text{ and}$$

$$\text{When } V_{IN} = 2.5 \quad V_O = 2.5 - 2.5 = 0$$

Under normal operation, the amplifier output voltage will remain approximately 0 volts. Only if there is a break in the seal will the voltage increase.

A single amplifier design is also given where only the BL1700 on board amplifier is used. For this design:

Input Range :

$$V_{inmax} = 0.15 \text{ Volts}$$

$$V_{inmin} = 0 \text{ Volts}$$

$$V_{OH} = \text{Max output of BL1700 amp}$$

These conditions can be used to determine the BL1700 gains :

$$G_H = \frac{V_{INMAX}}{V_{OH}} = \frac{.15}{2.5} = .06 = \frac{3}{50} = \frac{R_{FH}}{R_{GH}} = \frac{R_{FH}}{10000} \Rightarrow R_{FH} = 600 \text{ ohms}$$

$$G_L = \frac{1}{G_H} = \frac{50}{3} = \frac{R_{FL}}{R_{GL}} = \frac{R_{FL}}{10000} \Rightarrow R_{FL} = 166667 \text{ ohms}$$

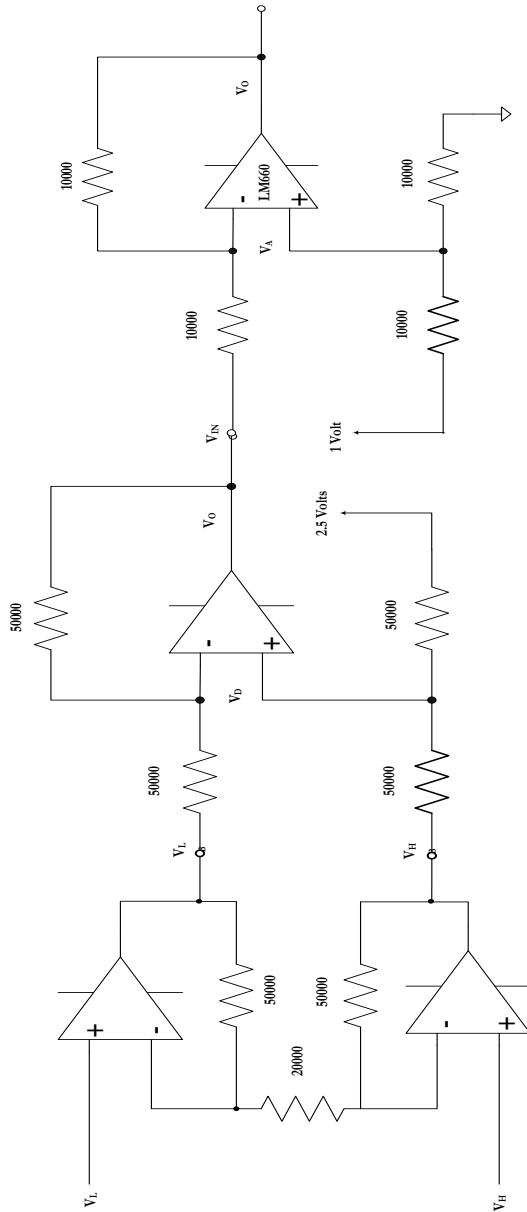
$$V_O = \left( \frac{1+G_L}{1+G_H} \right) G_H V_R - G_L V_{IN}$$

$$V_O = 2.5 - G_L V_{IN} = 2.5 - \frac{50}{3} V_{IN}$$

$$\text{When } V_{IN} = 0 \quad V_O = 2.5 \text{ and}$$

$$\text{When } V_{IN} = .15 \quad V_O = 2.5 - 2.5 = 0$$

The Tseal pressure sensor complete end to end circuit with resistor values is shown below.



**Figure 2.162** Tseal pressure sensor end to end circuit diagram

Tseal Sensor BL1700 Analog Input Buffer Amplifier Setup

Tseal Sensor AD623 Instrumentation Amplifier Setup  
 $V_H$  and  $V_L$  connect to Tseal Sensor Output (Bridge);  
 Tseal Sensors are Powered from 10 Volt Supply

### ***Cavity air pressure sensor circuit analysis:***

The sensor selected is an Omega pressure sensor. Because the output impedance of the pressure sensor is low, the circuit shown in Figure 2.149 (with  $R_s = \infty$  and  $R_{in} = 0$ ) applies. The gain resistor selection equations are derived as follows:

$$R_{GH} = 10000 \text{ ohms}$$

$$R_{GL} = 10000 \text{ ohms}$$

$$V_{OH} = V_R = 2.5 \text{ Volts}$$

$$V_{OL} = 0 \text{ Volts}$$

$$V_{INMIN} = 0.25 \text{ Volts}$$

$$V_{INMAX} = 4.25 \text{ Volts}$$

If  $V_{INMIN} = 0$  Volts is used instead of  $V_{INMIN} = 0.25$  Volts,

Equations 4 and 5 can be used to determine the gains :

$$G_H = \frac{V_{INMAX}}{V_{OH}} = \frac{4.25}{2.5} = \frac{17}{10} = \frac{R_{FH}}{R_{GH}} = \frac{R_{FH}}{10000} \Rightarrow R_{FH} = 17000 \text{ ohms}$$

$$G_L = \frac{1}{G_H} = \frac{10}{17} = \frac{R_{FL}}{R_{GL}} = \frac{R_{FL}}{10000} \Rightarrow R_{FL} = 5882 \text{ ohms}$$

$$V_O = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN}$$

$$V_O = \left( \frac{1 + \frac{10}{17}}{1 + \frac{17}{10}} \right) \left( \frac{17}{10} \right) 2.5 - \frac{10}{17} V_{IN} = 2.5 - \frac{10}{17} V_{IN}$$

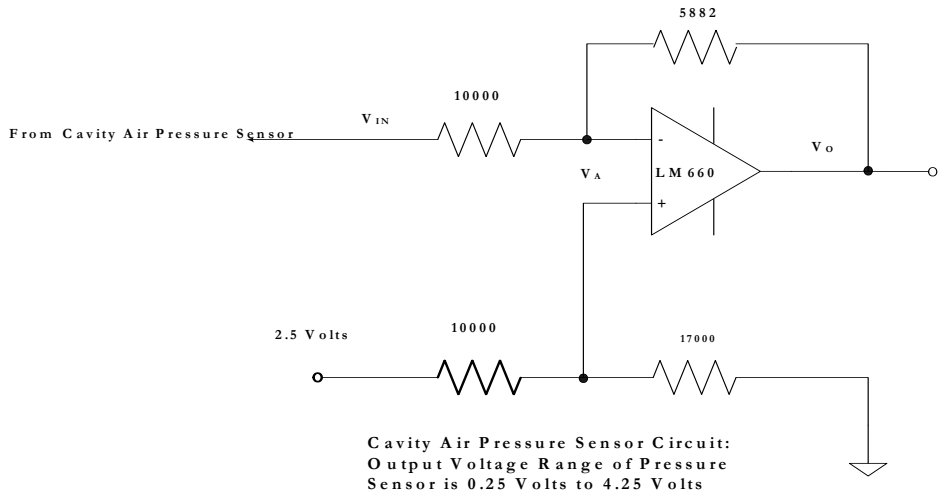
When  $V_{IN} = 0$   $V_O = 2.5$  and

When  $V_{IN} = 4.25$   $V_O = 2.5 - \frac{10}{17}(4.25) = 0$

Under normal operating conditions, the cavity air pressure should be approximately 15 psi so that for normal operation, the output voltage

should be approximately  $V_O = 2.5 - \frac{10}{17} V_{IN} = 2.5 - \frac{10}{17} 2.25 = 1.1765 \text{ Volts}$

The cavity air pressure sensor circuit and resistor values are shown in Figure 2.163.



**Figure 2.163** Cavity air pressure sensor circuit

***Regulator Input and Output Voltages circuit analysis:***

These voltages are applied through an 8 channel analog multiplexer to a voltage divider and the output of the divider applied directly to the two analog inputs that are not buffered (i.e. directly to the input of the Analog to Digital Converter). The corresponding ADC voltages are:

$V_{RI}$  = Regulator Input Voltage

$V_{RI\text{sense}}$  = Regulator Input Sense Voltage

$$V_{RI\text{sense}} = \frac{3570}{3570 + 100000} = .0345 V_{RI}$$

The peak regulator input voltage is approx 75 volts so that

$$V_{RI\text{sensemax}} = 2.585 \text{ volts}$$

$V_{RO}$  = Regulator Output Voltage

$V_{RO\text{sense}}$  = Regulator Output Sense Voltage

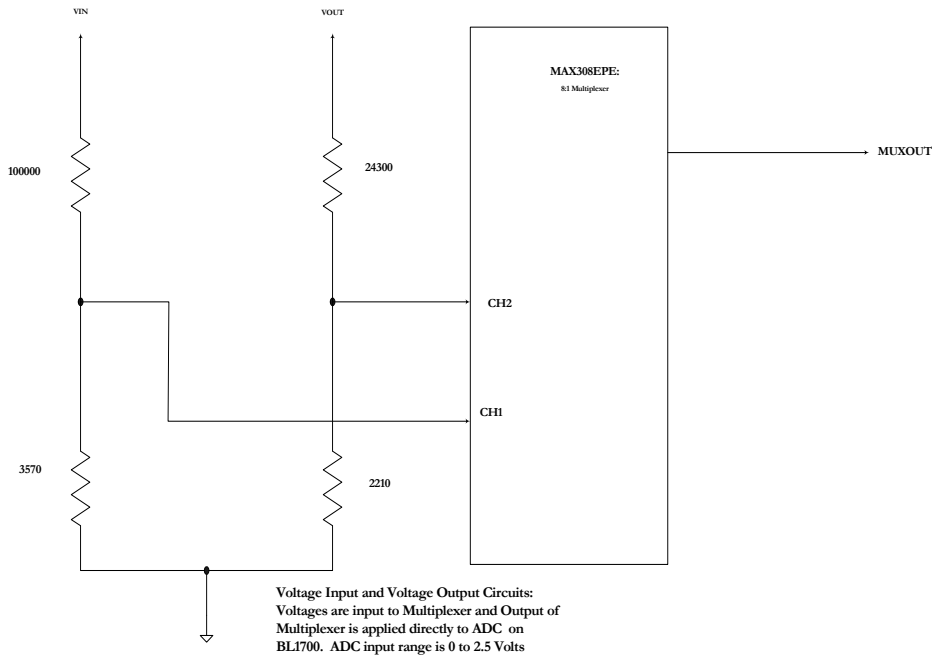
$$V_{RO\text{sense}} = \frac{2210}{2210 + 24300} = .08336 V_{RO}$$

The nominal regulator input voltage is 24 volts so that

$$V_{RO\text{sensenom}} \approx 2 \text{ volts}$$

The input/ output voltages circuit diagram is shown in Figure 2.164





**Figure 2.164** Voltage regulator input/ output voltages circuit

***BL1700 Gain Resistors:***

The values of the BL1700 gain resistors for all conditioned sensor inputs calculated above are listed in the table below, with an indication of whether the sensor was on the Amanda drill or not.

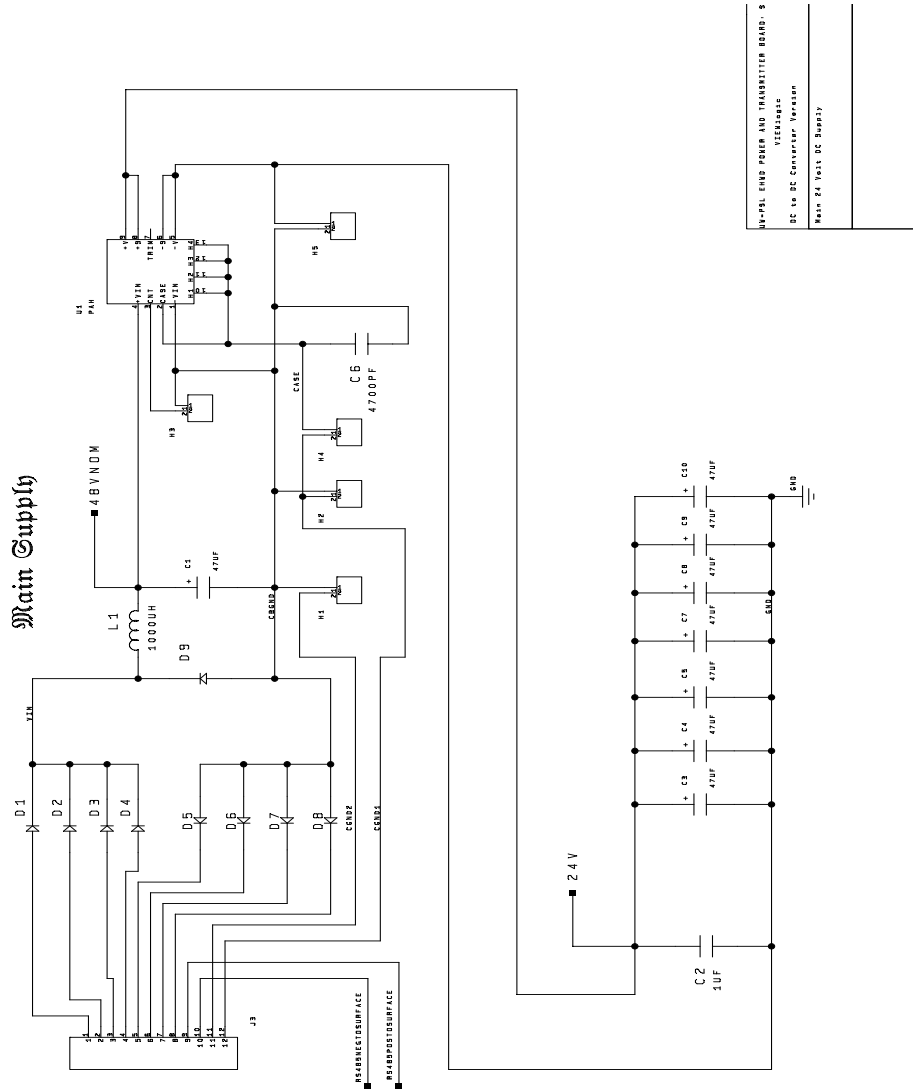
Channel	Sensor	Rbias (RFH)	R#	Rgain (RFL)	R#	Amanda
AIN0	T Seal2 Pressure	IAD: 10K SAD: 600	R20	IAD: 10K SAD: 166.67K	R21	No
AIN1	MLDT1	10K	R19	10K	R34	Yes
AIN2	Cavity Air	17K	R6	5882	R22	No
AIN3	Heat Sink Temp	9.09K	R18	475K	R35	Yes
AIN4	Load Cell	13K	R51	21.024K	R36	Yes
AIN5	Drill Hole Water Temp	9.09K	R52	475K	R49	Yes
AIN6	Hose Water Temp	9.09K	R53	475K	R37	Yes
AIN7	T Seal1 Pressure	IAD: 10K SAD: 600	R50	IAD: 10K SAD: 166.67K	R38	No
AIN8	MLDT2	Direct Input		Direct Input		No
AIN9	MUXOUT (REGIN and REGOUT)	Direct Input		Direct Input		Yes

**Figure 2.165** BL1700 sensor analog input channels and gain resistor summary

Notes: IAD= Instrumentation Amp design. SAD= Single Amp design

### 2.6.3.3.3 Power and transmitter board

#### Main 24V supply



**Figure 2.166** Power and transmitter board main 24V supply

The main 24 VDC drill power supply, shown in Figure 2.166 above, is fed by a higher voltage DC supply on the surface. This high voltage DC supply runs through 3200 meters (10500 feet) of multiconductor cable. There are a total of 15 wires in the cable: three 20 AWG twisted shielded pairs with drain wires (total 9 wires) and 6 individually insulated 18 AWG power wires. The power wires are allocated into three supply and three ground wires. Steering diodes are placed in series with each line on

HW-PA END POWER AND TRANSMITTER BOARD, S
VEELOGIC
DC to DC Converter Version
Main 24 Volt DC Supply

the main 24 volt supply. The steering diodes insure that if any one power wire is shorted to ground, the other wires will not be affected.

The surface DC supply must be sized to supply the minimum required operating voltage to the drill main 24 VDC power supply under worst case operating conditions. The worst case operating condition would occur if two of the power wires were shorted to ground.

Because the surface DC supply must be sized for maximum resistance in the cable, under normal operating conditions, the voltage delivered to the main 24 VDC supply will be significantly higher than the minimum required input voltage. In the EHWD, the main 24VDC supply is designed such that the surface supply voltage can be fixed and the 24 VDC supply can operate over the voltage extremes from normal operation to worst case fault condition

***Worst case fault condition design:***

*Cable resistance and power supply voltage calculations:*

The cable resistance for a variety of operating conditions, along with the required surface power supply voltage and corresponding maximum voltage input to the 24 VDC supply have been calculated using the following formulas.

$$R_{CNORM} = \frac{R_w}{3} + \frac{R_w}{3} = \frac{2R_w}{3} = \text{Cable Resistance under normal operating conditions}$$

Where  $R_w$  = Total resistance of one power wire at 20 °C

$$R_w \approx \rho L \quad \text{Where}$$

$$\rho = 6.636 \text{ } \Omega / 1000 \text{ feet for 18 AWG copper at } 20 \text{ } ^\circ\text{C and}$$

$$L = \text{length of cable} = 3200 \text{ meters} = 10500 \text{ feet}$$

$$R_{CWC} = R_w + \frac{R_w}{3} = \frac{4R_w}{3} = \text{Cable Resistance under worst case conditions}$$

$$R_w \approx 70 \text{ } \Omega = \text{approximate resistance of a single strand of power wire in cable at } 20 \text{ } ^\circ\text{C}$$

$$R_{CNORM} = 46.67 \text{ } \Omega \approx 46 \text{ } \Omega = R_{Cmin}$$

$$R_{CWC} = 93.33 \text{ } \Omega \approx 94 \text{ } \Omega = R_{Cmax}$$

$$R_{WT} = R_w [1 + \alpha T] \quad \text{Where}$$

$$R_{WT} = \text{Resistance of Single Power Wire in Cable at temperature} = T \text{ } ^\circ\text{C}$$

$$\alpha = 0.00393 \text{ } \Omega / ^\circ\text{C} = \text{Temperature coefficient of 18 AWG cable}$$

$$\text{At } -0 \text{ } ^\circ\text{C} \quad R_{Cmin} = 42.4 \text{ } \Omega \text{ and } R_{Cmax} = 86.6 \text{ } \Omega$$

$$\text{At } -20 \text{ } ^\circ\text{C} \quad R_{Cmin} = 38.7 \text{ } \Omega \text{ and } R_{Cmax} = 79 \text{ } \Omega$$

$$V_{SS} - V_{INMIN} = I_{LMAX} R_{Cmax} \quad \text{where}$$

$$V_{SS} = \text{Required Surface Supply Voltage}$$

$$V_{INMIN} = \text{Minimum permissible input voltage to 24 Volt supply}$$

$$I_{LMAX} = \text{Maximum current draw of EHWD electronics}$$

$$V_{SS} = V_{INMIN} + I_{LMAX} R_{Cmax} = \text{Surface Supply Voltage required to guarantee that 24 VDC supply input is } \geq \text{to the minimum required voltage}$$

$$V_{INMAX} = V_{SS} - I_{LMAX} R_{Cmin} = \text{Maximum input to 24 VDC supply} = \text{normal operating input voltage at } 20 \text{ } ^\circ\text{C and no fault conditions}$$

A copy of the calculations for a 24 volt supply minimum input voltage of 38 volts is shown in Figure 2.167. Based on these calculations, a surface supply voltage set to 75.2 volts would eliminate the need for operator adjustment if one or two of the power lines were shorted to ground. With the surface supply set to this value, the normal operating input level at the 24 VDC supply would be 56.5 Volts.

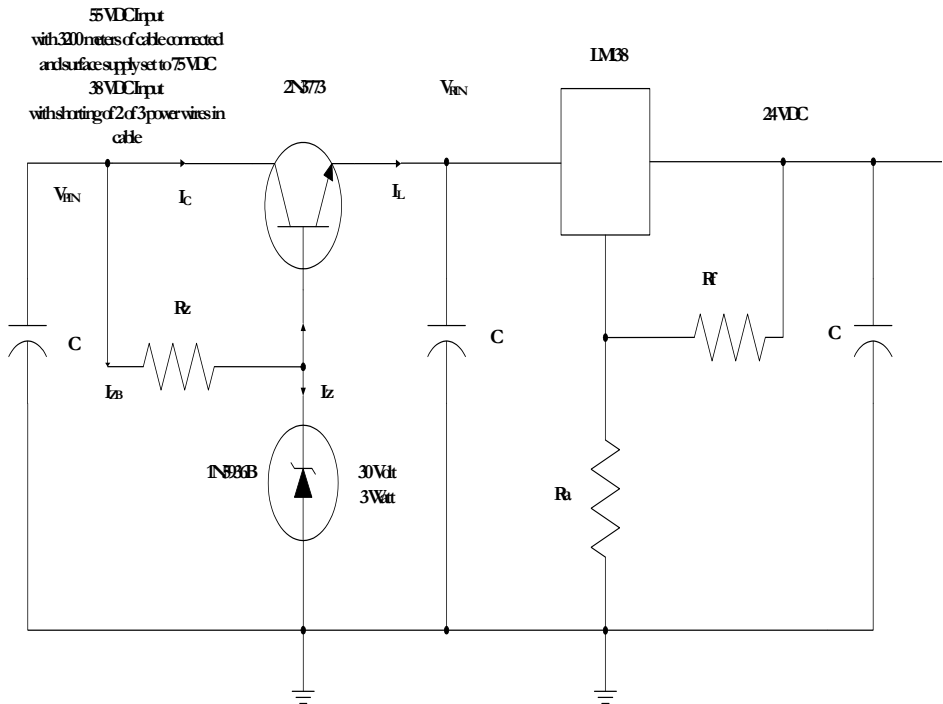
	H	I	J	K	L	M
9	<b>Constants</b>					
10						
11						
12	$\rho$	Resistivity	0.006636	ohms/feet		
13	$\alpha$	Tempco	0.00393	ohmsperohm-degree C		
14	L	CableLengthM	3200	meters		
15	L	CableLength	10499	feet		
16	Rv	PWRWireR	70	ohms		
17						
18		Vinmin	38	Minimum Required Input		
19				Voltage for 24 VDC Supply		
20		Imax	0.4	Max Main Supply Current		
21		Romin	46.44619423	Minimum Power Line		
22				Resistance		
23					Max Voltage at	Max Voltage at
24	Number of GND	Number of Power		Minimum Req Voltage	Input to 24 VDC Supply	Input to 24 VDC Supply
25	Wires	Wires	Total Cable Res	Output of Surface Supply	Max Supply Current	Half Max Supply Current
26						
27	3	3	46.44619423	56.57847769	38	47.28923885
28	3	2	58.05774278	61.22309711	42.64461942	51.93385827
29	3	1	92.89238845	75.15695538	56.57847769	65.86771654
30	2	2	69.66929134	65.86771654	47.28923885	56.57847769
31	2	1	104.503937	79.8015748	61.22309711	70.51233596
32	1	1	139.3385827	93.73543307	75.15695538	84.44619423

**Figure 2.167** EHWD Cable Resistance and Power Supply Voltage Calculations for 38 Volt Minimum Input to 24 VDC Supply

Various drill head power supply designs have been used, including a simple linear regulator version, a linear regulator with pre regulator circuit, a version incorporating an off the shelf DC-DC converter and a design taking account of the extra power consumption of the new drill heads which incorporate two MLDT circuits. Design notes will be given for the pre-regulator version, the DC-DC converter version and the design and a design to supply the two MLDT circuits.

### 1 Main 24 VDC Power Supply Design: Pre-regulator Version

The main 24 VDC drill power supply pre-regulator version uses a pre regulator in front of the LM 138 linear regulator. This permits operation of the supply with a shorter cable length or no cable (direct connection to the surface supply). The complete circuit consists of a power transistor and zener pre-regulator designed to drop the input supply voltage to approximately 30 VDC. The 30 VDC serves as the input to a LM138 variable linear regulator which delivers a regulated 24VDC output that serves as the main drill power supply. A simplified circuit of this part of the Power and Transmitter Board is shown in Figure 2.168.



**Figure 2.168** Main 24V supply, pre-regulator version

***Pre-regulator Analysis:***

The pre regulator 30 volt zener combined with the base to emitter voltage drop of the pass transistor hold the input voltage of the LM138 to a range of 29 to 33 volts based on the tolerances of the zener. The nominal input voltage will be approximately 31 volts. In order to insure proper operation of the pass transistor, an additional 5 volt drop is provided. The nominal input to the pass transistor should therefore be 36 volts. An additional 2 volts is required in order to account for tolerances of the zener. This means that a minimum of 38 volts should be supplied to the input of the pass transistor.

In order to guarantee that the surface supply can remain fixed under both normal operation and a fault condition where one or two of the power wires short to ground, the surface supply voltage should be set to 75 volts (see Figure 2.167). That will insure that 38 volts is supplied to the input under this fault condition and that the surface supply need not be adjusted. Under normal operating conditions, the input to the pre-regulator with 3200 meters of cable containing three 18 AWG power wires and three 18 AWG ground wires connecting the 75 VDC source to the pre-regulator will be 56.5 or approximately 57 volts.

The pre-regulator design equations are as follows:

$$I_{z\text{bmin}} = \frac{V_{\text{PINMIN}} - V_Z}{R_Z} = \frac{38 - 30}{R_Z} = \frac{8}{R_Z} \quad \text{Minimum Zener - Base Current}$$

$$I_{z\text{bmax}} = \frac{V_{\text{PINMAX}} - V_Z}{R_Z} = \frac{57 - 30}{R_Z} = \frac{26}{R_Z} \quad \text{Maximum Zener - Base Current}$$

$$I_L = 0.4 = I_C + I_B = (1 + h_{FE})I_B$$

$$I_B \approx \frac{.04}{150} = 2.67 \text{ MA} = 0.00267 \text{ A}$$

$$I_{z\text{bmin}} = \frac{8}{R_Z} = I_{z\text{min}} + I_B = I_{z\text{min}} + 0.00267$$

$$I_{z\text{min}} = \frac{8}{R_Z} - 0.00267$$

$$I_{z\text{max}} = \frac{27}{R_Z} - 0.00267$$

$$I_{\text{rated}} = 0.01 \quad \text{and} \quad I_z = I_{z\text{max}} \quad \text{under normal operation} \Rightarrow$$

$$I_{z\text{max}} = 0.01 = \frac{27}{R_Z} - 0.00267 \Rightarrow R_Z = 2131 \quad \Omega$$

Let  $R_Z = 1500 \quad \Omega \Rightarrow$

$$I_{z\text{min}} = \frac{8}{R_Z} - 0.00267 = \frac{8}{1500} - 0.00267 = 2.67 \text{ ma}$$

$$I_{z\text{max}} = \frac{27}{R_Z} - 0.00267 = \frac{27}{1500} - 0.00267 = 15.3 \text{ ma}$$

## 2 Main 24 VDC Power Supply Design: Off the Shelf Half Brick DC to DC Converter Version

This version of the main 24 VDC drill power supply replaces the LM138 linear regulator in the simple linear version with a commercial DC to DC converter such as the Lambda PAH50S48-24.

The Lambda PAH50S48-24 is an isolated 24 VDC, 2.10 Amp output regulated supply. The allowable input range is 36 volts to 76 volts DC. In order to insure sufficient input voltage, the minimum design voltage (under the fault condition of two shorted power lines) is set to 38 volts. Referring to Figure 2.167, it is seen that a surface supply voltage of 76 volts will guarantee 38 volts at the input to the DC to DC under this fault condition. Because 76 volts is maximum allowable input voltage to the DC to DC, setting the surface supply voltage to 76 volts will guarantee that this maximum will never be exceeded.

### 3 Main 24 VDC Power Supply Designs for New Hot Water Drills with Two MLDT's

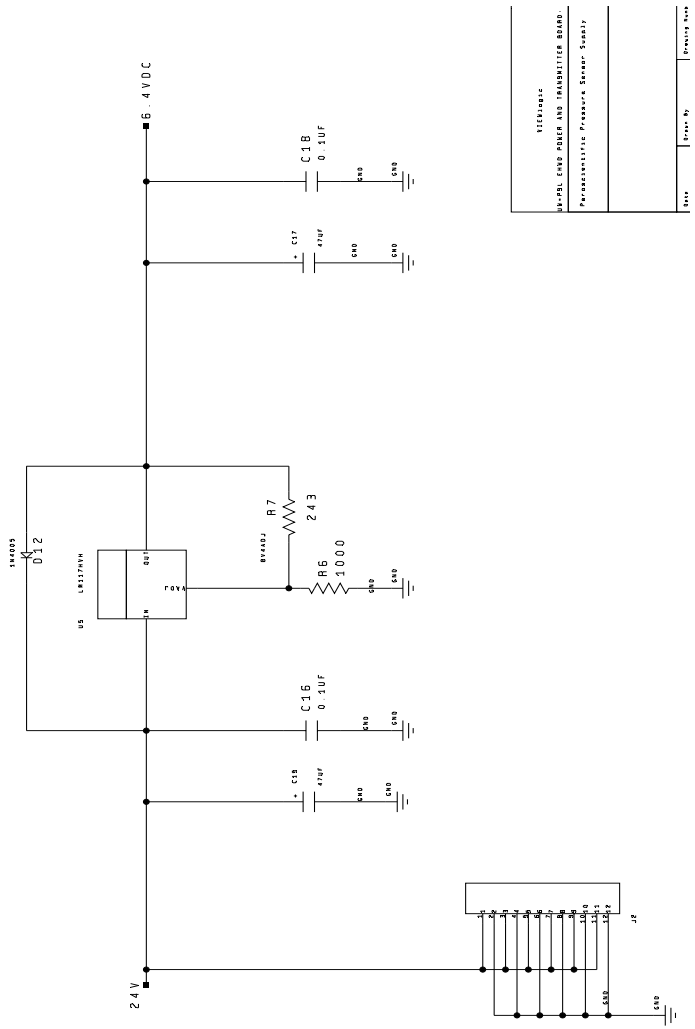
The two new drill heads each have two MLDT's. An additional MLDT adds another 100 ma to the power supply current draw. The analysis for this additional current for the pre-regulator and DC-DC converter supplies is presented here.

For these two designs, the minimum input voltage to the supply is 38 volts. The voltage calculations under normal and fault conditions are given in Figure 2.169. It is seen that the required surface supply voltage will increase from 76 to 80 volts in order to guarantee operation under the fault condition of the shorting of two power wires to ground. The highest expected voltage with cable attached (assuming actual power supply current is ½ the maximum or 225 ma) will be about 70 volts with 3200 meters of cable attached and no faults in the cable. This is within the permissible operating range of the LAMBDA DC to DC converter (max input = 76 Volts) and the preregulator transistor (VCEmax = 150 volts). If the supply is applied with no cable (short wire), the preregulator transistor will operate without problems but the max input voltage of the LAMBDA will be exceeded. There is 125% overvoltage protection so no damage will occur, however, it may not operate.

	H	I	J	K	L	M	N
9	Constants						
10							
11							
12	$\rho$	Resistivity	0.008836	ohms/feet			
13	$\alpha$	Tempco	0.00393	ohms per ohm degree C			
14	L	CableLengthM	3200	meters			
15	L	CableLength	10499	feet			
16	Rw	R/WireR	70	ohms			
17							
18		Vmin	38	Minimum Required Input			
19				Voltage for 24VDC Supply			
20		I <sub>max</sub>	0.45	Max Min Supply Current			
21		R <sub>min</sub>	46.44619423	Minimum Power Line			
22				Resistance			
23					Max Voltage at	Max Voltage at	Max Voltage at Input
24	Number of GND	Number of Power		Minimum Req Voltage	Input to 24VDC Supply	Input to 24VDC Supply	To 24 VDC Supply: 23
25	Wires	Wires	Total Cable Res	Output of Surface Supply	Max Supply Current	Half Max Supply Current	Max Supply Current
26							
27	3	3	46.44619423	589007874	38	48.460937	4496692913
28	3	2	58.05774278	64.1259425	4322519666	53.6756055	50.19212598
29	3	1	92.89239946	798015748	589007874	69.3511811	6586771654
30	2	2	69.66929134	693511811	48460937	589007874	5541732283
31	2	1	104.503857	8502677165	64.1259425	74.5763785	7109291339
32	1	1	139.336827	1007023622	798015748	90.256855	867660394

**Figure 2.169** EHWD Cable Resistance and Power Supply Voltage Calculations for 38 Volt Minimum Input to 24 VDC Supply: DC to DC Converter and Pre Regulator Design Versions for New Drills

# Paroscientific pressure sensor and RS485 buffer amplifier power supplies



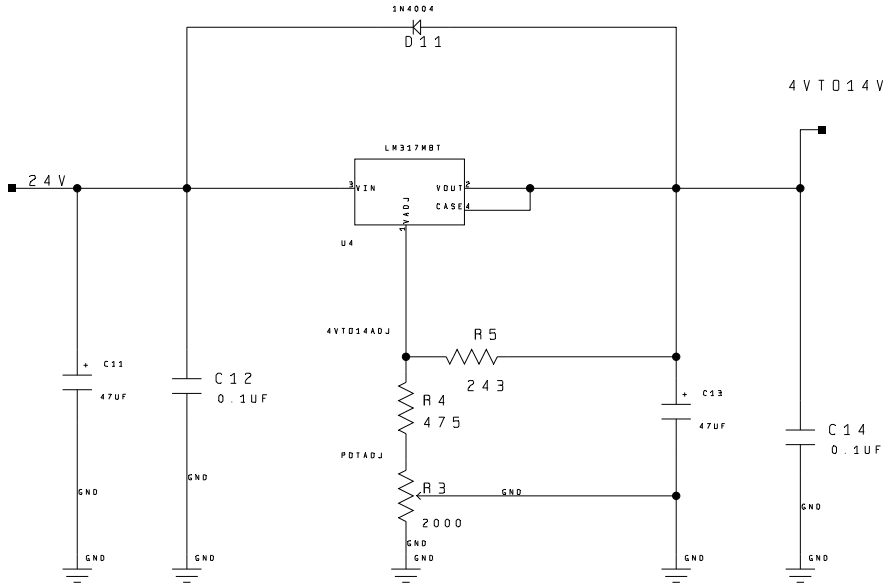
11/20/2016 64-PEL CRAP POWER AND TRANSDUCER BOARD Paroscientific Pressure Sensor Supply	
Date:	Drawn by:
	Revised by:

**Figure 2.170** Paroscientific pressure sensor power supply on PTB board

The PTB board includes the circuits for the Paroscientific pressure sensor as well as the RS 485 buffer amplifier.

Figure 2.170 above shows a standard linear regulator circuit providing a 6.4V output to the pressure sensor from a 24V input.

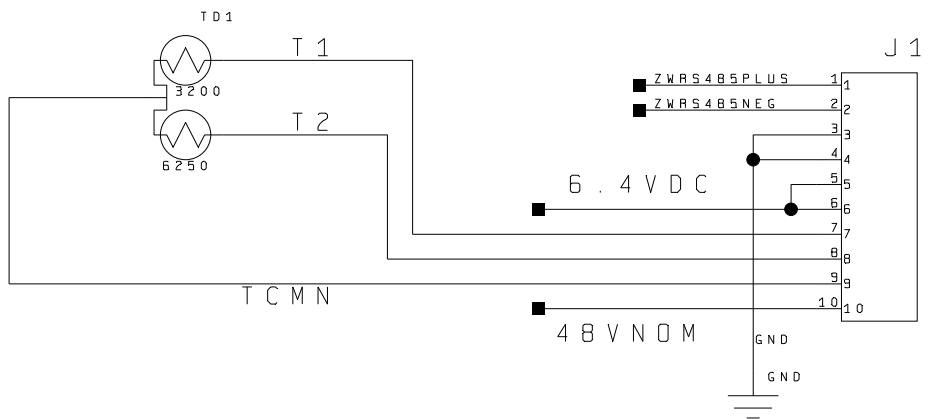




**Figure 2.171** RS485 buffer amplifier power supply

Figure 2.171 above is again a standard linear voltage regulator design with an output adjustable from 4-14V.

### Heat sink temperature sensor



**Figure 2.172** Heat sink temperature sensor circuit

The drill uses an Omega 44018 Thermistor to measure the heat sink temperature. The heat sink temp thermistor circuit output is applied to Analog Input 3 on the BL1700 board. The corresponding gain (RFL) and bias (RFH) resistors are R35 and R18. The thermistor-amplifier configuration is shown in Figure 2.156. The resistor values used and corresponding output equation are given below. Because the Thevenin equivalent resistance of the thermistor and linearizing resistor network (RLA, RLB, RTA, and RTB) is much smaller than the value of RIN (432k), the thermistor-amplifier circuit can be approximated as a voltage source with zero source impedance as shown in Figure 2.149 (with  $R_s = \infty$  and zero source resistance  $R_{in} = 0$ ) and with RGL replaced with  $R_{GLI} = R_{GL} + R_{IN}$ . The circuit is the same as for the hose water temperature thermistor.

$$R_{FH} = R50 \text{ (bias)} = 9090 \text{ ohms}$$

$$R_{FL} = R38 \text{ (gain)} = 475000 \text{ ohms}$$

$$R_{GH} = 10000 \text{ ohms}$$

$$R_{GLI} = R_{GH} + R_{IN} = 10000 + 432000 = 442000$$

$$G_H = \frac{R_{FH}}{R_{GH}} = \frac{9090}{10000} = .909$$

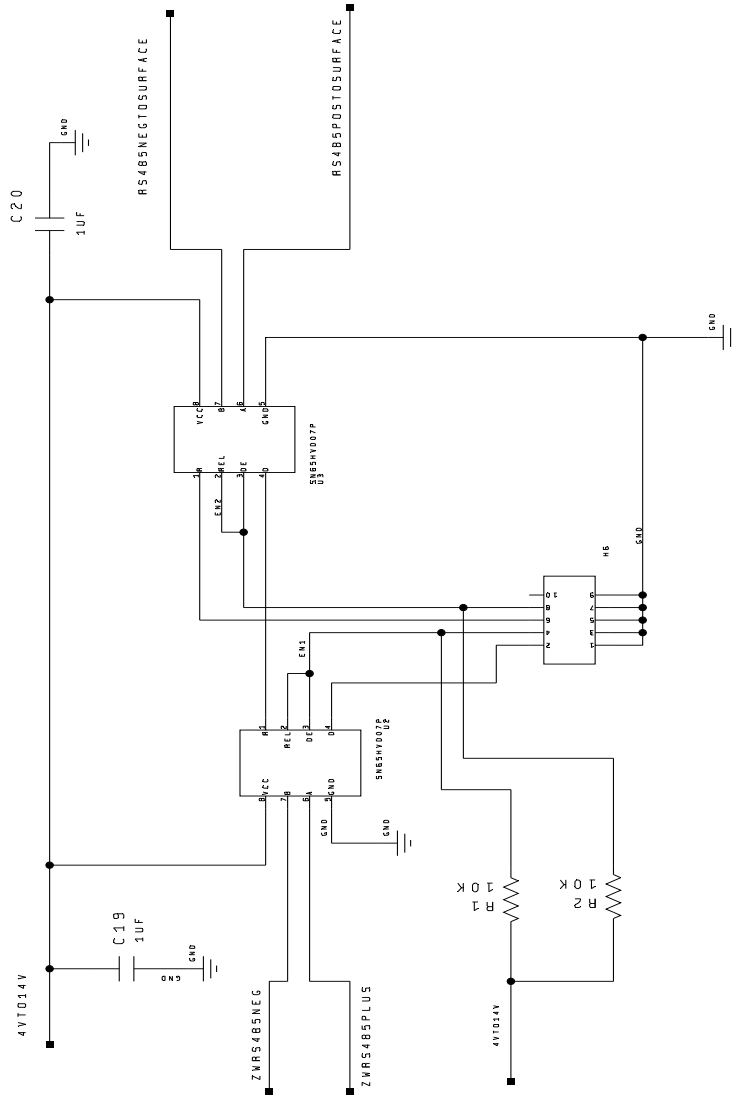
$$G_L = \frac{R_{FL}}{R_{GLI}} = \frac{475000}{442000} = 1.075$$

$$V_O = \left( \frac{1 + G_L}{1 + G_H} \right) G_H V_R - G_L V_{IN}$$

$$V_O = \left( \frac{2.1075}{1.909} \right) .909 V_R - 1.075 V_{IN}$$

$$V_O = .987881884 V_R - 1.075 V_{IN}$$

## RS485 high output amplifier circuit



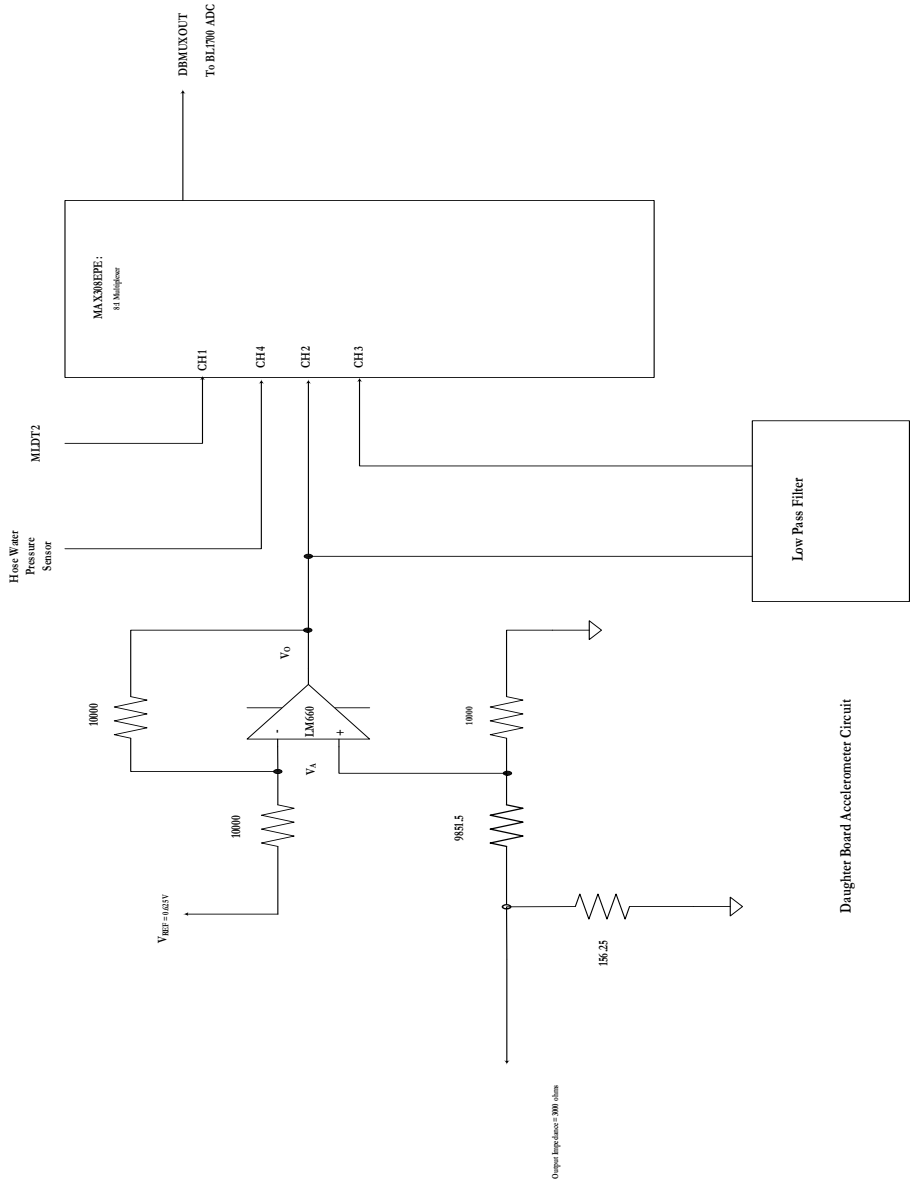
**Figure 2.173** RS485 high output amplifier circuit

### 2.6.3.3.4 Daughter board

The daughter board whose block diagram is shown in Figure 2.147 is an addition to the refurbished Amanda drill head. It was added to include two accelerometers circuits and drill hose pressure sensor in order to study the drill oscillations (bouncing up and down

in the hole) at higher drill speeds that were observed during drilling in the first season in 2004. The daughter board is only present in the refurbished drill head.

**Daughter Board Accelerometer Circuit:**



**Figure 2.174** MA321 accelerometer circuit

This analysis refers to the Accelerometer Circuit shown in Figure 2.174. The MA321 2g accelerometer full range output is 4 to 20 ma with 0 ma corresponding to 0 g. The amplifier is setup as a unity gain differential amplifier. The positive input to the amplifier is developed by converting the 4-20 ma current into a voltage using the 156.25 ohm dropping resistor. The resulting voltage range is 0.625 to 3.125. A 0.625 reference is applied to the negative input of the amplifier giving an amplifier output range of 0 to 2.5 volts for a 4 to 20 ma input. This signal is passed through a multiplexer and applied directly to the BL1700 input ADC which has a range of 0 to 2.5 Volts.

$$V_O = V_{ACC} - V_{REF} = V_{ACC} - 0.625$$

When  $I_{IN} = 4 \text{ ma}$   $V_{IN} = 0.625 \text{ V}$  and  $V_O = 0 \text{ Volts}$

When  $I_{IN} = 20 \text{ ma}$   $V_{IN} = 3.125 \text{ V}$  and  $V_O = 2.5 \text{ Volts}$

### Daughter Board Hose Water Pressure Circuit :

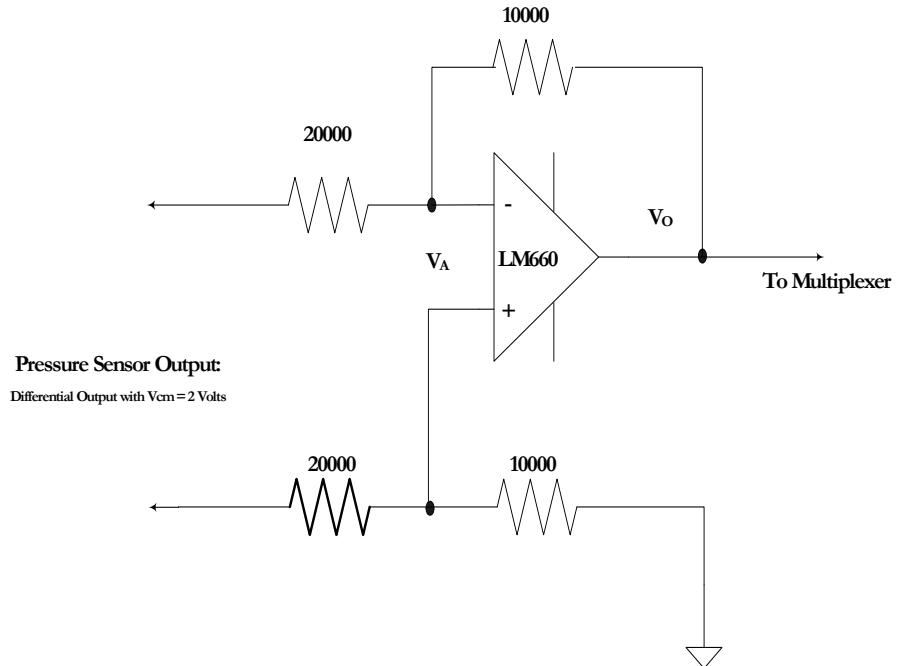


Figure 2.175 Daughter board drill hose pressure sensor circuit

This analysis refers to the Hose Water Pressure Circuit shown in Figure 2.175. The Entran EPXM-X33-5KP pressure sensor full range output is 2 to 7 volts. The amplifier is setup as gain of 0.5 differential amplifier. The 2 Volt common mode voltage is subtracted from the output resulting in an output range of 0 to 2.5 Volts. This voltage is applied to the input ADC of the BL1700 through a multiplexer.

$$V_O = \frac{1}{2}(V_{HWP} - V_{CM}) = \frac{1}{2}(V_{HWP} - 2)$$

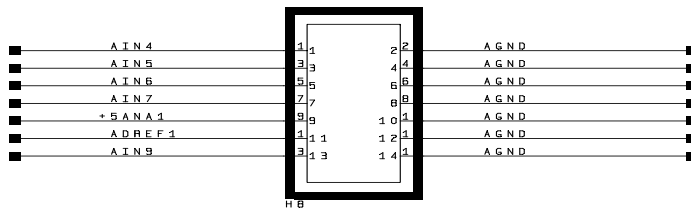
When  $V_{IN} = 2\text{ V}$  then  $V_O = 0\text{ Volts}$

When  $V_{IN} = 7\text{ V}$  and  $V_O = 2.5\text{ Volts}$

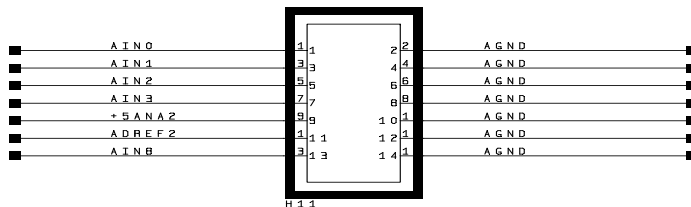
### 2.6.3.3.5 Bridge Board:

As the name suggests, the bridge board provides an interface bridge between the BL1700 controller board and the input conditioning and Power and transmitter boards.

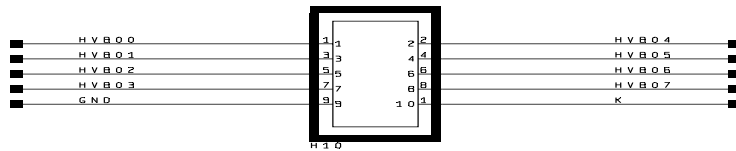
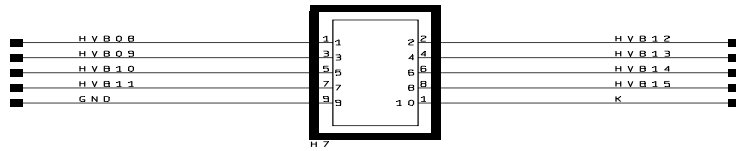
Shown below in Figure 2.176 to Figure 2.180 are the connectors on the boards and their pinouts.



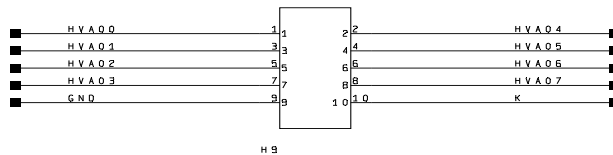
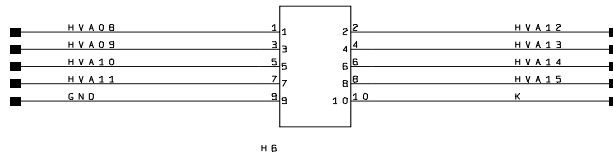
Note:  
+5ANA1 and +5ANA2 are same on BL1700  
ADREF1 and ADREF2 are same on BL1700



**Figure 2.176** Bridge board BL1700 board analog input connectors



**Figure 2.177** Bridge board BL1700 digital output port B connectors



**Figure 2.178** Bridge board BL1700 digital input port B connectors

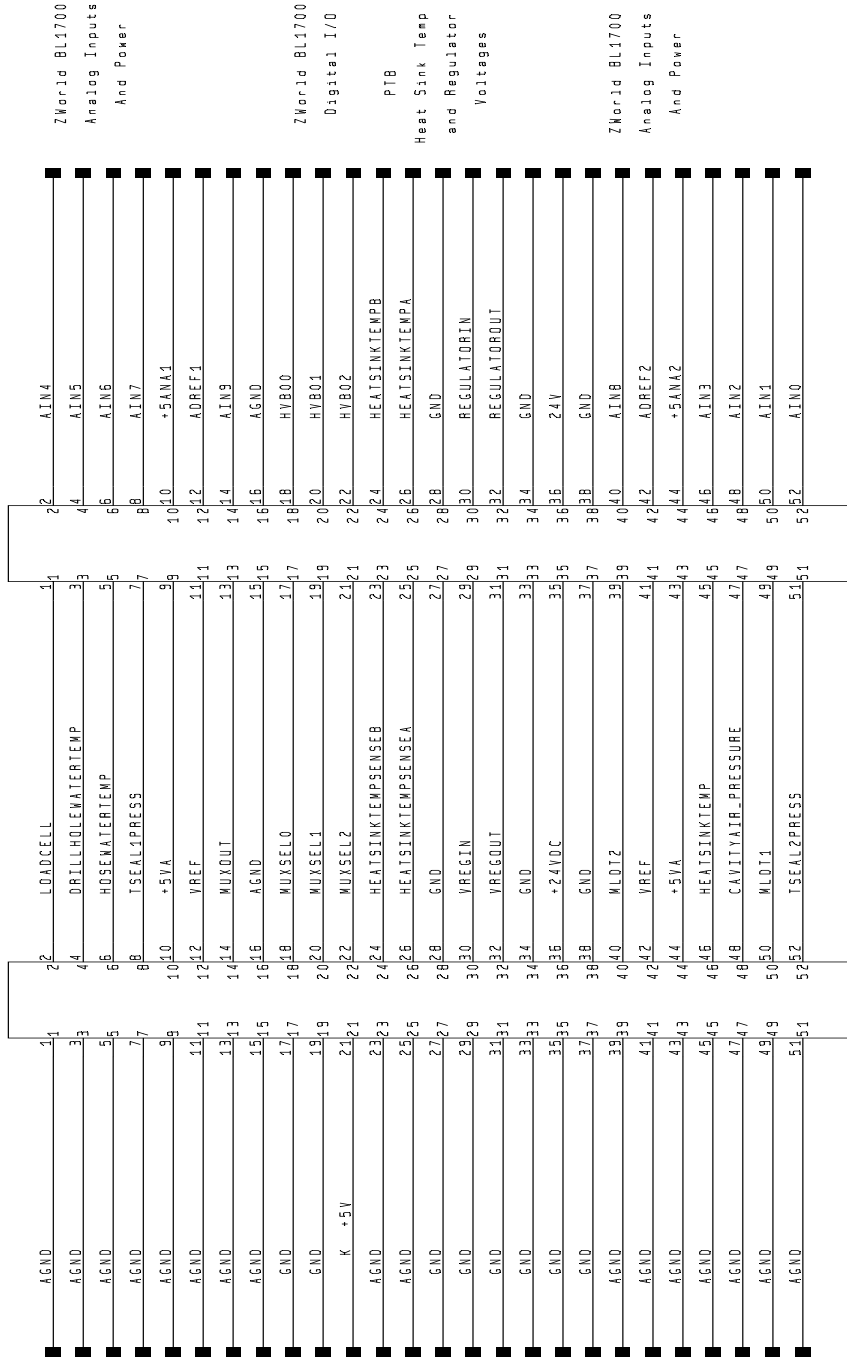
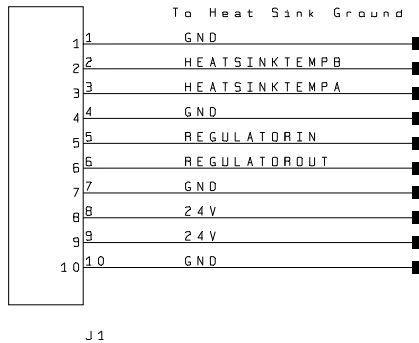


Figure 2.179 Bridge board input conditioning board connectors





**Figure 2.180** Bridge board PTB input (heat sink temp) and regulator voltages

## 2.6.4 Drill Head Software

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The drill head embedded software is written for the drill head single board computer - a Z World (now Rabbit Semiconductor) BL1700. It is written in Dynamic C and there are separate versions for the new drill heads (NDHX and NDHY) and the refurbished drill head (RDH). The drill head test software is written in Visual Basic. There are two sub categories of drill head test software. The first sub category is drill head logging and monitoring software. It displays the incoming drill head data in real time and logs the data to a user named data file when enabled. Other functions are also performed. There are separate programs for the New Drill Heads and the Refurbished Drill Head. The second sub category of test software is a drill head output emulator also written in Visual Basic. This software outputs previously logged data either continuously or manually one record at a time at selectable rates. The final category of drill head software is drill head data processing software which is used to process raw drill head data log files and move the processed data into spreadsheets for analysis and graphing.

The document below list and describes all drill head software developed to run the drill head, test the drill head, and process the drill head data.

- Note:
- RDH- refers to refurbished drill head
  - NDHX- refers to new drill head X
  - NDHY- refers to new drill head Y

Drill Head	Version	Description
RDH	V20050701A	Refurbished Drill Head BL1700 single board computer operating system software: <a href="#">ICECUBE_RDH_RRCode_V20050701A.c</a> Specifications: <ol style="list-style-type: none"> <li>Record Size: 169 bytes including CRLF</li> <li>Output Rate: 1 record every 369 milliseconds (approximately)</li> <li>ID = R</li> </ol>
NDHX	V20030907X	New Drill Head X BL1700 single board computer operating system software: <a href="#">ICECUBE_RefubishedDrillCode_V20030907X.c</a> Specifications: <ol style="list-style-type: none"> <li>Record Size: 125 bytes including CRLF</li> <li>Output Rate: 1 record every 200 milliseconds (approximately)</li> <li>ID = X</li> </ol>
NDHY	V20030907Y	New Drill Head Y BL1700 single board computer operating system software: <a href="#">ICECUBE_RefubishedDrillCode_V20030907Y.c</a> Specifications: <ol style="list-style-type: none"> <li>Record Size: 125 bytes including CRLF</li> <li>Output Rate: 1 record every 200 milliseconds (approximately)</li> <li>ID = Y</li> </ol>

**Figure 2.181** BL1700 Drill Head SBC operating software: Dynamic C

Drill Head	Version	Description
RDH	V20050622A	Logging and monitoring software for the Refurbished Drill Head (RDH): <a href="#">EHWD2005_RDH_Project.exe</a> <ol style="list-style-type: none"> <li>Displays incoming raw RDH data in real time in separate window</li> <li>Displays scaled or unscaled (selectable) values of each variable in separate text box with variable name to the left in label box. Displays all variables common to all three drill heads in addition to accelerometer, hose pressure sensor variables unique to the RDH</li> <li>Displays max and min of selected variable in text box</li> <li>Enables creation and naming of log file and logging of raw incoming data to that file</li> <li>Enables selection of scaling factor file, and display of scale factors</li> </ol>
NDHX	V20041124	Logging and monitoring software for the New Drill Head X (NDHX): <a href="#">EHWD_FT01_COMIOnly_Project.exe</a> <ol style="list-style-type: none"> <li>Displays incoming raw NDHX data in real time in separate window</li> <li>Displays scaled or unscaled (selectable) values of each variable in separate text box with variable name to the left in label box.</li> <li>Displays max and min of selected variable in text box</li> <li>Enables creation and naming of log file and logging of raw incoming data to that file</li> <li>Enables selection of scaling factor file, and display of scale factors</li> </ol>
NDHY	V20041124	Logging and monitoring software for the New Drill Head Y (NDHY): <a href="#">EHWD_FT01_COMIOnly_Project.exe</a> <ol style="list-style-type: none"> <li>Displays incoming raw NDHY data in real time in separate window</li> <li>Displays scaled or unscaled (selectable) values of each variable in separate text box with variable name to the left in label box.</li> <li>Displays max and min of selected variable in text box</li> <li>Enables creation and naming of log file and logging of raw incoming data to that file</li> <li>Enables selection of scaling factor file, and display of scale factors</li> </ol>

**Figure 2.182** Drill Head Data Logging and Monitoring: Visual Basic Test Software

Drill Head	Version	Description
RDH or NDH	V20051017	Visual Basic Drill data output program: <a href="#">EHWD2005_RDH_IO_Project.exe</a> <ol style="list-style-type: none"> <li>1. Sends out data continuously or single record from EHWD_DrillDataOutput.log</li> <li>2. EHWD_DrillDataOutput.log must be in same directory as program</li> <li>3. To output different files, copy desired drill data file to program folder and rename it EHWD_DrillDataOutput.log</li> <li>4. To open file click Open Data Output File button</li> <li>5. To toggle between Single Shot and Continuous output – click Single Shot/Continuous button</li> <li>6. To Pause output click Pause Output button</li> <li>7. To stop output click End Output button</li> <li>8. To increment time interval between messages click Increment button</li> <li>9. To decrement time interval between messages click Decrement button</li> </ol>
NDH	V20051006A	C Drill data output program: <a href="#">NDHX_OutputEmulator_2005.exe</a> Not completed

**Figure 2.183** Drill Head Auxiliary Test Software

Drill Head	Version	Description
RDH, NDHX, and NDHY	V20060718	Name: <a href="#">SPDrillHeadDataProcessing_AllVariables_V1001.exe</a> Operation: See SouthPoleDrillHeadDataProcessingSoftware_Operation_20061106.doc
RDH, NDHX, and NDHY	V20061109	Name: <a href="#">SPDrillHeadDataProcessing_AllVariables_V1003.exe</a> Operation: See SouthPoleDrillHeadDataProcessingSoftware_Operation_20061106.doc

**Figure 2.184** Drill Head Data Processing Software

### Drill head data formats:

The tables below give an explanation of the data formats of the new drill heads and refurbished drill head, as well as an example of some sample lines of output received at the surface.

As can be seen from Figure 2.185 and Figure 2.187, the new drill heads have a 121 byte data string, while the refurbished drill head has a 160 byte data string. This is mainly as a result of the accelerometers and drill hose pressure sensor added to the refurbished drill head in order to study the drill oscillations observed during initial drilling.

Number	Item Name	Description	Bytes	Format
	Drill ID	Single Byte ID for Drill: P = Primary Amanda Drill (Not Used) S = Secondary Amanda Drill (Not Used) R = EHWD Refurbished Amanda Drill X = EHWD New Drill Head 1 Y = EHWD New Drill Head 2	1	ASCII
	Timer	25 millisecond tick counter	10	ASCII - Decimal
	System Status	G = Good B = Bad	1	ASCII
	Power Supply Heat Sink Temperature Status	G = Good B = Bad	1	ASCII
	Power Supply Heat Sink Temperature Data	Unscaled Raw ADC output of heat sink temperature sensor signal	3	Hex ASCII
	MLDT1 Status	G = Good B = Bad	1	ASCII
	MLDT1 Data	Unscaled Raw ADC output of first MLDT sensor signal	3	Hex ASCII
	MLDT2 Status	G = Good B = Bad	1	ASCII
	MLDT2 Data	Unscaled Raw ADC output of second MLDT sensor signal	3	Hex ASCII
	Load Cell Status	G = Good B = Bad	1	ASCII
	Load Cell Data	Unscaled Raw ADC output of amplified load cell signal	3	Hex ASCII
	Well (Drill Hole) Temperature Status	G = Good B = Bad	1	ASCII
	Well (Drill Hole) Temperature Data	Unscaled Raw ADC output of well (drill hole) temperature sensor signal	3	Hex ASCII
	Hose Water Temperature Status	G = Good B = Bad	1	ASCII
	Hose Water Temperature Data	Unscaled Raw ADC output of hose water temperature sensor signal	3	Hex ASCII
	Power Supply Input Voltage Status	G = Good B = Bad	1	ASCII
	Power Supply Input Voltage Data	Unscaled Raw ADC output of power supply input voltage signal	3	Hex ASCII
	Main Regulator Output Voltage Status	G = Good B = Bad	1	ASCII
	Main Regulator Output Voltage Data	Unscaled Raw ADC output of main regulator voltage signal (nominally 24 VDC)	3	Hex ASCII
	Cavity Air Pressure Sensor Status	G = Good B = Bad	1	ASCII
	Cavity Air Pressure Sensor Data	Unscaled Raw ADC output of cavity air pressure sensor signal	3	Hex ASCII

	TSeal 1 Pressure Sensor Status	G = Good B = Bad	1	ASCII
	TSeal 1 Pressure Sensor Data	Unscaled Raw ADC output of TSeal 1 pressure sensor signal	3	Hex ASCII
	TSeal 2 Pressure Sensor Status	G = Good B = Bad	1	ASCII
	TSeal 2 Pressure Sensor Data	Unscaled Raw ADC output of TSeal 2 pressure sensor signal	3	Hex ASCII
	Well (Drill Hole) Pressure Sensor Status	G = Good B = Bad	1	ASCII
	Well (Drill Hole) Pressure Sensor Message ID	Well (drill hole) pressure sensor message ID	5	ASCII
	Well (Drill Hole) Pressure Sensor Data	Scaled well (drill hole) pressure sensor signal (PSI)	11	Signed Decimal ASCII
	Watson Nav Pack Status	G = Good B = Bad	1	ASCII
	Watson Nav Pack Message ID	Watson Nav Pack message ID	1	ASCII
	Watson Nav Pack: Bank Tilt Reading	Scaled Watson Nav Pack Bank Tilt Reading (Degrees)	6	Signed Decimal ASCII with leading space
	Watson Nav Pack: Elevation Tilt Reading	Scaled Watson Nav Pack Elevation Tilt Reading (Degrees)	6	Signed Decimal ASCII with leading space
	Watson Nav Pack: Heading Reading	Scaled Watson Nav Pack Heading Reading (Degrees)	6	Unsigned Decimal ASCII with leading space
	Watson Nav Pack: X Axis Magnetic Field Reading	Scaled Watson Nav Pack X Axis Magnetic Field Reading (milligauss)	7	Signed Decimal ASCII with leading space
	Watson Nav Pack: Y Axis Magnetic Field Reading	Scaled Watson Nav Pack Y Axis Magnetic Field Reading (milligauss)	7	Signed Decimal ASCII with leading space
	Watson Nav Pack: Z Axis Magnetic Field Reading	Scaled Watson Nav Pack Z Axis Magnetic Field Reading (milligauss)	7	Signed Decimal ASCII with leading space
	Watson Nav Pack: Temperature Reading	Scaled Watson Nav Pack Temperature Reading (degrees C)	6	Signed Decimal ASCII with leading space
	End of Message ID and Checksum		3	ASCII

**Figure 2.185** New drill heads “X” and “Y” data format

R	Drill ID
0000080259	25 Millisecond Timer
G	Drill Status
G	Power Supply Heat Sink Temperature Sensor Status
37C	Power Supply Heat Sink Temperature Sensor Reading
G	MLDT1 Status
784	MLDT1 Reading
G	MLDT2 Status
111	MLDT2 Reading
G	Load Cell Status
E48	Load Cell Reading
G	Well (Drill Hole) Temperature Sensor Status
251	Well (Drill Hole) Temperature Sensor Reading
G	Hose Water Temperature Sensor Status
279	Hose Water Temperature Sensor Reading
G	Power Supply Input Voltage Status
82F	Power Supply Input Voltage Reading
G	Main Regulator (24 VDC) Output Voltage Status
CD8	Main Regulator (24 VDC) Output Voltage Reading
G	Cavity Air Pressure Sensor Status
7CF	Cavity Air Pressure Sensor Reading
G	Tseal1 Pressure Sensor Status
7FD	Tseal1 Pressure Sensor Reading
G	Tseal2 Pressure Sensor Status
800	Tseal2 Pressure Sensor Reading
G	Well(Drill Hole)Pressure Sensor Status
*0001	Well(Drill Hole)Pressure Sensor Message ID
+14.2100000	Well(Drill Hole)Pressure Sensor Reading
G	Watson Nav Pack Status
N	Watson Nav Pack Message ID
+9.99	Watson Nav Pack: Bank Tilt Reading
+9.99	Watson Nav Pack: Elevation Tilt Reading
301.8	Watson Nav Pack: Heading Reading
-053.3	Watson Nav Pack: X Axis Magnetic Field Reading
+555.0	Watson Nav Pack: Y Axis Magnetic Field Reading
-093.4	Watson Nav Pack: Z Axis Magnetic Field Reading
+25.1	Watson Nav Pack: Temperature Reading
K63	End of Message ID and Check Sum

R0000080259G37CG784G111GE48G251G279G82FGCD8G7CFG7FDG800G\*0001+14.2100000GN+9.99+9.99301.8-053.3+555.0-093.4+25.1K63  
R0000080267G37CG784G12AGE43G250G279G82FGCD7G7CFG7FDG802G\*0001+14.1900000GN+9.99+9.99301.8-053.8+555.2-093.4+25.1K7C  
R0000080273G37CG784G127GE40G250G279G82EGCD8G7CFG7FDG803G\*0001+14.1400000GN+9.99+9.99301.8-053.3+554.9-093.2+25.1K69

**Figure 2.186** New drill heads example values and example string transmitted to surface

Item Name	Description	Bytes	Format
Drill ID	Single Byte ID for Drill: P = Primary Amanda Drill (Not Used) S = Secondary Amanda Drill (Not Used) R = EHWD Refurbished Amanda Drill X = EHWD New Drill Head 1 Y = EHWD New Drill Head 2	1	ASCII
Timer	millisecond tick counter	10	ASCII - Decimal
System Status	G = Good I = Invalid	1	ASCII
Power Supply Heat Sink Temperature Status	G = Good I = Invalid	1	ASCII
Power Supply Heat Sink Temperature Data	Unscaled Raw ADC output of heat sink temperature sensor signal	3	Hex ASCII
MLDT1 Status	G = Good I = Invalid	1	ASCII
MLDT1 Data	Unscaled Raw ADC output of first MLDT sensor signal	3	Hex ASCII
MLDT2 Status	G = Good I = Invalid	1	ASCII
MLDT2 Data	Unscaled Raw ADC output of second MLDT sensor signal	3	Hex ASCII
Load Cell Status	G = Good I = Invalid	1	ASCII
Load Cell Data	Unscaled Raw ADC output of amplified load cell signal	3	Hex ASCII
Well (Drill Hole) Temperature Status	G = Good I = Invalid	1	ASCII
Well (Drill Hole) Temperature Data	Unscaled Raw ADC output of well (drill hole) temperature sensor signal	3	Hex ASCII
Hose Water Temperature Status	G = Good I = Invalid	1	ASCII
Hose Water Temperature Data	Unscaled Raw ADC output of hose water temperature sensor signal	3	Hex ASCII
Power Supply Input Voltage Status	G = Good I = Invalid	1	ASCII
Power Supply Input Voltage Data	Unscaled Raw ADC output of power supply input voltage signal	3	Hex ASCII
Main Regulator Output Voltage Status	G = Good I = Invalid	1	ASCII
Main Regulator Output Voltage Data	Unscaled Raw ADC output of main regulator voltage signal (nominally 24 VDC)	3	Hex ASCII
Cavity Air Pressure Sensor Status	G = Good I = Invalid	1	ASCII
Cavity Air Pressure Sensor Data	Unscaled Raw ADC output of cavity air pressure sensor signal	3	Hex ASCII
TSeal 1 Pressure Sensor Status	G = Good I = Invalid	1	ASCII
TSeal 1 Pressure Sensor Data	Unscaled Raw ADC output of TSeal 1 pressure sensor signal	3	Hex ASCII
TSeal 2 Pressure Sensor Status	G = Good I = Invalid	1	ASCII
TSeal 2 Pressure Sensor Data	Unscaled Raw ADC output of TSeal 2 pressure sensor signal	3	Hex ASCII
Well (Drill Hole) Pressure Sensor Status	G = Good I = Invalid	1	ASCII
Well (Drill Hole) Pressure Sensor Message ID	Well (drill hole) pressure sensor message ID	5	ASCII
Well (Drill Hole) Pressure Sensor Data	Scaled well (drill hole) pressure sensor signal (PSI)	11	Signed Decimal ASCII
Watson Nav Pack Status	G = Good I = Invalid	1	ASCII
Watson Nav Pack Message ID	Watson Nav Pack message ID	1	ASCII
Watson Nav Pack: Bank Tilt Reading	Scaled Watson Nav Pack Bank Tilt Reading (Degrees)	6	Signed Decimal ASCII with leading space
Watson Nav Pack: Elevation Tilt Reading	Scaled Watson Nav Pack Elevation Tilt Reading (Degrees)	6	Signed Decimal ASCII with leading space
Watson Nav Pack: Heading Reading	Scaled Watson Nav Pack Heading Reading (Degrees)	6	Unsigned Decimal ASCII with leading space
Watson Nav Pack: X Axis Magnetic Field Reading	Scaled Watson Nav Pack X Axis Magnetic Field Reading (milligauss)	7	Signed Decimal ASCII with leading space
Watson Nav Pack: Y Axis Magnetic Field Reading	Scaled Watson Nav Pack Y Axis Magnetic Field Reading (milligauss)	7	Signed Decimal ASCII with leading space
Watson Nav Pack: Z Axis Magnetic Field Reading	Scaled Watson Nav Pack Z Axis Magnetic Field Reading (milligauss)	7	Signed Decimal ASCII with leading space
Watson Nav Pack: Temperature Reading	Scaled Watson Nav Pack Temperature Reading (degrees C)	6	Signed Decimal ASCII with leading space
Accelerometer #1 Reading #1 Status	G = Good I = Invalid	1	ASCII
Accelerometer Reading #1	Unscaled Raw ADC output reading #1 of Accelerometer	3	ASCII
Accelerometer #1 Reading #2 Status	G = Good I = Invalid	1	ASCII
Accelerometer Reading #2	Unscaled Raw ADC output reading #2 of Accelerometer	3	ASCII
Accelerometer #1 Reading #3 Status	G = Good I = Invalid	1	ASCII
Accelerometer Reading #3	Unscaled Raw ADC output reading #3 of Accelerometer	3	ASCII
Accelerometer #1 Reading #4 Status	G = Good I = Invalid	1	ASCII
Accelerometer Reading #4	Unscaled Raw ADC output reading #4 of Accelerometer	3	ASCII
Accelerometer #1 Reading #5 Status	G = Good I = Invalid	1	ASCII
Accelerometer Reading #5	Unscaled Raw ADC output reading #5 of Accelerometer	3	ASCII
Filtered Accelerometer #1 Status	G = Good I = Invalid	1	ASCII
Filtered Accelerometer #1 Output Data	Unscaled Raw ADC output reading of Filtered Accelerometer Output	3	ASCII
Hose Water Pressure Status	G = Good I = Invalid	1	ASCII
Hose Water Pressure Data	Unscaled Raw ADC output reading of Hose Water Pressure Sensor	3	ASCII
Accelerometer #2 (Hi Level Output 3) Status	G = Good I = Invalid	1	ASCII
Accelerometer #2 (Hi Level Output 3) Data	Unscaled Raw ADC output reading of HI Level Output 3	3	ASCII
Hi Level Output 4 Status	G = Good I = Invalid	1	ASCII
Hi Level Output 4 Data	Unscaled Raw ADC output reading of HI Level Output 4	3	ASCII
Lo Level Output 1 Status	G = Good I = Invalid	1	ASCII
Lo Level Output 1 Data	Unscaled Raw ADC output reading of LO Level Output 1	3	ASCII
Lo Level Output 2 Status	G = Good I = Invalid	1	ASCII
Lo Level Output 2 Data	Unscaled Raw ADC output reading of LO Level Output 2	3	ASCII
End of Message ID and Checksum		3	ASCII
		160	

Figure 2.187 Refurbished drill head data format

R	Drill ID
0000149700	Millisecond Timer
G	Drill Status
G	Power Supply Heat Sink Temperature Sensor Status
381	Power Supply Heat Sink Temperature Sensor Reading
G	MLDT1 Status
77E	MLDT1 Reading
G	MLDT2 Status
000	MLDT2 Reading
G	Load Cell Status
E4F	Load Cell Reading
G	Well (Drill Hole) Temperature Sensor Status
003	Well (Drill Hole) Temperature Sensor Reading
G	Hose Water Temperature Sensor Status
005	Hose Water Temperature Sensor Reading
G	Power Supply Input Voltage Status
AB1	Power Supply Input Voltage Reading
G	Main Regulator (24 VDC) Output Voltage Status
CC5	Main Regulator (24 VDC) Output Voltage Reading
G	Cavity Air Pressure Sensor Status
7D7	Cavity Air Pressure Sensor Reading
G	Tseal1 Pressure Sensor Status
014	Tseal1 Pressure Sensor Reading
G	Tseal2 Pressure Sensor Status
013	Tseal2 Pressure Sensor Reading
G	Well(Drill Hole)Pressure Sensor Status
*0001	Well(Drill Hole)Pressure Sensor Message ID
+14.2100000	Well(Drill Hole)Pressure Sensor Reading
G	Watson Nav Pack Status
N	Watson Nav Pack Message ID
+9.99	Watson Nav Pack: Bank Tilt Reading
-1.25	Watson Nav Pack: Elevation Tilt Reading
278.8	Watson Nav Pack: Heading Reading
+015.3	Watson Nav Pack: X Axis Magnetic Field Reading
+489.1	Watson Nav Pack: Y Axis Magnetic Field Reading
+150.3	Watson Nav Pack: Z Axis Magnetic Field Reading
+26.6	Watson Nav Pack: Temperature Reading
G	Accelerometer #1 Reading #1 Status
982	Accelerometer #1 (Sensotek MA321) Reading #1
G	Accelerometer #1 Reading #2 Status
983	Accelerometer #1 (Sensotek MA321) Reading #2
G	Accelerometer #1 Reading #3 Status
981	Accelerometer #1 (Sensotek MA321) Reading #3
G	Accelerometer #1 Reading #4 Status
982	Accelerometer #1 (Sensotek MA321) Reading #4
G	Accelerometer #1 Reading #5 Status
983	Accelerometer #1 (Sensotek MA321) Reading #5
G	Accelerometer #1 Filtered Value Status
94F	Accelerometer #1 (Sensotek MA321) Filtered Value
G	Hose Water Pressure Status
003	Hose Water Pressure
G	Accelerometer #2 Status
997	Accelerometer #2 (Kistler 8305A2)
G	Hi Level Input 4 Status
FF1	Hi Level Input 4 (Dedicated as Reference Voltage)
G	Low Level Input #1 Status
035	Low Level Input #1 (Spare Input)
G	Low Level Input #2 Status
034	Low Level Input #2 (Spare Input)
K31	End of Message ID and Check Sum

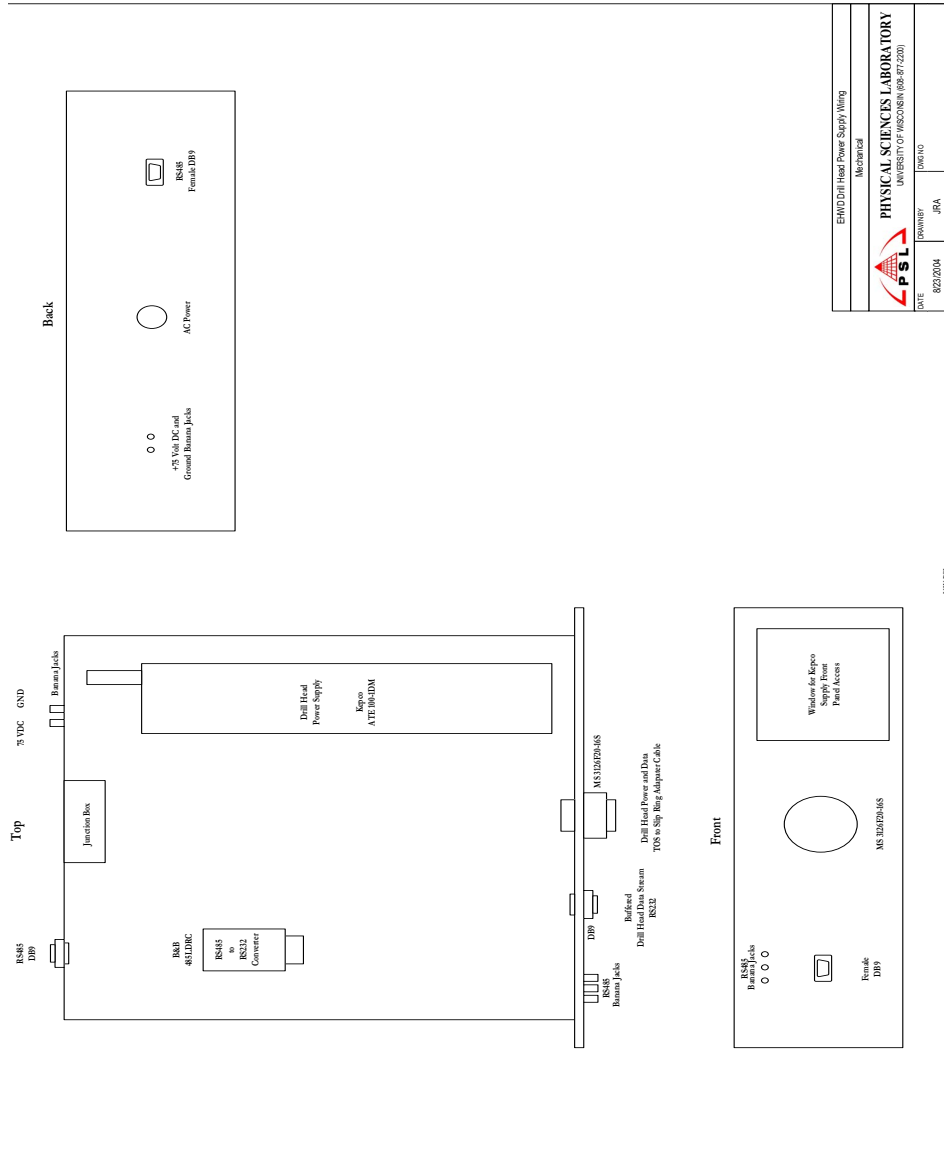
R0000149700GG381G77EG000GE4FG003G005GAB1GCC5G7D7G014G013G\*0001+14.2400  
+489.1 +150.3 +26.6G982G983G981G983G982G94FG003G997GFF1G035G034K31

**Figure 2.188** Refurbished drill head example values and string transmitted to surface

The figures above give a summary of the software available for the drill heads and of the output data string format. For a listing of the software, refer to the appendices.

## 2.6.5 Drill Head Surface Power Supply

The drill head surface power supply consists of a programmable power supply module and an RS232 to RS485 converter module housed in a 4RU enclosure, as shown in Figure 2.189 and Figure 2.190. The unit sits in the computer rack in the TOS computer room.



EHWD Drill Head Power Supply Wiring	
Mechanical	
<b>PHYSICAL SCIENCES LABORATORY</b> UNIVERSITY OF MISSOURI (RB-87-220)	
DATE: 8/23/2004	DRAWN: JRA
	ENG: JG

**Figure 2.189** Drill head surface power supply mechanical layout



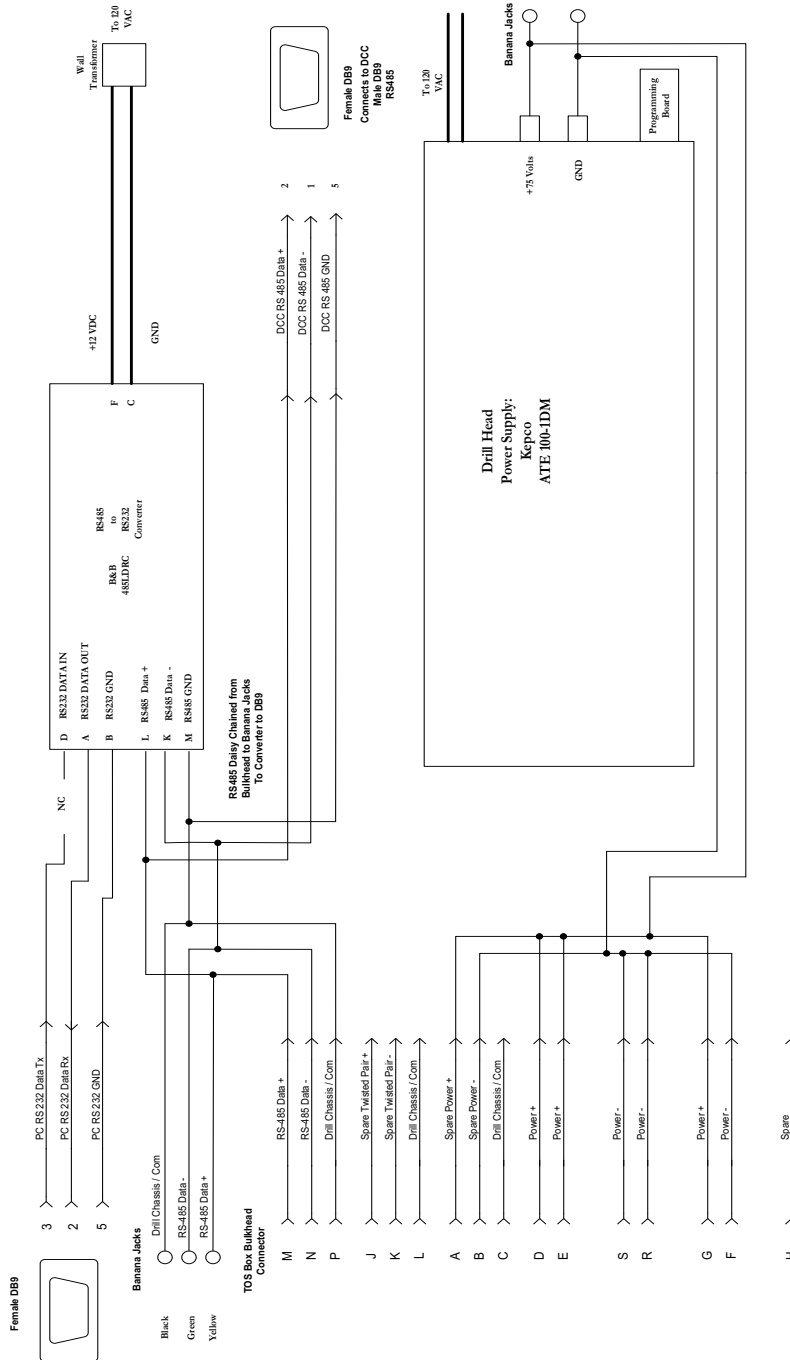


Figure 2.190 Drill head surface power supply electrical wiring

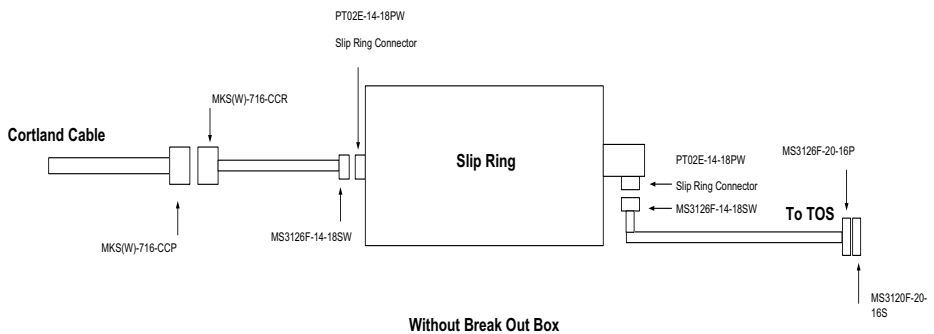
The power supply module is a Kepco ATE 100-1DM programmable precision power supply module which can deliver either stabilized output voltage or current. The unit has a 10 turn high resolution front panel potentiometer which can be used to accurately set the voltage and a similar potentiometer which is used to set the a current limit on the output. Alternatively, the unit can be programmed to a set voltage via a rear programming connector. This disables the voltage set potentiometer and allows for a fixed output with no chance of accidentally changing the output voltage. In the case of the drill head, the unit is programmed for a 7V output which results in a 38V input to the drill head power supply. See 2.6.3.3.3, “Main 24V supply”.

The RS 232 to RS-485 converter is a B&B 485LDRC industrial DIN rail mounted, optically isolated converter which can transmit at up to 115.2 kbps. The unit also provide surge suppression on the RS485 line. The unit also features “send data control” circuitry, so no software control of handshake lines is required in RS 485 mode.

The converter is used to provide conversion of the RS485 signals between the drill control computer and the drill head into an RS232 signal which is output to a connector on the front of the power supply, as shown in Figure 2.189 and Figure 2.190. This RS232 output is used by a test PC running drill test software to communicate with the drill head and read the raw data stream being transmitted by the drill head.

## 2.6.6 Drill head external system wiring

This section documents the system wiring from the connector on the drill head to the connector on the drill head surface power supply, the components of which are shown in the block diagram in Figure 2.191.



**Figure 2.191** Drill head to surface power supply wiring block diagram

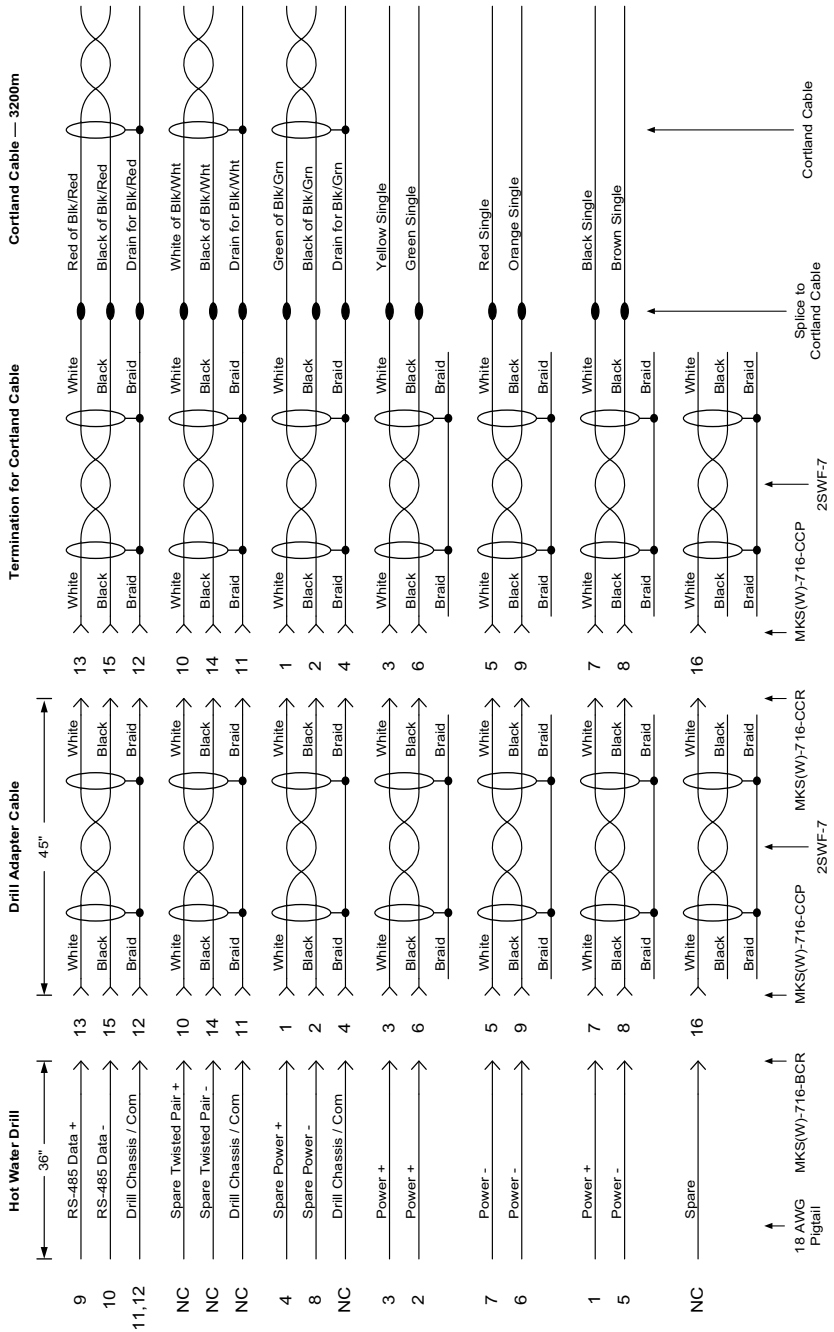


Figure 2.192 Cable wiring diagram between drill head and cortland cable

Power/Telemetry Cable Interconnections for Enhanced Hot Water Drill Head

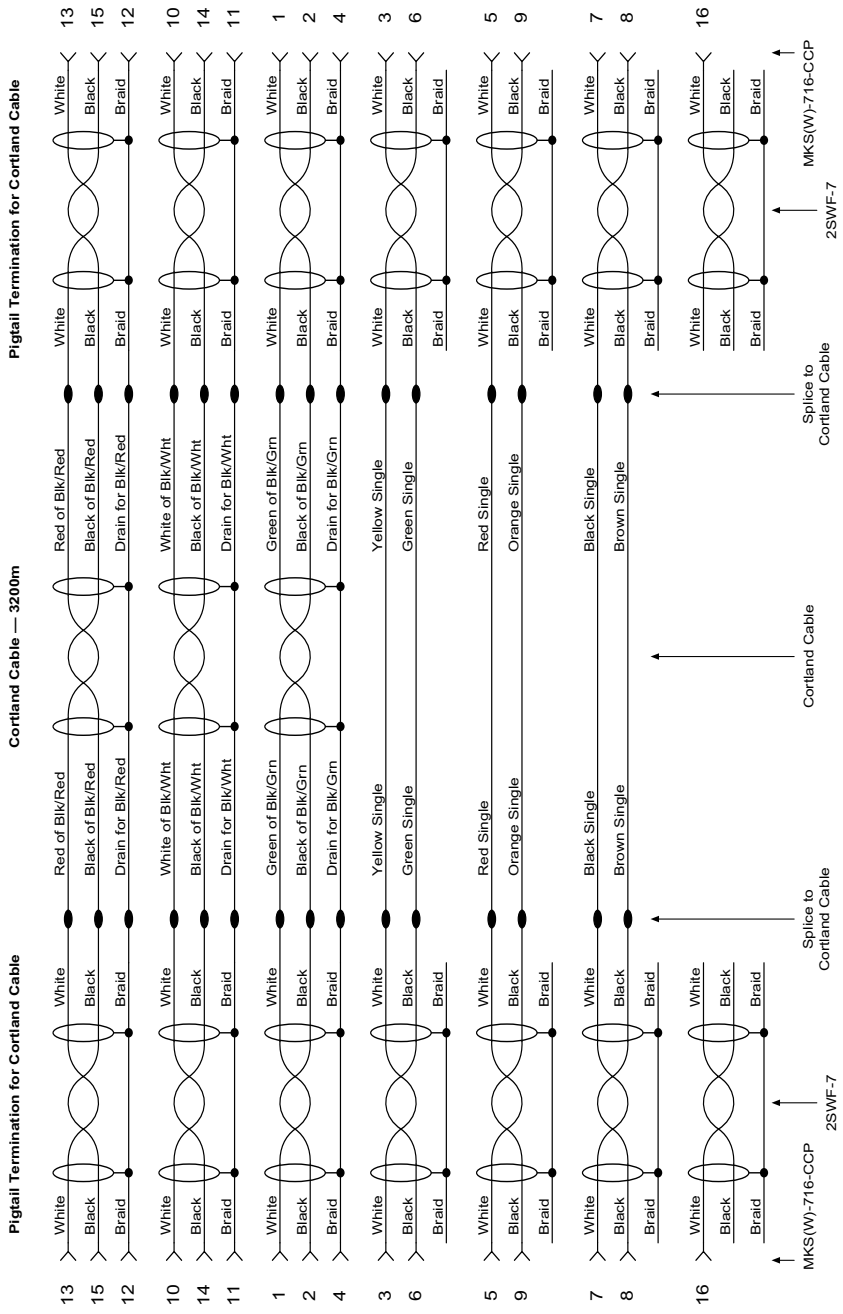


Figure 2.193 Cortland cable wiring diagram from pigtail to pigtail

Terminations for Kevlar Electro-Mechanical Drill Support Cable for University of Wisconsin

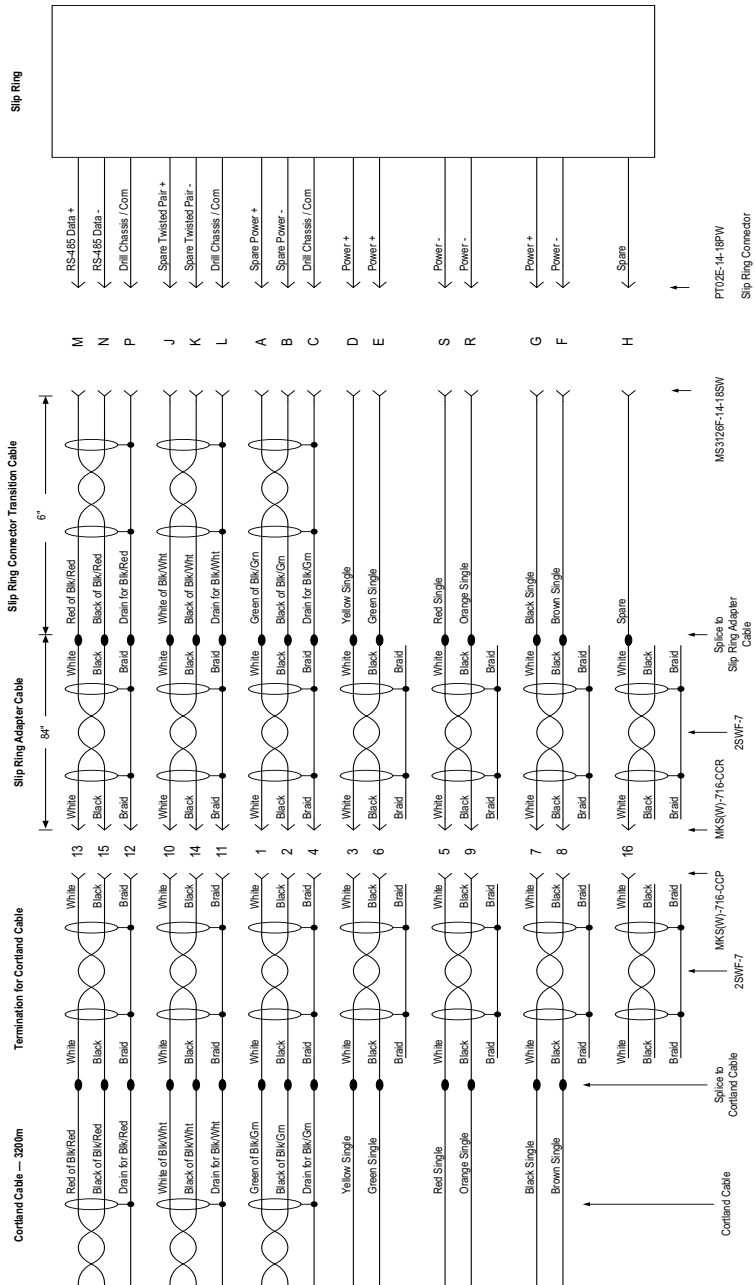
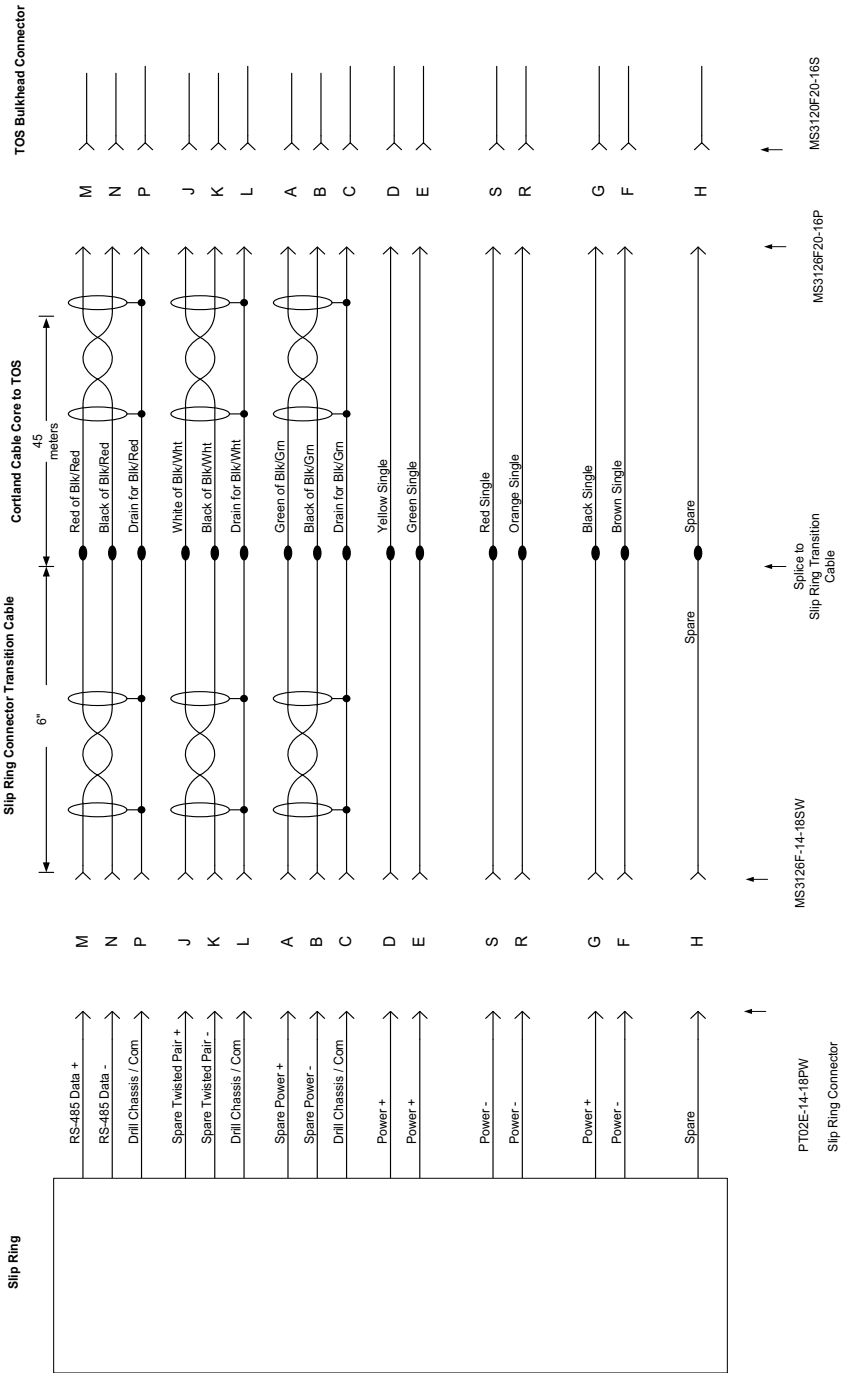


Figure 2.194 Cortland cable surface connector to slip ring wiring diagram

Power/Telemetry Cable Interconnections for IEC Slip Ring



**Figure 2.195** Slip ring to TOS bulkhead connector wiring diagram

The diagram in Figure 2.196 below is a wiring diagram of the adaptor cable that connects directly between the drill head (while it's at the surface) and the TOS bulkhead connector, which connects to the surface power supply. This cable is used for drill head testing purposes while the drill head is at the surface.

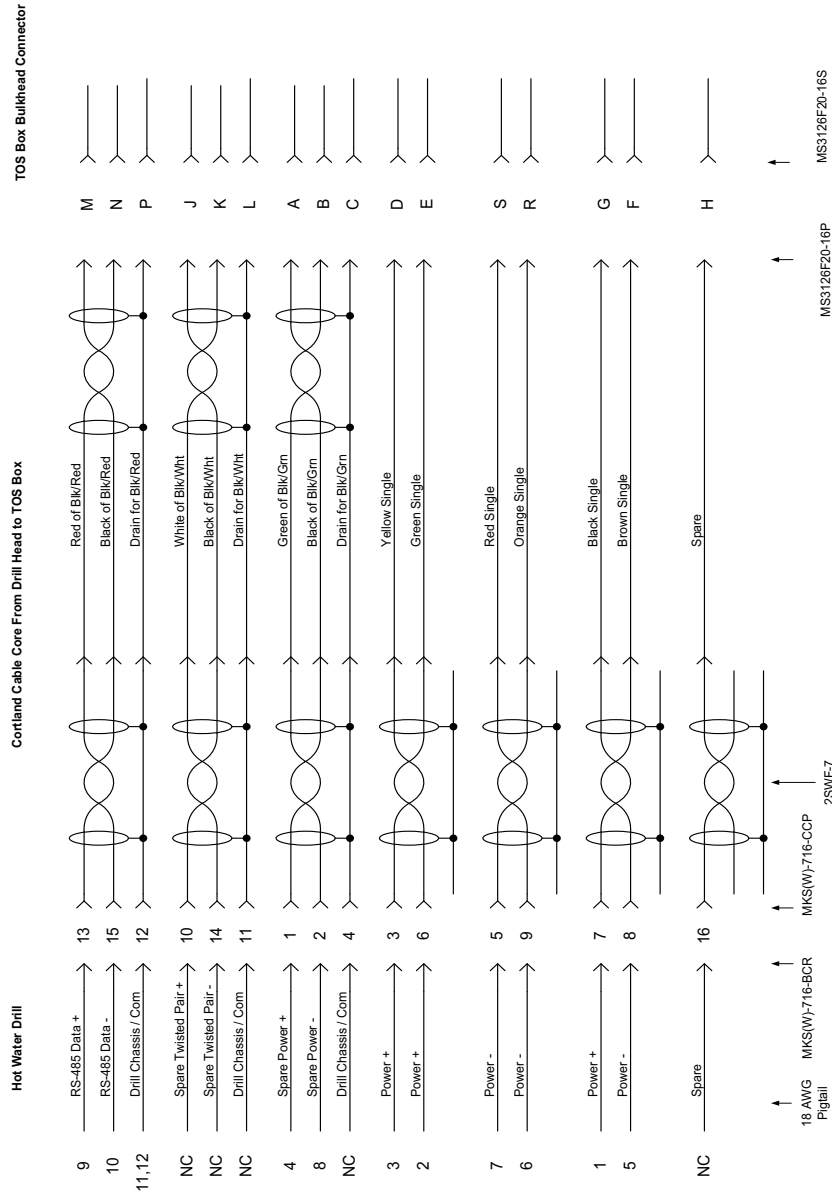
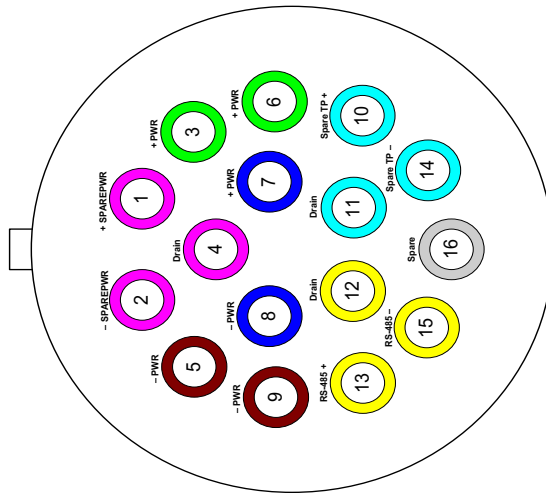
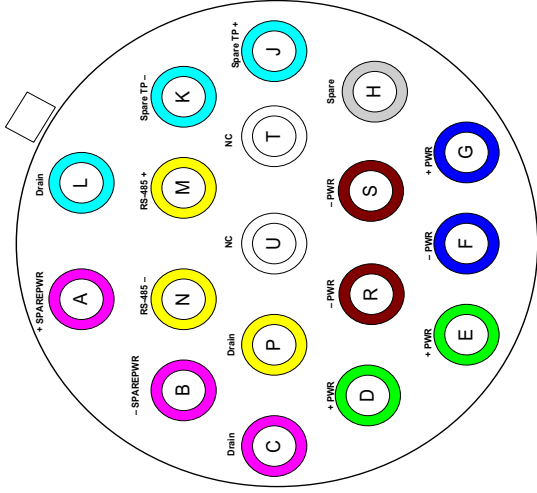


Figure 2.196 Drill head to TOS adaptor cable

TOS to Drill Head Adapter Cable (for Testing Using TOS and Environmental Test Box)



**MKS(W)-716-CCR Contact Configuration  
Receptacle Face View (= CCP Solder Side)**

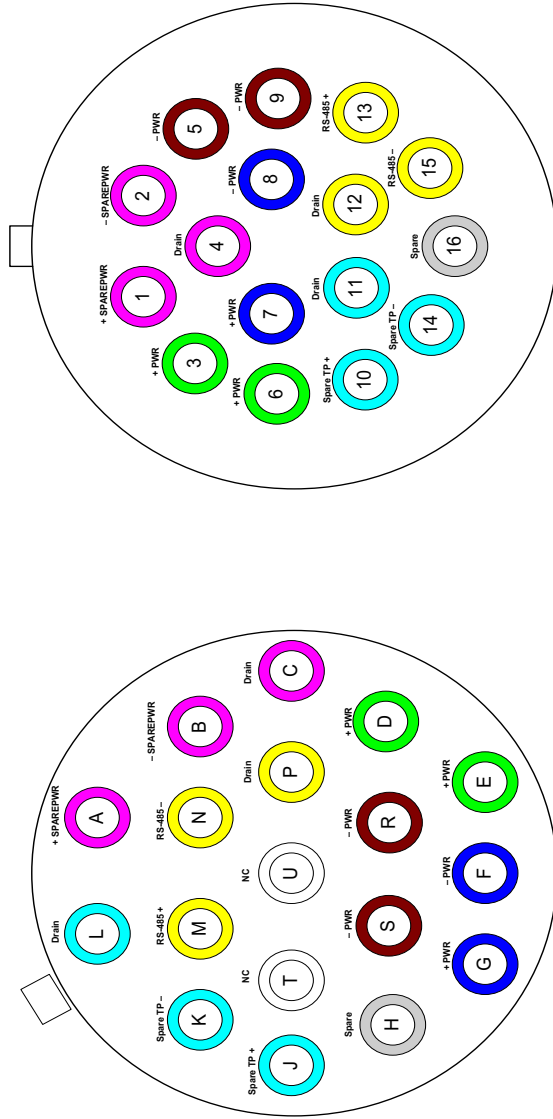


**PT06E-14-18SW and MS3126F-14-18SW Contact Configuration  
Socket Face View**

DRILL HEAD ELECTRONICS - Drill Head Connectors	
Impulse MKS(W)-716-CCR and CCR Connectors and Amphenol PT Connector	
<b>PSL</b> PHYSICAL SCIENCES LABORATORY UNIVERSITY OF MISSOURI (R06070200)	
DATE	01/02/2005
DRAWN BY	JUKA
DESIGNED	ROVING

**Figure 2.197** Impulse MKS(W)-716-CCP and CCR Connectors and Amphenol PT Connector pinouts





**MKS(W)-716-CCR Contact Configuration**  
**Receptacle: Solder Side**  
**MKS(W)-716-CCP Contact Configuration Plug: Face Side**  
**(CCR is Female Barrel (Receptacle) with Male Pins)**

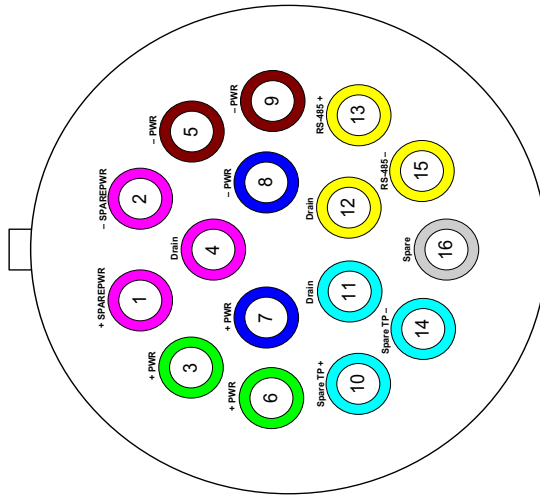
**PT06E-14-18SW and MS3126F-14-18SW Contact Configuration**  
**Socket: Solder Side**

DRILL HEAD ELECTRONICS – Drill Head Connectors  
 Impulse MKS(W)-716-CCP and CCR Connectors and Amphenol PT Connector

**PSL**  
 UNIVERSITY OF WISCONSIN (608) 725.2800

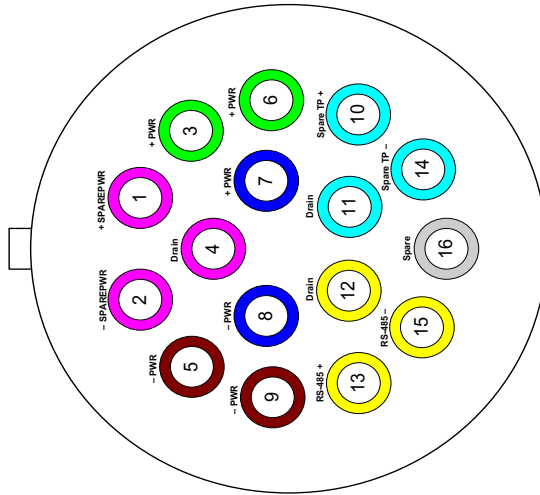
DATE: 01/03/2005 DRAWN BY: JRA  
 JRA

**Figure 2.198** Impulse MKS(W)-716-CCP and CCR Connectors and Amphenol PT Connector pinouts




**MKS(W)-716-CCR Contact Configuration Receptacle: Solder Side**  
**MKS(W)-716-CCP Contact Configuration Plug: Face Side**

(CCR is Female Barrel (Receptacle) with Male Pins)



**MKS(W)-716-CCR Contact Configuration Receptacle Face View**  
**MKS(W)-716-CCP Contact Configuration Plug: Solder Side**

DRILL HEAD ELECTRONICS – Drill Head Connectors	
Impulse MKS(W)-716-CCP and CCR Connectors	
 <b>PHYSICAL SCIENCES LABORATORY</b> UNIVERSITY OF WISCONSIN (608.877.2269)	
DATE	01/03/2005
DRAWN BY	JRA
DESIGNED	DW/MS

**Figure 2.199** Impulse MKS(W)-716-CCP and CCR Connectors pinouts

# Chapter 3

## 3: MOTOR DRIVES



## 3.1 Introduction

---

The purpose of this section is to provide the necessary information to bring the motor drives of the EHWD out of cold storage and to operational status.

Each subcomponent of this chapter contains specific information about the HPP, PHS, RWS and TOS(s). Additional subsections contain information regarding common software used throughout the motor drives as well as how to load Firmware, Projects and Archives.

The MDS specific sections of this chapter provide several subsections that outline the steps necessary to mount, connect, and perform pre-operational tests of the drives and associated equipment. In addition, these subsections contain information showing how to check the overall health of the drive as well as the basic setup and operational testing.

Copies of drive specific software are also shown to assist the user in understanding the operation of the motor controller. Descriptions of options that allow them to provide other motor drive functions are also addressed.

UNICO hardware, firmware and UEdit manuals are available under the UNICO section of DocuShare.

### 3.1.1 Assumptions

---

- Camp has power
- MDS(s) is up to temperature
- E-Stop network is running
- Drill Network is running

#### **Before you begin:**

- Check for proper lock out tag out (LOTO) of all drive related circuits.
- Check to see if the environment is conducive to the operation of the drive(s).

### 3.1.2 Operating Environment

---

- |                    |   |
|--------------------|---|
| Temperature:       | Control Section: 32° to 131° F (0° to 55° C)      |
|                    | Heat sink (standard): 32° to 104° F (0° to 40° C) |
|                    | Heat sink (derated): 32° to 122° F (0° to 50° C)  |
| Relative humidity: | 5% to 95%, noncondensing                          |

Attention:



**Exercise care during installation to prevent metal shavings, conduit knockouts and other debris from falling into the unit. Personal injury and/or equipment damage may result.**

**High voltages may be present, even when all electrical supplies are disconnected. Wait at least 15 minutes for bus circuit capacitors to discharge before working on the drive or associated equipment. Use an appropriate voltmeter to further verify that capacitors are discharged before beginning work. Do not rely exclusively on the bus voltage indicator. DANGEROUS voltage levels may remain even when the indicator is off.**

## 3.2 Drill MDS Drives

---

Five of the MDSs within the EHWD will be of concern. They are the HPP, PHS, RWS, TOS1 and TOS2. These MDS units contain motor controllers, and the associated electronics will be discussed in this chapter.

### 3.2.1 High Pressure Pump (HPP) Drives

---

There are four high pressure pumps. All use the same start up procedure with the exception of drive number one. Although all the drives are identical in hardware and software, additional setup and testing is necessary for the MDS environmental control.

#### Installation of the drive

Install the appropriate drive on the aluminum mounting plate using  $\frac{1}{4}$ -20 button head cap screws. Take care to locate the drive labeled HPP1 at the HPP1 location and so on to avoid having to reload the drive specific archives. Continue with HPP 2 through 4.

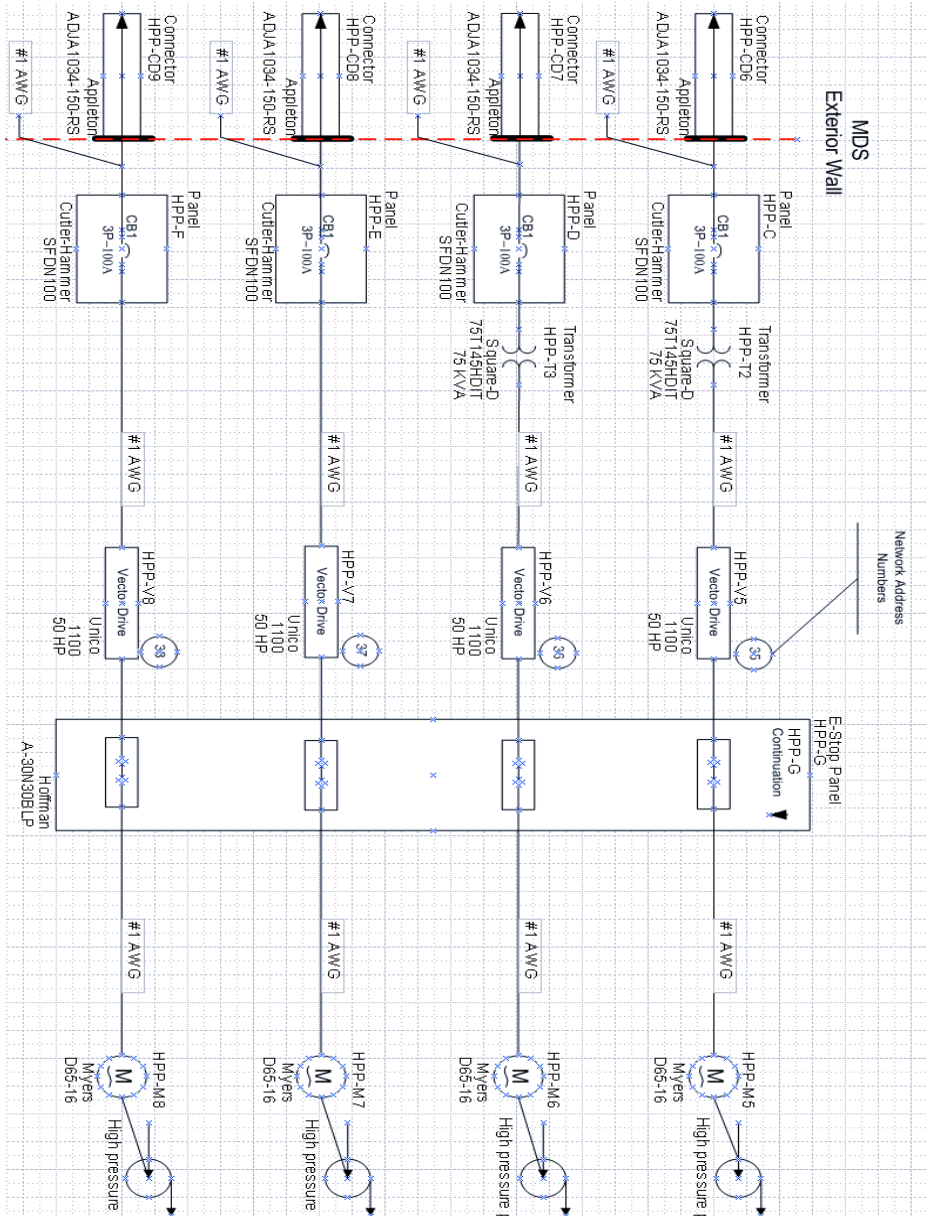
Attention:



**Exercise care during installation to prevent metal shavings, conduit knockouts and other debris from falling into the unit. Personal injury and/or equipment damage may result.**

## Hi-Pot

Figure 3.1 below is a one line wiring diagram of the motor drive and motor connections. It is recommended that a hi-pot test be performed on each of the motors and wiring before making any connections.

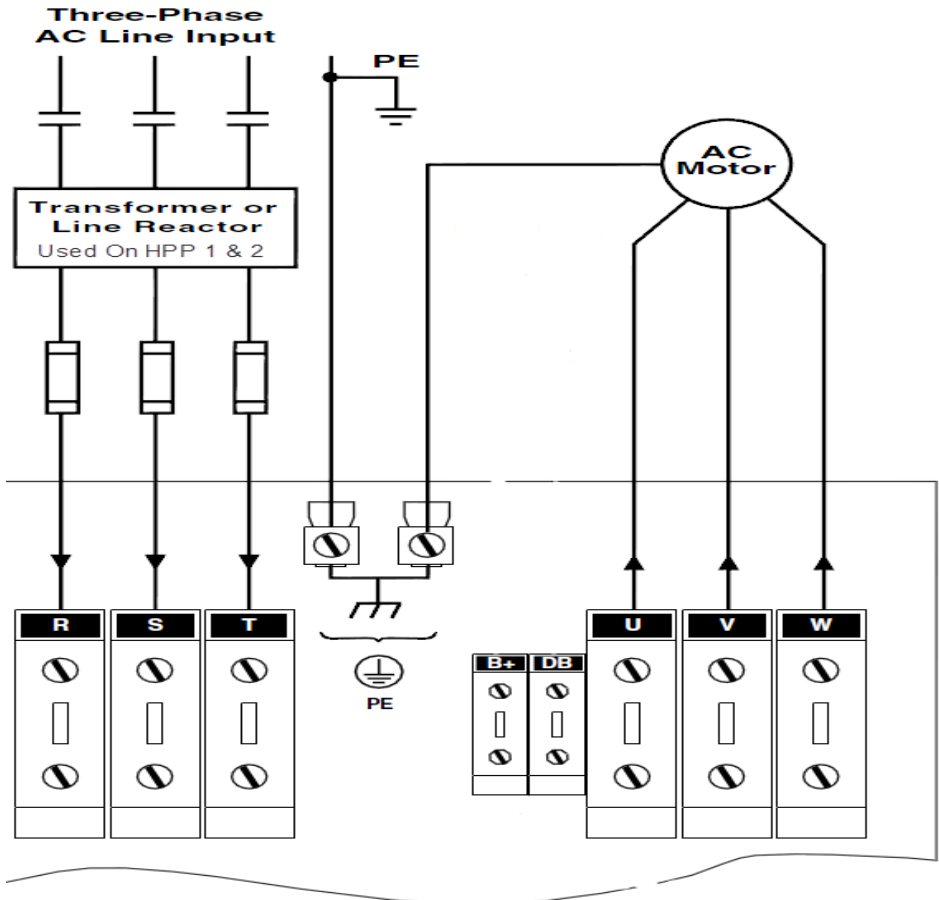


**Figure 3.1** Motor controllers and motor one line diagram in the HPP

## Main Power and Load Connections

Figure 3.2 below shows a typical 50HP terminal configuration. Terminals R, S, and T should be connected to the 480 three phase source. Terminals U, V, and W are the drive's output which will connect to the motor. Chassis/green ground is also provided. Connect top mounted external cooling fan to 110 VAC outlet.

**Note:** *The DIN mounted terminal strip providing power input and output are worn and loose; use care when making connections.*



**Figure 3.2** Typical 50HP terminal configuration

## Network/E-Stop Connection

Connect the Network/E-Stop connector into the MS3122E14-18P connector on the side of the UNICO drive, as shown in Figure 3.3 below.

## Charge Pump Pressure Switch Connection

Connect the charge pump pressure switch cable into the Conex connector located near the military connectors on the side of the UNICO drive, as shown in Figure 3.3.

## Temperature Connection

Connect the temperature monitoring/control cable to the DB25 connector located on the bottom of the UNICO drive, as shown in Figure 3.3.



**Figure 3.3** HPP motor drive showing the Network, charge pump and temp control connections

## Power up

Once all connections have been reconfirmed secure the drive door, remove the LOTO device and turn on disconnect.



## **Check for Proper Software**

After a brief initialization period, the drive will display "Performance AC Drive 480V 50HP" briefly then it will go to the RPM display. Press the "ENT" key to enter the menu section of the drive. Press "7" followed by the "ENT" to enter the help menu. Press "1", "1" followed by the "ENT" key; this will put the drive in the UEdit menu.. If the drive does not display "HPP\_805493\_001\_1010B", you will need to reload the project. Instructions are located in the "Software" section of this chapter.

## **Set Date & Time (Calendar)**

From the previous operation press "QUIT" once, then press "6" then "ENT"; this will put you in the calendar menu. If the date and time are not correct, this may indicate a problem with the battery backup nonvolatile memory module. Set the time by pressing the "ENT" key until the cursor is at the item desired to change. Next press the arrow key to change the desired item until it displays the correct value. The password "1111" will be necessary to make any changes.

## **Test Charge Pump Pressure Switch**

Have the DCC operator start the charge pump (assuming the system has water). Pressing the "Fn" and the "0" key on the UNICO drive keypad simultaneously will clear the "Charge Pump" fault. Have the DCC operator shut down the Charge Pump and confirm the "Charge Pump" fault returns.

## **Test E-Stop**

Assuming the E-Stop is operational and a green indicator is illuminated on the E-Stop panel you may confirm the E-Stop function is working by pressing the "Fn" and the "0" key simultaneously on the UNICO keypad to clear any faults. Once the faults have been cleared, pressing an E-Stop button will indicate an "Ext Trip" fault on the UNICO display.

Note: Any command from the DCC to the UNICO drives will clear any fault. Pressing "Fn" "0" should only be necessary when troubleshooting.

## **Check Drill Network Communications**

When viewing the appropriate HPP Pump screen on the DCC computer, you will see a flashing ready bit. If the bit is not flashing and yellow, communications have not been established to the UNICO drive. Note: It is not uncommon to see the ready bit flash yellow for very brief periods.

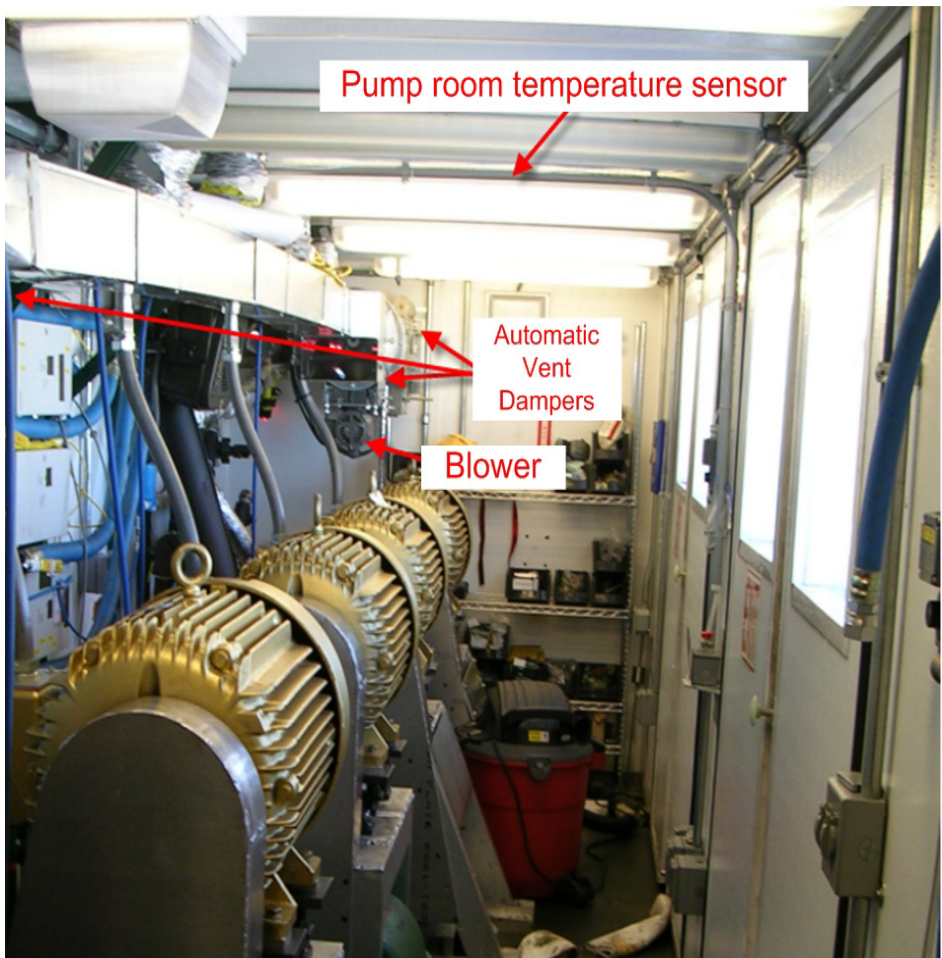
## **Test Run Pump**

Before attempting to run an HPP, confirm that the accumulator is installed and charged, a sufficient amount of water is available and input and output valves

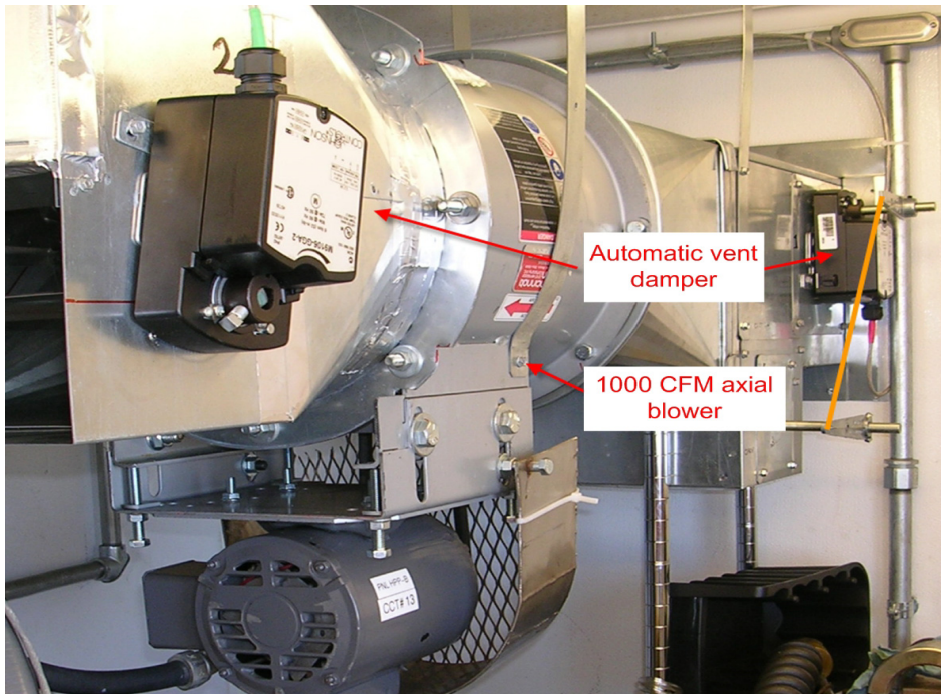
are open. Have the DCC operator start the desired HPP at "0" RPM. While watching the HPP keypad display you will see the "Charge Pump" fault clear. At the selected motor listen for a hissing noise which indicates the motor stator is energized. Have the DCC operator enter the desired RPM; confirm proper rotation and operation.

### 3.2.1.1 HPP MDS Environmental Control - HPP 1 UNICO

Figure 3.4 below shows the environmental control setup in the HPP MDS while Figure 3.5 shows a closeup of the automatic vent damper system and the blower.



**Figure 3.4** HPP environmental automatic control system



**Figure 3.5** Closeup of HPP environmental control automatic vent damper and blower

### Starting the system

Check the axial fan motor disconnect located above HPP 4, ensuring it is reset and on. Turn on breaker number 13 in the 120/208 volt breaker box. Confirm operation of the axial fan above HPP pump number 4. Adjust electrical closet exhaust fan thermostat to 70 degrees Fahrenheit. Adjust electric heaters and oil furnace to 65 degrees Fahrenheit.

### Settings

HPP UNICO drive number 1 is used to adjust the MDS temperature control. To enter the control menu press "ENT" select "1" then "ENT" press "1", "2", "ENT". You are now able to scroll through and set the temperature of the pump room, electrical closet and set the hysteresis. These settings are password protected ("1111").

### Testing

By adjusting the settings in the "Temp Ctrl" menu, operation of the automatic vent dampers can be confirmed. Confirm the temperatures displayed are correct for the electrical closet, pump room and the HPP 1 motor.

## **3.2.1.2 HPP Options**

### **Manual Start**

In the event of a network failure, construction or breakdown of the drill it may be desirable to run the HPP locally. To do so select the dictionary by pressing "ENT", "1", then select MAN CTRL/CAL by selecting "1", "1", "ENT". Use the arrow key to navigate through the menu to start the pump. Set the drive to manual mode, select the RPM then start.

### **Torque Limit**

Within the MAN CTRL/CAL menu the torque command and the RPM will be shown in registers 4 and 5 respectively. Torque limit can be set in register 3 to limit the maximum pressure output of each HPP.

### **Rapid Pressure Loss (hose burst) Fault**

This fault should not require any additional adjustment, but if erroneous trips occur the trip point can be adjusted in the global dictionary register 547. Note: A bypass button is provided on the HPP pump page of the drill control software.

### **Deadhead Fault**

In the event of a deadhead (no flow) the HPP will torque limit, if the torque limit causes a substantial decrease in motor RPM the drive will fault.

### **Temperature Control**

Refer to environment control section above.

## **3.2.1.3 HPP Specific Programming**

### **Charge Pump Fault**

The Ladder Logic diagram in Figure 3.6 contains the logic for the charge pump pressure switch. This shuts down the High pressure pump if water is removed from it's input.

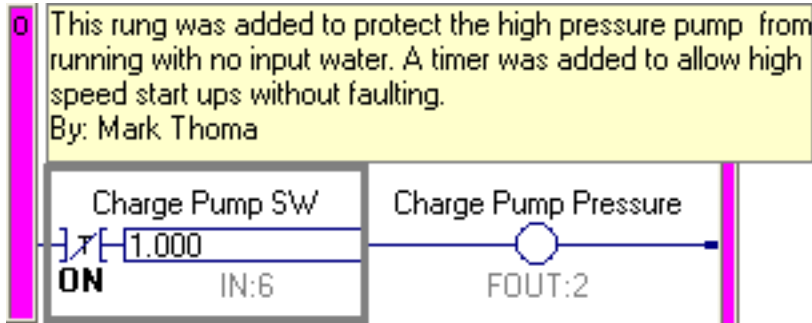


Figure 3.6 Charge pump fault logic ladder diagram

### Temp Control FXN

This block diagram is for the environmental control of the HPP MDS and monitoring the pump motor temperature.

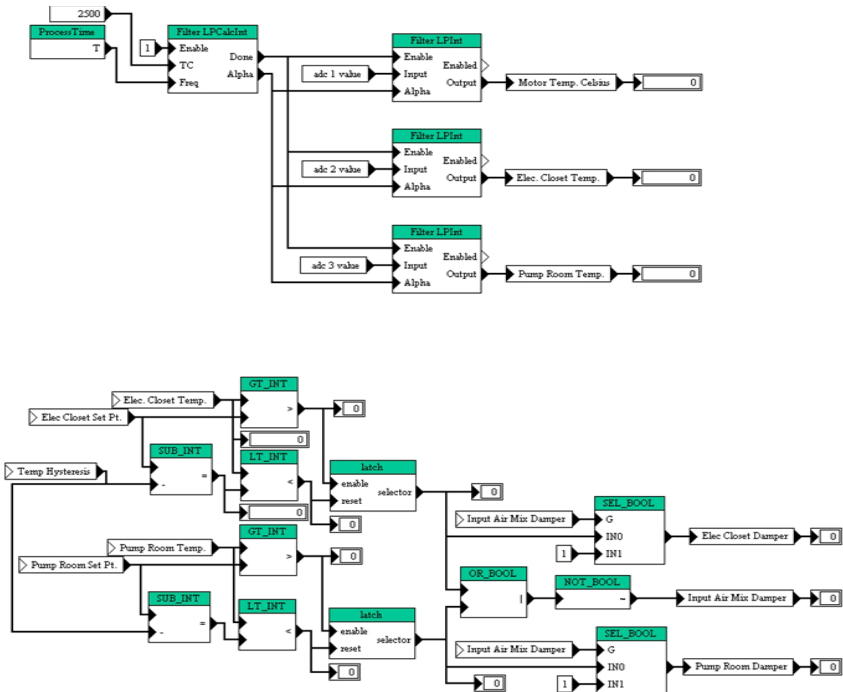
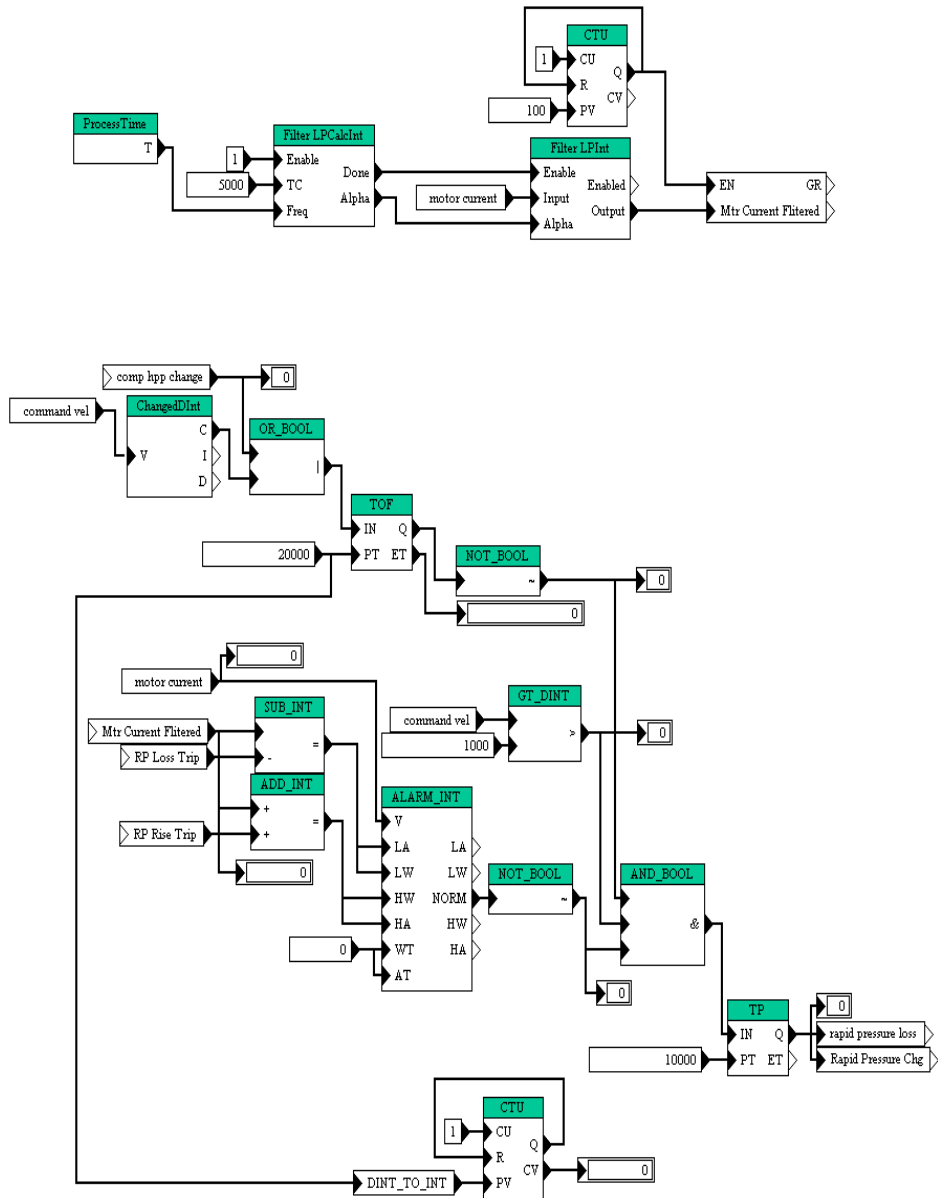
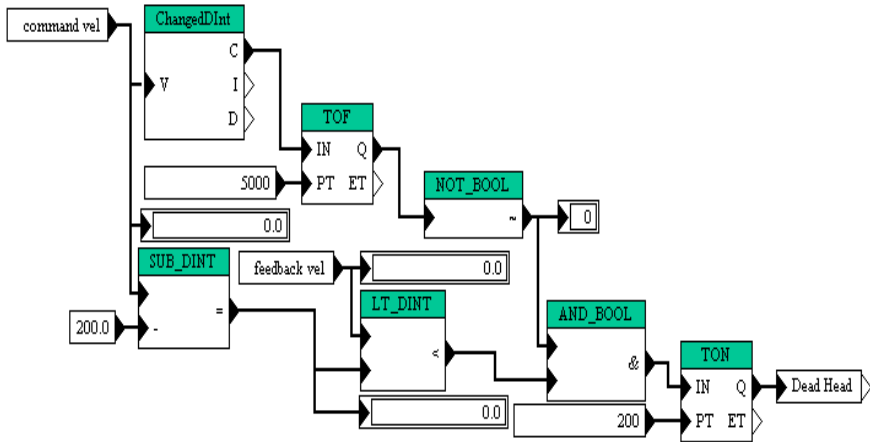


Figure 3.7 HPP environmental temperature control block diagram

## Blow Out Protection (Hose Burst and Dead Head) Fault

This program is used to detect a rapid change in current which would indicate a hose burst triggering a "Rapid Pressure Loss" fault. This program monitors requested and actual RPM. If the difference is too great (torque limiting) a "Dead Head" fault is triggered.

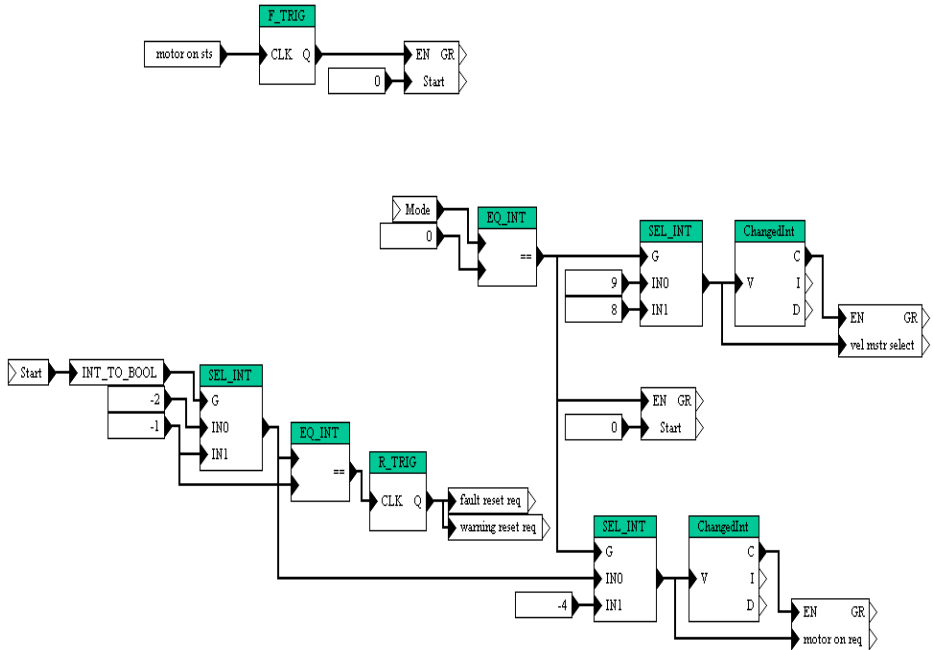




**Figure 3.8** Blow out protection fault block diagram

### Manual Mode Select

This program is used for local/keypad control of the pump.



**Figure 3.9** HPP manual mode select block diagram

## 3.2.2 PHS (Pre-heat System)

---

### Installation of the drive

Four UNICO drives are used in the PHS. Two 3HP UNICO drives are for the transfer pumps and there are two 10HP UNICO drives; one is for the vertical Turbine Pump and one for the Booster Pump. Install the appropriate drive on the aluminum mounting plate using ¼-20 button head cap screws. Take care to install the drive in the correct location to avoid having to reload the correct archives.

Attention:



**Exercise care during installation to prevent metal shavings, conduit knockouts and other debris from falling into the unit. Personal injury and/or equipment damage may result.**

### Hi-Pot

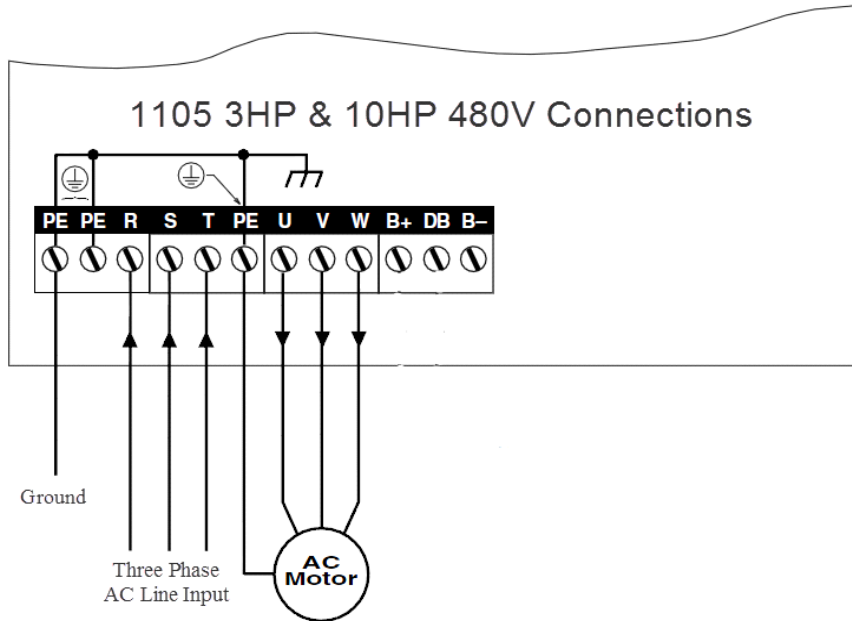
It is recommended that a hi-pot test be performed on each of the motors and wiring before making any connections. This may be accomplished by installing the motors/pumps and the associated cabling preceding drive installation, therefore allowing the technician to hi-pot the entire system from the drive location prior to the drive being connected.

### Main Power and Load Connections

Terminals R, S, and T should be connected to the 480 three phase source. Terminals U, V, and W are the drive's output which will connect to the motor. Chassis/green ground is also provided.

**Note:** *Do not over tighten; terminal strips are somewhat fragile and strip easily.*





**Figure 3.10** 3HP and 10HP terminal configuration

### Network/E-Stop Connection

Connect the Network/E-Stop connector into the MS3122E14-18P connector on the side of the UNICO drive.

### Power up

Once all connections have been reconfirmed secure the drive door, remove the LOTO device and turn on disconnect.

### Check for Proper Software

After a brief initialization period the drive will display "Performance AC Drive 480V 3HP" for the transfer pumps and "Performance AC Drive 480V 10HP" for the booster and vertical turbine pump; it will then go to the RPM display. Press the "ENT" key to enter the menu section of the drive. Press "7" followed by the "ENT" to enter the help menu. Press "1", "1" followed by the "ENT" key. This will put the drive in the UEdit menu. Go to the project name window using the arrow key to navigate through the menu. If the drive does not display "PHS\_805493\_001\_1003B", you will need to reload the project. Instructions are located in the "Software" section of this chapter.

## **Set Date & Time (Calendar)**

From the previous operation press "QUIT" once, then press "6" then "ENT"; this will put you in the calendar menu. If the date and time are not correct, this may indicate a problem with the battery backup nonvolatile memory module. Set the time by pressing the "ENT" key until the cursor is at the item desired to change. Next press the arrow key to change the desired item until it displays the correct value. The password "1111" will be necessary to make any changes.

## **Test E-Stop**

Assuming the E-Stop is operational and a green indicator is illuminated on the E-Stop panel you may confirm the E-Stop function is working by pressing the "Fn" and the "0" key simultaneously on the UNICO keypad to clear any faults. Once the faults have been cleared, pressing an E-Stop button will indicate an "Ext Trip" fault on the UNICO display.

**Note:** *Any command from the DCC to the UNICO drives will clear any fault. Pressing "Fn" "0" should only be necessary when troubleshooting.*

## **Check Drill Network Communications**

When viewing the appropriate PHS Pump screen on the DCC computer, you will see a flashing ready bit. If the bit is not flashing and yellow, communications have not been established to the UNICO drive. Note: It is not uncommon to see the ready bit flash yellow for very brief periods.

## **Test Run Pump**

Before attempting to run a pump, confirm that a sufficient amount of water is available and any input and output valves are open. Have the DCC operator start the desired pump at "0" RPM. While watching the keypad of the selected drive you will see any faults clear. At the selected motor listen for a hissing noise which indicates the motor stator is energized. Have the DCC operator enter the desired RPM; confirm proper rotation and operation.

## **3.2.2.1 PHS Options**

### **Manual Start**

In the event of a network failure, construction or breakdown of the drill it may be desirable to run a pump locally. To do so select the dictionary by pressing "ENT", "1" then select MAN CTRL/CAL by selecting "1", "1" "ENT". Use the arrow key to navigate through the menu to start the pump. Set the drive to manual mode, select the RPM then start



Attention:



**Exercise care during installation to prevent metal shavings, conduit knockouts and other debris from falling into the unit. Personal injury and/or equipment damage may result.**

### **Install Rod Well Pump Filter**

Wiring and terminal strips are numbered for easy installation.

### **Install Pendant Control Box (Suitcase)**

This may only require the installation of the Micro DAC.

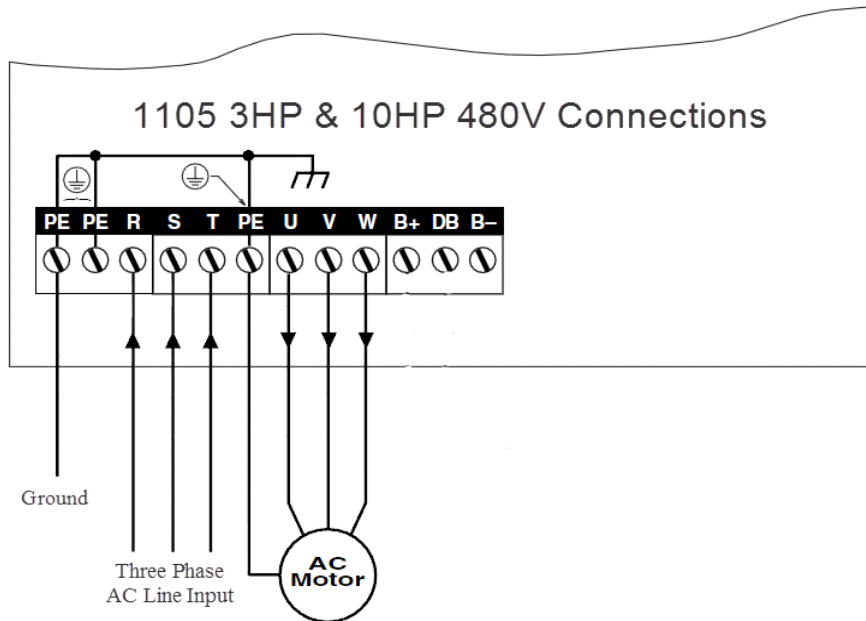
### **Hi-Pot**

It is recommended that a hi-pot test be performed on each of the motors and wiring before making any connections. This may be accomplished by installing the motors/pumps and the associated cabling preceding drive installation, therefore allowing the technician to hi-pot the entire system from the drive location prior to the drive being connected.

### **Main Power and Load Connections**

Terminals R, S, and T should be connected to the 480 three phase source. Terminals U, V, and W are the drive's output which will connect to the motor. Chassis/green ground is also provided.

**Note:** *Do not over tighten; terminal strips are somewhat fragile and strip easily.*



**Figure 3.12** RWS 3HP and 10HP drive terminal strip configuration

### Filter Connection

Reinstall filter board in filter box located next to the 10HP Rod Well Pump UNICO. Connect filter fan to 110 volt outlet.

### Network/E-Stop Connection

Connect the Network/E-Stop connector into the MS3122E14-18P connector on the side of the UNICO drive.

### Pendant Control Box (Suitcase)

Connect the pendant control box cable to the Rod Well Winch UNICO drive MS3122E16-8P connector located on the side of the UNICO drive. Note: For TU15 operation this same connection is moved to the Rod Well Pump UNICO (see instructions in the RWS electrical closet).

### Power up

Once all connections have been reconfirmed secure the drive door, remove the LOTO device and turn on disconnect.

## Check for Proper Software

After a brief initialization period the drive will display "Performance AC Drive 480V 3HP" for the transfer pumps and "Performance AC Drive 480V 10HP" for the booster and vertical turbine pump; it will then go to the RPM display. Press the "ENT" key to enter the menu section of the drive. Press "7" followed by the "ENT" to enter the help menu. Press "1", "1" followed by the "ENT" key. This will put the drive in the UEdit menu. It may be necessary to push the arrow key to view the project name. If the drive does not display "PHS\_805493\_001\_1004B", you will need to reload the project. Instructions are located in the "Software" section of this chapter.

## Set Date & Time (Calendar)

From the previous operation press "QUIT" once, then press "6" then "ENT"; this will put you in the calendar menu. If the date and time are not correct, this may indicate a problem with the battery backup nonvolatile memory module. Set the time by pressing the "ENT" key until the cursor is at the item desired to change. Next press the arrow key to change the desired item until it displays the correct value. The password "1111" will be necessary to make any changes.

## Test E-Stop

Assuming the E-Stop is operational and a green indicator is illuminated on the E-Stop panel you may confirm the E-Stop function is working by pressing the "Fn" and the "0" key simultaneously on the UNICO keypad to clear any faults. Once the faults have been cleared, pressing an E-Stop button will indicate an "Ext Trip" fault only on the Rod Well Hose Winch UNICO display. All other drives will remain operational.

**Note:** *Any command from the DCC or Pendant to the UNICO drives will clear any fault. Pressing "Fn" "0" should only be necessary when troubleshooting.*

## Check Drill Network Communications

When viewing the appropriate RWS Pump screen on the DCC computer, you will see a green flashing ready bit. If the bit is not flashing and yellow, communications have not been established to the UNICO drive.

**Note (1):** *If the Rod Well Pump UNICO is being used for TUI5 operation no communication will be seen at the DCC.*

**Note (2):** *It is not uncommon to see the ready bit flash yellow for very brief periods.*

## **Test Run Pump**

Before attempting to run a pump, confirm that a sufficient amount of water is available and any input and output valves are open. Have the DCC operator start the desired pump at "0" RPM. While watching the keypad of the selected drive you will see any faults clear. At the selected motor listen for a hissing noise which indicates the motor stator is energized. Have the DCC operator enter the desired RPM; confirm proper rotation and operation.

## **Test Run Winch**

Before attempting movement of the winch, make sure all safety protocols have been followed i.e.; moving parts are clear of obstructions and personnel are at a safe distance. Check the yellow reel stop slap switch to ensure it is not depressed. Press the "REEL START" button on the E-Stop panel. Turn the pendant mode selector to "COMP", then to "PEND"; the yellow PEND indicator will be illuminated. Press the blue "VEL" button. It will also illuminate. Check for hissing of motor stator. Pump up the brake. Using the velocity control knob and the "UP" and "DOWN" buttons, confirm movement for each direction is correct. Press the reel stop slap switch, confirm the pendant shows a fault and the UNICO shows an "Ext Trip."

## **3.2.3.1 RWS Options**

### **Manual Operation**

In the event of a network failure, construction or breakdown of the drill, it may be desirable to run a pump locally. To do so select the dictionary by pressing "ENT", "1" then select MAN CTRL/CAL by selecting "1", "1" "ENT". Use the arrow key to navigate through the menu to start the pump. Set the drive to manual mode, select the RPM then start.

### **TU15 Operation**

During drill camp construction and breakdown it is sometimes desirable to use the TU15 for spooling purposes. When using the Rod Well Pump UNICO it is possible to manually select TU15 operation. Press "ENT" to enter the menu. Press "1", "ENT" to enter the dictionary then press "1", "2", "ENT" to enter the "DRV SELECT" menu. Select drive type and move the pendant cable from the RWS Hose Winch drive to the MS3122E16-8P connector located on the side of the Rod Well Pump UNICO drive. Power cycle the drive before attempting any movement.

### 3.2.3.2 RWS Specific Programming

#### Manual Mode Select

This Program allows local/keyboard control of the RWS pumps. (see "manual start" under the RWS options section for additional information). This function is only available on the pump drives (Vertical Turbine(s) and Rod Well Pump) with register 478 of the global dictionary set appropriately.

**Note:** *The Rod Well Pump drive can be reconfigured to run the TU15; in this mode this option is disabled.*

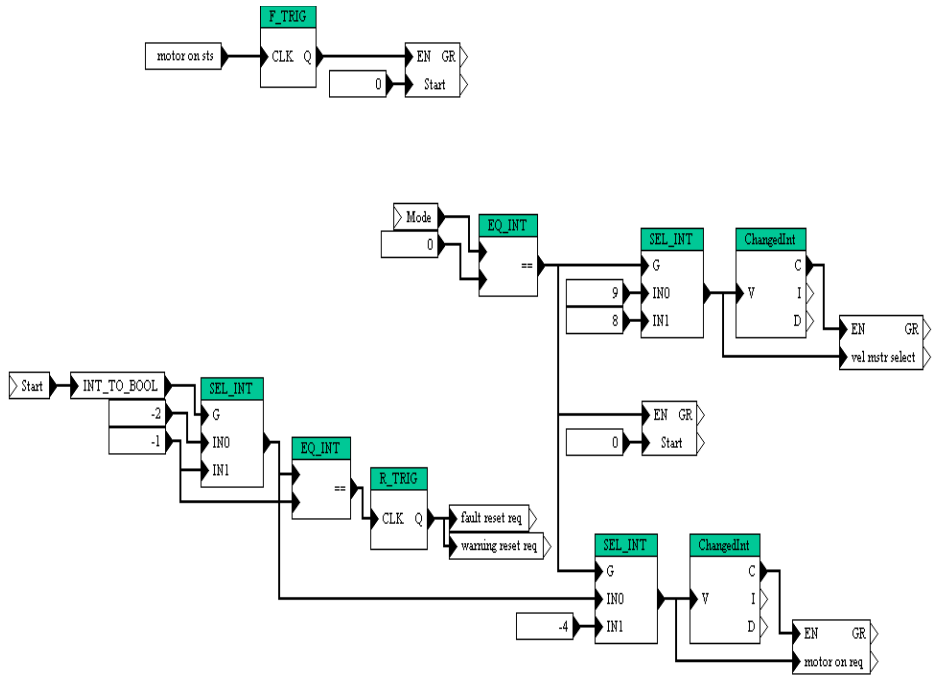


Figure 3.13 RWS manual mode select block diagram

#### 3.2.3.3 Drive Select

This Program is used to change the configuration for the drive between the Rod Well Pump and the TU15. In TU15 mode computer control is disabled



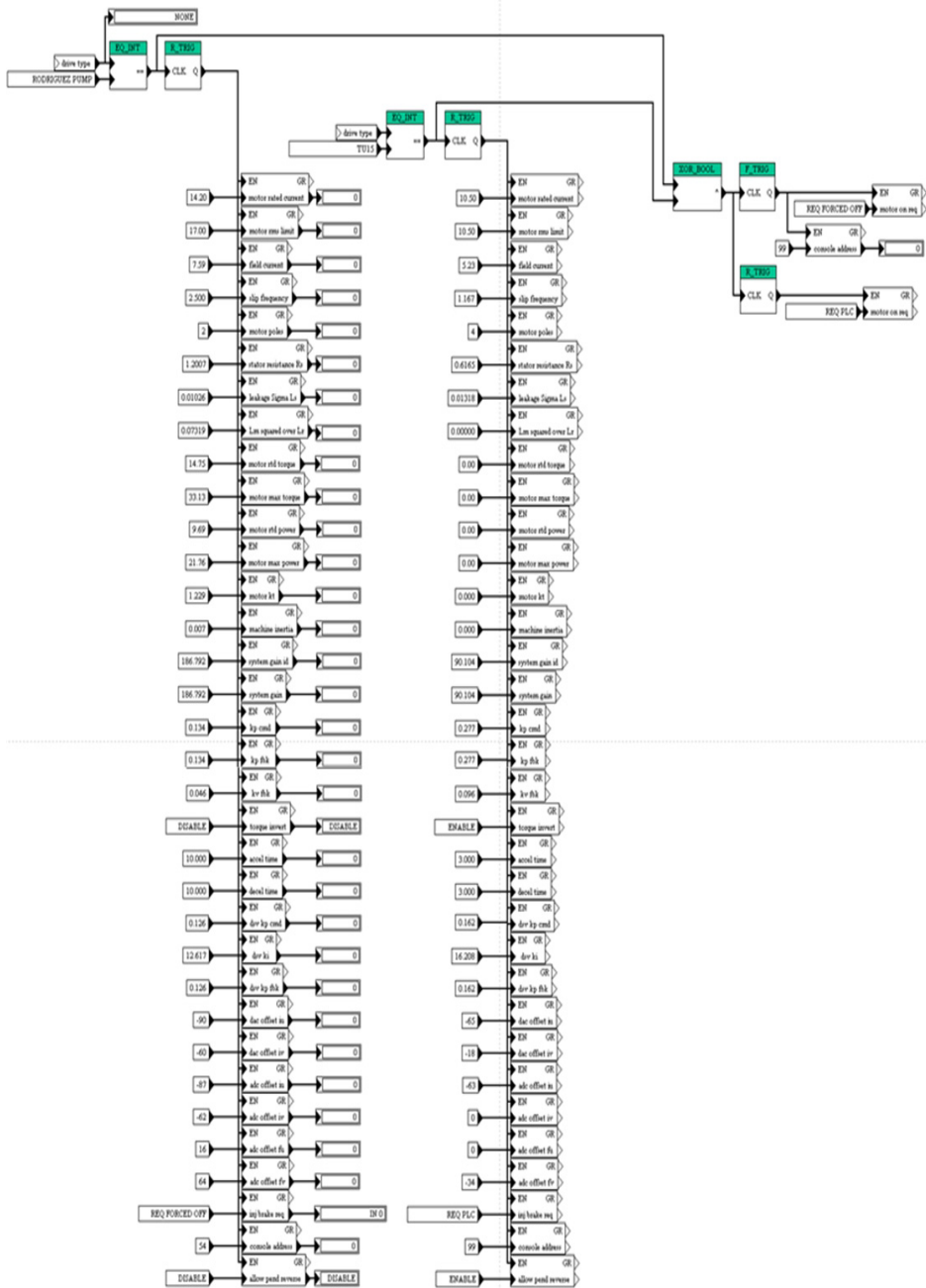


Figure 3.14 RWS drive select block diagram

## 3.2.4 TOS(s) Tower Operation Structure

---

### Installation of the drive(s)

Each TOS contains eight UNICO Drives for the following uses.

- Three 3HP drives,
  - one for the Main Hose winch level wind
  - one for the Drill Cable Winch Level Wind
  - one drive for the Return Water Cable Winch.
- Two 10HP drives,
  - one for the Tower Hoist
  - one for the Return Water Hose Reel.
- Two 30HP drives
  - one for the Main Hose Drum winch
  - one for the Drill Cable Drum Winch
- One 50HP drive for the Return Water Pump.

Install the appropriate drive on the aluminum mounting plate using  $\frac{1}{4}$ -20 button head cap screws. Take care to install the drive in the correct location to avoid having to reload the correct archives.

Attention:



**Exercise care during installation to prevent metal shavings, conduit knockouts and other debris from falling into the unit. Personal injury and/or equipment damage may result.**

### Hi-Pot

It is recommended that a hi-pot test be performed on each of the motors and wiring before making any connections. This may be accomplished by connecting the reels, Tower Hoist, Return Water Pump and associated cabling preceding drive installation, therefore allowing the technician to hi-pot the entire system from the drive location prior to the drive being connected.

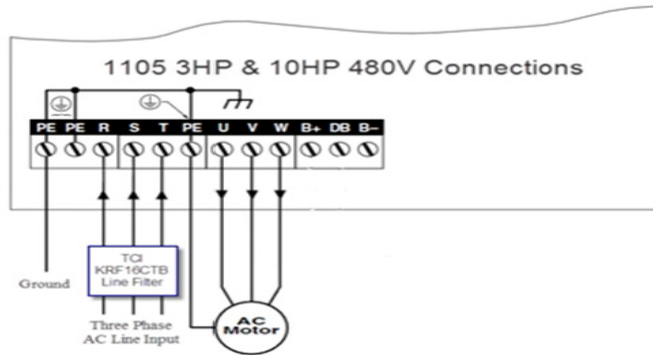
## Main Power and Load Connections

Terminals R, S, and T should be connected to the 480 three phase source. Terminals U, V, and W are the drive's output which will connect to the motor. Chassis/green ground is also provided.

**Note:** *Do not over tighten; terminal strips are somewhat fragile and strip easily.*

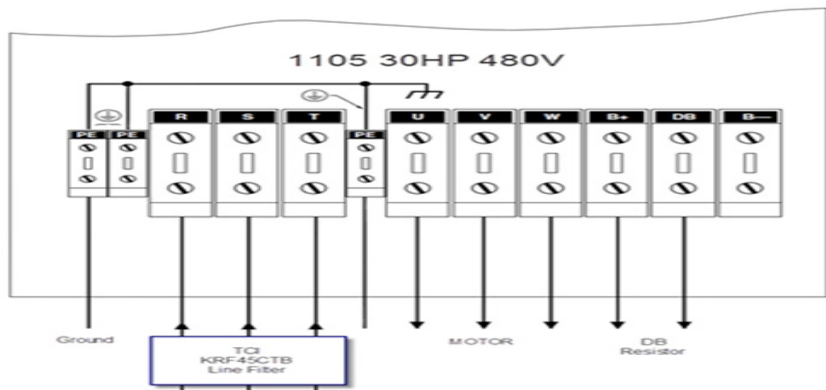
Figure 3.15 below shows a typical 3HP and 10HP terminal configurations.

**Note:** *TCI filter is external to the drive.*



**Figure 3.15** TOS 3HP and 10HP drive terminal configuration

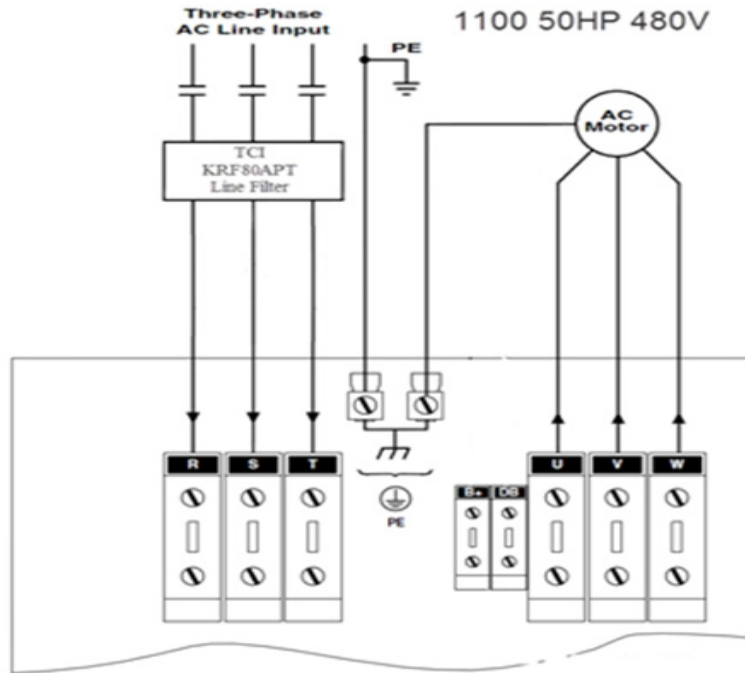
Figure 3.16 below shows a typical 30HP terminal configuration.



**Figure 3.16** TOS 30HP drive terminal configuration

**Note:** *A signal common has been added to the left side of the din rail not depicted in this picture.*

Figure 3.17 below shows a typical 50HP terminal configuration.



**Figure 3.17** TOS 50HP drive terminal configuration

**Note:** *The DB terminal is not present in the return water pump drive.*

### **Dynamic Brake Resistor**

Connect dynamic brake resistor to the Main Hose Reel Drum Drive, Drill Cable Reel Drum Drive, Tower Hoist Drive and Return Water Hose Reel Drive. One side of the dynamic brake resistor is connected to the "DB" terminal, the other to the "B+" terminal.

### **Dynamic Brake Over Temperature**

Connect the 18 AWG dynamic brake over temperature wires. Black connects to TB1-11 and red to TB1- 23. These wires are run in the same conduit as the dynamic brake wires. Note: in the Drum Drives (30HP UNICOS) a din mounted common was added to the far left of the electrical connections.

### **Network/E-Stop Connection**

Connect the Network/E-Stop connector into the MS3122E14-18P connector on the side of the UNICO drive.

### **Pendant Control Box (TOS I/O BOX)**

Connect the pendant control box cable to the Main Hose Reel Drum drive, Main Hose Reel Level Wind Drive, Drill Cable Drum Drive, Drill Cable Level Wind Drive, Return Water Hose Reel Drive and the Tower Hoist Drive via the MS3122E16-8P connector located on the side of each of the UNICO drives.

### **Encoder Connection**

Connect the Encoder cable to the MS3122E16-26P connector located on the side of the UNICO drives for Main Hose Reel Drum, Main Hose Reel Level Wind, Drill Cable Drum and the Drill Cable Reel Level Wind.

### **Resolver Connection**

Connect the Resolver cable from the Return Water Hose Reel to the CA3100E18-19 connector located on the side of the Return Water Hose Reel UNICO Drive.

Figure 3.18 below is a photo of a typical drive showing where the control and I/O connectors are located on the drive..



**Figure 3.18** Drive showing where the drive control and I/O connectors are located

### 3.2.4.1 TOS Drive Filter Installation

There are various line input/ output and buss filters on the TOS drives located as shown in Figure 3.19 below.



**Figure 3.19** TOS drive filter locations

#### **Install Line Input Filters**

All of the UNICO drives in the TOS have an input line filter except for the Return Water Cable Reel. The 3HP and 10HP drives use a TCI model KRF16CTB filter, the 30HP drives use the TCI model KRF45CTB, while the 50HP drive uses the TCI model KRF80APT. Observe phase rotation when making connections.

### Install Buss Filters

Additional buss filters are used on both the Main Hose Reel Drum and the Drill Cable Reel Drum drives to assist with dynamic breaking. Install in chassis next to UNICO drives.

### Install Output Filter/Reactor

Due to the length of cable used for the Return Water Pump a filter and reactor is installed to dampen ringing. Install in the output of the Return Water Pump UNICO drive.

### 3.2.4.2 Install Micro DACs

Install Hose Reel Drum, Hose Reel Level Wind, Cable Reel Drum, Cable Reel Level Wind, Tower Hoist and Return Water Hose Reel Micro DACs in TOS I/O cabinets as shown in Figure 3.20 below.

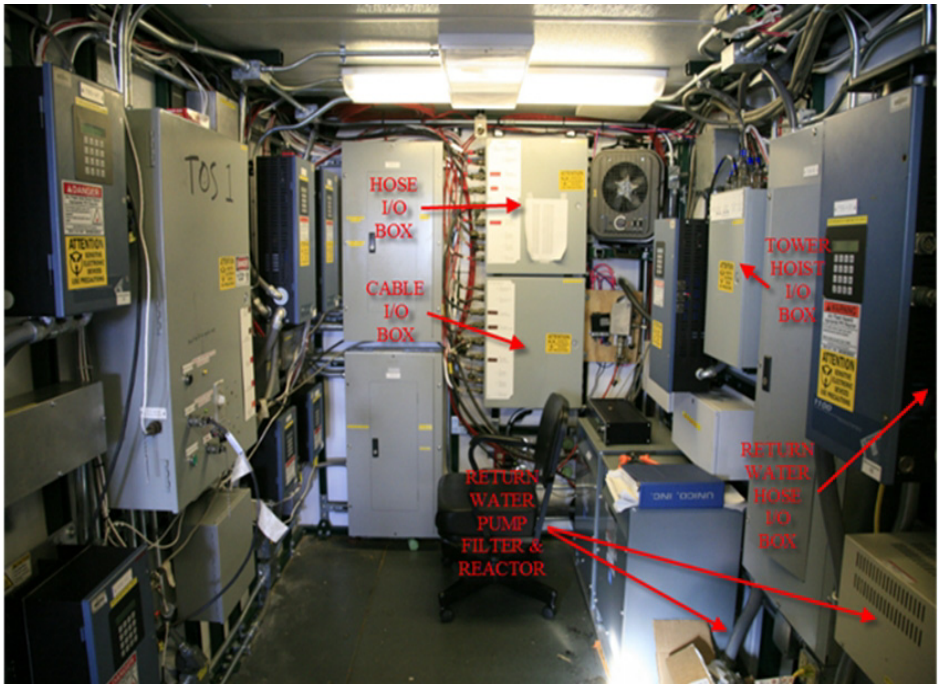
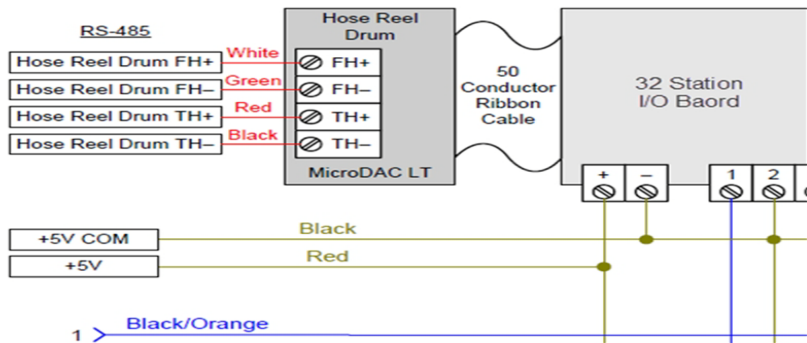


Figure 3.20 TOS I/O cabinet locations

Micro DAC power is provided through the 50 conductor ribbon cable, as shown in Figure 3.21 below.



**Figure 3.21** typical microDAC I/O connection

### 3.2.4.3 Load Cell Connection

Install the Load Cell Amplifier box. This is located across from the drill tower door above the weight stack rack, as shown in .

*find photo and refer to it above*

Two load cells are used on the Drill Tower. Main Hose tension is read out via a load cell which resides under the Main Hose crescent as well as a redundant load cell. Drill Cable tension is provided by a load cell located under the Drill Cable Sheave. The Cable and Hose load cells differ in many ways, three most obvious variations are physical size, capacity and electrical connections.

Connect the Hose Load Cell cable MS3126F10-6S connector to the Hose Crescent Load Cell. Connect the opposite end to the Load Cell Amplifier connector MS3129F10-6S.

Connect the Drill Cable Load Cell cable connector MS3106F14S-6S to the Cable Sheave Load Cell. Connect the opposite end to the Load Cell Amplifier connector MS3100F14S-6S.

Connect the I/O box cable (located by the pendants) to the MS3120F14-15P connector on the Load Cell Amplifier.

Figure 3.22 below shows a wiring schematic of the load cell connections to the load cell amplifier box.



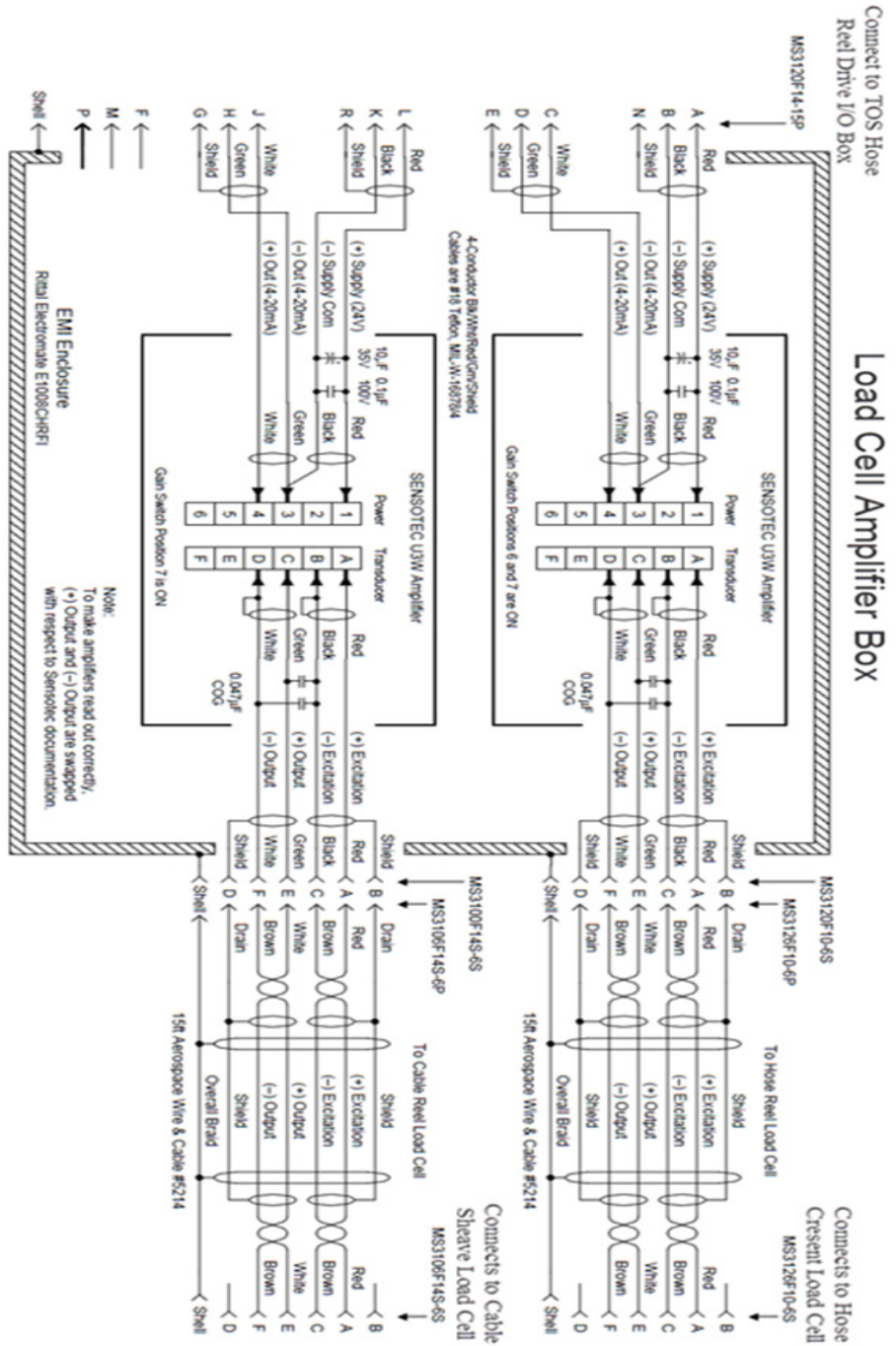
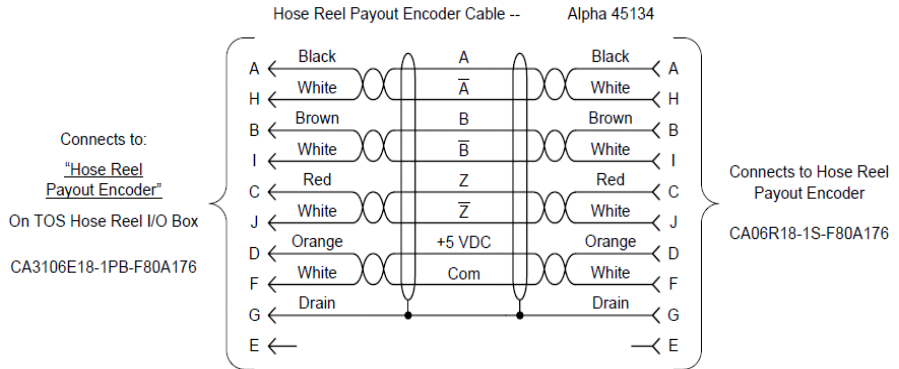


Figure 3.22 Load Cell wiring schematic

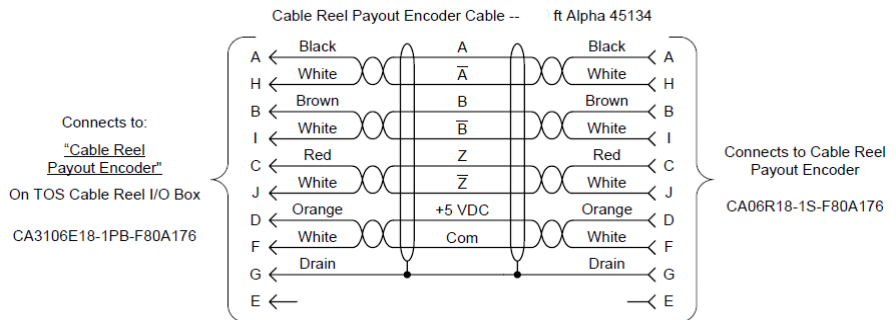
## Payout Encoder Connection

Using the cable shown in Figure 3.23 below, connect the Hose Crescent Payout Encoder to the Hose Reel Payout cable connector CA06R18-1S-F80A176. The opposite cable connector CA3106E18-1PB-F80A176 should already be connected to Hose Reel I/O Box.



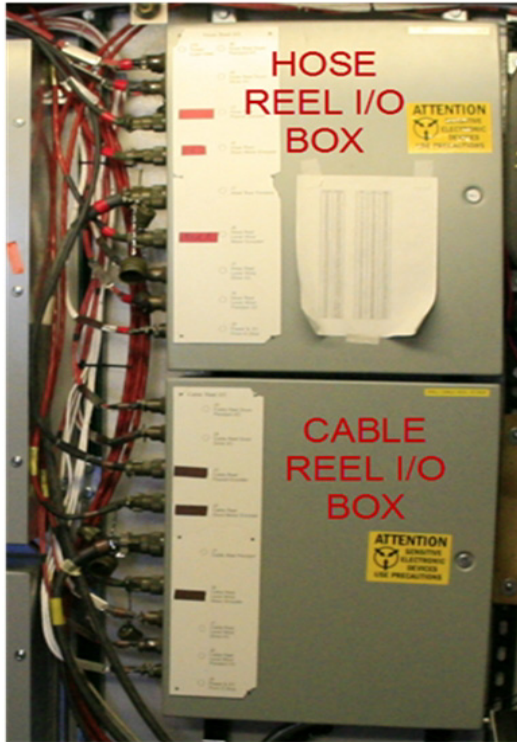
**Figure 3.23** Hose reel payout encoder cable

Using the cable shown in Figure 3.24 below, connect the Cable Sheave Payout Encoder to the Cable Reel Payout cable connector CA06R18-1S-F80A176. The opposite cable connector CA3106E18-1PB-F80A176 should already be connected to Hose Reel I/O Box.



**Figure 3.24** Cale reel payout encoder cable

Figure 3.25 below shows the hose and cable reel I/O boxes located in the TOS electrical cupboard to which the other ends of the payout encoder cables connect.



**Figure 3.25** Hose and Cable reel I/O boxes

### **3.2.4.4 Point to Point Wiring**

Due to many field modifications to the UNICO software additional interconnection of the Drill Cable and Supply Hose Winch drives was needed. Because the connectors lacked the necessary contacts, the wiring in the schematic below was added via a hardwire/point to point method. Note that the ANALOG COMMON "pin 11" connections are actually connected through the emergency stop connector MS3122E14-18P connector.

Figure 3.26 below shows a communications board common to all drives and the terminal connector to which the point ot point wiring is made.

Figure 3.27 below shows the Unico point to point wiring schematic.

Some of the functions provided by this wiring include the All Stop, Auto Reel Select, Drive Status and Deployment Over Velocity.

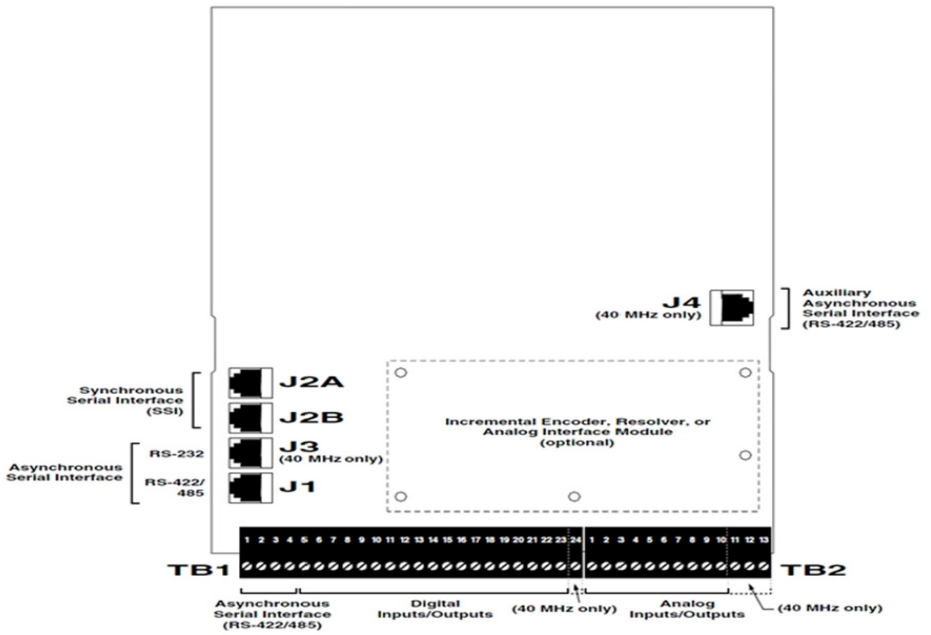


Figure 3.26 Motor drive communications board connector diagram

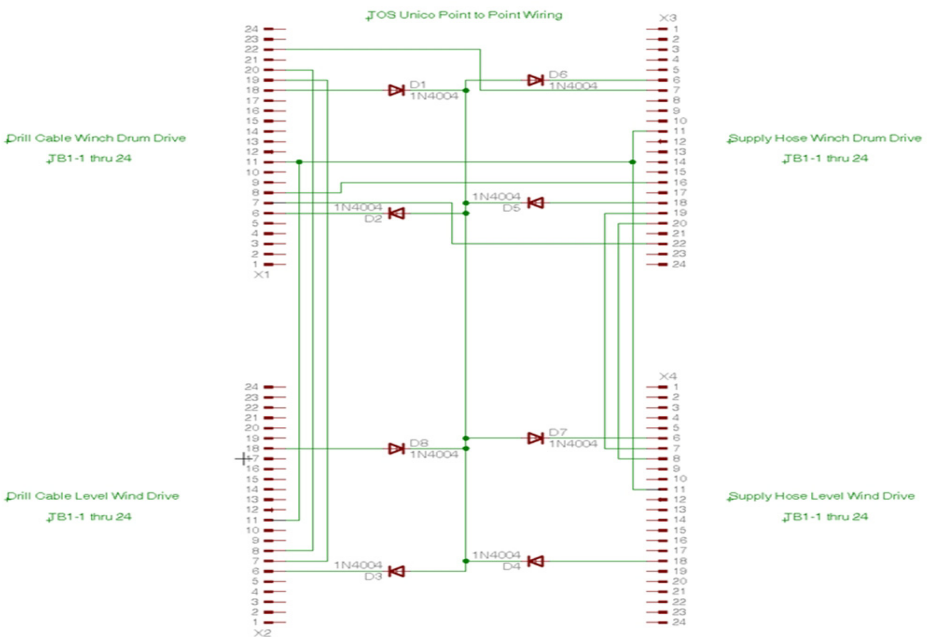


Figure 3.27 TOS motor drive point to point wiring diagram

### 3.2.4.5 Power up

Once all connections have been reconfirmed secure the drive door, remove the LOTO device and turn on the disconnect.

#### Check for Proper Software

After a brief initialization period the drive will display "Performance AC Drive 480V 3HP" (i.e. the rated horse power of the drive will be either 3HP or 10HP or 30HP or 50HP); it will then go to the RPM display. Press the "ENT" key to enter the menu section of the drive. Press "7" followed by the "ENT" to enter the help menu. Press "1", "1" followed by the "ENT" key. This will put the drive in the UEdit menu. It may be necessary to push the arrow key to view the project name. If the drive does not display "PHS\_805493\_001\_1022B", you will need to reload the project. Instructions are located in the "Software" section of this chapter.

#### Set Date & Time (Calendar)

From the previous operation press "QUIT" once, then press "6" then "ENT"; this will put you in the calendar menu. If the date and time are not correct, this may indicate a problem with the battery backup nonvolatile memory module. Set the time by pressing the "ENT" key until the cursor is at the item desired to change. Next press the arrow key to change the desired item until it displays the correct value. The password "1111" will be necessary to make any changes.

#### E-Stop/Reel Stop Test

Assuming the E-Stop is operational and a green indicator is illuminated on the E-Stop panel press the "REEL START" button on the E-Stop cabinet, the yellow indicator will illuminate. You may confirm the E-Stop and Reel Stop function is working by pressing the "Fn" and the "0" key simultaneously on the UNICO(s) keypad to clear any faults. Once the faults have been cleared, pressing a reel stop will indicate an "Ext Trip" fault only on the UNICO display. Reset the reel stop and again press the "Reel Start". Once again clear the faults manually on the UNICO(s) and press an E-Stop button, the drive(s) will once again indicate an "Ext Trip" fault.

**Note:** *Any command from the DCC or Pendant to the UNICO drives will clear any fault. Pressing "Fn" "0" should only be necessary when troubleshooting.*

#### Test Brake(s)

Turn on Brake circuit breaker number 18 in TOS electrical panel "E". With the E-Stop and Reel Stop active on both the Main Hose and Drill Cable Pendants turn the pendant mode selector to "COMP", then to "PEND"; the yellow PEND indicator will be illuminated. Press the blue "VEL" button. It will

also illuminate. Check for hissing of motor stator on each reel. Pump up the brakes. Move the pendant mode switch to the "COMP" position on one or both pendants. Confirm both the Hose and Cable reel brakes have set.

For the Return Water Hose Reel, turn the pendant mode selector to "COMP", then to "PEND"; the yellow "PEND" indicator will be illuminated. Press the blue "VEL" button. It will also illuminate. Check for hissing of motor stator on the reel. Pump up the brake. Move the pendant mode switch to the "COMP" position; confirm the reel brakes have set.

For Return Water Cable Reel, turn the selector switch to "ENABLE", pump up the brake. Turn mode switch to disable and confirm the brake set.

### **Check Drill Network Communications**

When viewing the Drill Screen on the TOS computer, you will see a flashing ready bit. If the bit is not flashing and yellow, communications have not been established to the UNICO drive.

**Note (1):** *Return Water Cable Reel drive, Return Water Hose Reel drive and Tower Hoist drive are not on the drill network.*

**Note (2):** *It is not uncommon to see the ready bit flash yellow for very brief periods.*

### **Test Run Pump**

Because the Return Water Pump is of the submersible variety it is necessary to test the pump dry. Have the TOS or DCC operator start the pump at "0" RPM. While watching the keypad of the selected drive you will see any faults clear. Listen for a hissing noise which indicates the motor stator is energized. Have the DCC or TOS operator enter 100 RPM; confirm proper rotation and operation.

**Note:** *Due to the lack of cooling and lubrication do not run the pump for extended periods of time or at high RPM.*

### **Test Run Winch(es)**

**Warning:** **Before attempting movement of any winch, make sure all safety protocols have been followed i.e.; moving parts are clear of obstructions and personnel are at a safe distance.**

With the E-Stop and Reel Stop active on both the Main Hose and Drill Cable pendants turn the pendant mode selector to "COMP", then to "PEND"; the yellow "PEND" indicator will be illuminated. Select "D/L" on the pendant drum level wind switch, a yellow D/L indicator will illuminate. Press the blue "VEL" button. It will also illuminate. Check for hissing of the motor stator on the drum and level wind motors on each reel. Pump up the brakes. Using the "UP" and "DOWN" buttons with the velocity control knob, confirm the direction and proper operation of both the drum and level wind of each winch.

Turn the Return Water Hose Reel pendant mode selector to "COMP", then to "PEND"; the yellow PEND indicator will be illuminated. Press the blue "VEL" button. It will also illuminate. Check for hissing of the motor stator. Pump up the brake. Using the "UP" and "DOWN" buttons with the velocity control knob, confirm the direction and proper operation of the winch.

Using the yellow Return Water Cable Winch pendant turn the selector switch to enable. Check for hissing of the motor stator. Pump up the brake. Using the velocity control and the "UP" and "DOWN" buttons confirm the proper operation of the winch.

### **3.2.4.6 TOS(s) Options**

#### **Reel mode**

Under Reel Mode the user is able to increase the speed for spooling operations on both the Main Hose and Drill Cable drives. Entering this mode is done locally at the UNICO keypad by pressing "ENT" to enter the UNICO menus then "1", "ENT" to enter the dictionary. Once in the dictionary entering "1", "1", ENT will get into the Reel Mode menu. Press the arrow key once and Reel Mode will be displayed. Under Reel Mode select 2X spooling for either drilling or deployment depend on the reel connected to the drive. A failsafe is built in to avoid running the drill in this mode. Once the drive receives a computer command all settings will revert to drill/deployment settings.

#### **Load cell calibration**

See Load Cell Calibration section in this manual.

#### **Auto reel select**

The Drill Cable Drum Drive and the Main Hose Drum Drive both have the ability to detect the type of winch connected. When a TU20 is connected to either drive the UNICO will reconfigure itself for that operation. No user input is necessary.

#### **TU15 reel select**

In each TOS, manual selection of the TU15 can be accomplished on the Return Water Hose Winch. Manual selection is done locally at the UNICO keypad by pressing "ENT" to enter the UNICO menus then "1", "ENT" to enter

the dictionary. Once in the dictionary, enter "1", "1", ENT to get into the Reel select menu. Under drive type select TU15. You must power cycle the drive!

### 3.2.4.7 Tension Sharing System

#### Description

The purpose of the tension sharing system is to keep the hose tension within the design limitations of the main hose. To accomplish this, the hose crescent rests on a load cell providing real time feedback to the Main Hose Winch UNICO Drive, which in turn corrects the hose speed to maintain the programmed tension via the Tension FXN. Hose tension can set in register 499 of the global dictionary or register 12 in the TENSION menu.

When the operator requests the drill to ascend or descend at a given speed, the command goes to the Drill Cable Drum Drive only, via the feedback from the load cell. The Main Hose Winch moves as necessary to maintain the programmed tension but ONLY if the TOS operator selects "Synchronize Reels" from the drill control page of the drilling software.

A load cell is also located under Drill Cable sheave assembly. This load cell is not part of the tension sharing system but is used for overload or under load faults as well as providing tension information to the drill computer for display via the user interface.

All load cell tension is fed into and read out of the Main Hose Drum UNICO drive. Calibration of the ADC in the UICO must be done before drilling.

Figure 3.28 below shows a schematic of the hose/ cable load sharing system.

**Note1:** *As can be seen in the diagram below, the level winds get feedback from the drum encoders allowing the level wind drive to respond accordingly.*

**Note2:** *Hose and Cable payout encoders also provide coil correction and constant velocity input to the drive as seen in the Coil FXN program in the TOS(s) Drive Specific Software section of this chapter.*



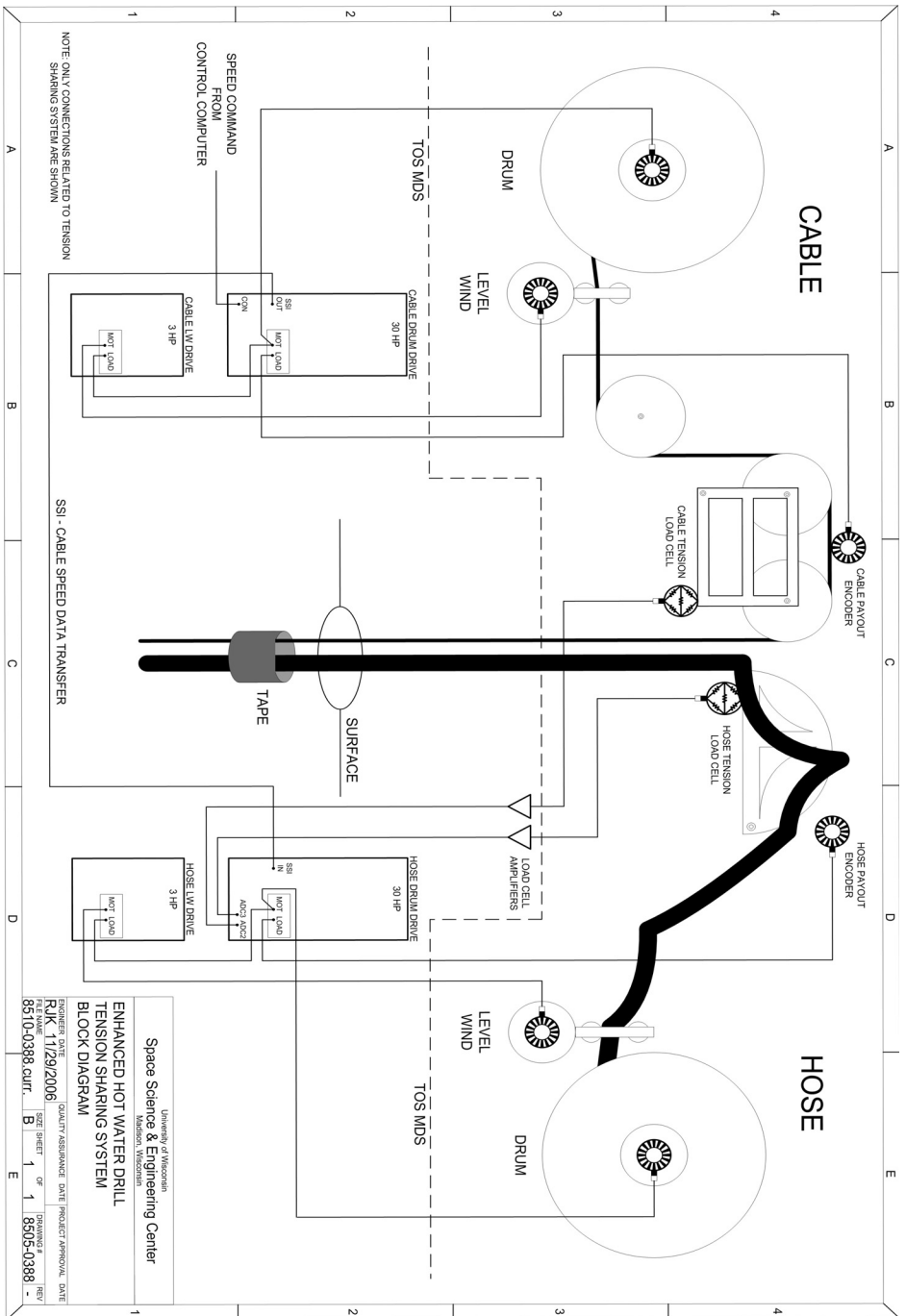


Figure 3.28 Hose/ Cable load sharing system block diagram

### 3.2.4.8 TOS(s) Specific Programming

#### Drum

Tension sharing, coil control and braking functions are handled by the ladder logic shown in Figure 3.29 below.

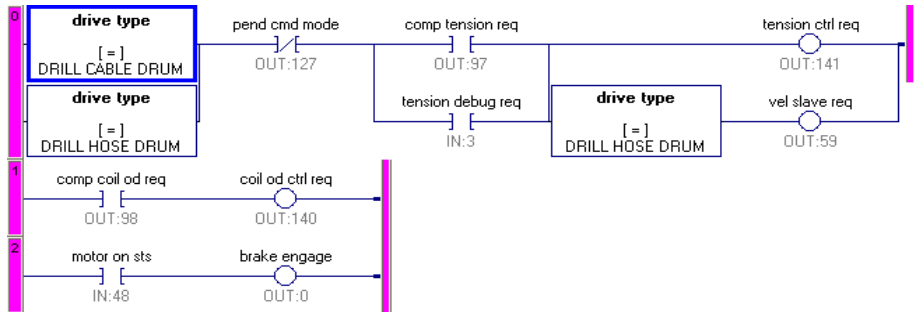
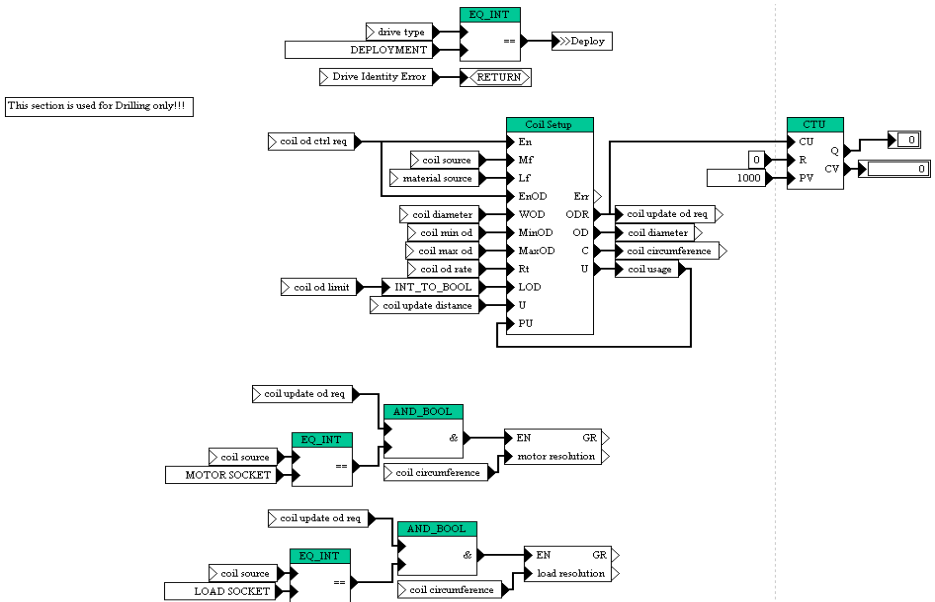


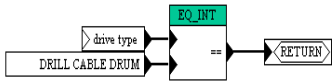
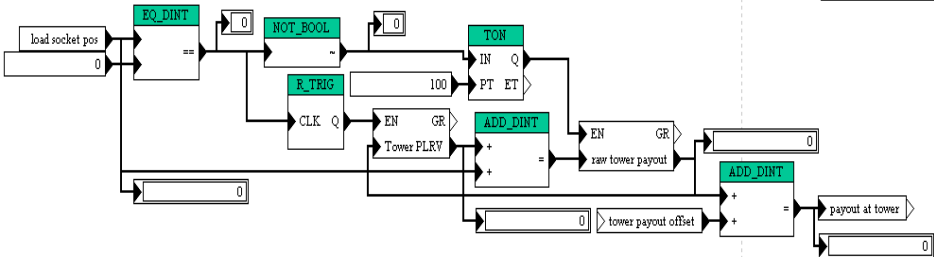
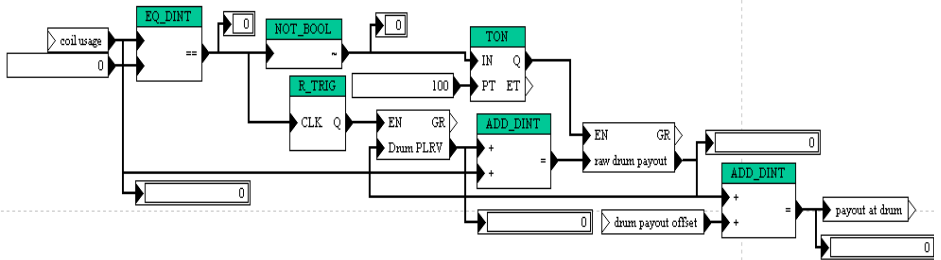
Figure 3.29 Hose and cable drum ladder logic diagram

#### Coil FXN (Drill Cable Drum)

The purpose of the Coil program shown in below is to control motor resolution in order to maintain the velocity of the winch despite the changing diameter of the reel.

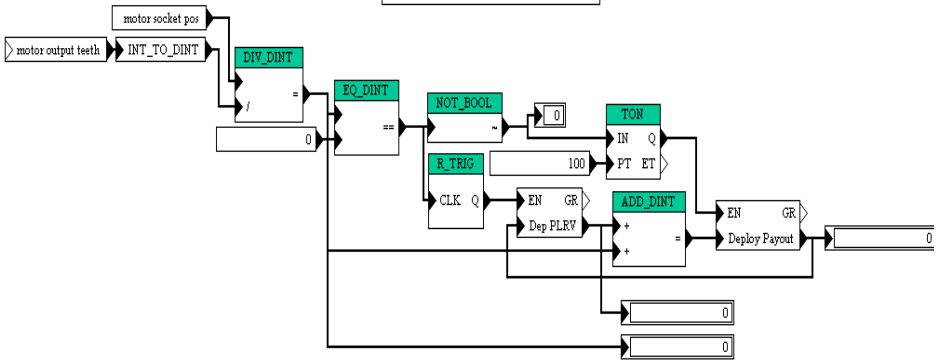


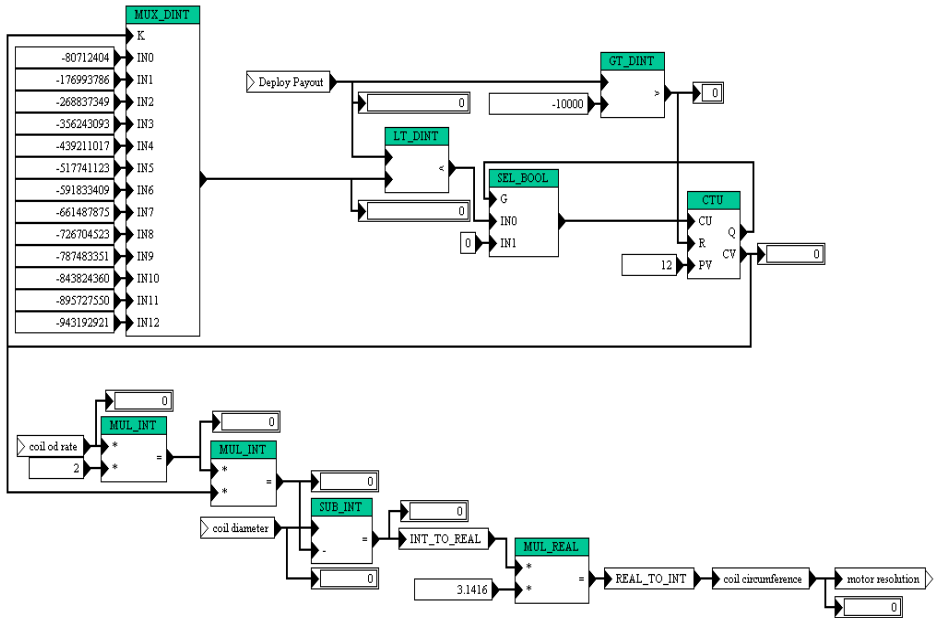
The next two parts are to allow the computer to reset the payout counters easily



Deploy:

This section is used for Deployment only!!!!



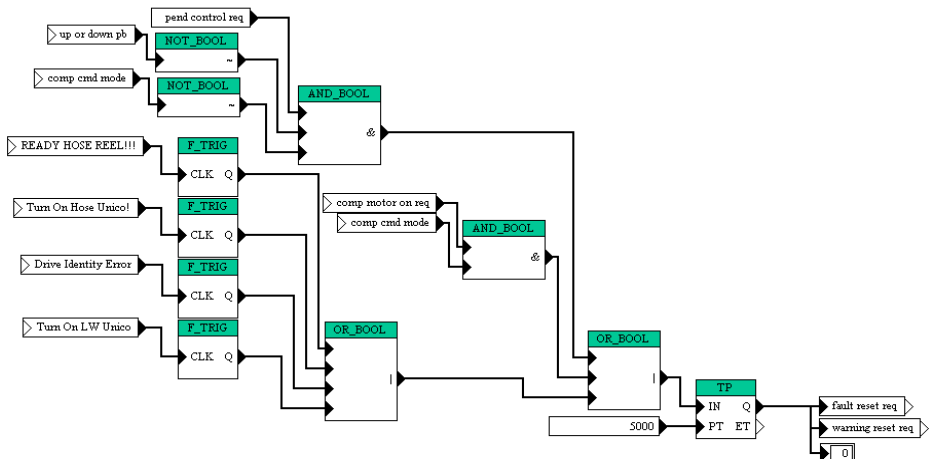


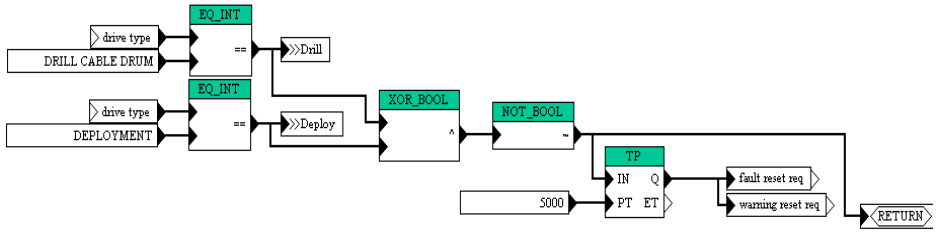
**Figure 3.30** Drill cable drum coil FXN

### All Stop/Fault Reset FXN (Drill Cable Drum)

The four drives that make up the tension control system need to synchronize correctly and need to react in unison in the event one drive faults. This FXN provides the necessary control logic.

The fault reset block below was moved from ladder logic to fix to curtail a timing problem when the four reel drives were synced up. MT





This section is to keep the Deployment Reel from going over maximum velocity by sending a bit to the Cable Reel drive tripping an over velocity fault. To protect from a brake being applied due to the hose reel being in the system during deployment but not active a bit is sent to the Cable Reel drive to enable the Fast Stop. MT 9/09

Deploy:

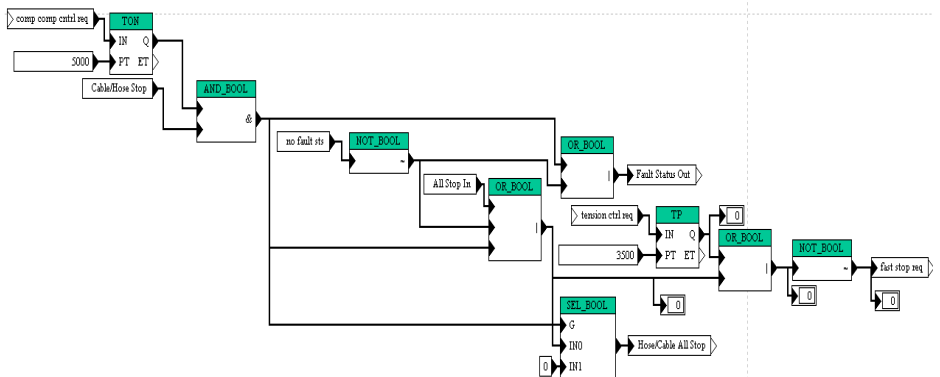
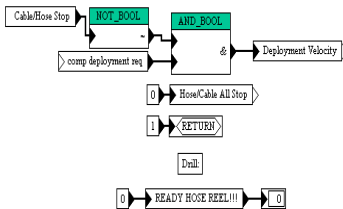
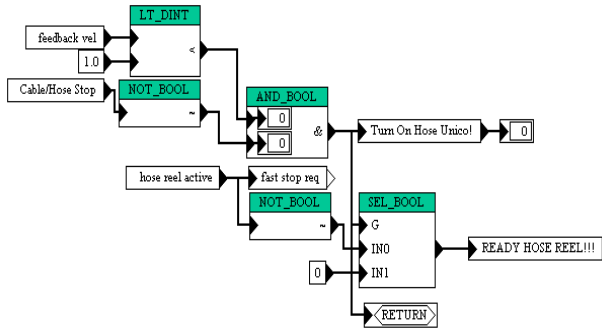
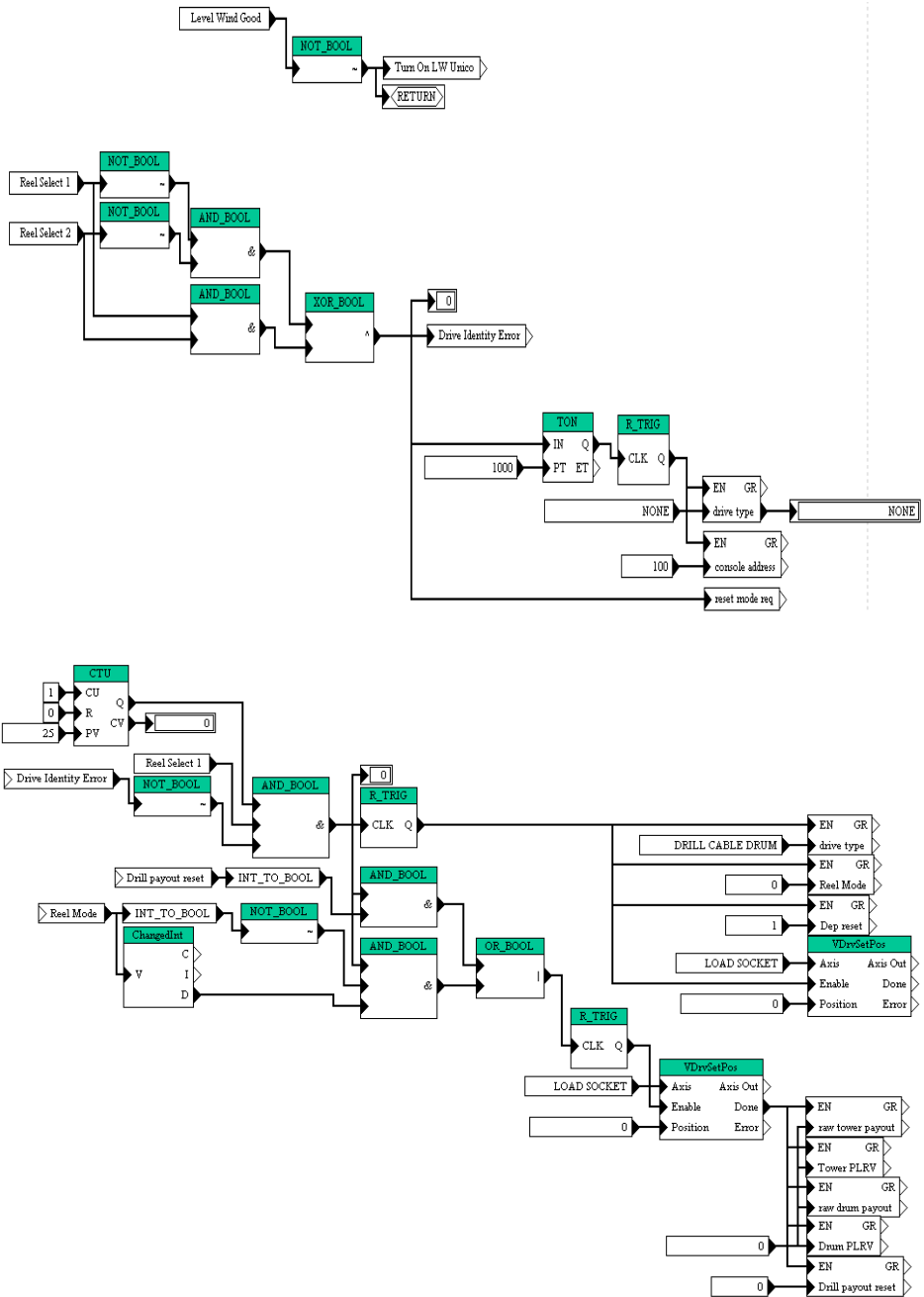
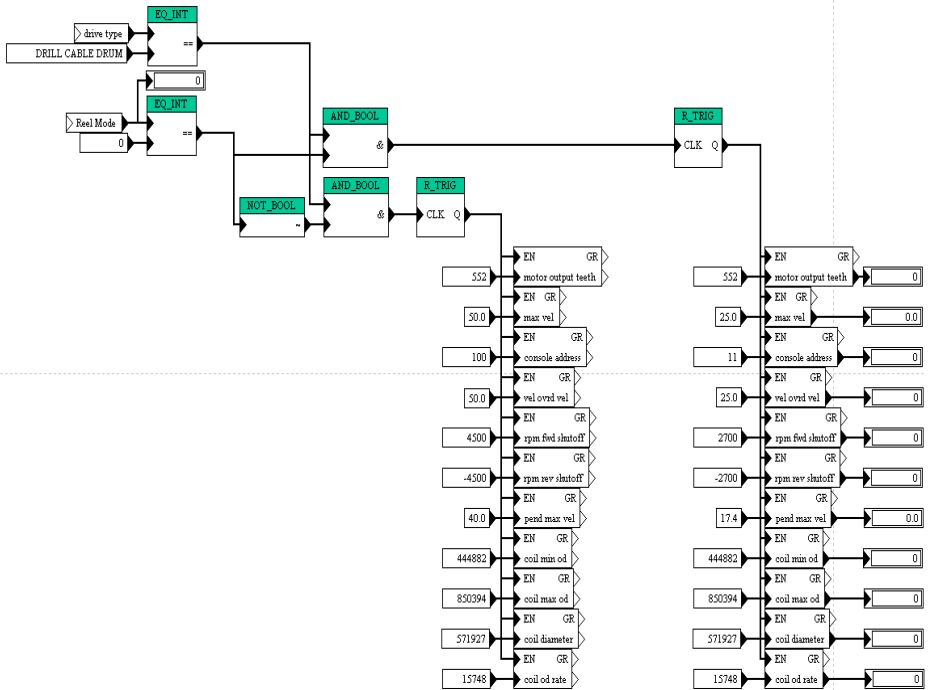
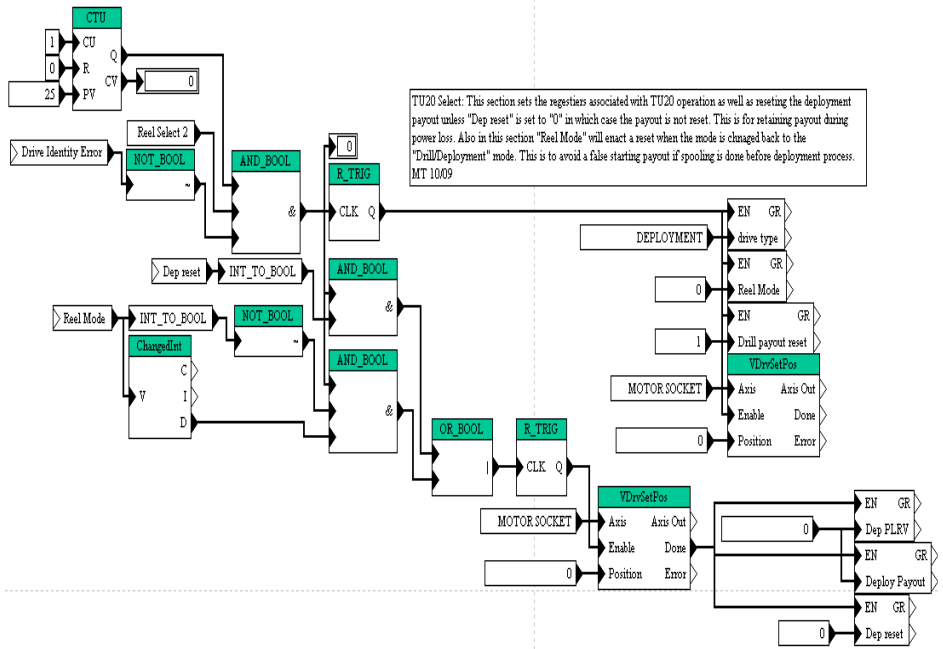


Figure 3.31 All Stop/ Fault Reset FXN

## Reel Selection FXN (Drill Cable Drum)

Auto reel selection reconfigures both the Drill Cable Winch and the Main Hose Winch drives to the TU20 configuration.





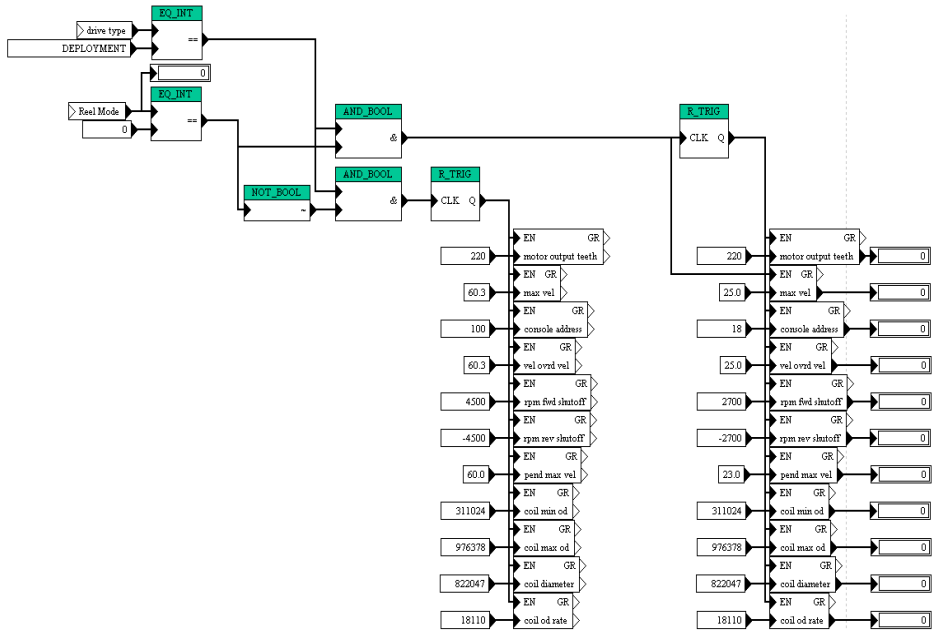


Figure 3.32 Reel selection FXN

### Load Cell Calibration (Drill Cable Drum)

During load cell calibration, this FXN limits torque and Pendant velocity to avoid damage to the calibration equipment and tower.

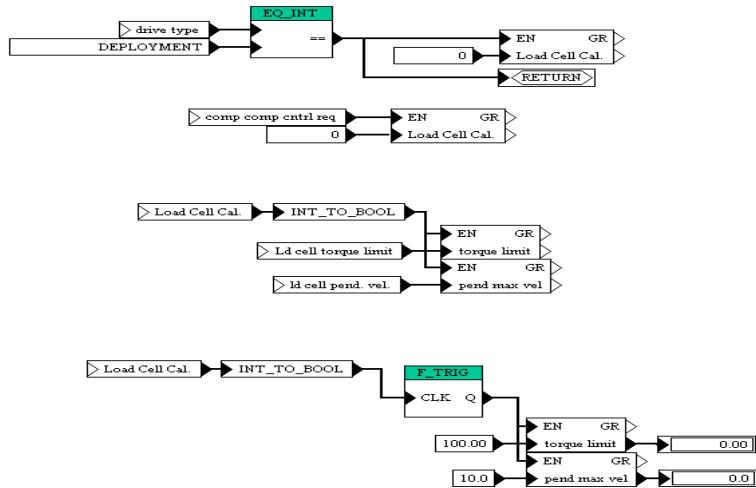
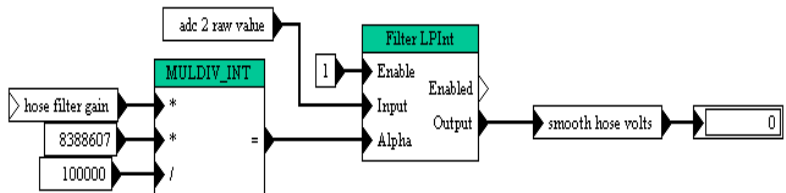
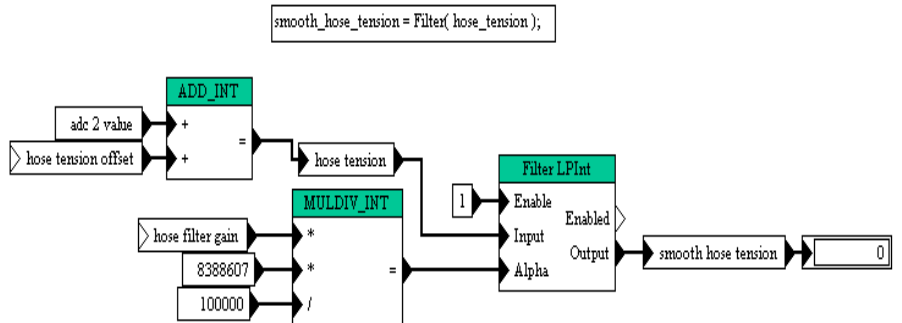
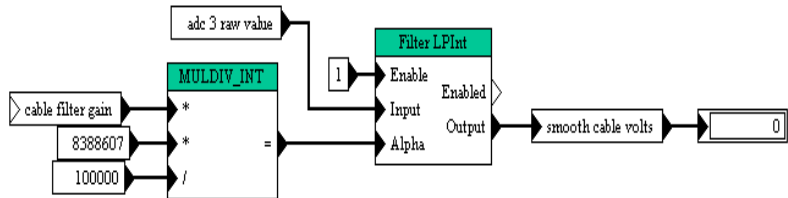
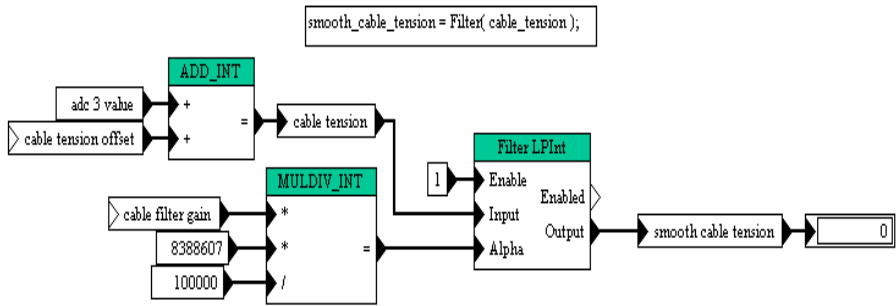


Figure 3.33 Drill cable drum load cell calibration torque and pendant limits FXN



## Tension Control FXN (Main Hose Drum)



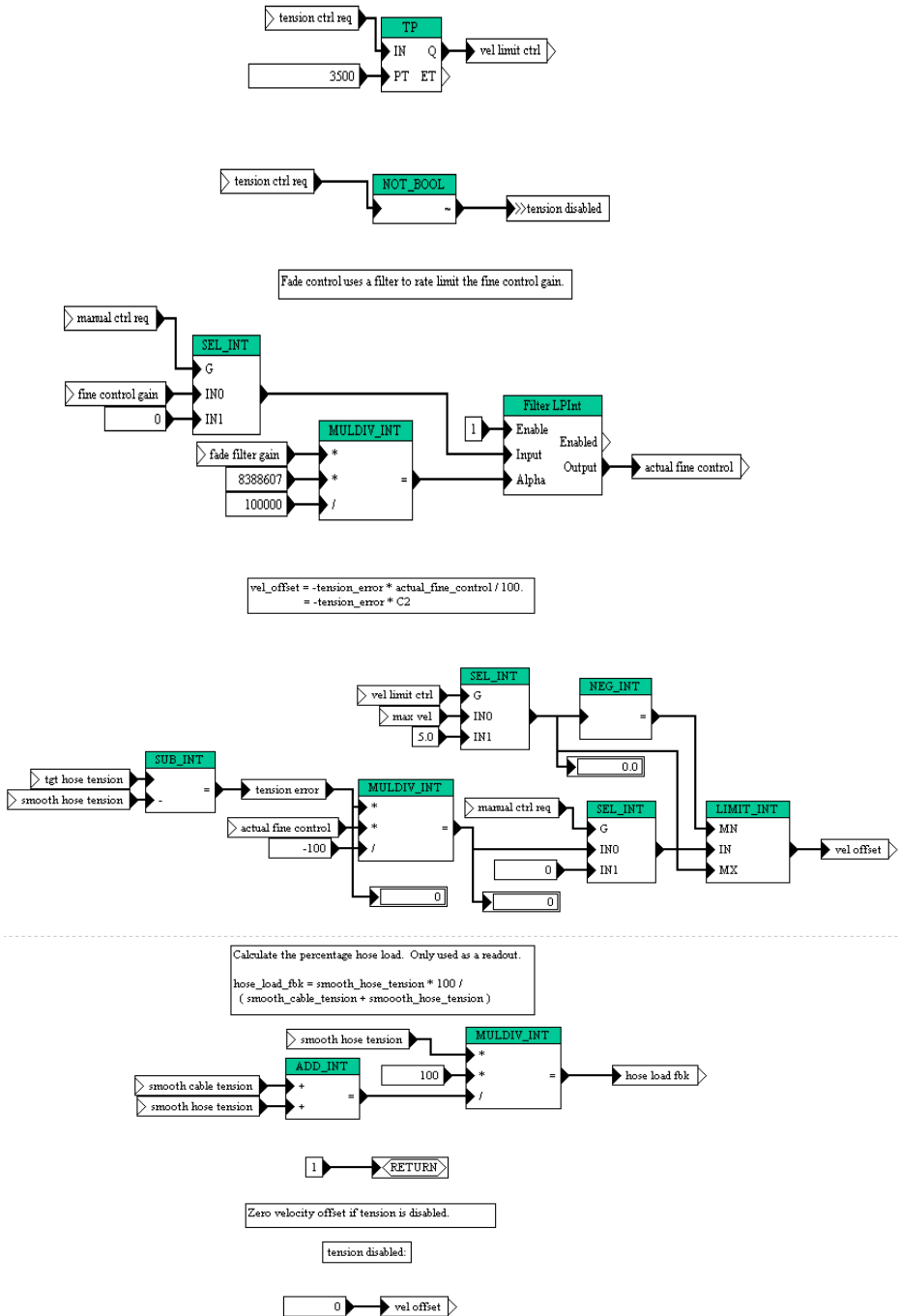
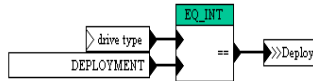
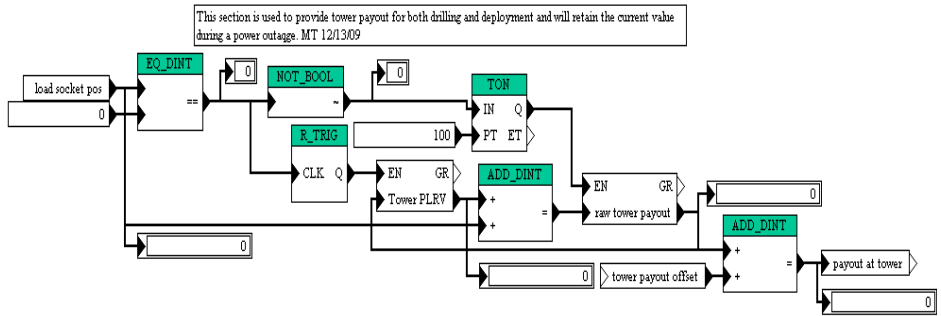


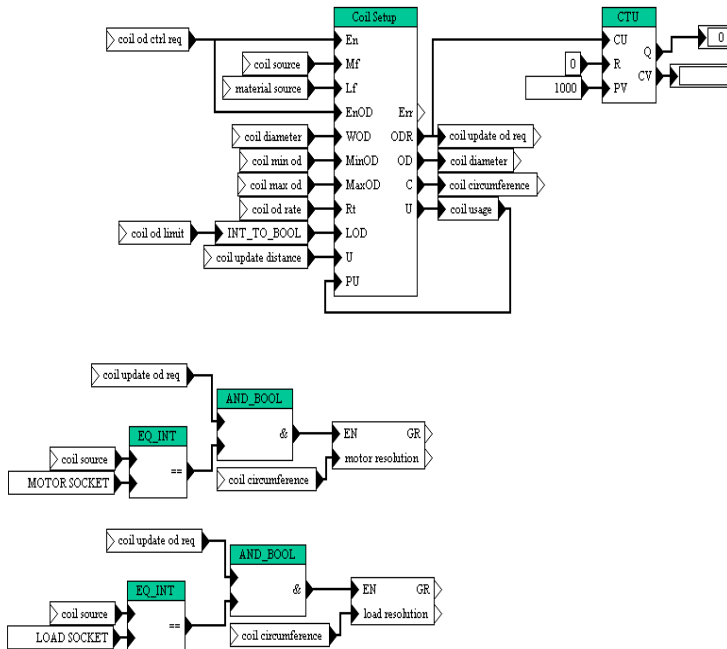
Figure 3.34 Main hose drum tension control FXN

## Coil FXN (Main Hose Drum)

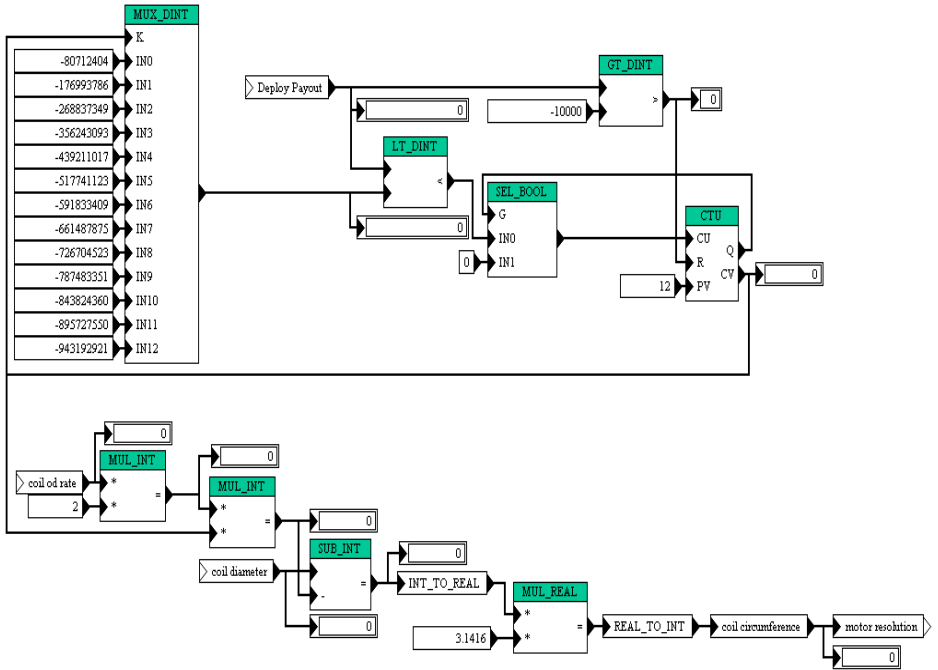
Coil correction adjusts the velocity for changing diameters of the hose reel. This is accomplished by adjusting the motor resolution.



This section is used for Drilling only!!! This section calculates the drum payout and provides coil usage updates. This section also has a retained payout that will remain after a power outage.



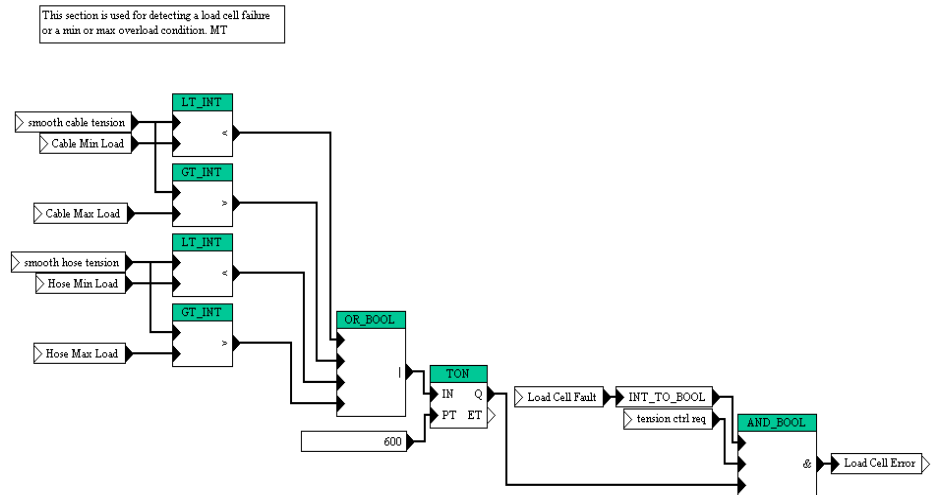




**Figure 3.35** Main hose drum coil FXN

### Tension Error FXN (Main Hose Drum)

This program is to catch any erroneous readings from the load cell circuit or overload scenario.



Due to the fact that it is difficult to program the cable load cell we take a sample of the smooth tension at the interval of 1000 clock pulses and then compare it to actual tension. If we see a spike within the 1000 clock pulse exceeding the cable tolerance then a fault is generated. If we see a dip in tension of 1000 pounds we also generate a fault. MT

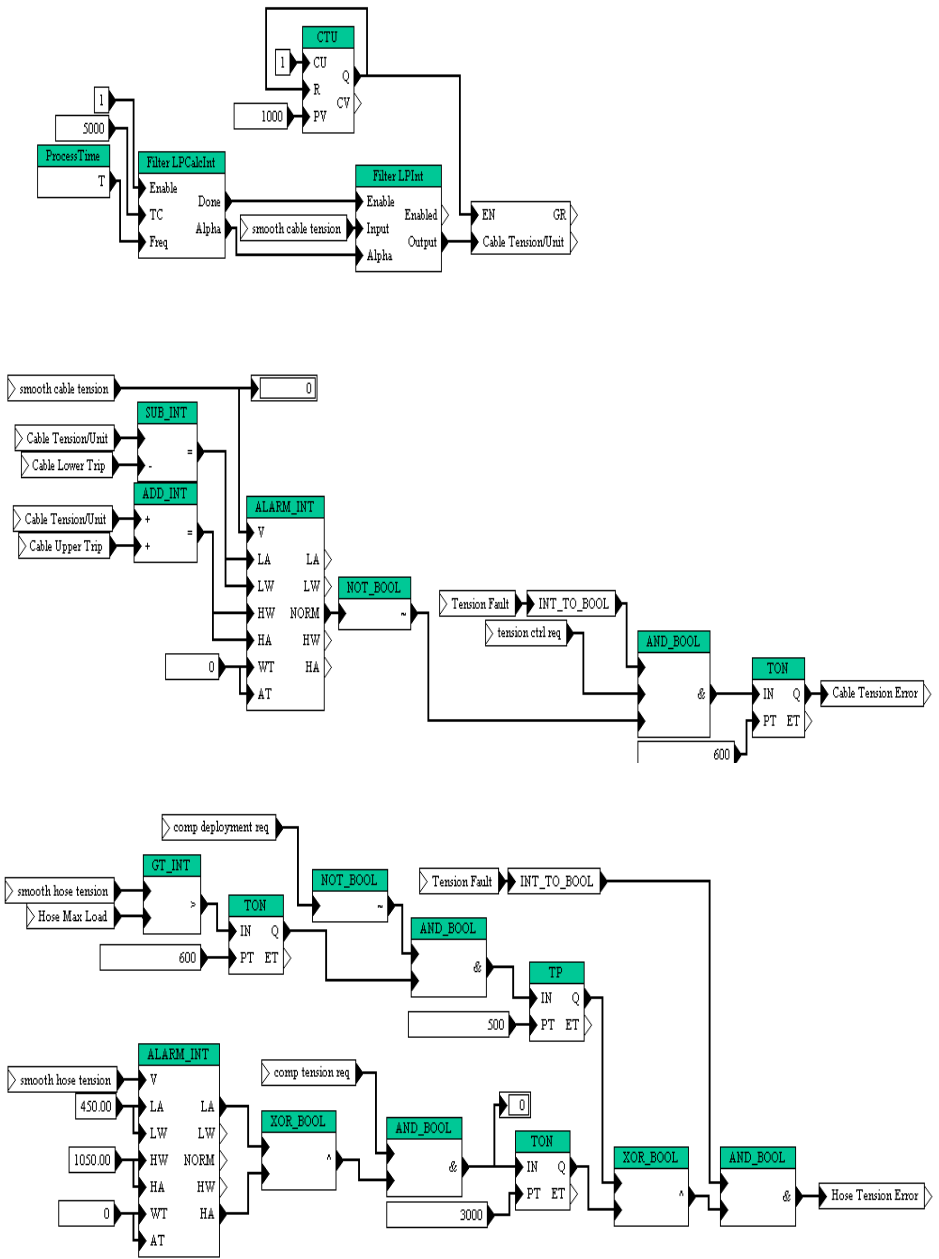
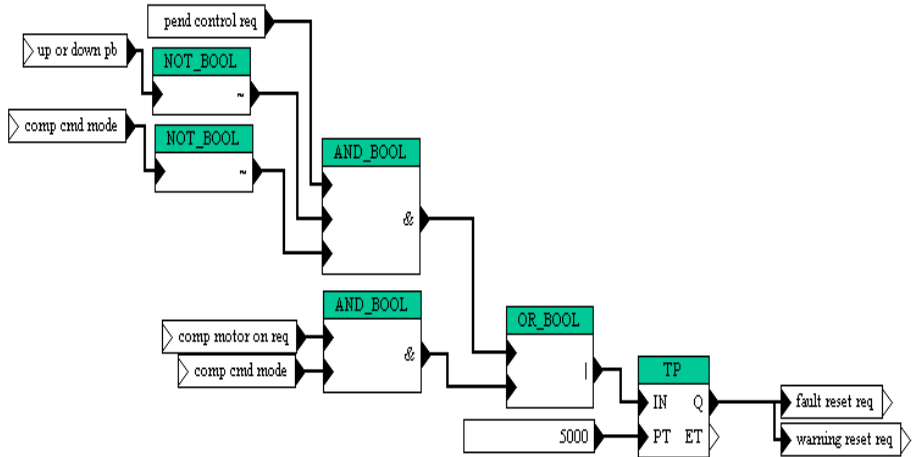


Figure 3.36 main hose drum tension error FXN

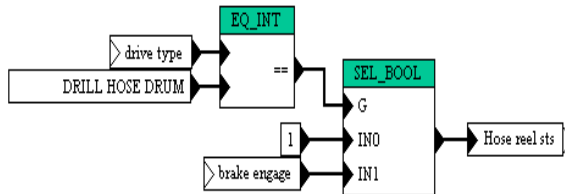
## All Stop/Fault Reset (Main Hose Drum)

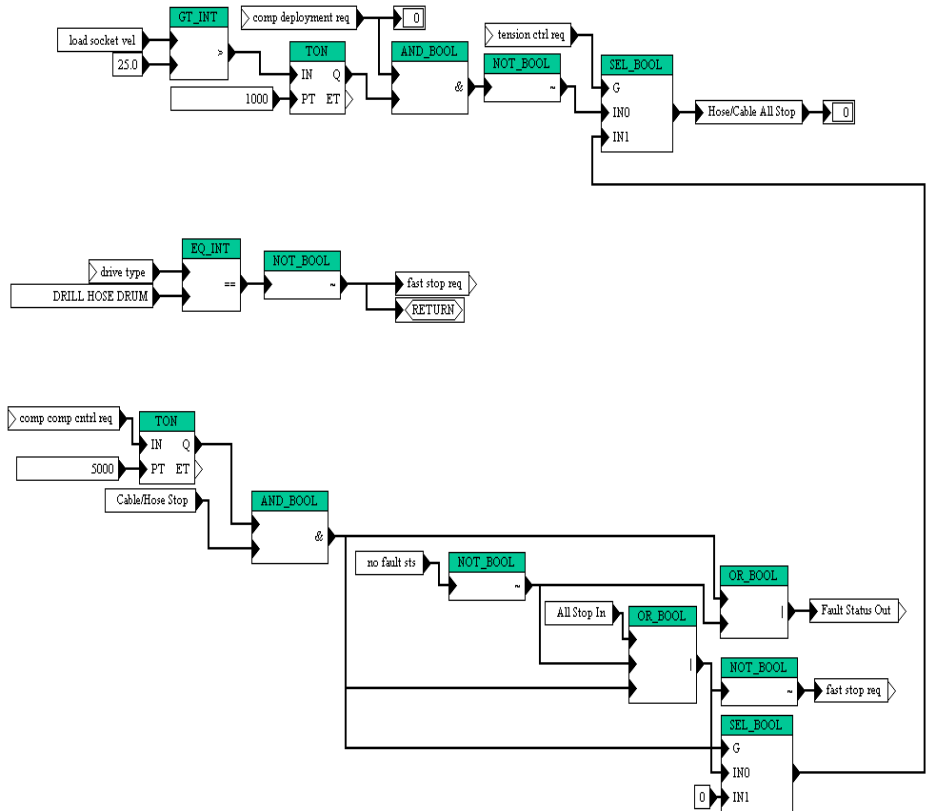
The four drives that make up the tension control system need to synchronize correctly and need to react in unison in the event one drive faults. This FXN provides the necessary control logic.

The fault reset block below was moved from ladder logic to fix to curtail a timing problem when the four reel drives were synced up. MT



This was added to keep the deployers from altering the velocity settings resulting in an over speed which is beyond the capabilities of the cresant and braking. Hose/Cable All Stop I/O is reset for this function. MT 08



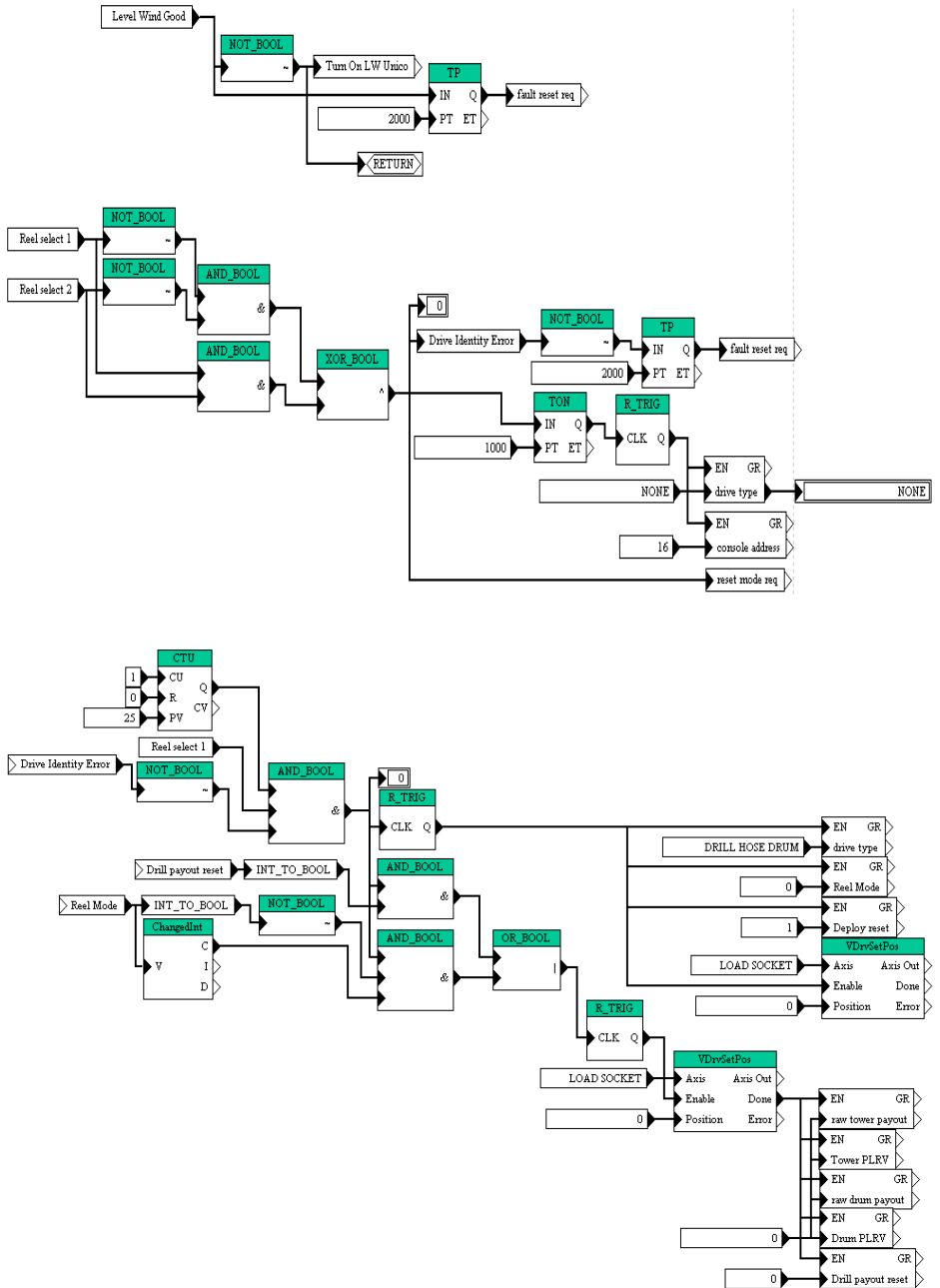


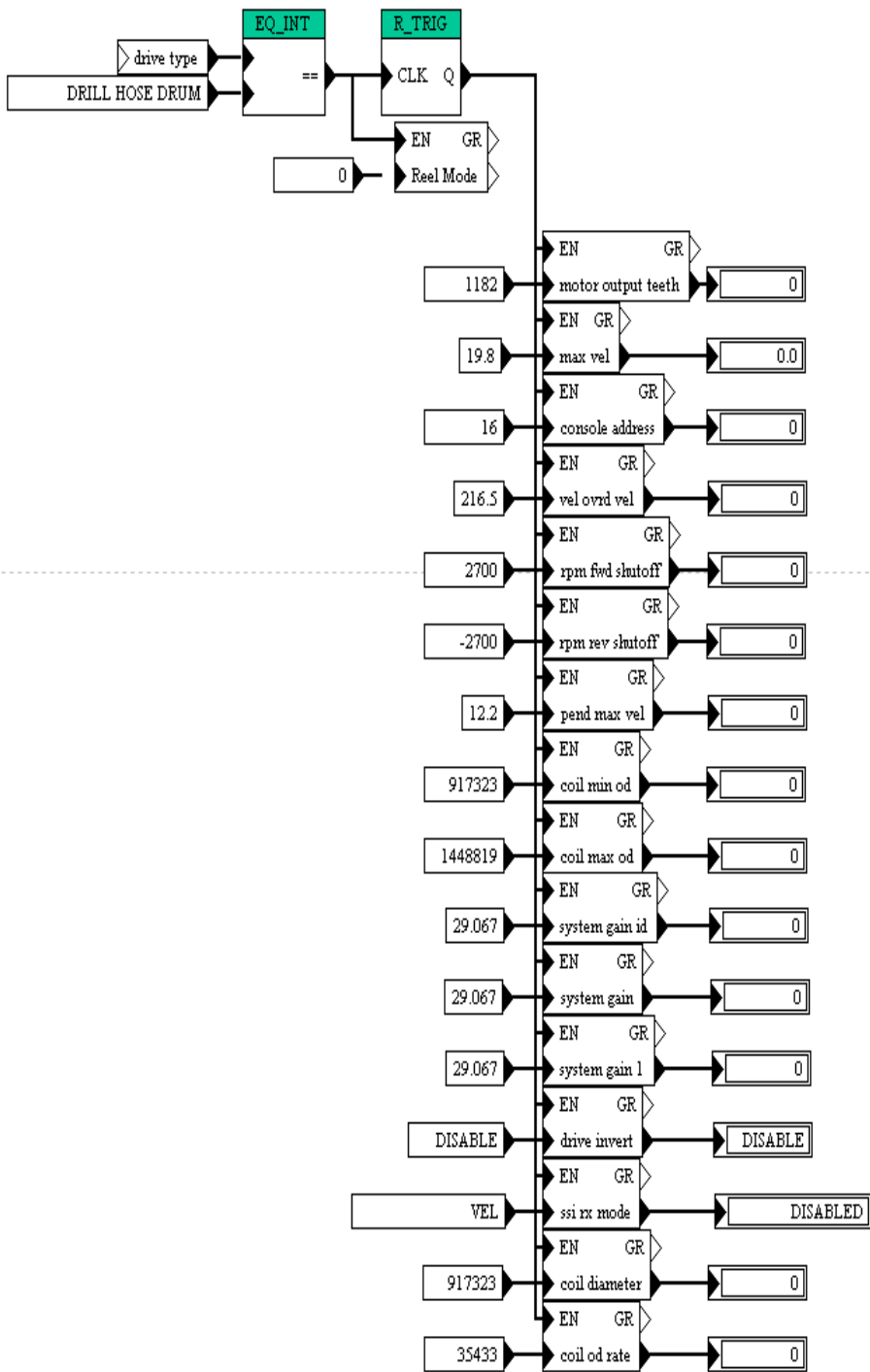
**Figure 3.37** Main hose drum All Stop/ Fault reset



## Reel Selection FXN (Main Hose Drum)

Auto reel selection reconfigures both the Drill Cable Winch and the Main Hose Winch drives to the TU20 configuration.





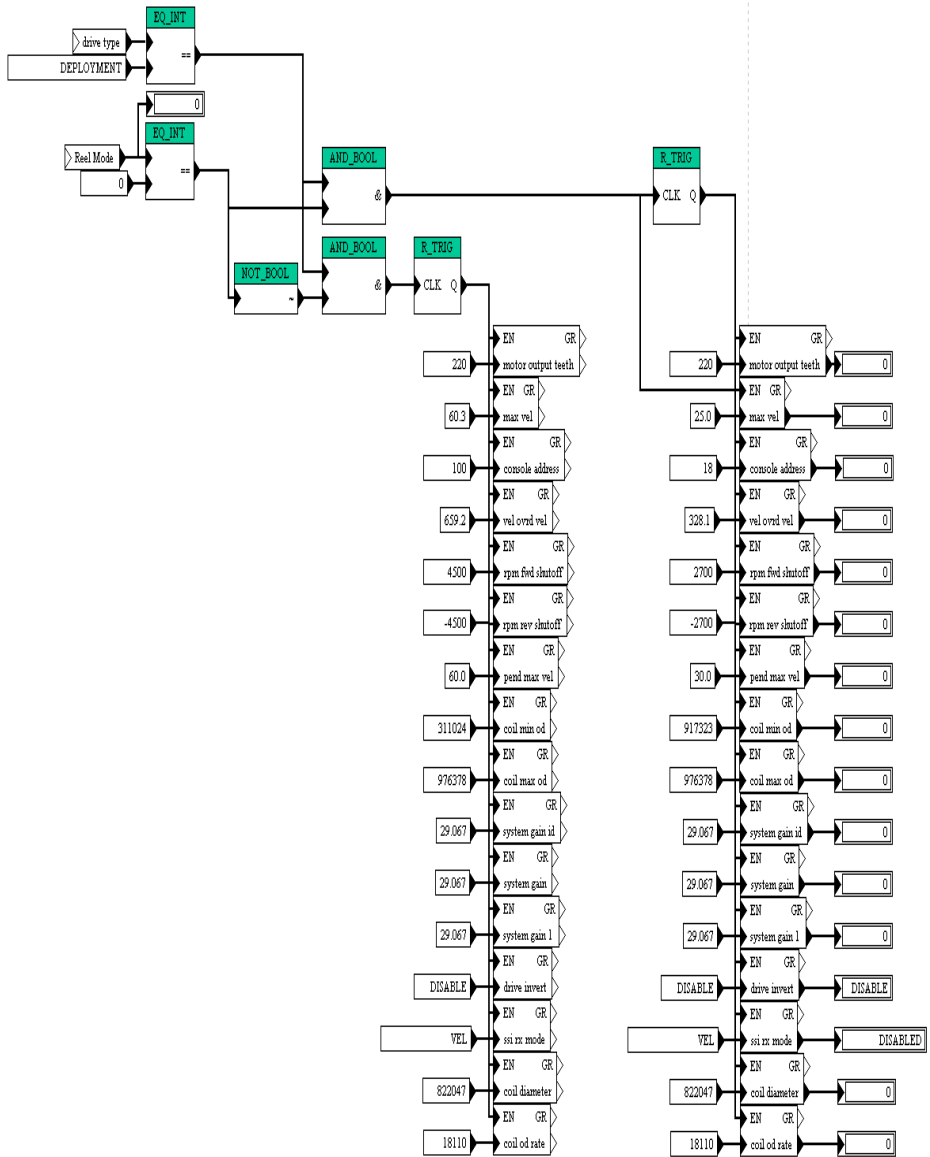
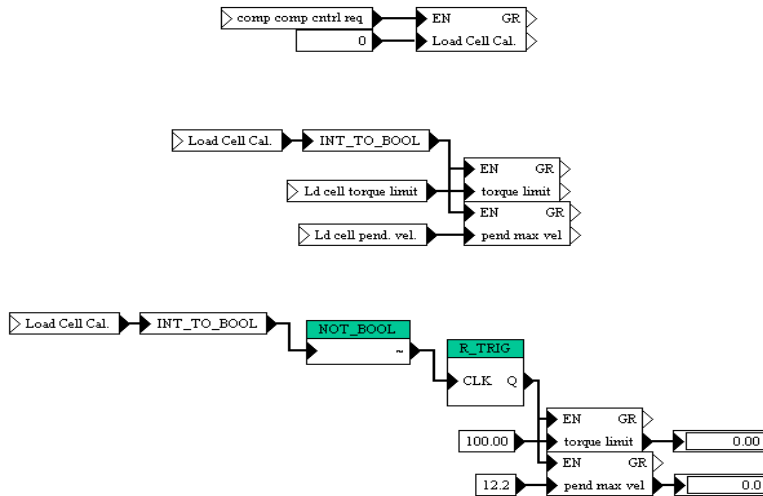


Figure 3.38 Main hose drum reel selection FXN

## Load Cell Calibration (Main Hose Drum)

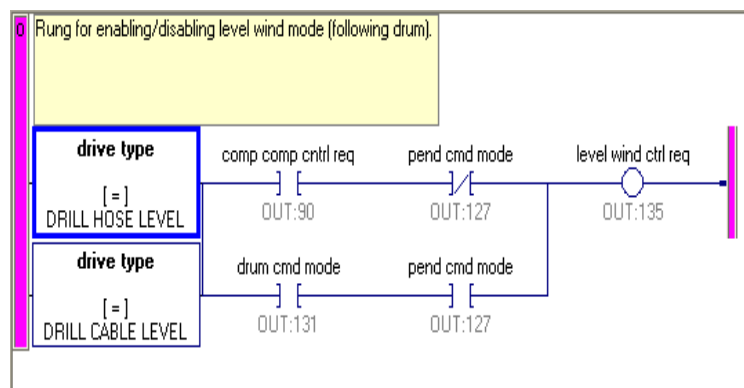
During load cell calibration this FXN limits torque and Pendant velocity to avoid damage to the calibration equipment and tower.



**Figure 3.39** Main hose drum load cell calibration FXN

## Level LDR (Level Wind(s))

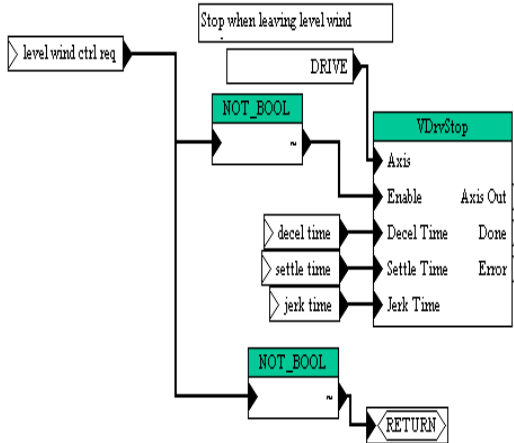
The level ladder logic enables the level wind allowing synchronization with the drum.



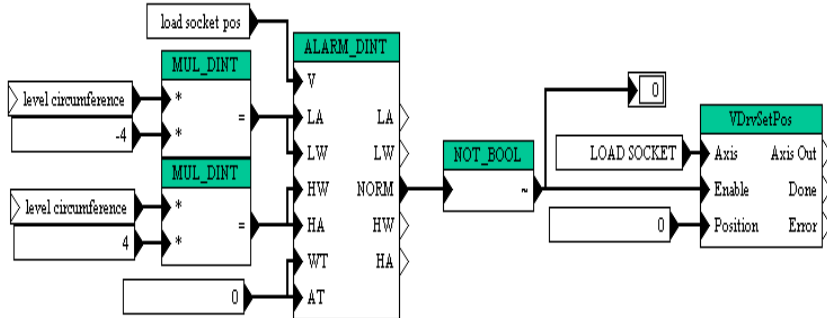
**Figure 3.40** Level wind ladder logic diagram

## Level FXN

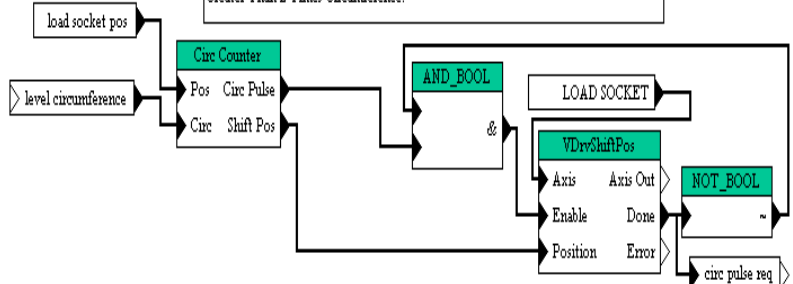
The level function block logic controls the gain of the level wind keeping the level wind in time with the drum as well as providing the control functions for dwell and change of direction.

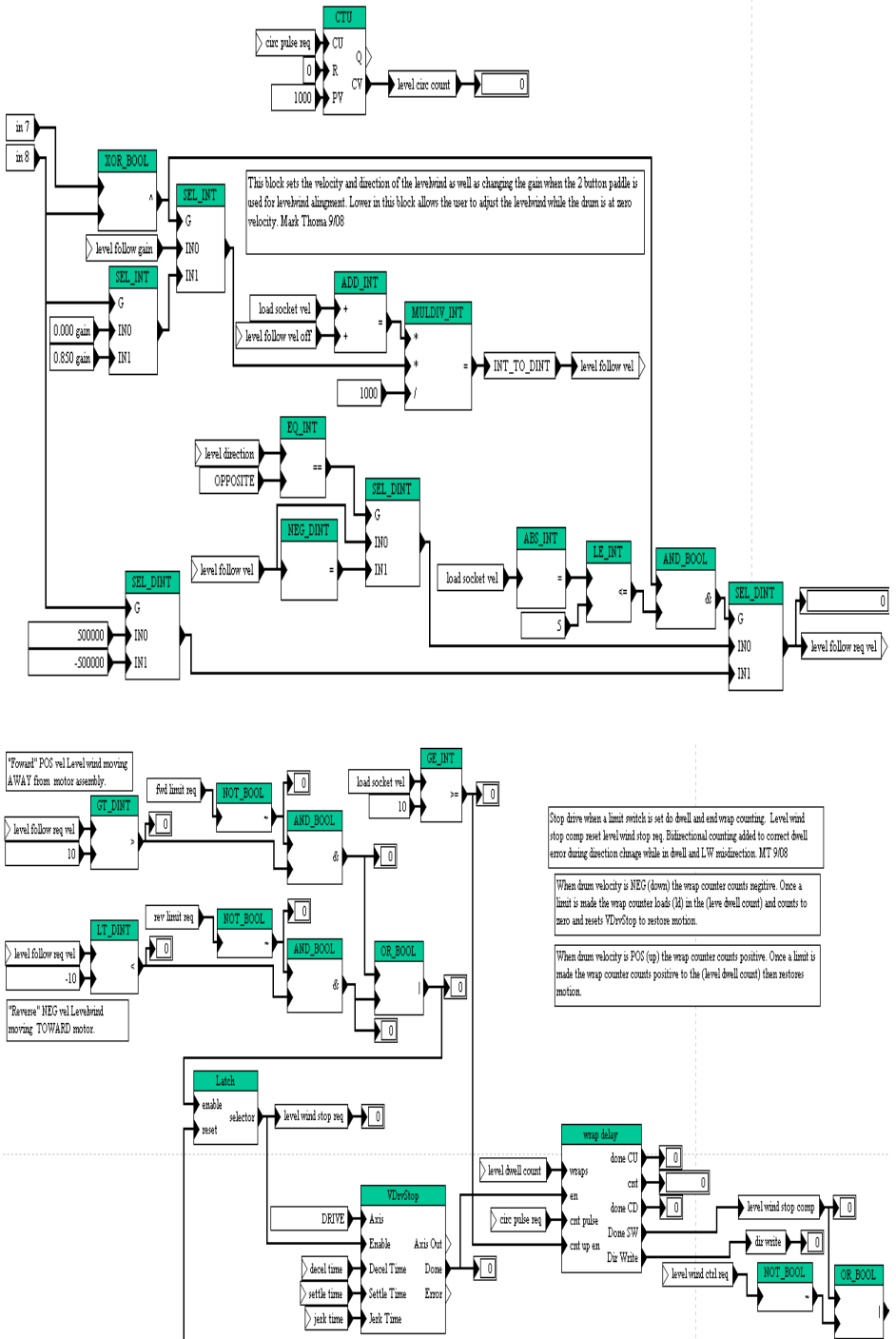


If Load Socket Pos Is Out Of Range By 4 Circumferences, Set Load Socket Pos To Zero.



Shift Back Circumference If Load Socket Pos Is Greater Than Circumference. The And Block And The Not Block Is For Handling The Case Where The Position Is Greater Than 2 Times Circumference.





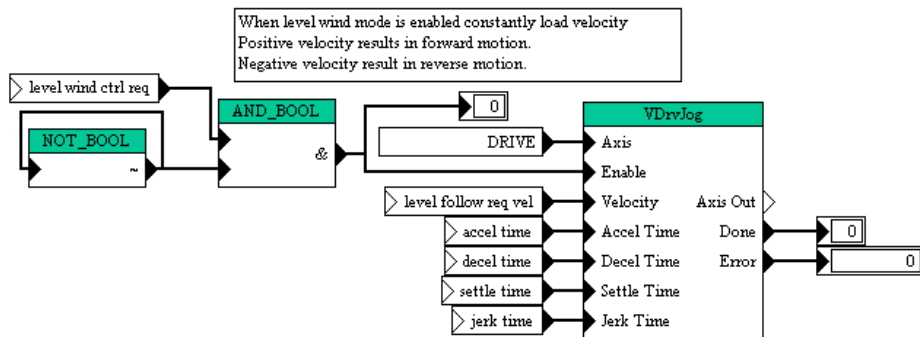
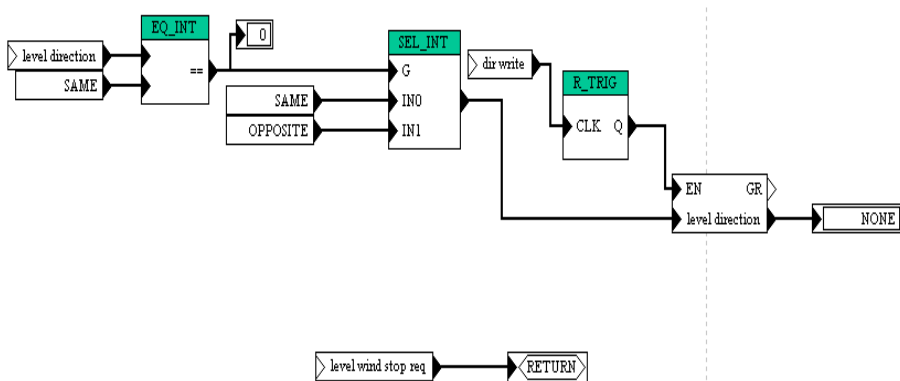


Figure 3.41 level wind logic FXN

### Reel Select (Level Wind)

Part of the automatic reel selection is done by sensing the level wind limits. Since these limits are connected directly to the level wind drive it contains the first piece of logic in the selection process.

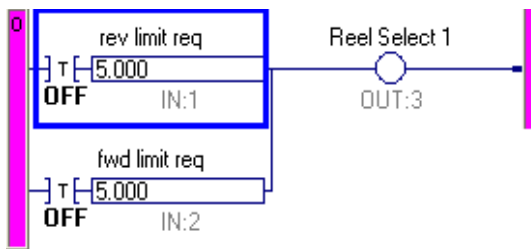
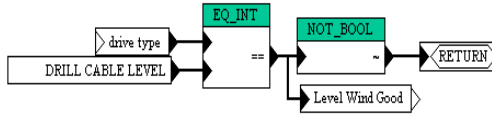


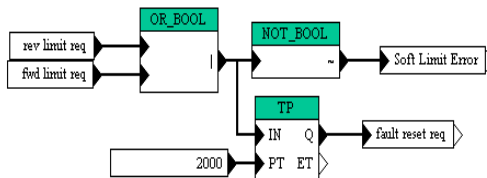
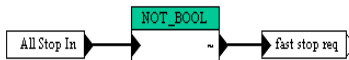
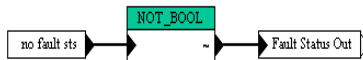
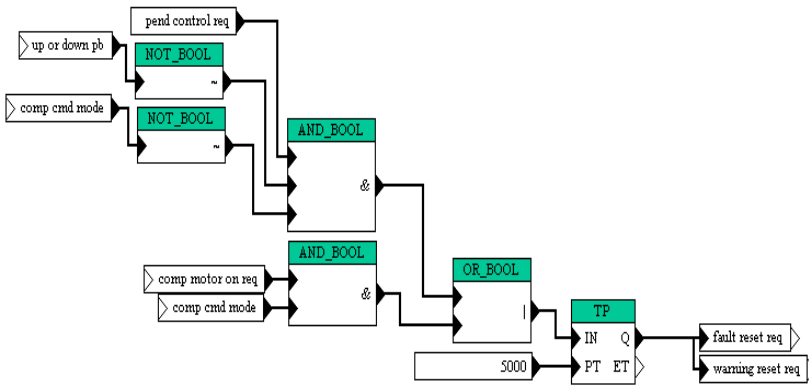
Figure 3.42 Level wind reel select logic diagram

## All Stop/Fault Reset (Level Wind)

The four drives that make up the tension control system need to synchronize correctly and need to react in unison in the event one drive faults. This FXN provides the necessary control logic.



The fault reset block below was moved from ladder logic to fix to curtail a timing problem when the four reel drives were synced up. MT



**Figure 3.43** Level wind All Stop/ Fault rest FXN



## Manual Mode Select (Return Water Pump)

This Program allows local/keyboard control of the pump. (see manual start under options for additional information).

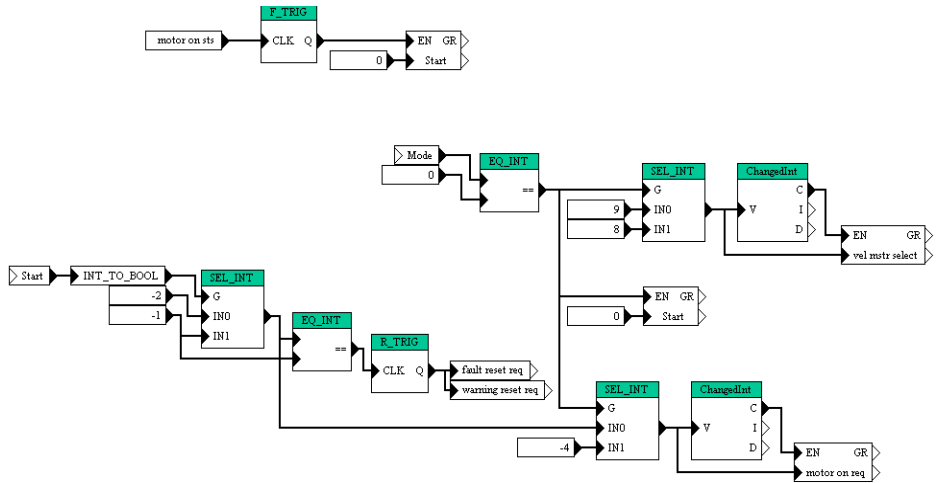
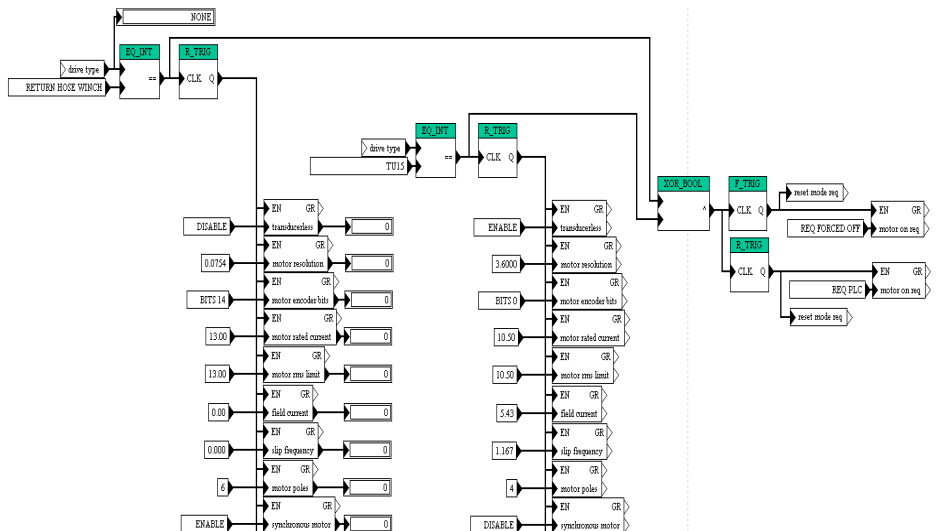


Figure 3.44 Return water pump manual mode select FXN

## Reel Select (Return Water Hose Winch)

This Program is used to change the configuration for the drive between the Return Water Hose Winch and the TU15.



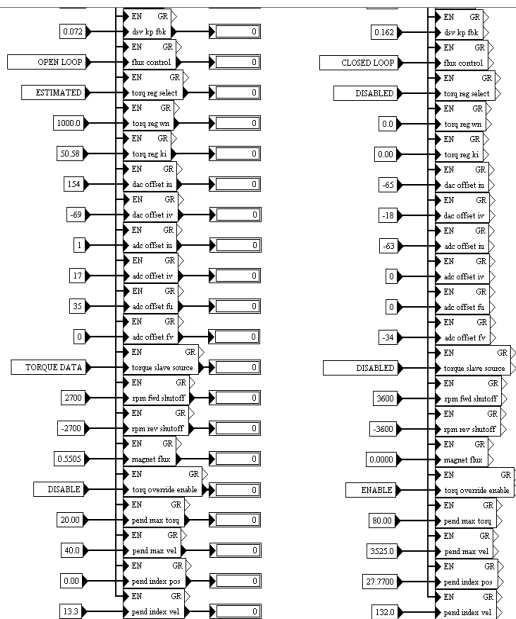
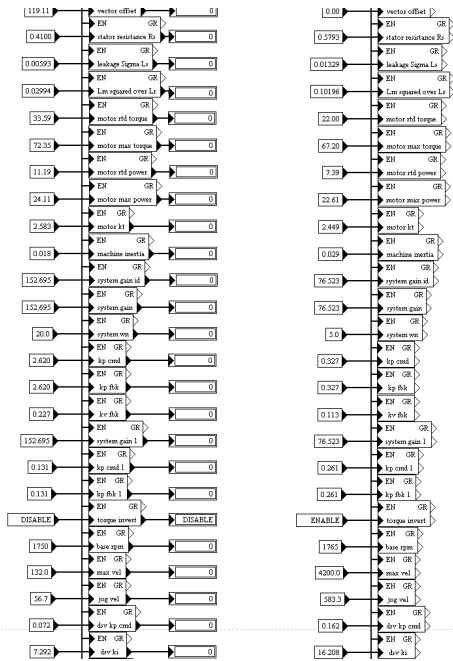
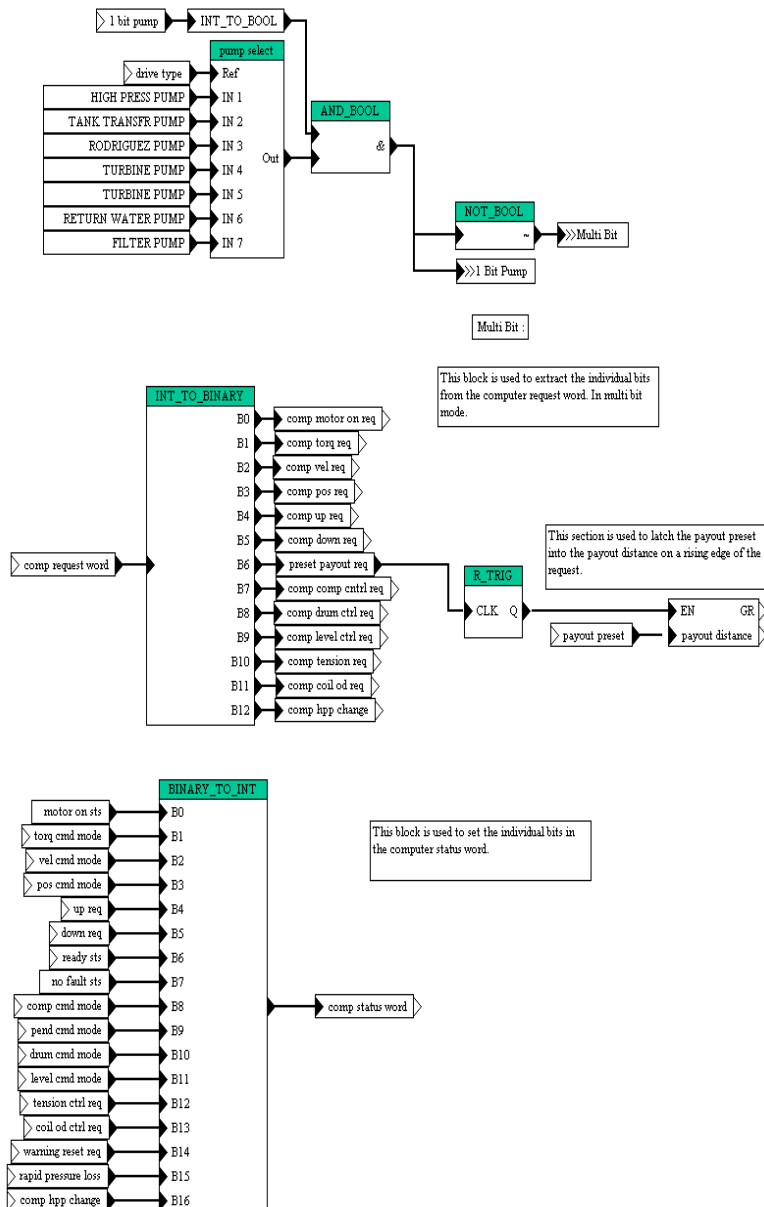


Figure 3.45 Return water hose winch/ TU-15 reel select FXN

## 3.2.5 Common Programming For All Drives

### Computer FXN

This function logic provides the bidirectional serial communications used to read and control the drives.



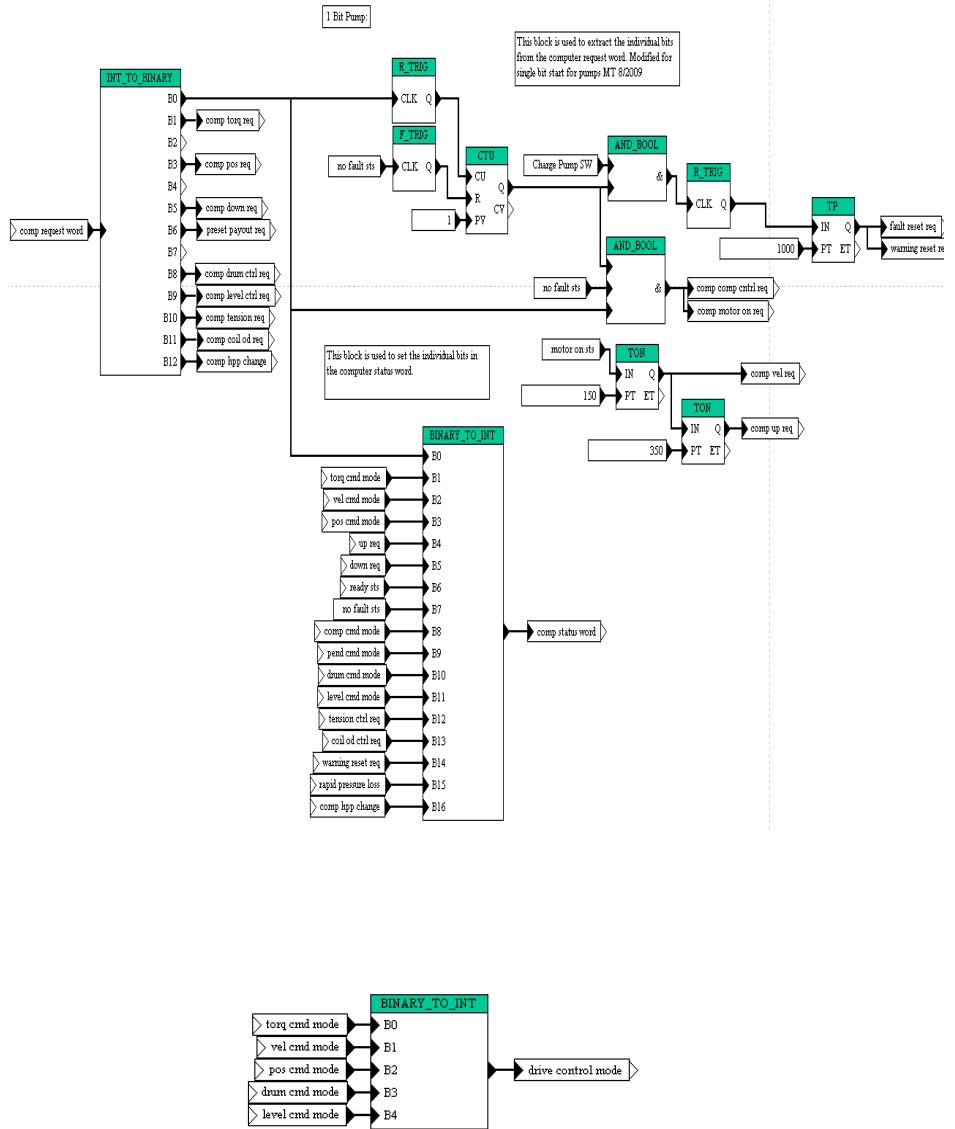
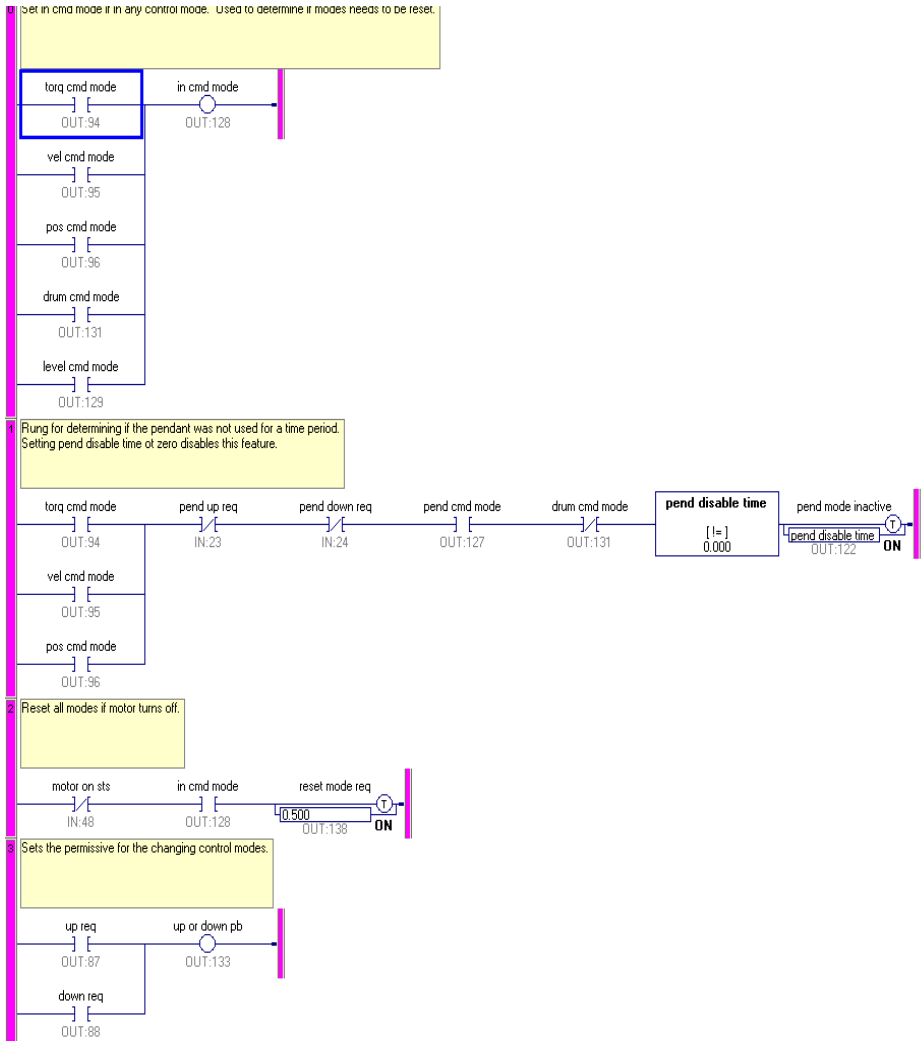


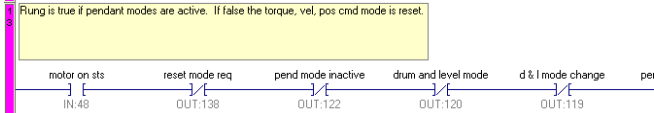
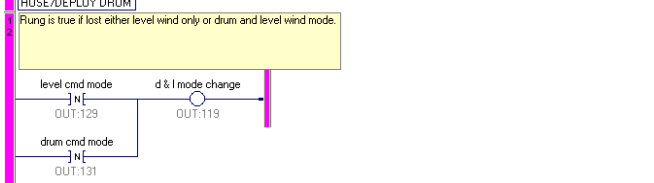
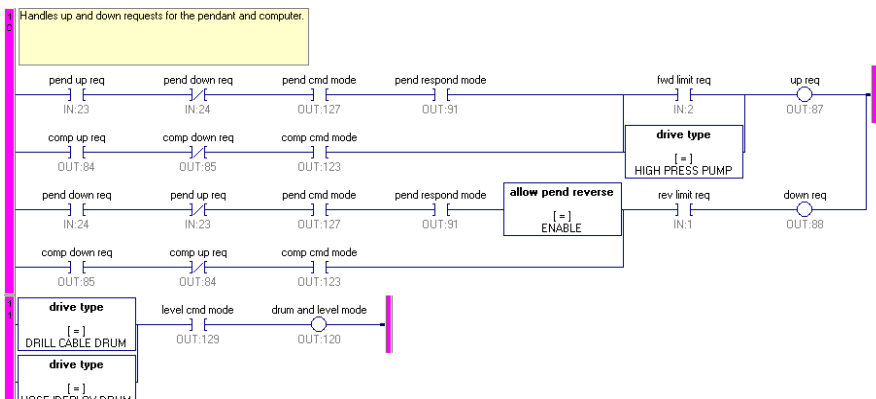
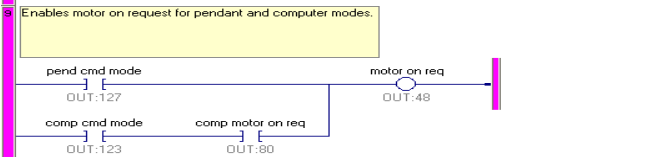
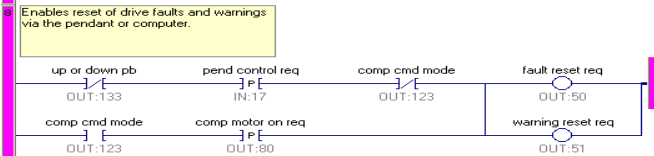
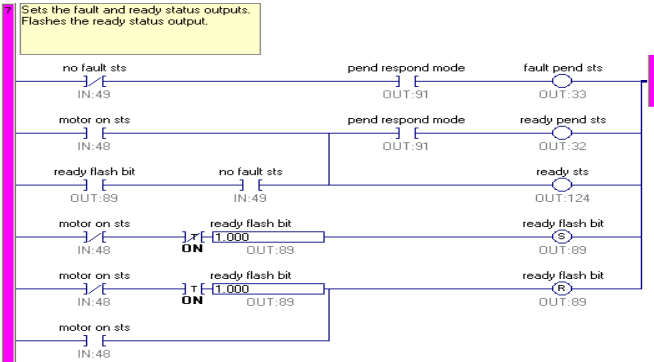
Figure 3.46 Computer serial communications FXN

## Pend - Comp LDR

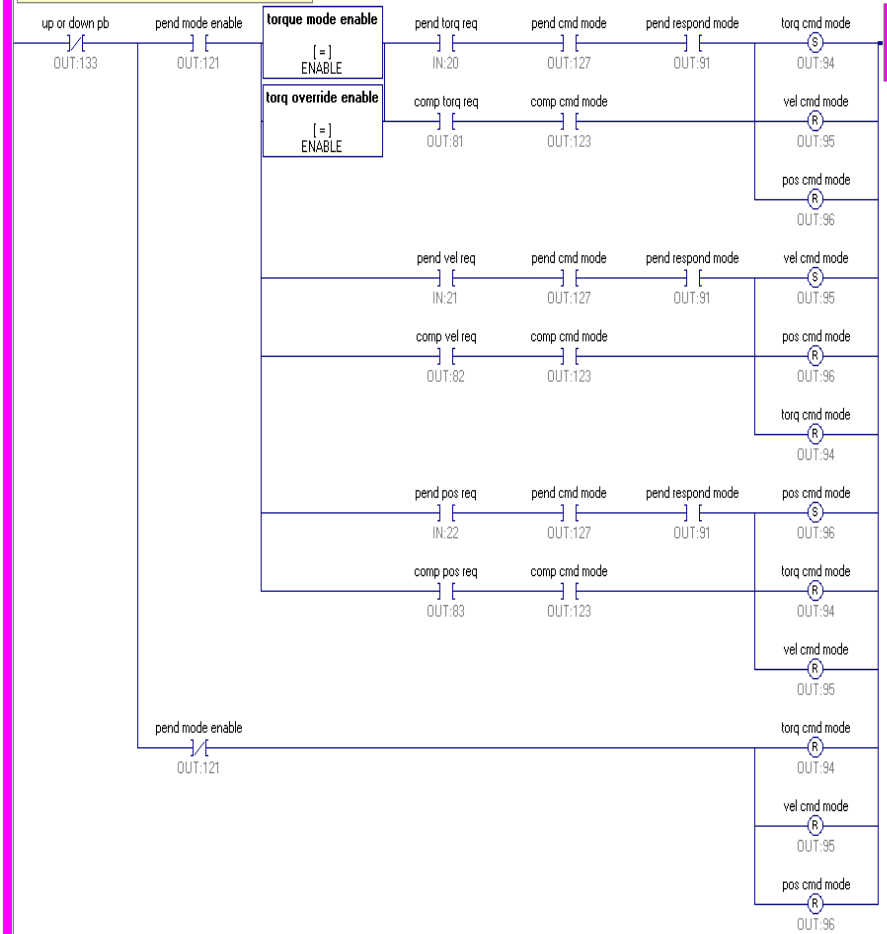
Pendant/computer ladder logic provides I/O control bits from the ModBus/Opto 22 serial lines, also simple functions such as faults.







1 Handles torque, velocity and position mode selection requests  
 4 from the pendant and computer.





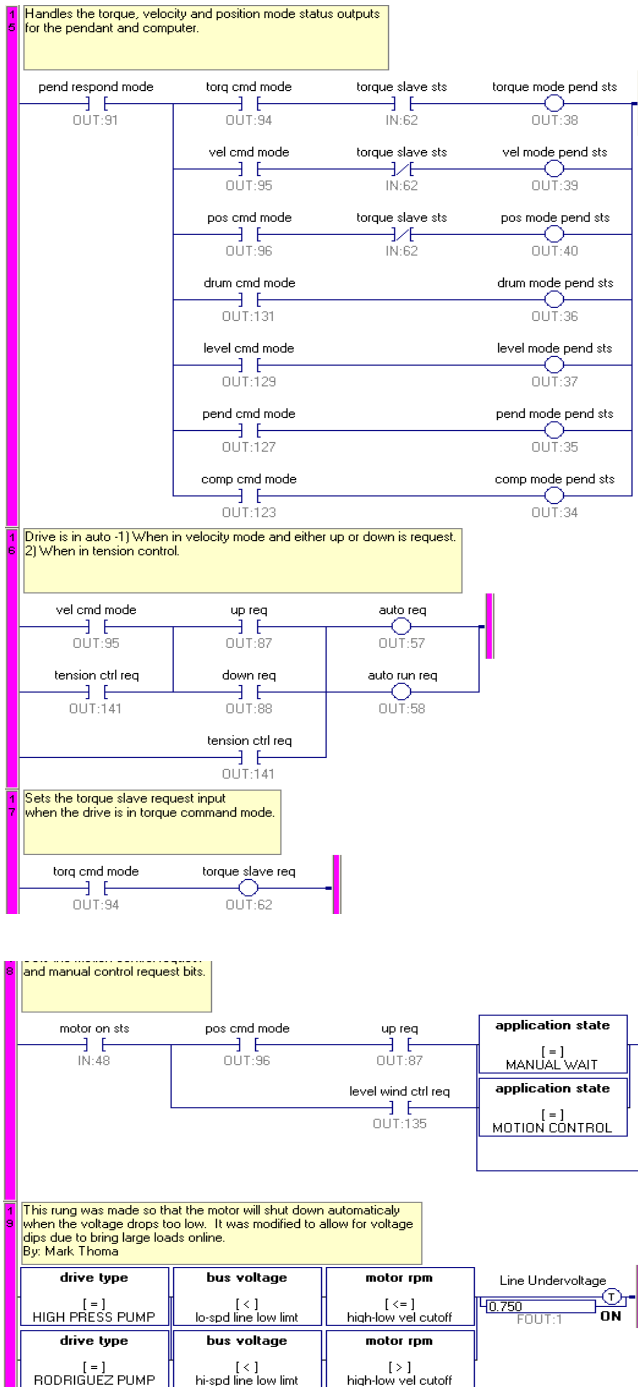
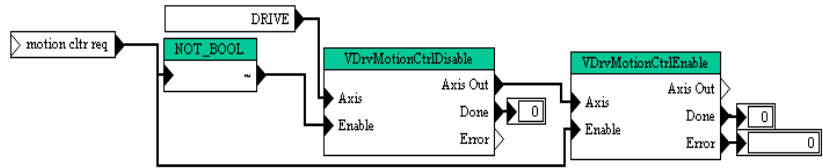


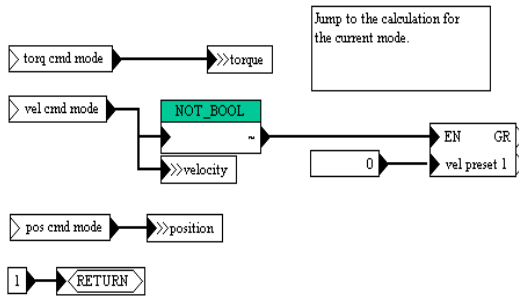
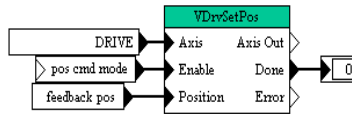
Figure 3.47 Pendant/ Computer ladder logic diagram

## Torq-Vel-Pos FXN

This program sets the mode of the drive.

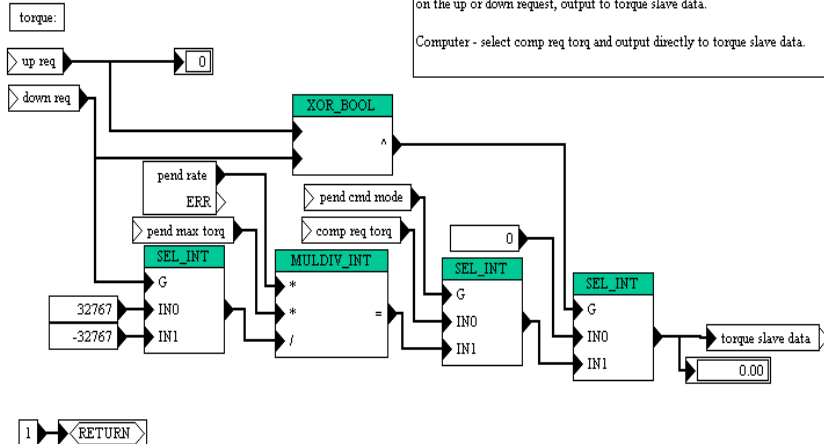


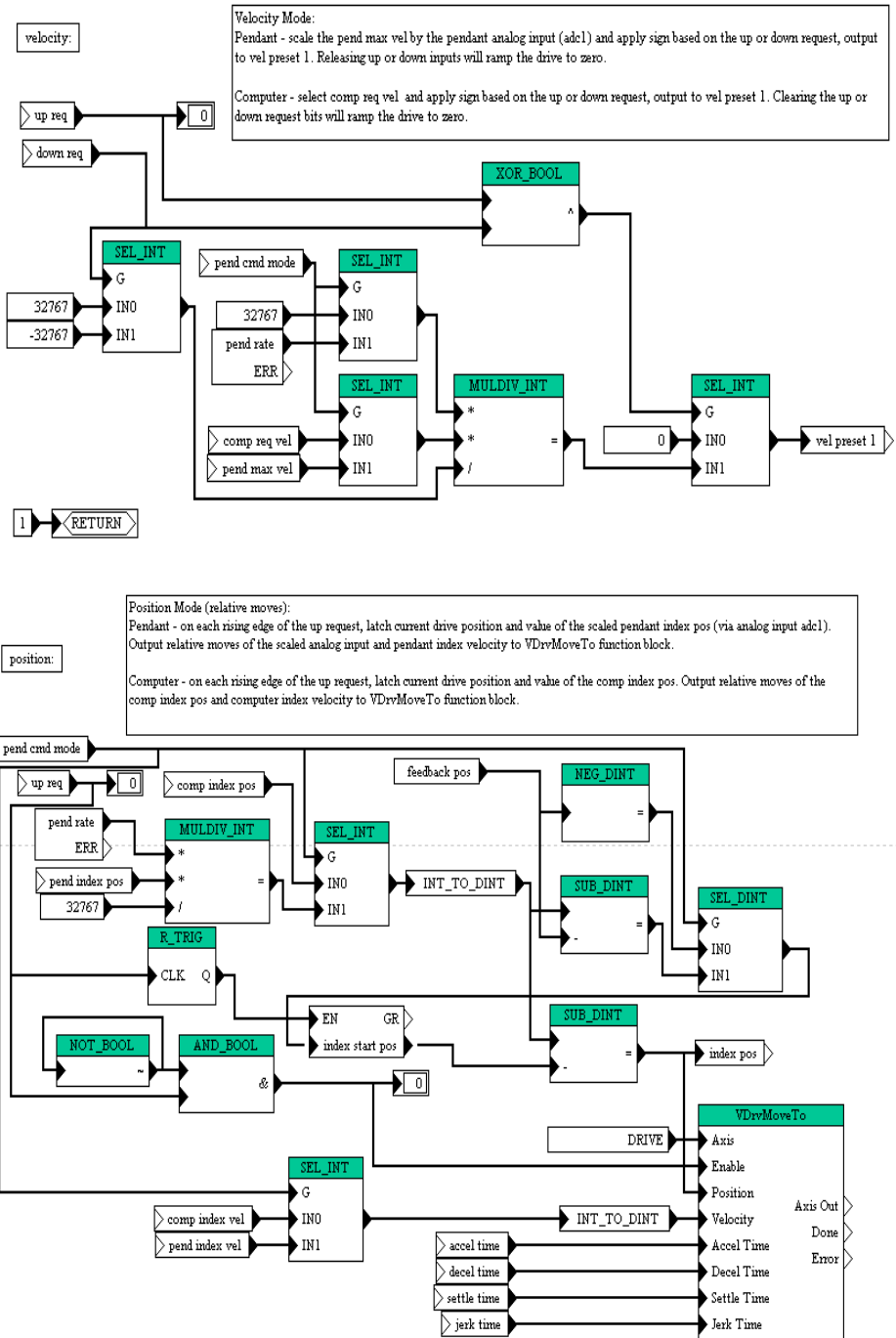
Make Sure Command Position and Feedback Pos Are The Same. They Can Diverge After Torque Mode.



Jump to the calculation for the current mode.

Torque Mode:  
 Pendant - scale the pend max torq by the pendant analog input (adcl) and apply sign based on the up or down request, output to torque slave data.  
 Computer - select comp req torq and output directly to torque slave data.





**Figure 3.48** Drive Torque/ Velocity/ Position mode FXN

## 3.2.6 Loading Firmware and Software

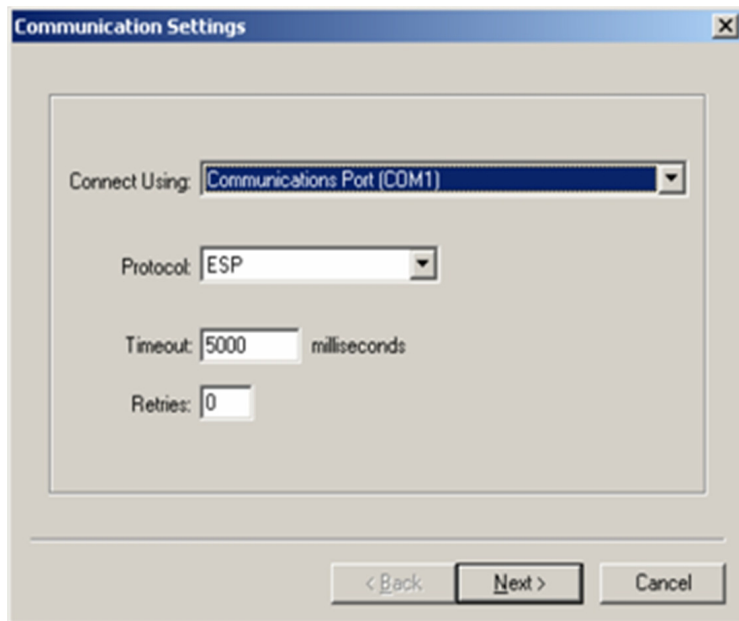
### 3.2.6.1 UEdit

UEdit (UNICO Embedded Drive Integration Tools) is a suite of tools that run on a PC using Windows. These tools can be used to configure and modify drive programs. UEdit as well as drive firmware, projects and archives can be found in the UNICO section of DocuShare.

#### Connecting to the Drive

The device that UEdit will be communicating with should be connected to the PC using a cable such as P.N.203-069 or P.N. 202-734. The device connected will have several options that must be adjusted in order to complete the serial protocol connection. Follow the communications settings section described below, and the communications settings for the specific device also described below to configure both the PC host and the device.

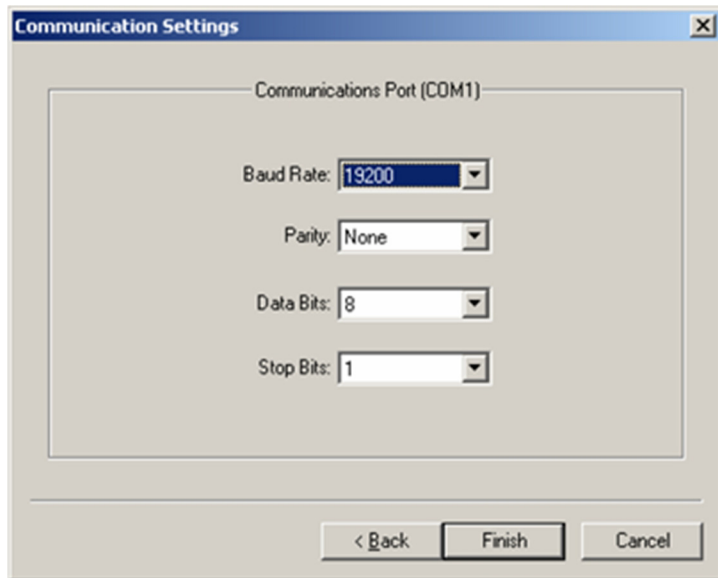
The communications settings for the application can be viewed by selecting the “Communications” menu and selecting the “Communications Settings...” option. The communications settings window will be displayed as shown in Figure 3.49 below. These settings are used to configure the host device. The host device is the PC and will originate the messages sent to the slave device(s).



**Figure 3.49** Communications settings window

The first page of the communications settings allows the user to select which communications device (serial port or modem) to connect with. The communication protocol, timeout and retries are also selectable. Here the user may choose between ESP and MODBUS RTU protocol, but any connected device must also support the selected protocol. The timeout time is typically set to 3000 milliseconds and the retries are typically set to 3. If more time or retries are needed, these values may be set higher, with the understanding that the higher values may take longer to report error conditions as the device must first time out the number of retries before failing.

To continue configuring the communications, the “next” button should be pressed. The next page varies, depending on whether a serial port or modem was selected on the first page. If a “serial port” was chosen in the first screen, the second page will display serial port configuration selections, as shown in Figure 3.50 below.





**Figure 3.50** Communications serial port settings screen

Select the communication “baud rate”, “data bits” and “stop bits”. Unico drives are typically configured with “None” for parity, “8” for data bits and “2” for stop bits. Baud rates up to 230400bps are supported with this application.

Once the serial port or modem settings are complete, the “finish” button saves and applies the changes. The application then attempts to connect or open the communications device. If successful, the status bar, shown in Figure 3.51 below, displays the communication status. If not, “Disconnected” is displayed.



**Figure 3.51** Communications status bar

The connection to the configured communication device may be manually opened and closed using the ‘Connect’ and ‘Disconnect’ options under the ‘Communications’ menu. The user may also connect or disconnect using the ‘Toggle Connection’ toolbar button. This toolbar button displays  when disconnected, and  when connected.

Each Unico drive must be configured properly to talk to UEdit. The drive must be setup to use either the ESP (Embedded System Protocol) or MODBUS RTU, and any connected devices must also be configured to use the selected protocol. Locate the communication port on the drive, then find the appropriate setup that allows the communications protocol to be selected. Set the protocol to the same protocol and the same baud rate, data bits and parity as the settings in the UEdit communications settings on the host PC.

Attention:



**Only qualified personnel familiar with the drive and its application should install, start up, operate, trouble shoot and maintain the drive. You must be familiar with the electrical and mechanical components of the system to perform the procedures outlined in this manual. Failure to comply may result in personal injury, death and / or equipment damage.**

Attention:



**Machine safety is the responsibility of the integrator. This application software and the equipment it controls functions in response to customer programmed control logic. It is incumbent upon the application engineer to incorporate into the drive system the necessary interlocks to prevent motions that may result in injury, death, machine damage or other losses.**

### **Down Loading Firmware**

Device firmware is the embedded code that resides on board a device or drive. This code executes the UEdit tasks and provides memory management for UEdit objects. The firmware also provides communication protocols for the application. Each firmware can be modified to best suit the application. The UEdit code can then be installed on top of the firmware code using the UEdit tools suite to build and edit tasks. Once the UEdit application has been downloaded into the device, the firmware upload can be used to extract the

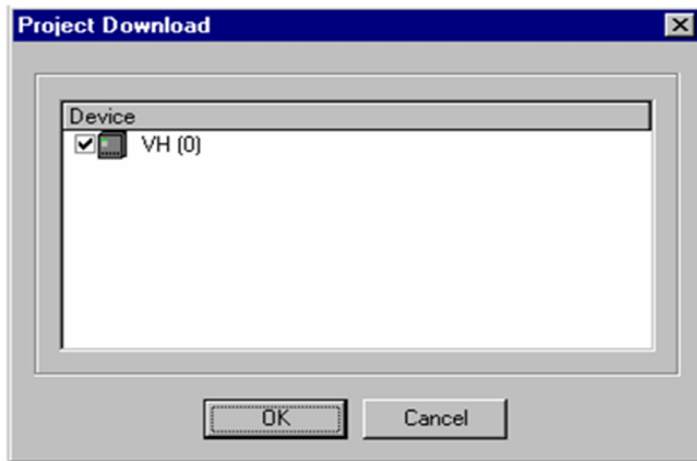
firmware code. UEdit code and any setup information stored in the device can be saved to a new file and used as a backup or disaster recovery file. This feature is not available in UEdit lite.

UEdit supports downloading of application programs targeted for the S2000 E40, S41, and E80 DSP, and the X40 S1100 drives. Downloading is accomplished by selecting the “download Firmware...” menu option from the “Tools” menu.

Downloading files is accomplished using the download wizard. Simply follow the instructions to proceed with the download operation.

### Downloading a Project

To download information from UEdit to the drive, select the download option from the project menu tab, or select the download button from the toolbar. The window shown in Figure 3.52 below will pop up. Downloading is necessary after editing the UEdit project. During the download the firmware creates the objects in the UEdit project and then makes the necessary connections to execute the project in the firmware.



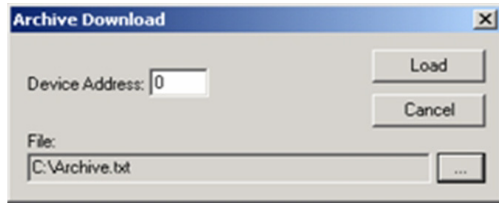
**Figure 3.52** Project download window

After downloading, the device will re-enable the tasks that have been loaded.

Project “full download” functions similar to the download, except that the entire project is downloaded. This forces a clean download that refreshes all of the drive’s objects, not just the ones that were modified.

## Loading an Archive

UEdit supports downloading a data archive file to a device outside of a UEdit project. The device must also support this feature. This tool will download the archive to the device specified by the file path. Click the “...” button to choose the file path that contains the data archive, as shown in Figure 3.53 below.



**Figure 3.53** Archive download window

After selecting the device address and output file path, click the “Load” button to start the download process. A window is displayed during the download to indicate download progress.



# Chapter 4

## 4: EHWD SOFTWARE CONTROL SYSTEM

### 4.1 Introduction

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#### 4.1.1 High level description:

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The basic control system consists of a computer running a control server that connects to devices over a serial network. A user interface connects to the control server via a TCP/IP connection. The user can send commands to the controller that will process them and forward commands on to the appropriate devices.

The serial networks have a limited reach and from the drill camp the drill towers are outside their reach. So a controller is run both in the drill tower ( TOS ), and in the drill camp. They connect to each other over an ethernet network.

#### 4.1.2 Hardware:

---

- 6 Drill Computers - HP DL360 - G3
- 2 Sunix 8 Port 8169 RS485 cards each
- 1 GeForce FX5200 graphics card in each machine
- 7 19 inch LCD monitors - various manufacturers
- 1 HP DL360 G4 ( quad xeon 3GHz - 1 TB ) - external webserver and data archiving
- 4 netsys NV-200 ethernet extenders

## DCC

Two HP DL360-G3's are located in the DCC in the leftmost rack. One of these machines has its sunix RS485 card interfaces connected to all of the RS485 networks in the drill camp ( of which there are 16 ). Both of these computers are connected to a private drill network. The drill network has connectivity to the TOS'es via a DSL modem ( netsys nv-200 ethernet extender). In addition the TOS'es have connectivity to the station network via the same type of modem.

The drill network is connected to the South Pole Station network via a cisco PIX firewall. This firewall performs network address translation, allowing only traffic originating from the inside of the firewall.

## TOS 1 / TOS 2

There are two HP DL360-G3's located in each TOS. One machine in each TOS has its sunix RS485 card connected to the three RS485 networks in each TOS. All TOS machines are connected to the drill network via a netsys NV-200 ethernet extender. This is a DSL modem. One modem is located in the electrical closet in the TOS and the other end is in the DCC.

## 4.1.3 Serial Devices:

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### DGH's (ascii and modbus)



**Figure 4.1** Typical DGH module used to connect various sensors to the network

## Unico Motor Controllers



**Figure 4.2** Unico Motor Controllers

### **Drill power supply box:**

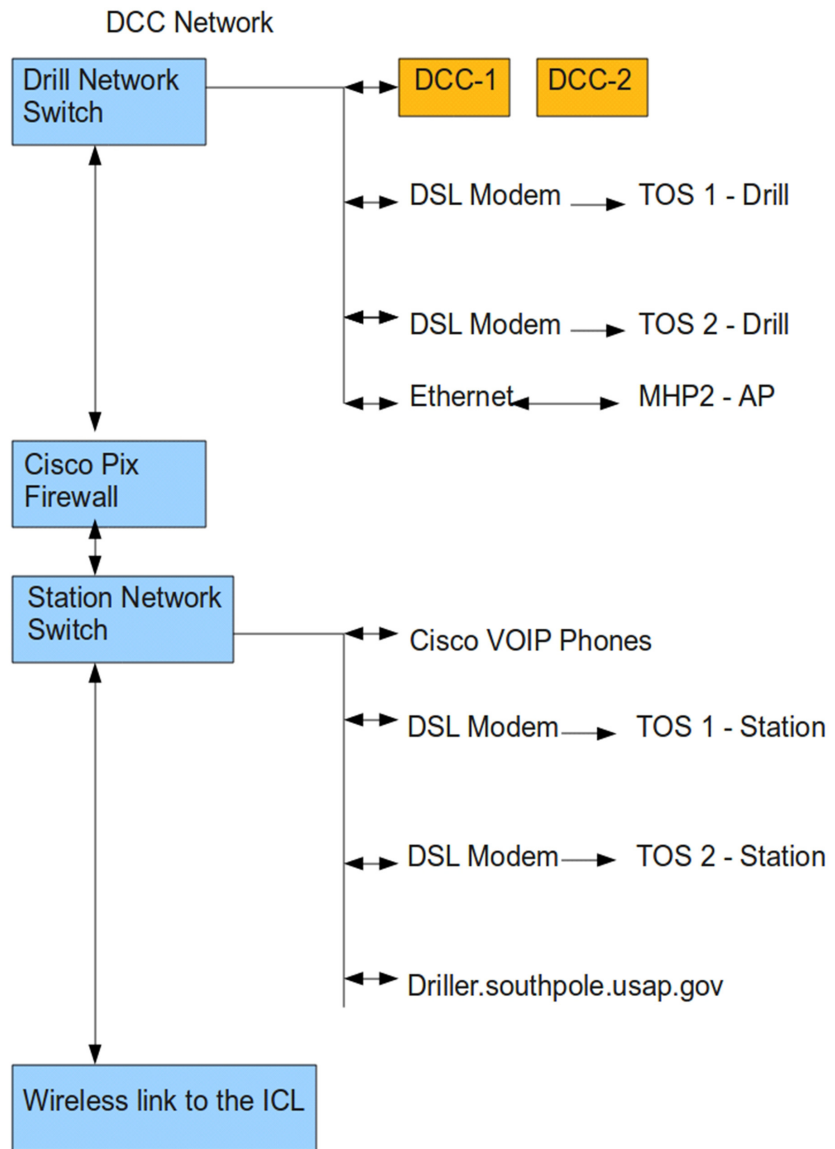
RS 485 connection to a TOS computer

### **DDB ( Deployment Data Box ):**

RS485 connection to a TOS computer

## 4.2 Networks

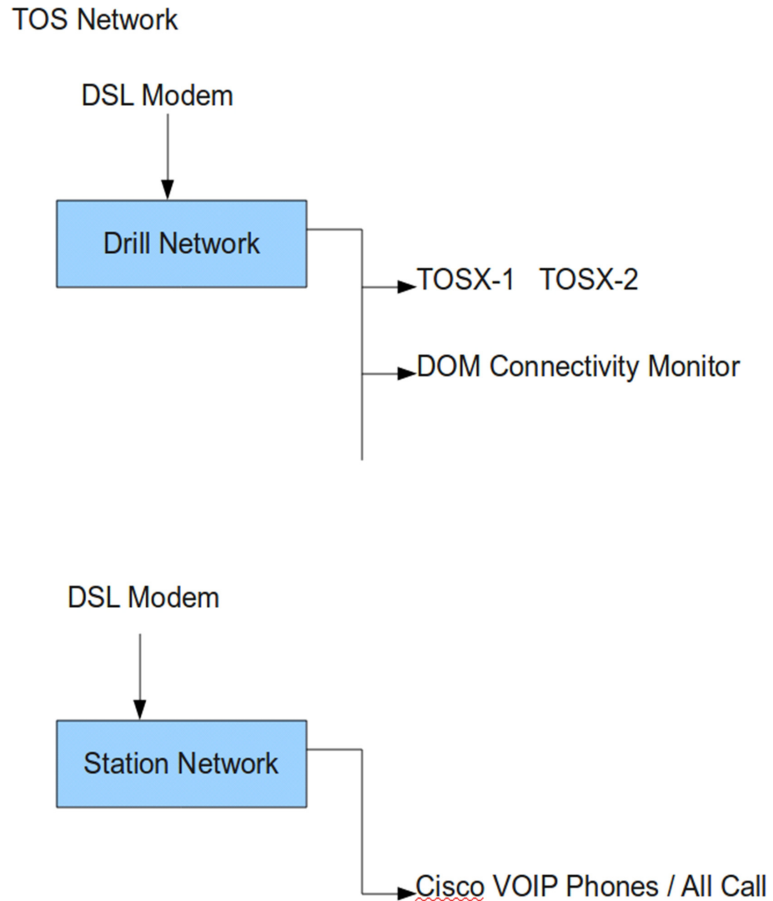
### 4.2.1 DCC Network



**Figure 4.3** DCC network block diagram

## 4.2.2 TOS Network

---



**Figure 4.4** TOS network block diagram

## 4.3 Software :

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The source and binaries for all control software is found in ~ehwd/ehwd on all drill computers. There are two components. The C/C++ controller and a python/wxpython based user interface.

### 4.3.1 C/C++ - controller

---

The controller is a threaded (pthreads) combination of C and C++. During drilling, the controller in the drilling tos shares information with the DCC controller. When run in that mode the controller in the TOS is referred to as slave controller. In all other configurations the controller is referred to as a master controller. The controller is driven by an event loop ( see system/mainsys.cpp ).

#### 4.3.1.1 Event Loop Details:

##### 4.3.1.1.1 Startup:

Call the task function "startup"

Any general constants may be initialized in this function. Note that the order of execution between the "startup" task and the recover preserve call is important. The current order is startup is called BEFORE recovering the values of the preserved variables. This means that if you set the value of a preserved variable in the startup function it will be overwritten by preserved value ( if a preserve.dat file exists ).

Recover preserved variables- only if not a slave controller

Recovers the values of any preserved variable from "preserve.dat". As a reminder you can cause a variable to be preserved by adding the "preserve" property to its definition. Note that preserved variables are not recovered in a slave controller. If this was not so, the controller running in the drilling TOS would write it's last remembered state of the drill camp back to the drill camp causing problems.

##### 4.3.1.1.2 Loop:

Log preserved variables -

Once every four iterations of the control loop all variables that are preserved have their current values written to the preserve.dat log file.

Schedule Serial I/O -

DGH -

libehwd/sysdghmod.h ?

Check() ? gets a reference to all ports with DGH's and calls port->Check.

Each port has a list of associated devices and how often they should be queried. On a call to port->Check the internal scheduler clock is updated by one tick and any devices that are due to be queried are placed on a run queue. Commands to be sent to a device are given priority over queries. Any outbound query will be put on the top of the queue. The guts of all of the serial I/O are in the port class.

Calculations:

Any one of a several hard coded unit conversions. Examples include milliamps to psi.

Tasks:

Tasks consist of code written in "chuck language" that, except for a special case, are executed once every iteration of the event loop. The task interpreter executes the "main" function. The location of "main" is specified at runtime. Note that main must not block!

- UpdateMissionTime ( only on non-slave controllers )

This function allows the programmer to call functions that should only be run on the master controller. Currently in addition to the mission time the status indicators for Estops, fire alarms are checked here.

### **4.3.1.2 Network Communications:**

If anything, the architecture of the network communications for the ehwd controller should probably be redesigned. It is somewhat sensitive to disruptions in network communications between the TOS and DCC and can cause the control system to appear to "freeze". The network communications is split into two calls.

All controllers make this call:

```
mpd->server->ProcessTransactions();
```

This processes all transactions from clients of the calling server. This includes user interfaces, the heater monitor PDA web server, client controllers, etc.

Only slave controllers make this call:

```
mpd->client->ProcessTransactions(&si);
```

This processes all transactions from the master control server.

### 4.3.1.3 Controller Threading Details:

- One thread per serial port.
  - A loop that continually calls "ServiceNextDev" while the port is active.
- drill port thread
- deployment port thread
  - Both these threads call a threadLoop that does all serial I/O and decoding of the telemetry string. The decoded telemetry is placed in a queue and made accessible to the drill control software on a call to "Check".
- One thread per incoming network connection.
  - reads an incoming message and parses it.
- Slave event thread
  - slave controllers start a thread that sends the values of changed variables to the master controller once every ~250 ms.

### 4.3.1.4 Configuration Files:

A typical ehwd configuration file is a human readable text file divided into sections delimited by titles surrounded by brackets ( ie. **[Settings]** ). Typically each section contains a list of name value pairs ( ie. DoLog2=On ) or a list of comma separated configuration values ( ie see the dgh or unico configuration files ).

There are two main configuration files. They are named "**system.cfg**" and "**default.cfg**". They are both to be located in the same directory as the ehwd-ctrla executable. When you run the ehwd-ctrla executable there is a command line option "settings". Normally you would see something like this;

```
ehwd-ctrla settings=Settings.TOS.Drilling
```

This will direct the ehwd-ctrla executable to open the **system.cfg** file, find the section with the title "**Settings.TOS.Drilling**" and read it's configuration information from there. That section references other configuration files.



Below is the Settings.TOS.Drilling section from system.cfg from the 2008/2009 season;

**[Settings.TOS.Drilling]**

Calculations Section=Calculations.TOS  
Calculations File=config/tos\_calculations.ecfg  
ModBus Section=ModBusSlaves.TOS  
MultiRegisterConfig=tosdrill-multireg.ecfg  
DGHModules Section=DGHModules.TOS  
DGHModules File=config/tos\_dghs.ecfg  
Drills Section=Drills.TOS  
Drills File=config/tos\_drills.ecfg  
Deployment Section=Deployment.TOSx  
Deployment File=config/tos\_deploy.ecfg  
Tasks Section=Tasks.TOS  
Print Statistics=On  
LogToFile=On  
History Recovery Hours=12  
DoLog2=On  
RAM Log Size=256  
Master=dcc1  
IsSlave=On  
Task Tests Section=Tasks.TOS  
    ! Make sure you set this to the specific TOS... TOS1 or TOS2  
NodeName=TOS1  
LogDGHIOErrors=On  
LogModbusIOErrors=On  
LogDrillIOErrors=On  
LogDeployIOErrors=Off  
PreserveFile=preserve.Drilling.dat

Let's go through this configuration section and explain what each option does and what the potential options are for each value.

### **Calculations Section=Calculations.TOS**

#### **Calculations File=config/tos\_calculations.ecfg**

These two options tell the controller that it should look for its calculations code in a file in the config directory in the "tos\_calculations.ecfg" file. All relevant code should be in a section labeled "Calculations.TOS". For more information on "calculations" see the section labelled "Calculations" in this chapter.

### **ModBus Section=ModBusSlaves.TOS**

This option tells the controller to look for unico configuration information in the defaults.ecfg file in a section titled "ModBusSlaves.TOS". Please note that you should avoid adding any READ variables to this configuration file and instead try to get any and all read unico variables added to the network map. Note that not all read variables are setup here. Some pumps are also setup in the tasks code.

### **MultiRegisterConfig=tosdrill-multireg.ecfg**

This option tells the controller where to look for a the unico configuration information for the network map.

### **DGHModules Section=DGHModules.TOS**

#### **DGHModules File=config/tos\_dghs.ecfg**

This tells the controller to look in the "tos\_dghs.ecfg" file for a section named "DGHModules.TOS" for any non-modbus dgh configuration information.

### **Drills Section=Drills.TOS**

#### **Drills File=config/tos\_drills.ecfg**

Names the section and configuration file for the drill telemetry data.

**Deployment Section=Deployment.TOSx****Deployment File=config/tos\_deploy.ecfg**

Names the section and configuration file for the deployment telemetry data.

**Tasks Section=Tasks.TOS**

This names the section in the defaults file to look for task configuration information.

**Print Statistics=On**

Setting this option to "On" will cause the controller to print some performance statistics every few minutes.

**LogToFile=On**

Setting this option to "On" will cause the controller to write out complete log files.

**DoLog2=On**

Setting this option to "On" will cause the controller to write out "log2" logfiles.

**Master=dcc1****IsSlave=On**

The ehwd controller can operate in one of two modes, master or slave. Typically the DCC is considered the master controller and the TOS is operated as a slave. The slave will connect to the master and receive value updates from it and send any updated variable values to it. For more information on how this works see the network communications section.

**PreserveFile=preserve.Drilling.dat**

Any variables that are configured with a "preserve" property have their values written out to a "preserve" file. This is so settings will remain constant through a controller restart.

## 4.3.2 Unico Configuration:

---

### 4.3.2.1 Read Variables:

**Note:** UNICO motor controllers have a communications peculiarity. If you ask them for the value of a given register they will take the same amount of time to read one register as they will to give you the value for up to fifteen registers.

When you send a request to read a given register it is specified by the starting register number and how many registers to read out. All of the registers we read are not numerically contiguous.

There is a feature called a "network map" that allows you to remap registers into any order you please. The network map starts at register number 1000.

So please keep in mind if you want to read a register out of a Unico, first and foremost get it added to the register map otherwise you will suffer a significant communications lag for that entire serial network.

To add a register to the network map:

- Contact whomever is in charge of the unico motor controllers and ask them to alter the unico's programming so the register you want to read is in the network map.
- Look at the system.cfg file section that is appropriate for the controller that will be reading this register, find the MultiRegisterConfig option and note the name of the associated configuration file. By default all configuration information in this file will be in a section named "multiregister.read.definitions".
- Add a line to that configuration file in the following format:

*serial port name, modbus address, mapped register number, unmapped register number, variable name, status variable name*

eg:

*/dev/ser5,12,1000,487,TOS.Drill Head Cable Drum.Requested Velocity In.Int,TOS.Drill Head Cable Drum.Requested Velocity In.Status*

*/dev/ser5* is the name of the serial device to which the unico is attached

*12* is the modbus address for the unico of interest

*1000* is the network map register number for this register

*487* is the original, unmapped register number

*TOS.Drill Head Cable Drum.Requested Velocity In.Int,*

This is the name of an intermediate value read from the Unico. All values read from a Unico are subject to a "format" that map from the internal Unico value to a value being sent to the outside world. For example, the internal unit for payout might be in inches but after the format for the serial port is applied it may come out in millimeters. Another complication is that all numbers are represented as integers. An implied part of the format is the number of decimal places. Adding a Unico output value will require you to come up with the appropriate conversion from the value read to a useful display value. Conversions are usually applied as a calculation.

*TOS.Drill Head Cable Drum.Requested Velocity In.Status,*

This is a status variable for communications with the Unico and this particular register.

For information on how to create variables see the section "Creating Variables" in this chapter.

### **4.3.2.2 Write Variables:**

There are two options to write a value to a Unico drive.

#### **Option 1:**

Look for the system.cfg configuration:

*ModBus Section=ModBusSlaves.TOS*

and find the named section in the defaults file. Then add a line in the following format:

Name,dev,addr+1,reg,type,io,datavar,statvar,extra

eg:

*TOS.Drill Head Cable Drum.2,/dev/ser5,12,487,VelocityDrive,out32,  
TOS.Drill Head Cable Drum.Requested Velocity.Int, TOS.Drill Head Cable  
Drum.Requested Velocity.Status*

“*TOS.Drill Head Cable Drum.2*” is a label given to the process for reading this variable. You can use any name and this is kept around for purely historical reasons.

“*/dev/ser5*” is the name of the serial device to which the unico is attached.

“12” is the modbus address ( +1 ) on the Unico to which you want to speak.

“487” is the number of the register to which you want to write

*"VelocityDrive"* labels this as unico configuration information.

*"out32"* specifies that the controller is to write 32 bits of information out for this register.

*"TOS.Drill Head Cable Drum.Requested Velocity.Int"*, this is the ehwd variable that contains the value to be written to the Unico register.

*"TOS.Drill Head Cable Drum.Requested Velocity.Status"*, This is a status variable to keep track of any errors associated with communicating with the named Unico.

## Option 2:

The other option to add a write variable is via a function call in a tasks routine.

An example call would look like this:

```
addmodbusslave $PUMP & ".2", $PUMPPORT, $PUMPADDR, 487,  
"VelocityDrive", "out32", $PUMP & ".Requested Velocity.Int", $PUMP &  
".Requested Velocity.Status";
```

Where;

*addmodbusslave \$PUMP & ".2"* is a label for the writing process

*\$PUMPPORT* is the serial device to which the unico is attached

*\$PUMPADDR* is the modbus address for the unico (+1)

487 is the register number to which to write

*"VelocityDrive"* is the type of the modbus slave "VelocityDrive" and is to be used for all unico's

*"out32"* specifies the number of bytes to write out to this register

*\$PUMP & ".Requested Velocity.Int"* is the name of the register to write to the unico

*\$PUMP & ".Requested Velocity.Status"* is a status variable for any communications errors that occurred when writing this register

### 4.3.3 Adding a DGH:

---

Note: *The majority of DGH's used on the drill speak an ASCII dgh protocol. At the time of writing this manual there is one modbus DGH in the system and that is used to start / stop the charge pumps.*

#### 4.3.3.1 ASCII Protocol DGH:

To add a DGH you need to know the address of the DGH, it's type ( D1000 series, D1700 series, etc ), if it's an input or output DGH, to which serial network it is connected and the name of the system variable it is to either write or read from.

Look in the system.cfg file and find the entries that look like this:

*DGHModules Section=DGHModules.TOS*

*DGHModules File=config/tos\_dghs.ecfg*

As an example, edit the "*DGHModules.TOS*" section in the "*config/tos\_dghs.ecfg*" file and add the following line;

*TOS.Hole Pressure Rdr,/dev/ser4,'C',D1000,in,TOS.Hole Pressure.Current,TOS.Hole.Pressure.Status*

Where;

*"TOS.Hole Pressure Rdr"* is a name and is used for logging purposes only.

*"/dev/ser4"* is the serial network to which this DGH is attached.

*'C'* is the address of the DGH.

*'D1000'* specifies that this DGH is in the D1000 series.

*'in'* means that the system will read from this DGH into the variable named "*TOS.Hole Pressure.Current*" and put any status information into the "*TOS.Hole Pressure.Status*" variable.

#### 4.3.3.2 Modbus DGH:

Modbus DGH configuration proceeds the same as a Unico, except instead of "VelocityDrive" as the type of modbus device, use "DghModbus".

Note that if you add a sensor to the system you have to create a variable in which to store the information read from it. The locations of the variable

configuration files is specified in the **default.ecfg** file. In this file you will see three lines that look like this;

```
uses file "config/variables_basics.ecfg" section "Variables";  
uses file "config/variables_structs.ecfg" section "Variables";  
uses file "config/variables_declare.ecfg" section "Variables";
```

Variables are organized into high level structures named after the building where the sensor is located. For instance if you were going to a temp sensor onto heater 1 in MHP1 and wanted the sensor to be named "bogus temp" you would open the "variables\_declare.ecfg" file, find the start of the "MHP1" variables section, and add;

```
dghmatempinput "Heater 1.bogus temp";
```

Note that if you wanted your bogus temp variable to be included in the log2 logfiles you could append "log2" to the end of the variable definition. If this variable is going to be an input you can also use the keyword "preserve" after the variable definition. This will cause the control server to memorize any changes to that variable and preserve them across control server restarts.

## 4.3.4 Calculations:

---

Once you read a raw data point in from a DGH or unico you may need to perform some calculation on that data point to get it into a preferred form. For example we have many 4 to 20 mA devices whose current is proportional to the pressure or temperature applied to the device and you have to scale the current reading from mA to degrees celsius or pounds per square inch.

There are a set number of predefined "calculations" that can be done on a raw data point. These are listed below and anything not described here can be done in a "task" ( for example the venturi flow meters have their flow calculated in a task).

### **mA to psig**

The actual calculation is:

$$((\text{input} - 4.0)/16.0) * \text{scale factor}$$

### **mA to 10GPM**

$$((\text{input}-4.0)/16.0) * \text{scale factor}$$

### **mA to GPM**

$$\text{scale factor 1} * \text{sqrt}((\text{input}-4.0)/16.0) * \text{scale factor 2} * 27.730)$$



**mA to deg C**

scale factor  $1 * (\text{input}-4.0)/16.0 + \text{offset}$

**Hz to GPM**

$\text{if}(\text{input} \geq 0) \text{ input} * 60.0 / \text{scale factor}$

**Hz to GPH**

$\text{if}(\text{input} \geq 0) \text{ input} * 3600.0 / \text{scale factor}$

**bitset**

Sets the specified bit to 1

**bittest****bitisone**

Returns 1 if the specified bit is set

**bitiszero**

Returns 1 if the specified bit is not set

**int162double**

Transforms a 16 bit integer to a double.

Output =  $\text{input} / \text{scale factor}$

**double2int16**

Transforms a double to a 16 bit integer

Output =  $\text{input} * \text{scale factor}$

**int322double**

Transforms a 32 bit integer to a double

output =  $\text{input} / \text{scale factor}$

**double2int32**

Transforms a double to a 32 bit integer

output =  $\text{input} * \text{scale factor}$

**sum**

Keeps a running sum of a ehwd variables value. It keeps this sum in a data type matching the variable it's summing ( ie if the variable you call "sum" on is an integer, the sum must be an integer ).

**timeaverage**

Calculates the average value for the last N values for a variable. If N is greater than the number of available values, the average will be calculated on only the points available.

Calculations are located in the designated section and file specified in the **system.cfg** file.

*Calculations Section=Calculations.TOS*

*Calculations File=config/tos\_calculations.ecfg*

The section will look like this:

*mA to deg C,PHS.Tank 2 Temperature 1.Current,PHS.Tank 2 Temperature 1.Value,133.521,-63.6317*

*mA to deg C,RWS.Tank 1 Temperature 1.Current,RWS.Tank 1 Temperature 1.Value,120.3,-34.8745*

*mA to deg C,RWS.Down Hole Temperature 1.Current,RWS.Down Hole Temperature 1.Value,121.12,-55.5959*

*Hz to GPM,RWS.Tank 1 Manifold.Flow.Hz,RWS.Tank 1 Manifold.Flow.Value,1100*

*mA to psig,RWS.Rod Well Reel Inlet.Pressure.Current,RWS.Rod Well Reel Inlet.Pressure.Value,250*

### **4.3.5 Calibration:**

---

So how do you come up with the scale and offset factors used in the calculations? There is a generic plotting and fitting package installed on all drill computers called "gnuplot". You need to generate a file with the raw data value from the DGH and the desired output from the calculation. For example when calibrating the tank temperatures put the temperature sensor in a bucket filled with water and measure the temperature of the water and write down the milliamps being read out by the DGH. Add some snow to the bucket to cool the

water, wait for the temperature to stabilize and repeat this procedure several times. Enter all of this information into a text file.

Note: These temperatures and current readings are made up for demonstration purposes:

# temperature (deg C)	mA
10	6.011
20	8.132
30	11.501
40	12.432
50	14.999

Save this file as 'test.dat' and start gnuplot. The following output will be generated by the gnuplot session;

*Script started on Mon 13 Jul 2009 03:51:20 PM CDT*

*\$ gnuplot*

*GNUPLOT*

*Version 4.2 patchlevel 3*

*last modified Mar 2008*

*System: Linux 2.6.27-14-generic*

*Copyright (C) 1986 - 1993, 1998, 2004, 2007, 2008*

*Thomas Williams, Colin Kelley and many others*

*Type `help` to access the on-line reference manual.*

*The gnuplot FAQ is available from <http://www.gnuplot.info/faq/>*

*Send bug reports and suggestions to <<http://sourceforge.net/projects/gnuplot>>*

*Terminal type set to 'wxt'*

```
gnuplot> f(x) = a*(x-4.0)/16.0 + b
gnuplot> fit f(x) 'test.dat' using 2:1 via a,b
```

Note: Output has been clipped for brevity

*After 4 iterations the fit converged.*

*final sum of squares of residuals : 20.6447*

*rel. change during last iteration : -3.17053e-09*

*degrees of freedom (FIT\_NDF) : 3*

*rms of residuals (FIT\_STDFIT) = sqrt(WSSR/ndf) : 2.62328*

*variance of residuals (reduced chisquare) = WSSR/ndf : 6.88158*

*Final set of parameters Asymptotic Standard Error*

=====

<i>a</i>	<i>= 70.3433</i>	<i>+/- 5.897</i>	<i>(8.383%)</i>
<i>b</i>	<i>= 0.917422</i>	<i>+/- 2.705</i>	<i>(294.9%)</i>

*correlation matrix of the fit parameters:*

	<i>a</i>	<i>b</i>
<i>a</i>	<i>1.000</i>	
<i>b</i>	<i>-0.901</i>	<i>1.000</i>

```
gnuplot> plot 'test.dat' using 2:1 title 'Raw Data Points'
```

```
gnuplot> replot f(x) title 'Calibration Curve'
```

So, in the above case, the scale factor is 70.3433, and the offset is 0.917422. Needless to say that the more data points you take the more measurement error will be averaged out of the final calibration.

You can use a similar technique for any other sensor you want to recalibrate. After you change the calculations file you must restart the control server for the changes to become active.

**Note:** Please do not restart the computer while drilling.

## 4.4 Log Files:

---

### 4.4.1 Rawdata

---

The ehwd drill head sends a telemetry string to the surface encoded as an ascii string via a 9600, 8n1 RS485 connection. This signal is available from the back of the drill power supply box located in the TOS computer rack directly below the drill control computers in the TOS.

The format of that string is as shown in Figure 4.5 below;

#### *Data Format*

```
X          Drill ID
0000010622 25 Millisecond Timer
G          Drill Status
G          Power Supply Heat Sink Temperature Sensor Status
374       Power Supply Heat Sink Temperature Sensor Reading
G          MLDT1 Status
348       MLDT1 Reading
G          MLDT2 Status
D41       MLDT2 Reading
G          Load Cell Status
BE8       Load Cell Reading
G          Well (Drill Hole) Temperature Sensor Status
320       Well (Drill Hole) Temperature Sensor Reading
G          Hose Water Temperature Sensor Status
32E       Hose Water Temperature Sensor Reading
G          Power Supply Input Voltage Status
B7B       Power Supply Input Voltage Reading
G          Main Regulator (24 VDC) Output Voltage Status
CC7       Main Regulator (24 VDC) Output Voltage Reading
G          Cavity Air Pressure Sensor Status
7AA       Cavity Air Pressure Sensor Reading
G          Tseal1 Pressure Sensor Status
013       Tseal1 Pressure Sensor Reading
G          Tseal2 Pressure Sensor Status
013       Tseal2 Pressure Sensor Reading
G          Well (Drill Hole) Pressure Sensor Status
*0001     Well (Drill Hole) Pressure Sensor Message ID
+15.390000 Well (Drill Hole) Pressure Sensor Reading
G          Watson Nav Pack Status
N          Watson Nav Pack Message ID
+0.10     Watson Nav Pack: Bank Tilt Reading
-0.15     Watson Nav Pack: Elevation Tilt Reading
226.2     Watson Nav Pack: Heading Reading
-110.2    Watson Nav Pack: X Axis Magnetic Field Reading
+122.0    Watson Nav Pack: Y Axis Magnetic Field Reading
+463.5    Watson Nav Pack: Z Axis Magnetic Field Reading
+27.1     Watson Nav Pack: Temperature Reading
K11       End of Message ID and Check Sum
```

**Figure 4.5** Enhanced Hot Water drill Head Data Format

## Notes:

1. All data is ASCII
2. Sensor Data is either unscaled ADC outputs (in Hex ASCII format) or scaled data decimal format
3. Letters Used In Data:

ABCDE	Hexidecimal Numbers
B	Bad Data Status Byte
G	Good Data Status Byte
K	Checksum ID
N	Starting Byte of Watson Navigation Pack data string
X	Drill ID for EHWd new drill head #1

4. All fields are fixed length

The telemetry string is decoded by the "*drillstatus.cpp*" file in *libehwd/drillstatus.cpp*.

Some of the sensor values require scaling to be output in the appropriate human readable units. The drill heads are, on a semi-regular basis, recalibrated by Jack Ambuel who issues a new calibration coefficients document.

The scaling is done as part of the task code in the TOS. See *system/tasks/tos.ecfg* and examine the "*DrillScaleInput*" function for the code. It should be noted that with one exception the scaling is directly reported to the user. That exception is the calipers. The calipers are read out by up to two sensors (MLDT1 and MLDT2). If the system variable "*Drill.MLDT Mode*" is set to either of those names, the caliper reading from that MLDT is reported to the user. In addition you may set "*Drill.MLDT Mode*" to "min" in which case the minimum of the two caliper readings is used.

## 4.4.2 Rawdeploy

---

The deployment sensors supply a telemetry string to the surface encoded as an ascii string via a 9600, 8n1 RS485 connection. This signal is available the Deployment Data Box (DDB) located in the TOS computer rack directly below the drill control computers in the TOS. The format of that string is described in a seperate document.

The DDB telemetry string is decoded by the *libehwd/deploystatus.cpp* file.

Some of the sensor values require scaling to be output in the appropriate human readable units. The keller calibration coefficients are extracted from an spreadsheet that lives on *driller.southpole.usap.gov*. The user interface uses the *python xldr* module to do the reading and then populates a list in the UI with the appropriate coefficients. The exact coefficients depend on the keller's serial

number, so the user is required to read the serial number and select the appropriate line in the user interface.

The appropriate scaling is done as part of the task code running in the TOS. See the *system/tasks/tos.ecfg* file and examine the "DeploymentScaleInput" function for the code.

### 4.4.3 Log2 File

---

With many thousands of variables to record, it is hard to send complete full resolution data to the north from the south pole. To alleviate this problem, a reduced set of variables are recorded in a log file known as a "log2" file. Selecting variables for a "log2" file is done by editing the *system/config/variables\_\*.ecfg* files and appending the "log2" property after a variables declaration.

If a particular variable is not to be added to a "log2" file you may also specify the "nolog2" property.

After editing a file you must restart the controller.

"Log2" files are transferred to *driller.southpole.usap.gov* roughly once every fifteen minutes via the python script "processlog2". This script lives in the system directory. Files are then put in a drop box for the SPADE system to transfer the data north.

The format of a "log2" file is identical to that of a "Log" file. See that section for a format description.

### 4.4.4 Log File

---

All variables known to the ehwd controller are written to a "Log" file. These logs are compressed and sent to *driller.southpole.usap.gov* once every four hours.

The format of a log file is:

```
<header>
(
<variable order description>
<data line>*
)*
```

The “header” is a single line with the following format:

```
##### DEPLOY log started at Thu Jan 7 13:40:00 2010 [1262824800.400056000]
```

The “variable order description” line will always start with:

```
time,seconds,ns
```

Following the above will be 1 or more descriptions of system variables in the following format:

```
[0] System.NodeName (string)
```

```
[variable id number] "system variable name" ( variable type - string/double/  
integer)
```

All data lines will be specified in the format described by the variable order description line. The first three entries ( time, seconds, ns ) are:

time - A human readable string ( from ctime ):

```
Thu Jan 7 13:40:00 2010
```

seconds - number of seconds since the epoch ( jan 1'st 1970 )

ns - number of nanoseconds past the second

All other types are as described in the variable order description line.

## **4.4.5 Tasks:**

---

### **4.4.5.1 Reserved Words:**

**sin**

calculate the sin of the argument ( argument assumed to be in radians )

**cos**

calculate the cosine of the argument ( argument assumed to be in radians )



**tan**

calculate the tangent of the argument ( argument assumed to be in radians )

**atan**

returns the arctangent of the argument

**ln**

return the natural logarithm of the argument

**log**

return the base-10 logarithm of the argument

**sqrt**

return the square root of the argument

**exp**

returns the exponent of the argument

**deg2rad**

convert degrees to radians

**rad2deg**

convert radians to degrees

**abs**

return the absolute value of the argument

**floor**

returns the largest integral value not greater than the argument

**random**

returns (val \* rand() / RAND\_MAX )

**min**

returns the minimum of the two arguments

**max**

returns the maximum of the two arguments

**pow**

returns X to the power of Y

**number**

returns atof of the argument

**bittest**

tests to see if a bit is set ( 1 = set )

**bitset**

set the requested bit to 1

**bitclear**

set the requested bit to 0

**replace**

replace all instances of a substring in a string with the given string

**format**

used in conjunction with a foreachtableitem - see that section

**atan2(x,y)**

returns the atan2(x,y) of the argument ( results in radians )

## **if**

generic if/then/else statement

Example:

```
    if ()
{
    }

    else if()
{
    }
    else
{
    }
```

## **warning**

## **print**

Print a string to the console running the ehwd controller

## **call**

Call a chuck-language function

Example ( with arguments )

```
    call setupPumpCalculations with $PUMP = "TOS.Return Water Pump";
endcall;
```

The above example executes the function “setupPumpCalculations”, setting the variable '\$PUMP' to "TOS.Return Water Pump". Note that in the function declaration you do not need to declare arguments.

Example (without arguments):

```
call SetDeploymentScaleFactors;
```

### **function**

defines a function in chuck language

Example:

```
function main  
{  
  
}
```

Note that arguments are not declared in the function declaration. They are only declared call to the function.

### **foreach**

Used to iterate over a list specified directly in the language.

Example:

```
foreach $heaternum = [ 1,2,3,4,5,6,7,8,9 ]  
{  
body  
}
```

Calls the code in body once for each item in the list, assigning '*heaternum*' to the appropriate value.

### **foreachtableitem**

Used to iterate over table entries.

### Example:

```
foreachtableitem
    section ^("Deployment.User Input.DDBID") & " Resistance Table"

    format [ $SLOPELABEL, $SLOPE, $INTERCEPTLABEL, $INTERCEPT,
            $STARTRANGE, $ENDRANGE ]
```

Table example:

[DDB01 Resistance Table]

TPWLSlope1,-8.976660682,TPWLIntercept1,40982.94434,3453,4009

TPWLSlope2,-14.68428781,TPWLIntercept2,60682.81938,3112,3452

The 'section' keyword specifies the name of the table over which to iterate

In the above example: ^("Deployment.User Input.DDBID") & " Resistance Table"

The caret dereferences the specified string as a system variable. Then the ampersand performs a string concatenation between the value of "Deployment.User Input.DDBID" and the string "Resistance Table".

the 'format' keyword specifies the format of each row of the table

**break**

**return**

**error**

**timeaverage**

arguments:

"variable name" - system variable

number of samples - number of samples over which to take an average

## **filteredaverage**

arguments:

"variable name" - system variable name

number of samples - number of samples over which to take a filtered average

max delta - maximum delta allowed between two samples ( if exceeds, not used in the average calculation

## **lsqslope -**

arguments:

"variable name" - system variable name

number of samples - maximum number of samples to use in the calculations

This command fits a straight line through the specified number of samples (minimizing the squared error) and returns the slope. This is useful for velocity calculations. For example payout numbers are reported as a given depth at a given time. If you want the payout velocity you can use this command. Note that due to a limitation in the drill control system this value can be slow to respond. Reported values may not be sampled at the same rate at which the system records them. When there is no new value recorded the system uses the last valid value. For example recorded history can look something like this:

1 1 1 1 2 2 3 3 3 3 4 4 5 5 5

## **lowpass**

Claims to calculate a low pass filtered value of the given variable.

Algorithm is doubtful.

## **addcalculation**

addcalculation CALCULATION\_TYPE,

INPUT\_VARIABLE\_NAME

OUTPUT\_VARIABLE\_NAME

CALCULATION\_ARGUMENT

CALCULATION\_TYPE - see the calculations section for possible names  
INPUT\_VARIABLE\_NAME - string name of a system variable  
OUTPUT\_VARIABLE\_NAME - string name of a system variable  
CALCULATION\_ARGUMENT - argument to send to the calculation

example:

```
addcalculation "bittest", "HPP.High Pressure Pump 1.Status Word.Value",  
              "HPP.High Pressure Pump 1.Status Pendant Mode",9;
```

The result of this calculation is if bit 9 of the system variable "HPP.High Pressure Pump 1.status Word.Value" is set, then the variable "HPP.High Pressure Pump 1.Status Pendant Mode" is set to 1, 0 otherwise.

### **addmodbusslave**

Example:

```
addmodbusslave $PUMP & ".2", $PUMPPORT, $PUMPADDR, 487,  
              "VelocityDrive",  
              "out32", $PUMP & ".Requested Velocity.Int", $PUMP & ".Requested  
              Velocity.Status";
```

```
addmodbusslave SLAVE_NAME,  
               PUMP_PORT,  
               PUMP_ADDRESS,  
               REGISTER_NUMBER,  
               TYPE_OF_DRIVE - VelocityDrive  
               INPUT_TYPE,  
               INPUT_VARIABLE,  
               INPUT_STATUS
```

SLAVE\_NAME - unique string specifying the name of of the slave  
PUMP\_PORT - the serial device name to which this slave is connected ( ie. /  
dev/ser6 )  
PUMP\_ADDRESS - modbus address  
REGISTER\_NUMBER - modbus register number  
TYPE\_OF\_DRIVE - only use "VelocityDrive"  
INPUT\_TYPE - in32, in - read a variable FROM the unico  
out32, out - write a variable TO the unico  
INPUT\_VARIABLE - string name of a system variable  
INPUT\_STATUS - string name of a system variable

Note: The in32/in arguments for an input type should not be used unless you have a very good reason. Instead you should get the register installed into the network map.

**Arithmetic symbols:**

+, -, % - modulus, \*\* power, \* multiply, / division

&& - logical and

|| - logical or

= ? equality test

<> ? not equal

string concatenate: '&'

comparison:

<, >, <=, >=

^ - get variable from string



#### 4.4.5.1.1 Important task functions:

##### ***WaterTankTransferPumpControl***

Implements a simple level control for the water tanks:

- If the tank 2 level is greater than the tank 2 high limit, the transfer pumps are turned off.
- If the tank 1 level is less than the tank 1 low limit the transfer pumps are turned on.
- If tank 1 is high and tank 2 is not high then the transfer pumps are turned on.
- If tank 2 is low and tank 1 is not low then turn on the transfer pumps

This is run only if the "*System.Control.Enable Level Control*" variable is set. It is only run once every 180 system ticks ( roughly 45 seconds ). It is not run if;

- the Tank 1 or Tank 2 pressure sensor status variables do not indicate a good status.
- If the water tank levels are outside sensible ranges (  $>3$  or  $<0$  ).
- If the outside atmospheric pressure is outside a reasonable range (  $<600\text{mB}$  or  $>800\text{mB}$  ).
- If the control parameters are not set sensibly ( low range  $>$  high range ).

The tank high limits are taken from the *System.Control.Tank [1|2] High* variables. If adding the high limits together are less than the current tank level sum the high limits are taken from the high warning limits minus 0.01 meters.

##### ***PresoFlowCalculation***

The drill uses preso venturi flow meters in the LPL-150 series. The flow curves are described online at the following location:

<http://www.preso.com/resources/tech/1.5inchLowLossCurves.pdf>

The flow is calculated as per the Preso Flow Calculation handbook retrieved from preso. Note that there are a few typos in the handbook. Namely:

On page 15 the reynolds number factor

Use:  $Fr = 1$  for pipe reynolds between 100K and 1000K

$Fr = 1.025$  for pipe reynolds below 100K

$Fr = .9985$  for pipe reynolds above 100K

According to an email from Mike Doherty from preso:

$Fr = 1.025$  for pipe reynolds below 100K

$Fr = 1$  for pipe reynolds between 100K and 1000K

$Fr = .9985$  for pipe reynolds above 1000K

### ***ReelAutomation***

Implements a state machine for controlling the drill cable and hose reels.

The current state of the Reel Automation state machine is stored in the "*TOS.Drill State*" variable.

The state machine is diagrammed in Figure 4.6 below. States with names in bold and italics are states that are entered only by the user interface.

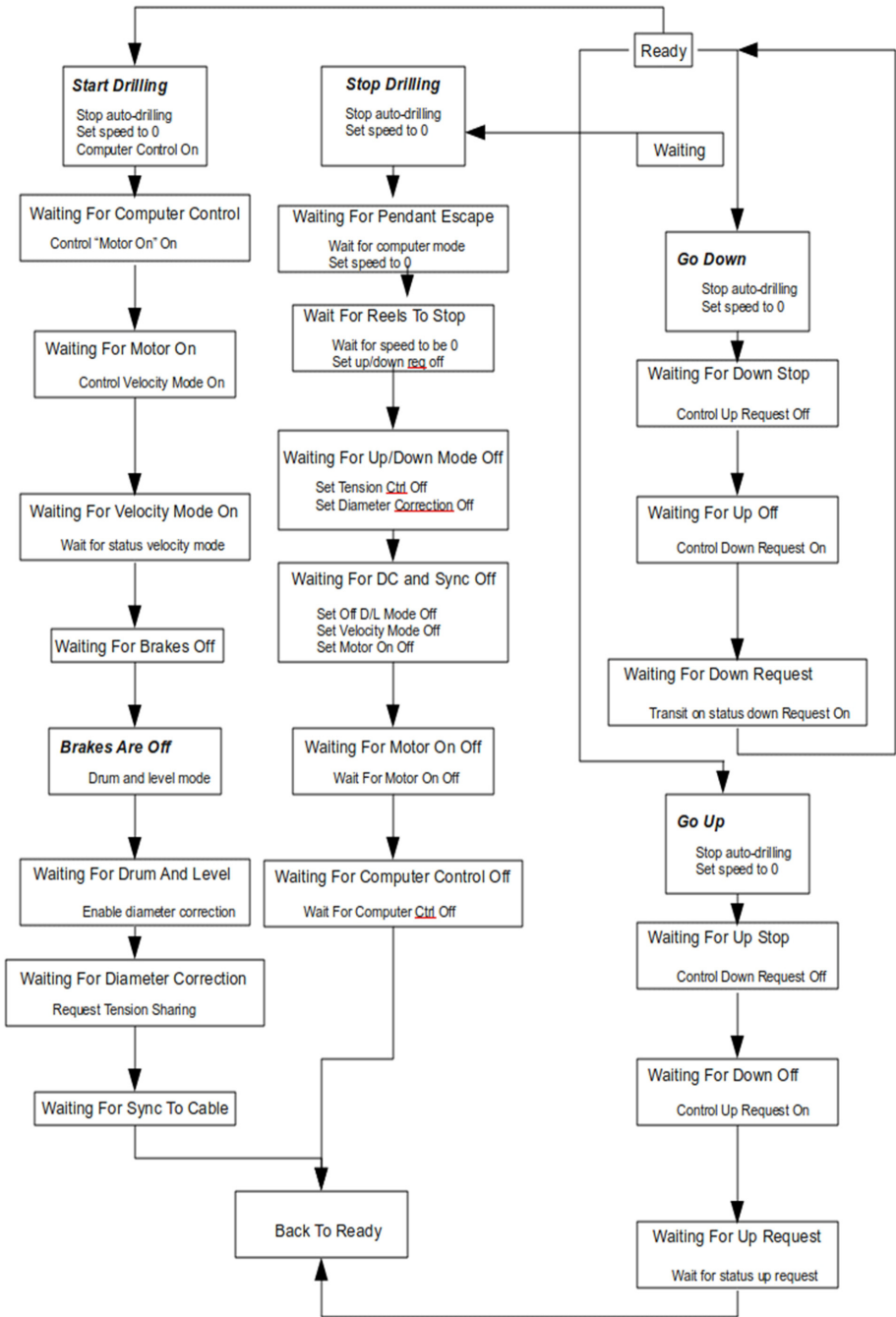


Figure 4.6 Reel automation state machine diagram

## HPP Pump Automation

Implements a state machine (diagram shown in Figure 4.7 below) for controlling the HPP pumps and the charge pumps for the HPP. If you ask for the HPP to be turned on it will not do that until the charge pumps are reporting that they are on.

This also has some built-in protection against hose bursts. If the HPP Unico reports a rapid pressure loss, all of the MHP heaters are turned off and the drill speed is set to 0. The unico will not report a pressure loss if sending the "State Change" bit. The state change bit is sent to the unico if the pump is stopped, the requested RPM is changed, or if the state change counter is 0.

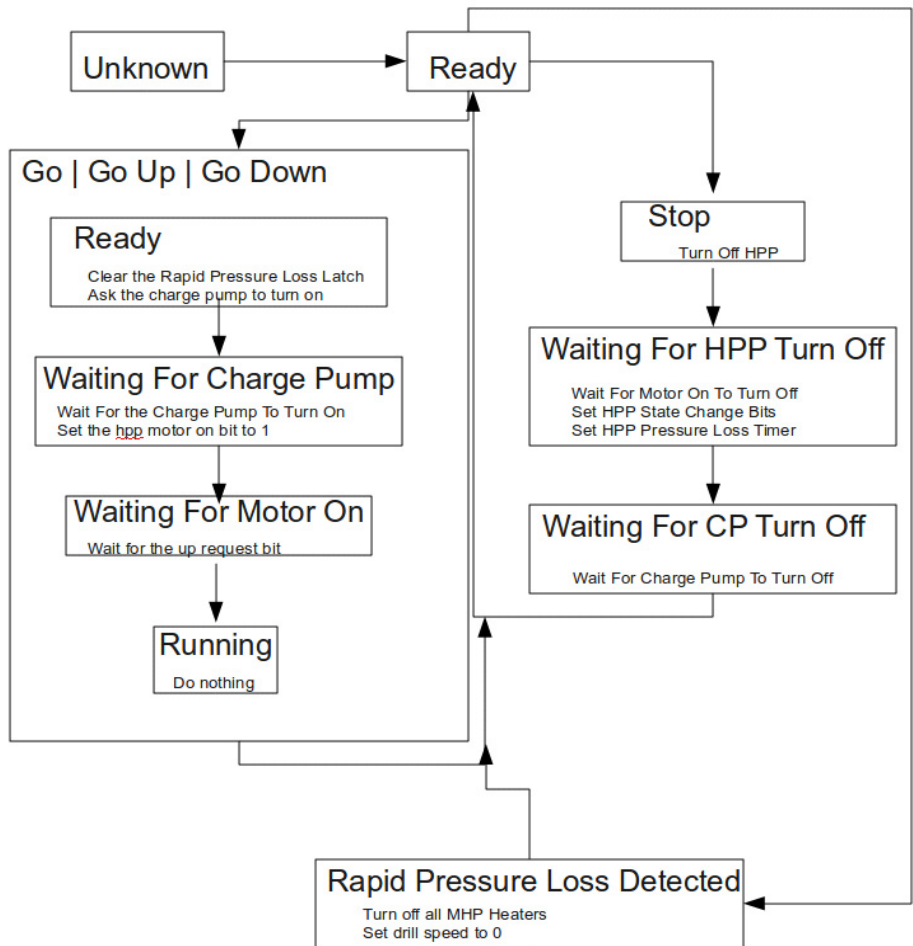
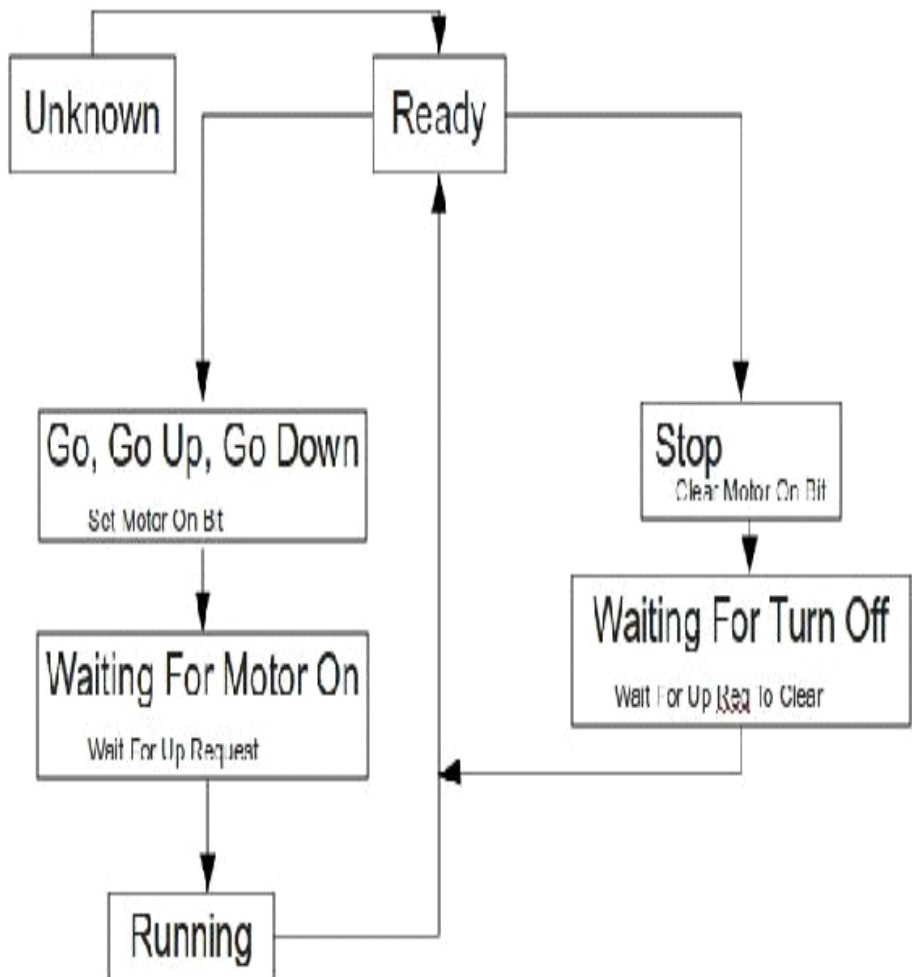


Figure 4.7 HPP pump automation state machine diagram

### ***PumpAutomation***

This is a state machine (the diagram of which is shown in Figure 4.8) used to control all non-hpp pumps. Note that most of the complexity is not needed in this function. Most of it is kept to make operation identical to previous versions. Before the 2009/2010 season the unico motor controllers had an internal state machine that required several round trips from the computer to the unico and back to turn on a pump. This has since been simplified so a single "on" bit is sent to the unico. The majority of the complexity here is kept to keep the user display unchanged.



**Figure 4.8** Pump automation state machine diagram

### ***DepthFromPressure***

Calculate the depth from pressure. This corrects for the compressibility of water (very low).

This is how to go from pressure (in PSI) to depth (in m) for the Paros:

$$\text{depth[m]} = C/(K*D)*(\exp(-K*P0)-\exp(-K*P))$$

where

D = density of water at 0C and 0PSI = 0.99987 g/cm<sup>3</sup>

C = conversion factor PSI -> mH<sub>2</sub>O = 0.7030696 (for D=1.0000)

K<sub>0</sub> = compressibility of pure water = 3.44557e-6 /PSI

K = compressibility of aerated water = K<sub>0</sub>\*1.0975 = 3.78151e-6 /PSI

P<sub>0</sub> = Paro pressure reading in air [PSI]

P = Pao pressure reading [PSI]

### ***UpdateMissionTime***

This function is incorrectly named. It started life as a function to update the mission time. It's since been extended to include any tasks that should only be run on the master controller. Right now it includes the mission time, the alarm disable, the system ticks, and the dcc alarm.

startup

Put any code here that should only be run once. This is good for variable initialization.

### **Variable History:**

Every variable known to the EHWD Control System that is not of a string type has stored history. Points are stored at approximately a four hertz rate. At the most the user wants to see history out to forty-eight hours into the past. With over three thousand known variables that would result in terrabytes worth of data for the full time period. So the data is decimated as time goes along.

Stored history resolution changes depending on how long ago the data was stored.

0 to 10 minutes ? full resolution

10 to 60 minutes ? one point every 15 seconds

1 hour to 1 day ? one point every minute

1 day onwards ? one point every ten minutes

A maximum amount of memory to use for history is set by the following entry in the system.cfg file:

RAM Log Size=512

The number is interpreted as the maximum number of megabytes to use for history. Any point stored past the maximum amount of memory specified is purged.

Decimation happens once every ten minutes so the resolution of stored history can vary.

The only thing large amounts of on line history is used for is plotting.

The task commands that use history are generally used for much smaller time ranges than plotting (less than a few minutes of history versus forty eight hours).

## 4.4.6 Network Communications:

---

Communications between the DCC and the TOS, between the controller and the user interfaces, and between the controller and the heater monitoring PDA uses the same network communications code. All communications are encoded with XDR ( eXternal Data Representation ). The controller uses the default XDR library included with redhat enterprise 4. The user interface uses the python xdrlib package (<http://www.python.org/doc/2.5.2/lib/module-xdrlib.html>).

Note: Reliable network communications requires that the clocks of the DCC and TOS be close

All communications refer to variables by an id number. The id number is given by the response to the "get variable list" message.

Message length - network order long

transaction id → xdr integer

message type → enum

**variable info->**

xdr\_unsigned\_char ( hasRange )

<type of union> → either int or double range

either:

int val low

int val high

or:

double val low

double val high

or:

nothing otherwise

double low limit

double high limitation

property value vector ( xdr\_int )

variable name ( xdr\_string )

**variable value->**

enum – variable type

integer → xdr\_int

double → xdr\_double

string-> xdr\_string

**Protocol Set Variable Info**

unsigned int → variable number

variable value

**Log History Entry:**

timespec → variable timestamp

double → value

double → value\_index



### **Get History Info:**

int → variable number

int → number of seconds to gethistory

int → flags

int → resolution

int → length

int → histogram slots

array → xdr\_LogHistoryEntry

double-> low value

double → high value

double → slot width

### COMMAND\_SETVARIABLE

→ variable info

→ variable value

### COMMAND\_SETVARIABLES

→ array of ProtocolSetVariableInfo

### COMMAND\_GETHISTORY

unsigned int → variable number

int → seconds of history to get

### COMMAND\_GETHISTORYEX

->GetHistoryInfo

### COMMAND\_GETUPDATE2

→ timespec ( last update time)

## RESPONSE\_VARIABLE\_LIST

→ array xdr\_variableinfo

## RESPONSE\_GETVARIABLEHISTORY

unsigned int → variable number

array xdr\_LogHistoryEntry

RESPONSE\_GETVARIABLEHISTORYEX → See  
COMMAND\_GETVARIABLEHISTORYEX

## RESPONSE\_UPDATE

### RESPONSE\_UPDATE2

xdr\_timespec → current time

xdr array → xdr\_variable\_val

xdr array → messages ( warning / error messages )

xdr array → streams ( user interface comments )

### **Note about time:**

The response ‘update 2’ message contains the time the message was generated. All system variables keep track of the time when they were last written. If the “update 2” message time is in the past compared to the stored time for a variable in a slave controller ( by more than 5 seconds ) the value in the update2 message is considered old. This breaks a loop where the user in the TOS would command a heater to go on, the set value command would be sent to the DCC, an “update 2” message would be received with the old value, sent out to the UI's oscillating for a short period of time.

### **Scenarios:**

- 1 Set a variable in the DCC and get the variable to be displayed in the user interface in the DCC.

User interface gets a variable list from the controller.

User interface subscribes for “update 2” messages

The user interface sends a set variable message to the controller for variable x.

The controller sends an “update 2” message to the user interface with the latest value for variable x.

- 2 Set a variable in the DCC and get the variable to be displayed in the user interface in the TOS.

User interface connects to the DCC controller, getting a variable list.

DCC user interface sends the set variable message to the DCC controller.

The DCC controller sends an “update2” message to the TOS.

The TOS controller sends an “update2” message to the TOS user interface for display.

- 3 Set a variable in the TOS and get the variable to be displayed in the user interface in the DCC.

User interface connects to the TOS controller, getting a variable list.

TOS user interface sends a set variable message to the TOS controller.

The TOS controller notes that it now has an updated copy of a variable and sends a set variables message to the DCC.

The DCC sends an “update 2” message to the DCC user interface for display.

### **4.4.6.1 Common Controller Problems:**

The controller has a few design 'features' that would not be easy to correct.

#### **4.4.6.1.1 User Interface:**

Written in python, assumes a version less than 3.0. For all information on python: [www.python.org](http://www.python.org)

Uses the wxpython gui libraries ([wxpython.org](http://wxpython.org)). There is a passable reference manual:

Title: WxPython In Action

Authors: Noel Rappin, Robin Dunn

## General description:

The user interface connects to the controller, gets a list of variables, and then subscribes for “update2” messages. Each time the UI receives an “update2” message it updates internal state to reflect the latest values for all variables and then the UI is repainted. Most of the ehwd ui display widgets all work by repainting themselves based on the current value of a system variable. Anything that requires setting a system variable is done via a “set variables message” as described in the network communications section. Note that other than the contents of an “update 2” message no internal state is stored in the user interface. If you click "on" to turn on a heater, the value is set on the controller and the display is not changed until the result returns to the UI via an update 2 message.

Plots are slightly more complicated. They are setup with a timer so they fetch the last N seconds of history from the controller at their defined update rate. It should be noted that the timer is disabled when a plot is not displayed so all plots are not fetching history at the same time.

## Getting an instance of a ehwd-ui widget:

All instantiation of ehwd ui widgets should be done via the wxEhwdFactory. This bit of code checks for valid variable names, status variables ( if they exist ) are also checked, and exceptions produced by a widget on instantiation are also checked. If any exceptions are thrown instead of the widget, the factory returns a wxPanel with a red background containing black text describing the error.

All ehwd-ui widgets are required to understand the following parameter:

**ehwdVarName** - The name of a ehwd system variable that is to be displayed by the widget.

### 4.4.6.2 List of ehwd-ui widgets:

#### **wxEhwdKellerCal** -

The pressure systems depth sensors ( referred to as 'kellers' ) cause 4-20mA of current to be produced in proportion of the pressure applied to them. Each sensor has a different linear calibration. The calibrations are supplied by the manufacturer and stored in a spreadsheet. The spreadsheet is stored on the web at the address specified in the pyui.cfg file with the key "kellerlocation" (currently: kellerlocation=<http://driller.southpole.usap.gov/keller>). The ui widget downloads the excel spreadsheet, parses it with the xlrd module, and

builds the user interface to match. The code is format sensitive but will produce some extensive debugging information that is displayed on the console in response to an error.

The keller inventory / calibration spreadsheet can be retrieved from the web and updated with a webpage at the given location, as shown in Figure 4.9.

## Keller Inventory Upload

Inventory Spreadsheet:

Get the latest inventory spreadsheet [here](#).

**Figure 4.9** Keller inventory upload window

The file upload code validates the spreadsheet before accepting it. If the file is not valid it reports the error on the webpage.

### **WxEhwdBool:**

Call signature:

```
class wxEhwdBool(wxEhwdGraphableWidget.wxEhwdGraphableWidget):  
  
    def __init__(self, parent=None, id=-1, ehwdVarName="",  
                 ehwdStatusVarName="", invert=False,  
                 onLabel="On", offLabel = "Off",  
                 onColor="GREEN", offColor="GRAY",  
                 timeOutColor="YELLOW", unknownColor="ORANGE",  
                 style=wx.ALIGN_CENTER,  
                 fixedWidth=0, BoolSize=(80,-1)):
```

Used to display a boolean variable. There is no built in boolean type built into the ehwd controller so the integer type is used. Zero is interpreted as false, and 1 as true. Note that as soon as the variable state changes the display is changed.

## **WxEhwdLatchedBoolButton**

```
class wxEhwdLatchedBoolButton(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=1, ehwdVarName="",
                 invert=False, isLatchable=True,
                 onLabel="ON", offLabel = "OFF",
                 onColor="RED", offColor="LIGHT GRAY",
                 latchedColor="ORANGE",
                 fixedWidth=0, BoolSize=(40,-1), testMode=False):
```

Used to display a boolean variable that can change and the user will want to know that the variable had changed state in the past. This widget is primarily used to display the state of the fire alarms in the drill camp.

## **WxEhwdSimpleCheckBox**

```
class wxEhwdSimpleCheckBox(wx.Panel):
    def __init__(self, parent=None, id=-1, ehwdVarName="",
                 label="", labelBkGd='LIGHT GREY', style=wx.ALIGN_RIGHT):
```

## **wxEhwdHPPFlowValue**

```
class wxEhwdHPPFlowValue(wxEhwdValue):
    def __init__(self, parent=None, id=-1,
                 ehwdVarName="",
                 ehwdVenturiVarName="",
                 ehwdStatusVar="",
                 formatString="",
                 style=wx.ALIGN_RIGHT,
                 ValueSize=(24,-1),
                 ValueFont=None):
```

This is a widget that compares the flow by rpm value and the measured value. If the two are different by a given percentage, it causes the flow value to start flashing red. This should indicate a blown spring or bad valve.

## **wxEhwdActionButton**

```
class wxEhwdActionButton(wx.Panel):
    def __init__(self, parent, id=-1,
                 ehwdVarName='',
                 valueToSet='',
                 theLabel='wxEhwdActionButton',
                 style=wx.BU_EXACTFIT,
                 debug=False,
                 ButtonSize=(80, -1),
                 callback=None
                 ):

```

## **wxEhwdCheckBox**

```
class wxEhwdCheckBox(wx.Panel):
    def __init__(self, parent=None, id=-1, ehwdVarName="",
                 label="", labelBkGd='LIGHT GREY', style=wx.ALIGN_RIGHT):

```

## **wxEhwdComboBox**

```
class wxEhwdComboBox(wx.Panel):
    def __init__(self,
                 parent=None,
                 id=-1,
                 ehwdVarName="",
                 choices=[],
                 initialize=wx.NO,
                 pos=wx.DefaultPosition,
                 size=wx.DefaultSize,
                 style=wx.ALIGN_RIGHT,
                 formatString=".2f",
                 confirmEntry=wx.NO,
                 validateMode="none",
                 lowSoftLimit="",
                 highSoftLimit="",
                 lowHardLimit="",
                 highHardLimit="",
                 funcToCall=defaultFuncToCall
                 ):

```

## **wxEhwdGauge**

```
class wxEhwdGauge(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1, ehwdVarName="",
                 minVal=0, maxVal=0,
                 highWarnVar="", highLimitVar="",
                 maxValFromVarRange=False,
                 minValFromVarRange=False,
                 maxValFromVariable=None,
                 minValFromVariable=None,
                 gaugeSize=(80, -1)):
```

## **wxEhwdInput**

```
class wxEhwdInput(wx.Panel):
    def __init__(self, parent=None, id=-1,
                 ehwdVarName="",
                 style=wx.ALIGN_RIGHT,
                 initialize=wx.NO,
                 formatString=".2f",
                 confirmEntry=wx.NO,
                 validateMode="none",
                 lowSoftLimit="",
                 highSoftLimit="",
                 lowHardLimit="",
                 highHardLimit="",
                 ValueSize=(80, -1),
                 funcToCall=defaultFuncToCall,
                 clearEntry=wx.NO,
                 maxStreamRecs=10,
                 font=None
                 ):
```

This widget is used to input numbers. You'll see this widget used to change all pump RPM's.



## **WxEhwdOnOffButton**

```
class wxEhwdOnOffButton(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1, ehwdVarName=None,
                 invert=False, onLabel="On", offLabel="Off",
setState=True,
                 disableVar="", style=0,
                 onValue=1, offValue=0,
                 valueType="int",
                 ButtonSize=(80,-1), disableVars=None, enableVars=None):
```

## **wxEhwdStatusLabel**

```
class wxEhwdStatusLabel(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1,
                 ehwdVarName="",
                 labelText="",
                 ehwdLabelTextDict=None,
                 ehwdStatusVarValueColorDict={' ': 'light gray', 'OK': 'light
gray', 'TIM
EOUT': 'yellow'},
                 style=wx.ALIGN_LEFT,
                 fixedWidth=0, BoolSize=(80,-1)):
```

## **wxEhwdTemperatureValue**

```
class wxEhwdTemperatureValue(wxEhwdValue):
    def __init__(self, parent=None, id=-1,
                 ehwdVarName="",
                 ehwdWarnVar="System.Heater Warning Temperature",
                 ehwdStatusVar="HEATER.Outlet Temperature.Status",
                 ehwdSwitchVar="HEATER.Switch",
                 hotColdValue = 65,
                 formatString="%d",
                 style=wx.ALIGN_RIGHT,
                 ValueSize=(24,-1),
                 ValueFont=None):
```

## **wxEhwdValue**

```
class wxEhwdValue(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1, ehwdVarName="",
                 ehwdWarnVar="", ehwdStatusVar="",
                 formatString="",
                 style=wx.ALIGN_RIGHT, ValueSize=(80,-1),
                 ValueFont=None,
                 ehwdHighWarningValue="",
                 ehwdLowWarningValue="",
                 ehwdHighWarningVar="",
                 ehwdLowWarningVar="",
                 ehwdWarningEnableVar="",
                 warningValueFunc="",
                 debug=False
                 ):

```

## **wxLowWarnedEhwdValue**

```
class wxLowWarnedEhwdValue(wxEhwdValue):
    def __init__(self, parent=None, id=-1,
                 ehwdVarName="",
                 formatString="", lowWarningValue=-1,
                 warningColor='yellow', normalColor='grey',
                 style=wx.ALIGN_RIGHT, ValueSize=(80,-1)):

```

## **wxEhwdRadioButton**

```
class wxEhwdRadioButton(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1, ehwdVarName=None,
                 invert=False, setState=True,
                 disableVar="", style=0,
                 labels = ['On', 'Off'],
                 values = ['1', '0'],
                 valueType="string",
                 ButtonSize=(80,-1), disableVars=None,
                 enableVars=None, sizerOrientation=wx.VERTICAL):

```

## **wxEhwdLogicValue**

```
class wxEhwdLogicValue(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1,
                 ehwdVarName="",
                 # varName, format, statusVarName
                 varFormatStatusTuple= [("Unknown", "%s", "Unknown")],
                 logicTableDict={' ': ('??', "ORANGE", True)},
                 style=wx.ALIGN_CENTER,
                 widgetSize=(-1, -1),
                 debug=False):
```

## **wxEhwdReelButton**

```
class wxEhwdReelButton(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1, ehwdVarName=None,
                 valueToSet="",
                 label="", enableVar="", invert=False, style=0,
                 enableVal="", ButtonSize=(80, -1)):
```

## **wxEhwdReelActionButton**

```
class wxEhwdReelActionButton(wxEhwdGraphableWidget.wxEhwdGraphableWidget):
    def __init__(self, parent=None, id=-1, ehwdVarName=None,
                 funcToCall=None,
                 label="", enableVar="", invert=False, style=0,
                 enableVal="", ButtonSize=(80, -1)):
```

## 4.5 EHWD Automation:

---

### 4.5.1 Auto Drilling:

---

The drill control software has a on/off button that is marked "auto drilling". Once the drill is in the hole and heading down, click the 'on' button. The drill will automatically control it's speed until it hits 2400 meters where it will stop. Drill to the desired depth, do whatever you have to do to your level winds, get the drill started reaming and click 'on' again. The drill will then ream until it hits the 100 meter depth by pressure mark or it comes within 20 meters of the return water pump.

The exact conditions for entering and exiting the auto drilling mode are as follows:

The auto drilling mode will only turn on if:

- The MHP temperature by nozzle temp model is greater than 63 degrees.
- The drill has been asked to go either up or down ( the speed may be 0 but the up request or down request need to be set ).
- The desired lifetime must be set to something between 20 and 40 hours.
- The return water pump must be on
- The return line pressure must be > 700 psi.
- The flow must be > 180 gpm.
- The drill must be in tension sharing mode.

While auto drilling, the drill will be stopped and auto drilling mode will exit if:

- The nozzle temperature drops too low.
- The drill head load cell drops below 900 lbs.
- An HPP rapid pressure loss fault is detected.
- The return line pressure drops below 700 psi.
- The flow drops below 180 gpm.
- The drill is not in tension sharing mode.

If reaming the auto drill function will exit if:

- The drill gets within 20 meters of the return water pump.
- The requested ream speed goes outside 0 to 8 meters per minute.
- The drill depth is less than 100 meters by pressure.

If drilling the auto drill function will exit if:

- The requested drill speed goes outside the 0 to 2.2 meter per minute range.
- The drill depth by pressure is greater than 2400 meters.

### How does this work?

Drill speeds were calculated by implementing the same algorithm as in the speed sheet we have been using for the past several years. Basically it's just a linear interpolation of a set of curves from Lee Greenler. These curves could be updated. Regardless, before implementing in the field I ran the drill speed calculator in a non-decision mode for several holes and compared the operator specified drill speed and the model specified drill speed.

The tricky part is the ream speeds. Strictly Lee's models require:

- the caliper diameter
- number of hours since the drill applied heat to a given depth
- mhp temperature

The caliper diameter is generated by saving the minimum caliper diameter inside each 20 meter block in the hole. When reaming, lookup that caliper diameter corrected for the weight stack length.

The number of hours since a drill applied heat to a given depth is generated by saving the time in which the drill was inside a 5 meter chunk of hole when the drill was asked to go in the downwards direction.

Instead of MHP temperature, the auto drill speed calculator uses the nozzle temperature. A fit to the nozzle temperature given an 88 degree MHP temperature resulted in the following:

$$\text{double modelNozzleTemp} = 83.19 * \exp(-1.0 * \text{depth} / 10069.14);$$

Lee provides a set of curves that give you the ream speed for a depth range at a certain time after the drill has passed for a desired hole lifetime. For a given depth range these curves fit the following equation:

$$1.0/(a+b*y+c*x+d*x*y + e*\text{pow}(x,2.0)+f*\text{pow}(x,2.0)*y)$$

Where:

a,b,c,d,e,f - fit parameters

x - hole diameter

y - desired hole lifetime

The residuals for this fit are available in the "Ream Residuals appendix".

For example, for the range from 0 to 500 meters there is one set of curves for 20 hours after the drill has passed and another for 50 hours after the drill has passed. Given the hole diameter and the desired lifetime, you can calculate the ream speed for those two times and fit a line through the resulting two points. Use that fit to get the desired ream speed for the actual time since the drill passed.

Take that result and then scale it by (actual nozzle temp / modeled nozzle temp).

### **Results:**

In general the above technique worked but required some modifications in the field:

- 1** Strictly following Lee's ream curves resulted in slight steps in hole diameter at switch between curves. To ameliorate this problem at +/- 100 meters from the switch between curves a and b, the average ream speed for curve a and curve b was used.
- 2** The calculated lifetime for the hole in the 0 to 500 meter section was slightly lower than expected resulting in an approximately 21 hour hole instead of a 24 hour hole. The nozzle temperature model was tweaked a bit to make the estimation better and a -0.15 meter per minute offset was added to the calculated ream speed in this region. The data for a drilled hole before these offsets was made available to lee greenler along with the calculated lifetime for possible tweaking of the ream speed model.
- 3** The auto drill code did not detect a failure of the drill head. For this coming season it will do this by using the drill clock. The drill head supplies a clock containing the number of ticks since it was last power cycled. It will look at this number and if it does not change inside a given time limit the drill head

will be considered uncommunicative. Exactly what the auto drill code does at this point has not been determined.

The code that implements this algorithm resides in the top level speedadvisor directory. The only necessary call is:

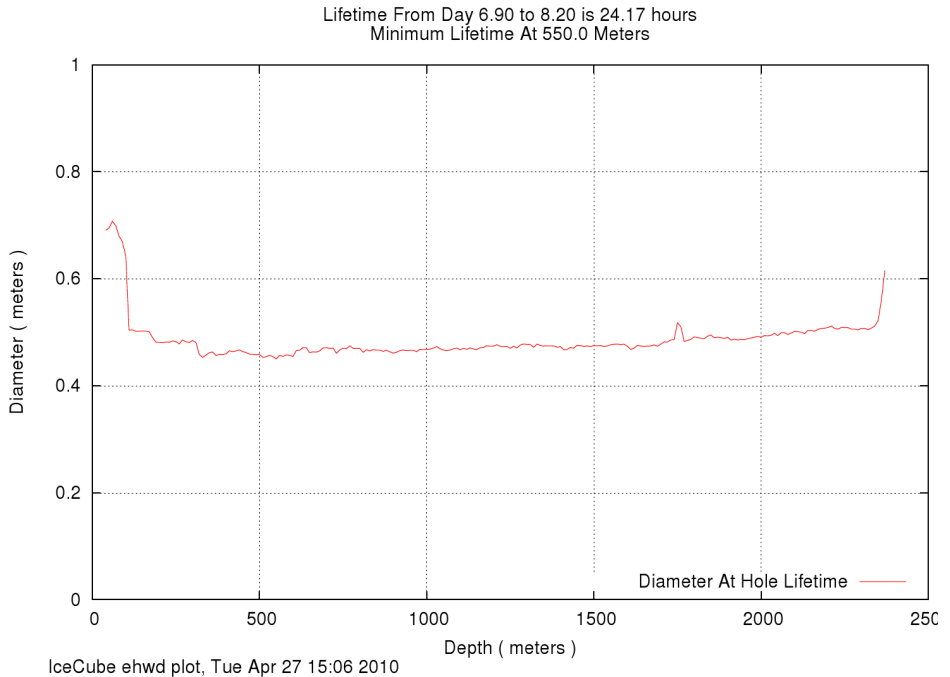
```
double CSpeedAdvisor::AdviseSpeed(struct timespec *timeNow,  
    double depth, double desiredLifetime,  
    double mhpFlow, double mhpTemp,  
    double nozzleTemp, double maxDrillSpeed,  
    double holeDiameter,  
    double maxReamSpeed, bool isDrilling) {
```

arguments:

- timeNow - the current system time
- depth - the current drill depth in meters
- desiredLifetime - the desired hole lifetime in hours
- mhpFlow - flow leaving the HPP in gallons per minute
- mhpTemp - temperature of the water leaving the HPP in deg C
- nozzleTemp - water temperature at the drill head in deg C
- maxDrillSpeed - the maximum drill speed in meters / minute
- holeDiameter - the hole diameter as measured by the calipers in meters
- maxReamSpeed - the maximum speed for reaming
- isDrilling - set this to true if the drill is heading downwards, false if reaming

This method call is accessible from "chuck language" with the "speedadvisor" function. It's called in the "CalculateAdvisedSpeed" function in tos.ecfg.

Hole 33 was drilled using the above algorithm. Here is the calculated lifetime for that hole:



**Figure 4.10** Calculated hole lifetime for hole 33 which was drilled using “auto drilling”

## 4.5.2 Heater Monitoring PDA's:

The heater monitoring PDA's consist of nokia N800's and N810's. The PDA's talk to the control system via a WIFI access point installed in MHP2 and connected to the drill network via an ethernet cable strung back to the DCC.

All communications to the drill control software is through the same python communications code used by the user interface.

The PDA's web browser is pointed at a cherryry web server running on DCC2. Cherryry runs python code returning the results to the browser. For more information on cherryry visit (<http://www.cherryry.org/>).

The initial page loaded is HTML with embedded javascript to query heater temperature and flow information from the web server for the desired MHP. Once the user clicks on a heater link a new page is loaded. That page contains a rather larger javascript program that retrieves 15 minutes worth of temperature and flow data for the given heater and plots it using the HTML 5 <canvas> tag.



### 4.5.3 DOM Connectivity Monitor ( DCM ):

---

A rabbit microprocessor lives inside the deployment reel. The device was originally the responsibility of the cable guys. After he departed the project, responsibility for this device passed to the drill software crew. The device tests connectivity from the surface to every DOM on a string by looking for a capacitor on the input of the DOM. This device is connected to the drill computer network in the TOS via a DSL network connection.

The DCM displays it's results via a web page. The problem is that it cannot serve a web page to more than one client at a time. As a consequence, the script that starts the deployment controller in the TOS is setup to also run a shell script to get the latest page from the DCM, put the current time on it, and make it available on the *driller.southpole.usap.gov* web server. The web page is also emailed to Matt Newcomb in the north in a email with the subject "DCM" where it is processed by "procmail" and made available to the world at <http://www.icecube.wisc.edu/~mnewcomb/dcm2/>

Note the web page has a meta refresh tag in it that causes it to reload fairly frequently. The page is shown in Figure 4.11.

**DOM Connectivity Monitor Page**  
**Total Number of DOMs: 60**  
**Time: 2010-01-20 21:32:08**

Breakout#	CC Test	DCT Test	Breakout#	CC Test	DCT Test
30	PASS	2 DOMs Connected	15	PASS	2 DOMs Connected
29	PASS	2 DOMs Connected	14	PASS	2 DOMs Connected
28	PASS	2 DOMs Connected	13	PASS	2 DOMs Connected
27	PASS	2 DOMs Connected	12	PASS	2 DOMs Connected
26	PASS	2 DOMs Connected	11	PASS	2 DOMs Connected
25	PASS	2 DOMs Connected	10	PASS	2 DOMs Connected
24	PASS	2 DOMs Connected	9	PASS	2 DOMs Connected
23	PASS	2 DOMs Connected	8	PASS	2 DOMs Connected
22	PASS	2 DOMs Connected	7	PASS	2 DOMs Connected
21	PASS	2 DOMs Connected	6	PASS	2 DOMs Connected
20	PASS	2 DOMs Connected	5	PASS	2 DOMs Connected
19	PASS	2 DOMs Connected	4	PASS	2 DOMs Connected
18	PASS	2 DOMs Connected	3	PASS	2 DOMs Connected
17	PASS	2 DOMs Connected	2	PASS	2 DOMs Connected
16	PASS	2 DOMs Connected	1	PASS	2 DOMs Connected

Figure 4.11 DOM connectivity monitor page

The source code to rebuild the DCM is:

DCM PROTO PROG 0801005 FINAL REV D.c

Written in C using rabbit's dynamic C version 10.64. There are two key changes to this source over the C revision. Both changes were made to the ADC readout code. The C revision tried to operate the ADC in power saving mode where the timing is not deterministic. This is believed to have caused an off by one error. Finally all values read out by the ADC had a one bit shift. Reading the datasheet for the ADC it was noted that the default clock state was low. The rabbit supports four SPI clock modes. The default clock mode had the default clock state as high. Changing this was accomplished with the define `SPI_CLOCK_MODE 0x01`.

### **DCMweb.zhtml**

This is an html file with rabbit's extensions. Namely the addition of the "<?z?>" tag. You can add bits of source code inside this tag and it will be run to produce the final web page sent to the client.

The source is available at the URL below. Ignore any source files not mentioned above.

*<https://docushare.icecube.wisc.edu/dsweb/View/Collection-4972>*

## **4.5.4 Drill Web Services:**

---

*Driller.southpole.usap.gov* runs red hat enterprise version 5 and the apache web server.

All code displaying or searching for drill data is written in python running under the apache "mod\_python" module. The python code uses "mysqldb" to connect to a mysql database running on the same machine. In the continental united states, *driller.icecube.wisc.edu* connects to a database server running on *dbs3.icecube.wisc.edu*.

### **Drill database tables:**

data table

columns:

C<field id>

One row in the data table corresponds to one row in the log file. Each column corresponds to a time series set of values for a variable. Note that the column names are not the variable names themselves due to a restriction in table size. To go from a variable name to the appropriate field id you have to use the header table as described below.

### **header table:**

columns:

data\_table\_col ? c<number>

col\_update:

unique\_id:

var\_id:

var\_name:

data\_type:

### **meta data table**

Kept for historical compatibility but not truly useful.

### **roi data table**

columns:

event\_name - string

startEpoch - double

stopEpoch - double

The drill database code has a concept called a "region of interest". Normally these are defined as the time ranges spanning either drilling a hole or deploying a string. These are defined by the operator at the south pole. Whenever the add region of interest script is run on a particular database the entire contents of the ROI table in the targeted database is emailed to Matt Newcomb in the north, processed by procmail and inserted into the appropriate database there.

Data in the database is queried by a python module called *drill\_db\_multip\_rut3.py*. The original version of which was written by Paul Charpentier. Give the python module a list of ehwd variables, a time range, and it will produce a data file containing that data. The web based interface places all data into a special temporary directory including a timestamp in the

directory name. On creating that temporary directory the code scans for other directories with a timestamp more than an hour in the past. If it finds some it deletes them.

Below are some useful web tools built on top of the database:

#### 4.5.4.1 Plotting:

There are three different databases maintained for each year. They are the Drilling, Deployment, and DCC. The drilling database contains a subset of the dcc database. It is downsampled in order to send the data north in near real time. The deployment database contains all interesting data taken during deployment. The DCC database contains all recorded information taken during drilling.

To build a plot the user must locate a variable to plot in one of the aforementioned databases. The interface for this page is shown in Figure 4.12.

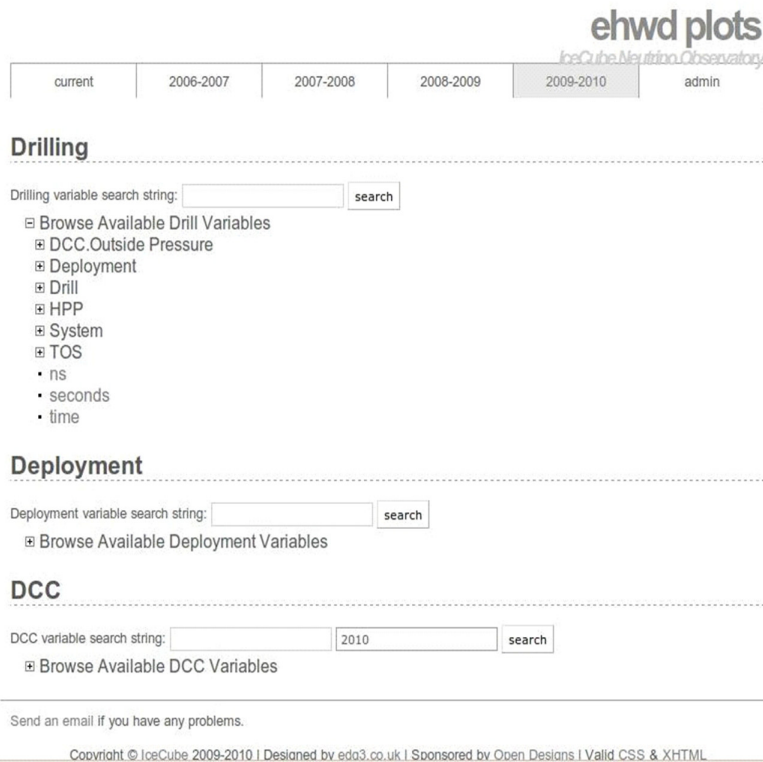


Figure 4.12 Plotting database interface

The user can enter a search string, or browse the variable tree shown in Figure 4.13. After selecting a variable the user is given another screen, again shown in Figure 4.13 to select the appropriate time range and clarify any ambiguity of variable names. If the checkbox labeled "Include drill depth information" is clicked then the depth of the drill is included on the second y axis of the plot.

**Select a variable to plot versus time:**

- 118 [1668] TOS.Payout at Tower from Cable.Slope (double)
- 119 [1669] TOS.Payout at Tower from Cable.Intercept (double)
- 120 [1670] TOS.Payout at Tower from Cable.Value (double)
- 121 [1671] TOS.Payout at Drum from Cable.Slope (double)
- 122 [1672] TOS.Payout at Drum from Cable.Intercept (double)
- 123 [1673] TOS.Payout at Drum from Cable.Value (double)
- 124 [1674] TOS.Payout at Tower from Hose.Slope (double)
- 125 [1675] TOS.Payout at Tower from Hose.Intercept (double)
- 126 [1676] TOS.Payout at Tower from Hose.Value (double)
- 127 [1677] TOS.Payout at Drum from Hose.Slope (double)
- 128 [1678] TOS.Payout at Drum from Hose.Intercept (double)
- 129 [1679] TOS.Payout at Drum from Hose.Value (double)
- 130 [1681] TOS.Payout at Tower from Cable.Velocity Filtered (double)
- 131 [1683] TOS.Payout at Drum from Cable.Velocity Filtered (double)
- 132 [1685] TOS.Payout at Tower from Hose.Velocity Filtered (double)
- 133 [1687] TOS.Payout at Drum from Hose.Velocity Filtered (double)
- 277 [1859] Drill.Payout Start (double)
- 281 [1863] Drill.Payout Start Hose (double)
- 282 [1864] Drill.Payout Current Hose (double)
- 292 [1874] Drill.Payout Current (double)
- 293 [1875] Drill.Payout Previous (double)
- 294 [1876] Drill.Payout Difference (double)
- 376 [1958] Deployment.Payout Start (double)

**Select a timespan to plot:**

Database contains data between: 12/3/2009 13:10 NZDT and 1/20/2010 11:34 NZDT

**Enter start date and duration for your plot:**

Start (mm/dd/yyyy):

Calendar:

Duration:

Include Drill Depth Information

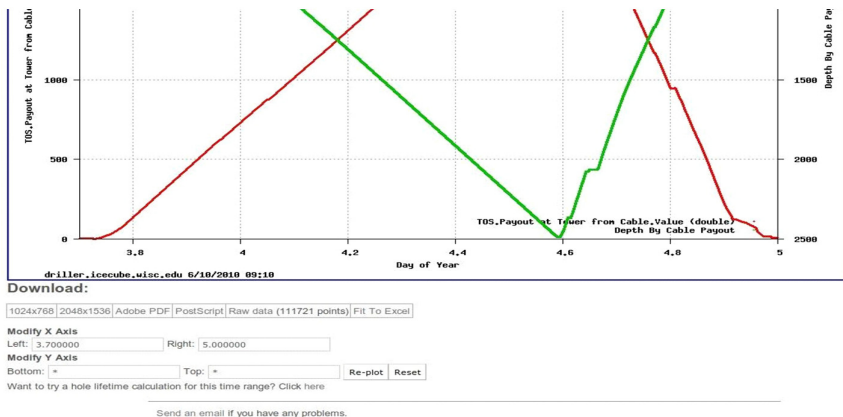
**Select a Region of Interest:**

Or

(Ordered by Date)

**Figure 4.13** Plotting variables tree and timespan selection interface

Once the user requests a plot to be generated, there will be a small delay as the data is extracted from the database, plotted and then displayed as shown in Figure 4.14. Below the display of the plot there are several options. The user can modify the X and Y axis of the plot, download a high resolution image of the plot, a pdf, the postscript of the plot, the raw data of the plot, and a down sampled set of the raw data making up the plot. The down sampling is done via the congrid recipe located at <http://www.scipy.org/Cookbook/Rebinning>.



**Figure 4.14** Plotting example

## 4.5.4.2 Plotting Mass Data Extraction Tool

The plotting interface talked about above only allows the user to get at one variable at a time. Sometimes for more a more complicated analysis it's necessary to get at more than one variable at a time. The mass data extraction tool is available at <http://driller.icecube.wisc.edu/lib/testajax/massExtract.html> and is shown in Figure 4.15.

### Database Variable Extraction Tool

This is a new idea for extracting data from a drill database. Give it a try and let me know what you think!

Matt

**Database:**

**Select Data By:** **Day Of Year:**  **Hole Number:**

**Hole Number**

**Resample Data For Excel:**

Variable
TOS.Payout at Tower from Cable.Value (double)
<input type="button" value="Add"/>

Variable
TOS.Payout at Tower from Hose.Value (double)
<input type="button" value="Add"/> <input type="button" value="Delete"/>

Figure 4.15 Database variable extraction tool

## 4.5.4.3 Event Searching Tool:

Users will frequently report events without time information, or events may be suspected but no one noticed if or when they occurred. The tool shown in Figure 4.16 is for searching the drilling database for time regions where a combination of sensor values meets a search criteria.

## Database Search

This is a new idea for a searching the drill database. This only searches the dcc database for now and only searches the entire database. Give it a try and let me know what you think!

Matt

Database:

Maximum Number Of Results:

Min Spacing In Seconds Of Results:

Variable	Comparison	Value
Drill.Depth by Pressure (double)	>= v	2500
<input type="button" value="And"/> <input type="button" value="Or"/>		

**AND**

Variable	Comparison	Value
HPP.MHP Return Line Temperature.Value (double)	>= v	80
<input type="button" value="And"/> <input type="button" value="Or"/> <input type="button" value="Delete"/>		

Form data: [Field('form', '0', Drill.Depth by Pressure (double), >= 2500'), Field('form', '1', AND.HPP.MHP Return Line Temperature.Value (double), >= 80')]  
Connecting to the database

Connected, executing 'select c2, c3, c1926 ,c230 from data\_table where cast(c1926 as DECIMAL) >= 2500.000000 AND cast(c230 as DECIMAL) >= 80.000000 group by c2;'

Figure 4.16 Database event search tool

### 4.5.4.4 Sensor Numerical Integration Tool:

Many drill camp sensors read rates of flow, instead of total-ized numbers. This tool lets the user specify a drill camp sensor and get the calculated total flow seen by that sensor. For instance, the system variable "HPP.MHP Return Line Flow by RPM" integrated over icecube hole 8 gives a total of 400,000 (398915.615) gallons of water. The user interface for the integrator resembles the mass extraction tool. The tool is currently installed at <http://driller.icecube.wisc.edu/lib/testajax/integrateCalc.html> and looks as shown in Figure 4.17.

### Integration Tool

Given a sensor this page will return a numerically integrated value of that sensor. Note that if there are any gaps in the data that any gap of over 10 minutes will be ignored.

Matt

Database:

Select Data By: Day Of Year:

Hole Number:

Hole Number

Variable
HPP\MHP Return Line Flow By RPM (double)

[HPP\MHP Return Line Flow By RPM \%(double)\]

tmpDir: /var/www/html/driller/lib

**About to extract data!**

Compiling... done  
Opening data file... done  
Connecting to database... connected  
Requesting variables... done  
Extracting data, start year=2009... [Raw Data](#) (134293 points)  
Integrating...  
Data Loaded... number of vars: 16786 Value = 398915.615061

Figure 4.17 Sensor numerical integration tool

### 4.5.4.5 Online Fuel Logbook:

At the start of each shift, before starting drilling, and at the bottom of each hole, a fuel dip is taken. This allows a calculation of the fuel consumption of the drill. The values of each of these fuel dips was recorded in a paper log book. The log books were later used to reconstruct a fuel log for the season. To reduce the administrative overhead required to build this fuel log, a web based utility was constructed that would populate an excel spreadsheet with the data from all fuel dips. The fuel log was written in a combination of javascript, python, and mysql. Python uses the xlwt module to write excel spreadsheet. The spreadsheet can be retrieved with a link at the bottom of the fuel logging webpage. This page is visible anywhere on the station and is shown in Figure 4.18.



## Online Fuel Logging

Date (yyyy/mm/dd):  Today

Time: (HH:MM)  Now

User (initials):

Type of reading:  Drill Camp  Firm Drill

System Status:  ▾

Tank	Dip	Gallons	New/Full	Online	Empty	
1	<input type="text"/>	Unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Clear
2	<input type="text"/>	Unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Clear
3	<input type="text"/>	Unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Clear
4	<input type="text"/>	Unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Clear
5	<input type="text"/>	Unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Clear
6	<input type="text"/>	Unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Clear

Fuel Meter Reading:

Outside Temperature (F):

Comment:

Date And Time	Reporter	T1	T2	T3	T4	T5	T6
2009-10-12 16:09:44	MGN	1.5	0.0	0.0	20.0	20.0	20.0
2009-08-28 09:36:00	dvd	66.0	0.0	0.0	0.0	0.0	0.0

Figure 4.18 Online fuel logging page



# Chapter 5

## 5: SES SYSTEM ASSEMBLY

### 5.1 Introduction

---

The aim of this chapter is to explain how the drill is assembled at the Seasonal Equipment Site (SES); how it's plumbed, wired with power, sensors, network cabling, E-stop cabling and how pumps and other equipment necessary to run the drill is installed.

The assumption in this chapter is that each of the drill MDS modules, workshop and break facilities have all been arranged in their final configuration for the season. Further assumption is that each MDS has been de-winterised and is ready for any DNF equipment to be installed and the building bought online.

### 5.2 Connecting Fuel System to MHP's

---

Prior to turning on fuel supply to the MHP's ensure there are no disconnected lines, open fuel filters or other means by which fuel would leak in the MHP building.

The Blue fuel line Hoses should be marked on each end to the corresponding connection point on MHP 1,2,3 &4. The end with the valve connects to corresponding MHP building and the Female JIC end connects to the Supply Manifold located on the Day Tank as shown in Figure 5.1.

Figure 5.2 gives a view of the front and back of the fuel day tank after it has been fully plumbed with fuel hoses going to all the MDS'.



**Figure 5.1** Photos showing fuel connection point on MHP and fuel tower

Connect the valve end first of the supply hose after you remove the Cam lock cap from the MHP building. Ensure the cap is placed where it is easily accessible when the supply line is removed at the end of the Drilling Season. Secure the Cam lock for the valve with a Tye wrap or wire to ensure it stays in place. Now connect the Female JIC fitting to the Supply Manifold on the day tank with a 1 ¼ inch size wrench and a 1 1/8 inch wrench to hold the valve from turning while tightening. Most all of our fuel lines have been trenched under the snow pack in areas that are driven over or walked over. We cover the lines with plywood and then fill the remaining trench in with snow.

After a check of the MHP building to ensure there are no points fuel could leak out, open the ball valve on the MHP building. Turn on the Building Furnace to verify fuel is present in the building, bleed out any air as needed.



**Figure 5.2** Fully plumbed fuel day tank

## 5.3 Connecting Plumbing Between MHP's

---

Water Plumbing connections between the HPP manifold and the MHP's are made with the 1 ½ inch hose with JIC fittings. A 2 ¼ inch wrench and a pipe wrench to keep the fitting from turning when tightening are tools needed.

Inside the HPP building on the discharge end of the HPP manifold there is marked Supply for MHP 1 & 3 and MHP 2 & 4. The line connected to the MHP 1 & 3 supply connects to MHP 1 cold water in. The line connected to MHP 2 & 4 supply then connects to MHP 2 cold water in.

The Cold and Hot water out lines from MHP 1 connect to MHP 3 cold and hot water inlet lines. The Hot out from MHP 3 goes back to the HPP Return manifold labeled MHP 1&3 return.

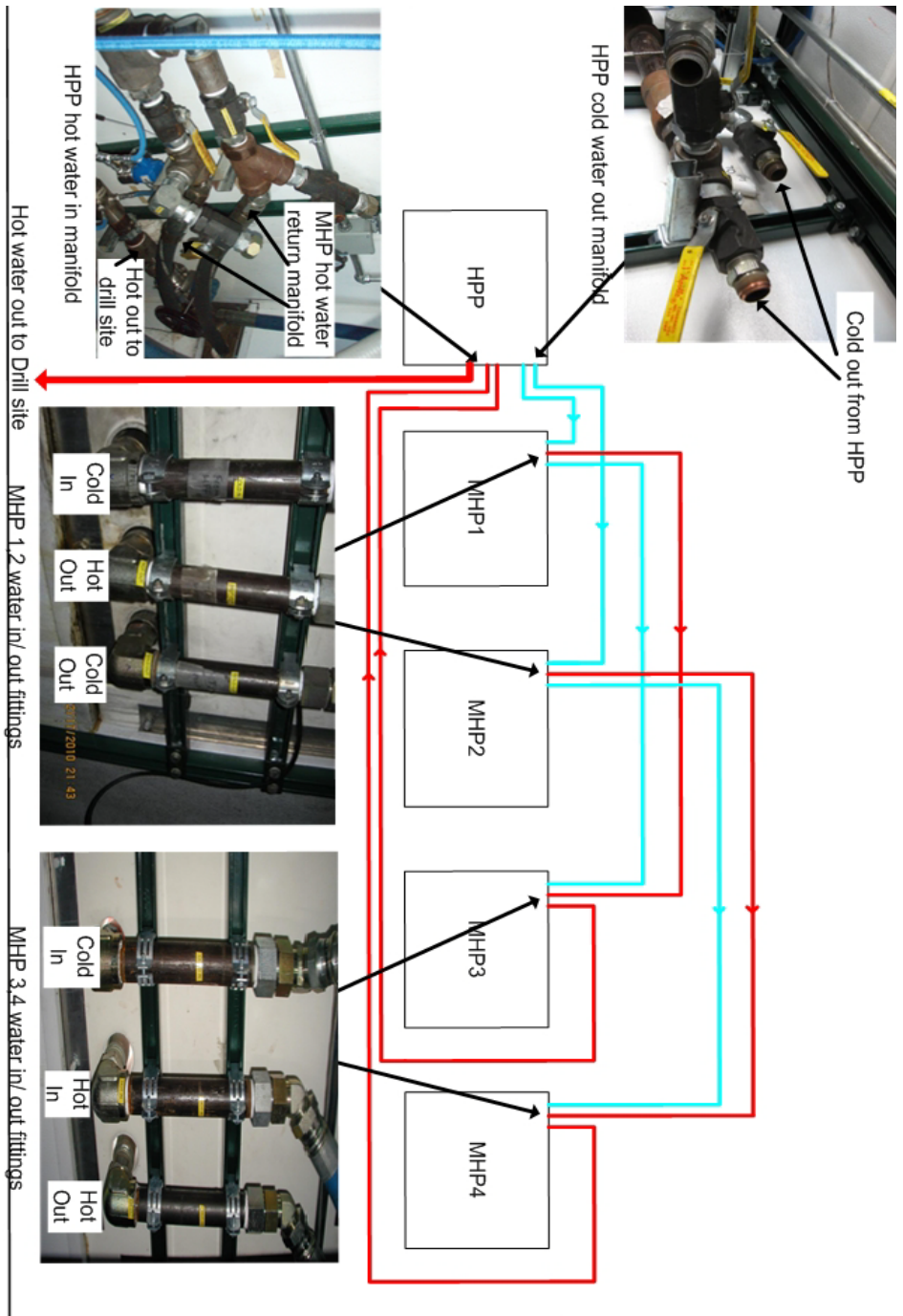
The Cold and Hot water out lines from MHP 2 connect to MHP 4 cold and hot water inlet lines. The Hot out from MHP 4 goes back to the HPP Return manifold labeled MHP 2&4 return.

This is shown illustratively in Figure 5.3 below. The figure shows the hose connections from the HPP to each of the MHP's and between MHP's, as well as the return from two of the MHP's back to the HPP. Also shown is the hot water out to the drill camp.

Figure 5.3 also shows the outlet and inlet manifolds inside the HPP and the inlet and outlet manifolds in the MHP's. Note the subtle difference in the manifold labelling between MHP 1-2 and MHP 3-4. Note the valve to the left on the HPP is used during startup to run a loop into tank 1. Also note that the extra valves on the HPP hot water return manifold are spares.

The return water outputs from MHP 2 and 4 are combined in the HPP then fed out again immediately to the main surface supply hose in order to allow the two hot water outputs from the MHP's to be combined in a convenient location and then run them through a flow and temperature sensor to monitor the water going out to the drill site.

All hoses in the past have been insulated with 2inch ID insulation and taped to keep the insulation in place. An insulated raceway may be a better option in the future, then insulating the hoses from the bottom of the raceway the where they enter the building.



**Figure 5.3** Schematic of hose connections between HPP and MHP's

Figure 5.4 below shows the hose entry and exit locations in the HPP and the MHP's. In the HPP the cold water out come out of the top ports while the hot water in and back out to the drill site come out of the bottom ports. The MHP hose entry and exit location shown is for MHP 1 and 2. This can be deduced from the labelling which shows “cold out”, “hot out” and “cold in”. MHP 3 and 4 locations would show “hot out”, “hot in” and “cold in”.

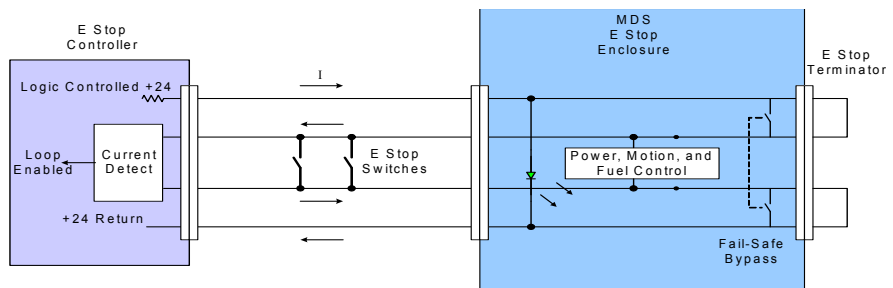


**Figure 5.4** MHP and HPP hose entry and exit locations

## 5.4 Connecting E-Stop System

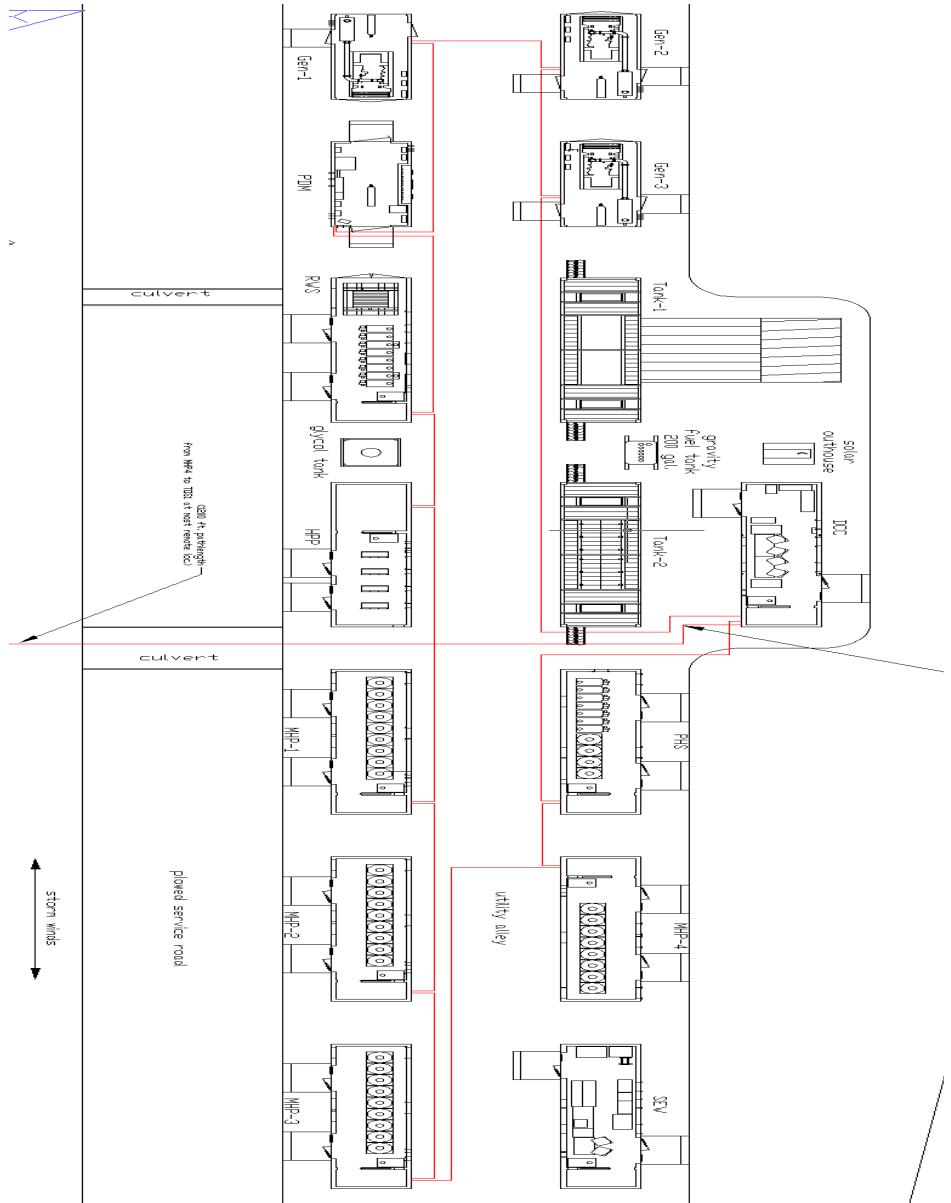
There are separate E-stop networks for Drilling (Global) and Deployment (Local)

Deployment is a stand alone operation that doesn't use hot water flow from the Seasonal Equipment Site (SES). It does not use the Cable or Hose reel.



**Figure 5.5** Simplified schematic of the E-Stop system

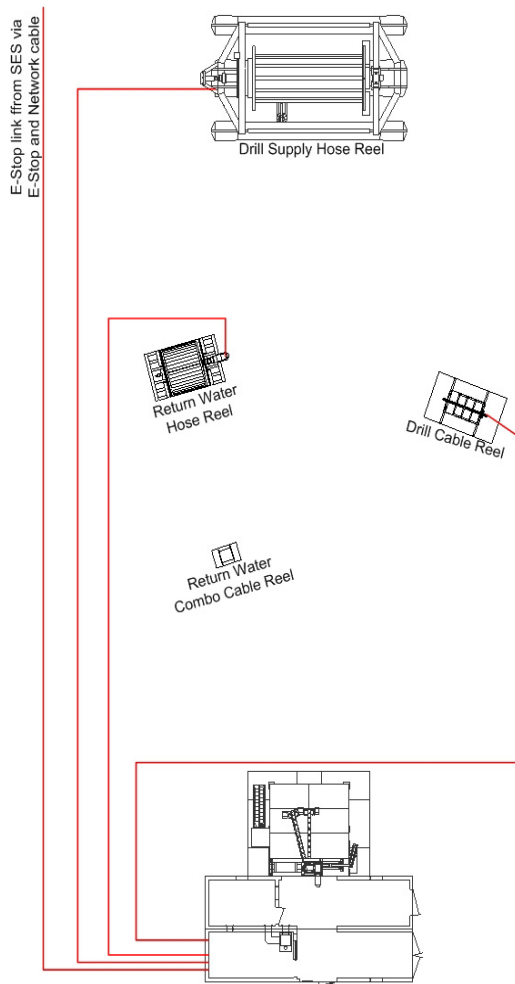
A simplified schematic of the E-Stop wiring is shown in Figure 5.5. The MDS E-stop wiring is a "Daisy Chain" configuration. The chain starts at the DCC and continues in a counter clockwise direction around the SES to the MHP4 then back to the PHS and ending again in the DCC utility closet, as shown in Figure 5.6 below.



**Figure 5.6** E-Stop cabling at the SES and at the TOS



Also in the closet are E-stop breakout boxes that provide a means to continue the circuit down to each of the TOS's. The E-Stop/ Reel Stop configuration at the TOS is as shown in Figure 5.7 below.



**Figure 5.7** TOS E-Stop/Reel Stop cabling

Each MDS contains an E-stop cable that is marked to indicate where each connector is plugged. Each MDS has an E-stop enclosure with a E-stop in and E-stop out connector, as shown in Figure 5.8 and Figure 5.9 below.



**Figure 5.8** E-Stop enclosure where the E-stop cables enter and exit at the front of the cabinet



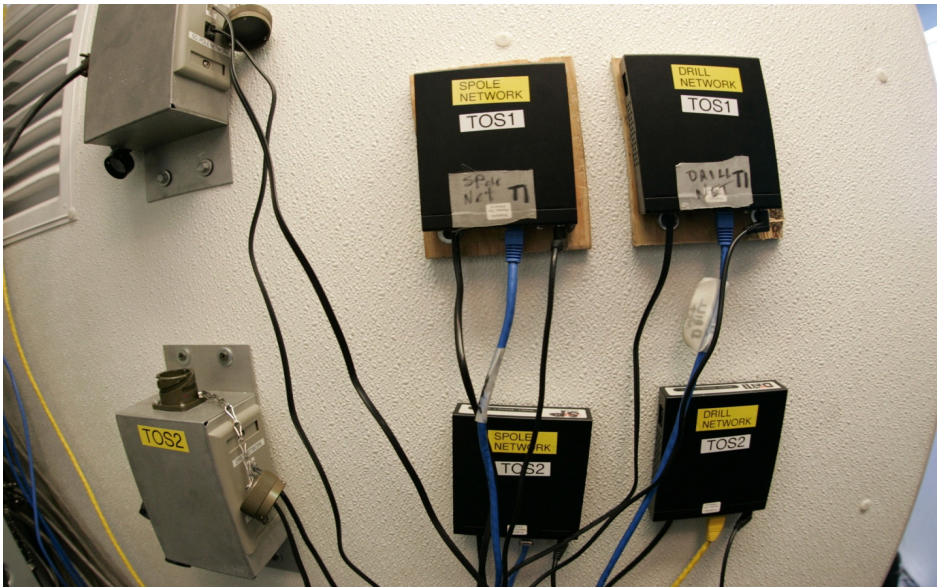
**Figure 5.9** E-Stop enclosure where the E-stop cable enters from the side of the closure

EHWD Drill Camp Layout Drawing #8510-0002 contains a sheet showing the connection path of the SES E-stop cables.

The utility closet in the DCC houses the E-Stop enclosure and the TOS1 and TOS2 breakout boxes as shown in Figure 5.10 below.



**Figure 5.10** DCC utility closet showing the breakout boxes to the right.



**Figure 5.11** A closeup of the TOS1 and TOS2 breakout boxes

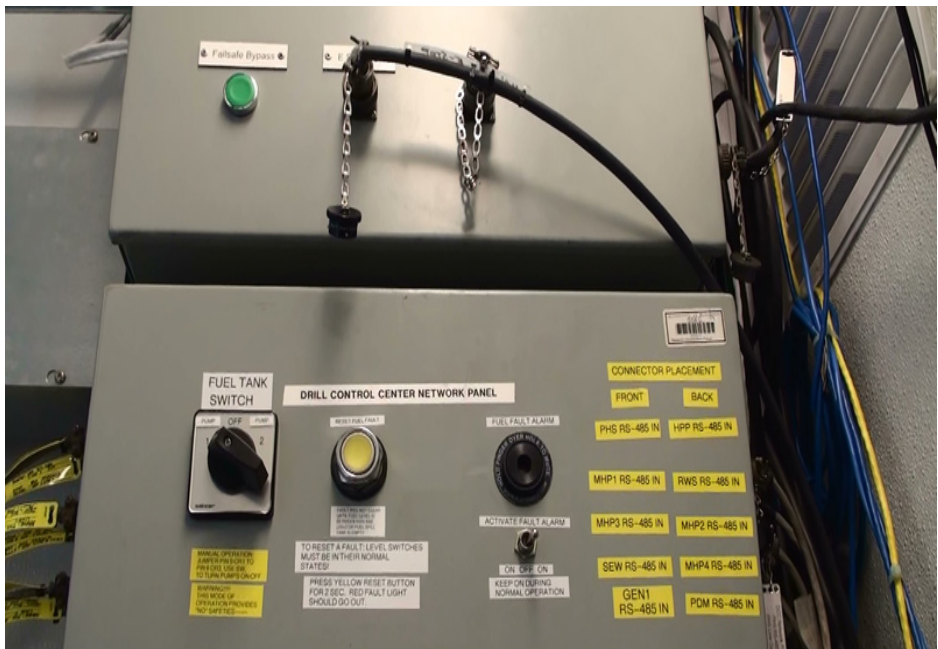
Click on the link below to view a video giving an overview of the E-Stop system.

## E-Stop Overview.mp4

### 5.5 Connecting Network System

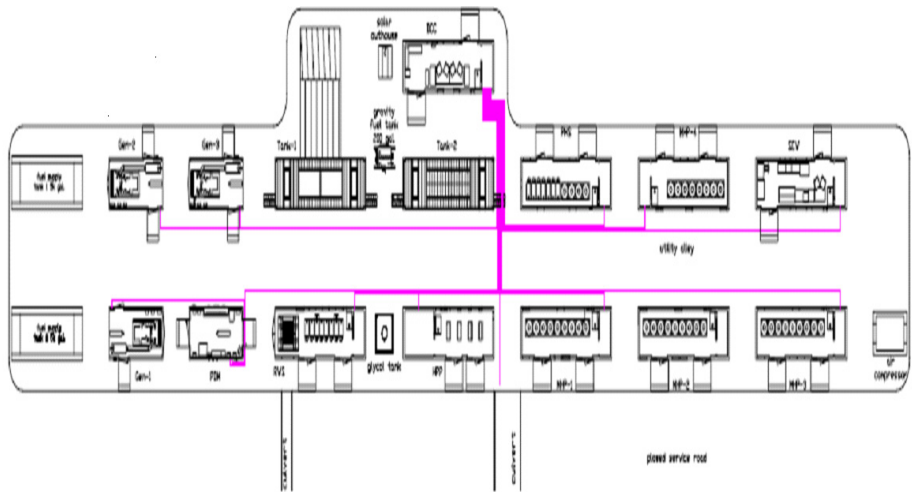
All network cables run from the utility closet of the DCC to each of the MDS's. The cables are grey and each has the connectors marked as to which end goes to the DCC. They are not reversible. The cables have been stored in the SEW.

The cables once entered into the DCC utility closet thru the rear wall connect to the right side of the Network distribution box, shown in Figure 5.12 below. Their position is important and must correspond to the markings on the door of the Network distribution box. The other end of each cable connects to a Network Box in the utility closet of each MDS.



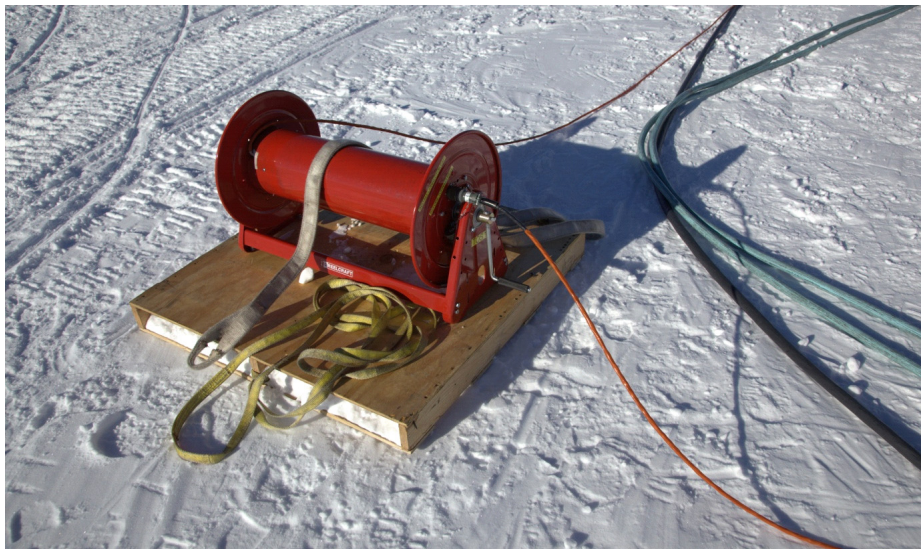
**Figure 5.12** DCC network panel below the E-Stop panel with incoming MDS connections on the right

The connections between each MDS and the DCC are shown in Figure 5.13 below.



**Figure 5.13** Network connections between the DCC and each MDS

Note one connection in the above diagram leaving the DCC but not connected to an MDS. This network cable connects to the TOS at the drill site. The cable used for this connection is shown in Figure 5.14 below.



**Figure 5.14** Comms, network and E-stop cable which connects DCC to TOS

As well as carrying the network information between the DCC and the TOS, this cable also provides comms between the two sites as well as links the two E-stop systems.

Two of these cables connect each TOS to the DCC. Switching between TOS1 and TOS2 is done via the breakout boxes shown in Figure 5.11 above.

EHWD Drill Camp Layout Drawing #8510-0002 contains a sheet that provides a depiction of the Network cable connections.

## 5.6 Installing Sensors

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All DNF sensors are located in boxes located in the IceCube Lab. Each box is clearly marked for each MDS. Each sensor is connectorized and all mounting brackets have been left in the MDS's. Installation consists of mechanically mounting the sensors to the brackets or screwing the sensor to a plumbing fitting and connecting the electrical pigtail to a matching electrical cable mounted nearby.

A complete list of EHWD sensors can be found in EHWD Control System I/O Summary Drawing #8510-0067. This file contains details on all the sensors on the drill and has been attached below for reference.



sensor list

## 5.7 Installing submersible water pumps in WT 1 & 2

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- 1 Locate pumps and riser hoses and check for damage to pumps, plumbing and power cords.
- 2 Locate transfer pumps and hoses for installation in WT-1. Transfer pumps are shorter and have 4 inch riser hoses.

- 3 Lower transfer pumps down on the screened well on the end of WT-1 that is closest to WT-2. Make sure that the power cord is taped to the riser hose and the electrical plug for the pump will reach well above the high water line in the tank.
- 4 Install the transfer hoses to WT-2 into the transfer pump riser hose.
- 5 Locate 4 charge pumps for installation into WT-2. The pump arrangement is, 2 charge pumps in each screened well.
- 6 Lower the pumps into the wells avoiding tangling the riser hoses and make sure the power cables are secured and have enough length so the electric plugs clear the high water line of WT-2.
- 7 Connect the riser pipes to the HPP supply lines, making sure to make sure that the charge pump supply line is connected to the correct HPP inlet.
- 8 Connect the power cord from each charge pump to the correct numbered connector on the side of the HPP cord number, located on side of HPP.

## 5.8 Providing Ramp to Water Tank 1

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A snow ram must be built to allow the dumping of snow into Water Tank 1 after 3000 gallons of seed water is in the tank. This is typically done with a dozer, but could be constructed with a 953 track loader as well. The Water tank is 8 feet tall and the ramp length is around 54 feet for the approach to the ramp and approximately 15 feet wide.

As seen in the picture we have constructed steps to the top of the water tank for access to the Dog House Manifold valves and access to the Water Tank covers where snow is dumped into the water Tank.



**Figure 5.15** Ramp to water tank 1

## 5.9 Burying Cables and Fuel Lines

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The need arises to bury cable and fuel lines through traffic areas when connecting the MHP's, PHS, Shop, MECC, DCC, HPP, RWS and Purple palace. The 287 aka "Gus" is a piece of equipment that can be used to start the trenching in between the buildings and across. A pick and spade shovel are also useful tools to bury the cables and fuel lines.

We have found that placing a chain on top of the cables or fuel lines prior to placing plywood over the lines aides in removal at the end of the season. Mark and leave the end of the chain out on both sides of the trench prior to filling the trench back in with snow. This will enable you to connect to "Gus" and pull up with the bucket exposing the lines or cables for easy removal.



**Figure 5.16** Preparing to bury cables



# Chapter 6

## 6: SES SYSTEM COMMISSIONING

### 6.1 Introduction

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The aim of this chapter is to describe the steps involved in testing the Seasonal Equipment Site (SES) once it's assembled, setting the safety systems and making the SES ready to accept water at the start of the season. Finally, a description is given of how to introduce seed water to the system and how the water tanks are filled.

Once these steps are completed the SES should be ready to run and to start circulating water into the Rod Well in order to develop the Rod Well to the point where it has a big enough volume for drilling to commence.

This chapter assumes the SES has been fully assembled, with all plumbing, electrical wiring, sensor wiring, network, E-stop cabling and fuel system in place.

### 6.2 Leak Testing Fuel system

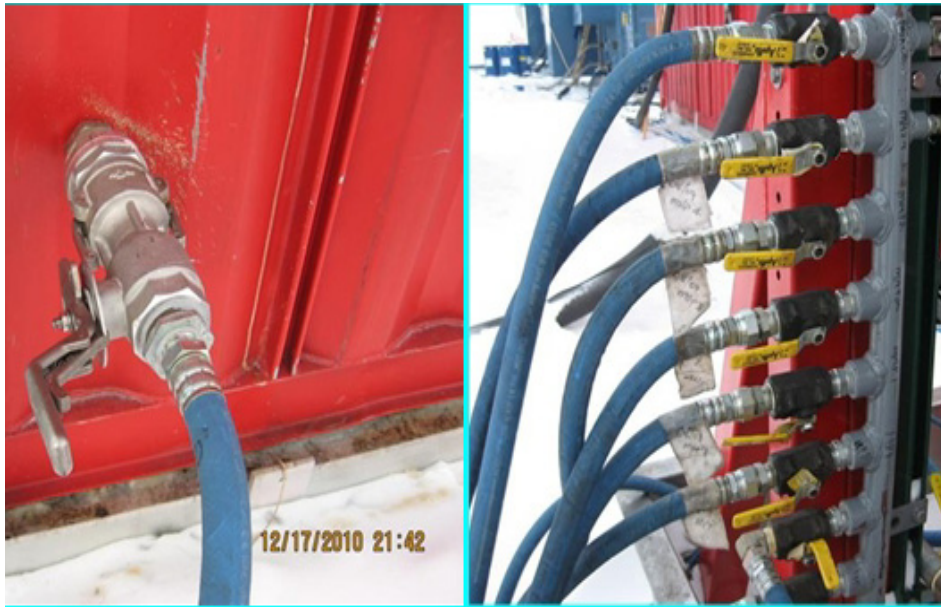
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To leak test the fuel system you will need to have a fully operational E-stop system to allow the fuel solenoids to be in the open position in MDS' that are equipped with them.

Tools needed; flashlight, fuel absorbent pads, open ended wrench set, fire extinguisher, line and catch container for the air bleeder tube.

To leak test the fuel system:

- 1 Make sure all fuel valves at the day tank, shown to the right in Figure 6.1, are in the off position.



**Figure 6.1** MDS dry disconnect and Fuel day tank showing output valves

- 2** Make sure all fuel lines are connected to the MDS's and dry disconnects, shown to the left in Figure 6.1, are in the closed position
- 3** Check MDS's for any open valves or lines to atmosphere and close or replace.
- 4** Open fuel valve on day tank to one MDS and check fuel line to MDS for leaks.
- 5** Open dry disconnect valve on outside of MDS and check valve for leaks,
- 6** Go inside MDS and if MDS is so equipped, open air bleeder until air bleeder is full of fuel.
- 7** Check all fuel lines, fuel valves, fuel connections, heater bleeder valves, and fuel radiators for leaks.
- 8** If any leaks are detected shut dry disconnect valve, repair leak, open dry disconnect and re test for leaks. Once MDS is determined to have no fuel leaks proceed to next build and repeat the last five steps.
- 9** Generator sets are done the same as MDS's with the exception that the generator needs to be running before the return fuel return line to the day tank, which also has valve which must be open, can be checked for leaks.

## 6.3 Leak Testing Plumbing System

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Leak testing needs to be done on the SES system after the plumbing systems are in place, pumps in service and water is flowing through the SES.

**note: Low pressure systems are not included nor have been included in pressure testing in the past. This includes generator cooling loop, Rodwell/RWS system, transfer lines between WT-1 and WT-2, PHS system, vertical turbine pumps and the condensate system. The low pressure systems are done by visual inspection after they have been put into service.**

To do the leak test in the high pressure plumbing side of the SES you will need the following:

- 3 people: one DCC operator and 2 drillers
- Radios
- One temporary valve to install on the output manifold of the HPP
- One 1.5” jumper line to connect from the temporary valve to WT-2

There are 2 MHP flow loops; MHP1&3 and MHP 2&4. A recommendation would be to do The initial leak testing of this system through one of these loops prior to getting the other loop “wet”.

- 1 Check HPP and MHP's for any open drain valves, open water lines, loose fittings etc.
- 2 When SES plumbing system is first activated, flow water through the HPP and MHP's using only the charge pumps in WT-2.
- 3 Divert water flow from normal flow loop through the temporary valve and jumper line.
- 4 Once flow is established, make sure all valves are open to allow flow through all MHP heaters.
- 5 Check for and repair any leaky fittings, valves or hoses and recheck system.
- 6 Once it is determined that there are no leaks, have DCC operator bring one HPP main pump on line at 800 RPM.
- 7 Check for and repair any leaky fitting, valves or hoses in the system and recheck.
- 8 If no leaks are found have, DCC increase the HPP pump to maximum RPM.

**Warning: make sure all valves are open to the MHP heaters to avoid over pressuring.**

- 9** Check for and repair any leaky fitting, valves or hoses in the system and recheck.
- 10** Once it is determined there is no water leaks, have the DCC operator lower the RPM of the HPP back to 800 RPM.
- 11** Once the high pressure system is back to minimum RPM coordinate with the DCC operator and second driller to watch the computer and pressure gauges in the HPP and slowly throttle down the temporary valve on the output line of the HPP until the system pressure is at 600 PSI and holding.
- 12** Check for and repair any leaky fitting, valves or hoses in the system and recheck.
- 13** If no leaks are found, have the DCC operator slowly increase HPP speed until the high pressure system is at normal operating pressure 1,000 to 1,100 PSI
- 14** Check for and repair any leaky fitting, valves or hoses in the system and recheck.
- 15** If no more leaks are located have the operator shut down HPP and return to system flow using the HPP charge pump.
- 16** Return to a normal SES high pressure system loop and shut the temporary valve and remove the temporary 1.5” jumper line between HPP output manifold and WT-2.

## 6.4 Pressure testing Plumbing System

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There are of course a number of “plumbing systems” in the drill system. For the purpose of this sub chapter we will be discussing the high pressure water systems. These can be broken into two sub categories; SES and TOS.

### **SES MHP Water loop:**

This is the main drilling water loop as it travels through the SES. When first starting the drill system for the year, this will be a closed loop, not leaving the SES.

### **TOS Water Loop:**

This loop includes the Surface Hoses going to and from SES and TOS, the Main Hose Reel, and the Return Water Hose Reel.

The purpose of this testing is twofold. The first is to test the plumbing system for high pressure leaks, and second is to test the overpressure safety systems in a

controlled and monitored test. These Safety systems include torque limits of the HPP motors, pressure sensors in the HPP manifold, overpressure bypass valves at each high pressure pump and in each MHP, and at the Main hose reel (MHR), as well as a high pressure burst disc at the MHR.

The minimum number of people to do this test is four; One DCC operator, One in HPP and two in MHP's. Radios, and Wrenches for tightening fittings are also required.

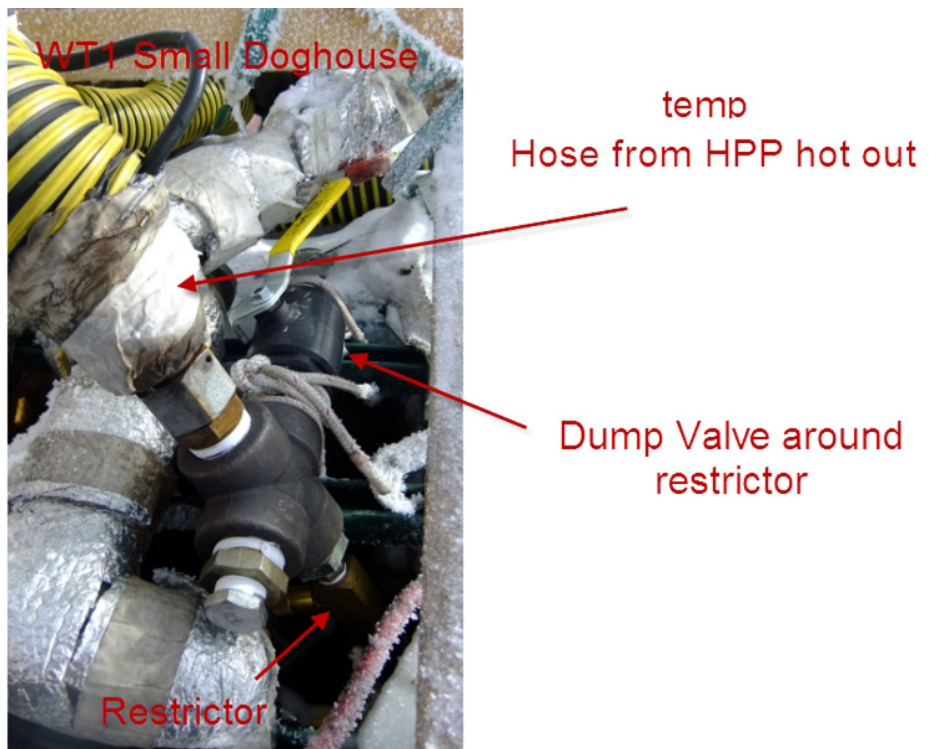
**Assumptions:**

Flow has been established From WT2 to HPP through all MHP heaters back to HPP and then through a high pressure jumper hose from HPP to WT1. Y-strainer screens have been cleaned and flow is established through all MHP heaters.

### 6.4.1 SES pressure test

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This test requires at least one operational HPP pump. The SES water flow loop may be established using charge pumps only.



**Figure 6.2** Restrictor setup at WT1 for pressure testing the SES high pressure loop

A restriction must be put into the loop in order to increase the pressure. The idea is to minimize the flow rate while enabling the required system pressure. An easy, but discouraged method is to crack open a ball valve. The problem with this method is that extended flow through a partially open valve will damage the valve. Additionally there is a human error component which could dead head the HPP. The restriction can be installed in a number of places. In order to test the complete section, it is logical to put the restriction in the HPP HOT OUT manifold, or as was done in the 10/11 season, at the WT1 return, as shown in Figure 6.2. The restriction could be a high pressure cap with a 3/16 hole in it dumping into WT1, or a small valve such as one of the flow control valves used in Figure 6.2.

The temporary HPP hot out to WT1 or WT2 jumper will also need to be a good condition high pressure hose in order to restrict the flow at the water tank.

**Caution: Make sure the hose is secured to WT1 well. The water coming through the restriction will spray with high velocity, resulting in a whipping hose if the hose is not secured.**

- 1 Set up Valves by closing valves back flowing to the high pressure pumps which are not used for the test. Open the rest of the valves through the MHP's being tested. Have Plumbers standing by to service leaks.
- 2 Start one High Pressure Pump at minimum rpm. Have one person stationed in each MHP that has flow going through it. Expect there will be leaks.
- 3 Close Dump Valve while making sure the restriction is open. The DCC operator should be closely monitoring the system to make sure the loop pressure does not spike too high. Pressure should come up as the system pressurizes. Check the full line for leaks. Leaks may be marked at this time to fix when pressure is relieved. Some leaks may be shut of by closing the top and bottom valve to a heater, for example. Make sure to check at WT1 in case the hose comes flying away from the dump area. One man in the DCC and one man in the HPP can monitor pressure and be ready with the e-stop.
- 4 Ramp up the RPM in stages. With water flowing through the restriction the pressure will rise as the HPP rpm increases. Good communication from DCC to HPP to MHP is required. Everyone should know the current pressure and leak status. When the pressure is at a reasonably low pressure; eg. 150 psi, it would be a good idea to open the dump valve to check the "rapid pressure loss" pump shutdown routine programmed into the control system. This will be a safety feature programmed into the system in case there is a hose blow out during testing and throughout the season's operation.
- 5 Fix leaks as required. Stop and make repairs and then ramp up again, until all leaks are stopped at 1000 PSI. Do be wary that a lengthy stop in flow could result in a frozen line. Plan accordingly!

- 6 After the SES loop is complete, then you can connect flow through the surface hose to the TOS and back. The return line is generally not considered to be a full high pressure line. Although there is potential for the return line to be pressurised accidentally, so a 600 psi check may be prudent. For a full 1000psi (at the HPP) check of the supply side, a restriction will need to be put in at the hose reel manifold. You will want to test the manifold itself, so, putting the restriction at the jumper outlet might be a good idea. An old 1.5" valve may be a good idea here, then you can crack this valve without worrying about damaging an in line hard plumbed valve. This should pressurize the manifold and allow the flow after the bypass valve area to go around and back to camp.

## 6.5 Setting and Inspecting System Pressure Limits

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There are a number of pressure safeties throughout the system. Their location, nominal setting, and whether or not they must be set/tested during commissioning is shown below (PRV = Pressure Relief Valve):

Pressure Safety	Location	Nominal Setting	Set/Check Seasonally
Torque Limit	HPP motor drive	1150 psig (44% max torque)	yes
HPP PRV (x4)	Outlet of each HPP	1250 psig	yes
MHP PRV (x4)	Hot manifold of each MHP	1300 psig	yes
DSHR PRV	Inlet manifold of DSHR	1000 psig	no, see Note 1
Burst Disk	Inlet manifold of DSHR	1200 psig	no, see Note 1
PHS HTR PRV	PHS heater inlet manifold	150 psig	yes
PHS FLTR PRV	PHS main filter inlet	150 psig	yes
RWS PRV	RWS idle inlet from HPP	300 psig	yes

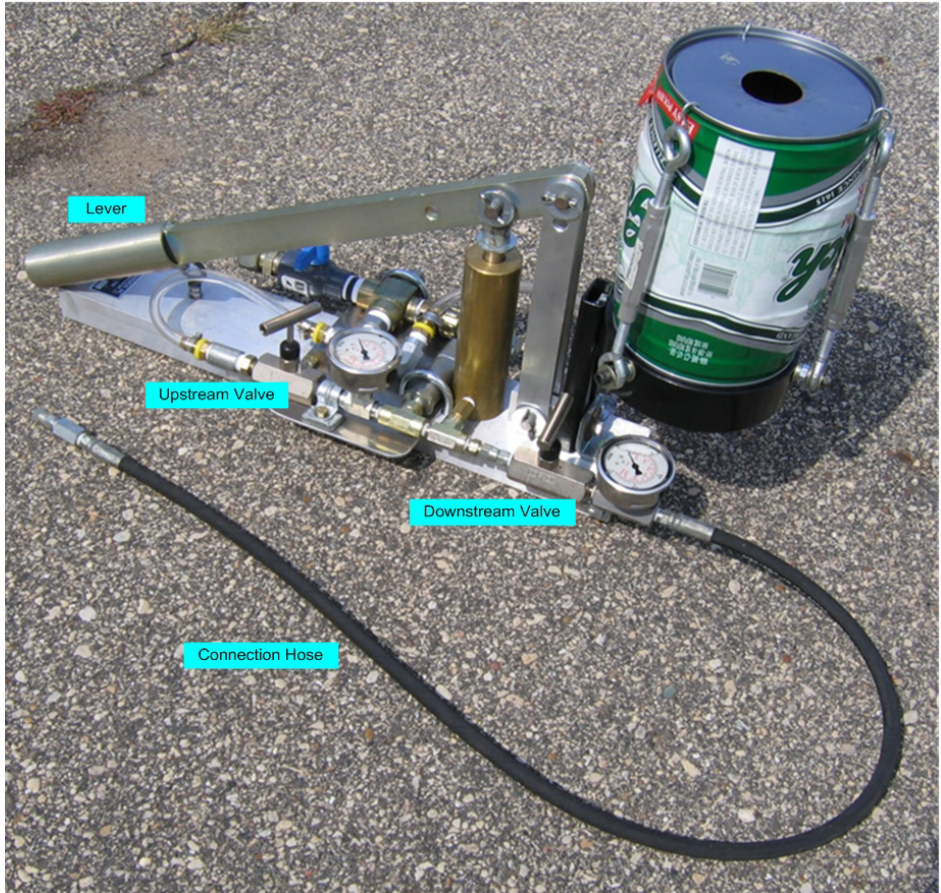
**Figure 6.3** Table of pressure relief safeties, their settings and testing requirements

Note: These safeties do not need to be reset each season, but should be inspected at the start of each season along with their discharge plumbing. See explanation below.

Before running the system up to pressure for testing, it's a good idea to guarantee at least one of the pressure safety systems is properly set. The MHP PRVs are easy to set independent of the primary system by using the proof pump, discussed below.

## 6.5.1 Proof Pump Primer

The proof pump, shown in Figure 6.4, is a low volume, high pressure hand pump. It has an onboard reservoir for water, but can also be hooked up to a low pressure water source to fill a larger test volume. When using the proof pump, always assure the test volume is free of air pockets and completely full of water! This typically requires the test volume to have a vent at its highest point so air vents out during fill, and that can be capped afterwards for pressure testing.



**Figure 6.4** Proof Pump. An onboard PRV limits the proof pump to 2000 psig

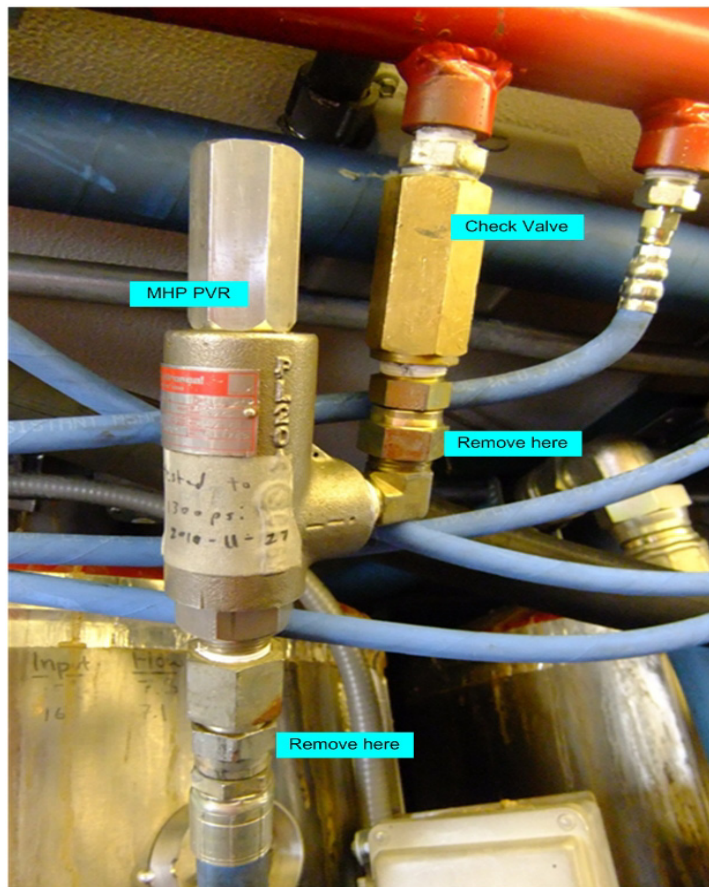
The proof pump can be used to set pressure relief valves, however the valve's pressure setting cannot be verified at rated flow using this method. Always make sure the valve has a properly rated flow capacity for the line it's being installed on by checking the nameplate and specification.



The proof pump can also be used to test pressure integrity over a period of time. First, pressurize the test volume to desired test pressure, then close the downstream valve to isolate small leaks in the proof pump plumbing from the test volume plumbing. The proof pump can be detached while the test continues, leaving the monitoring pressure gauge behind with the test. Before unhooking any plumbing at the completion of the test (or to detach proof pump from test instrumentation), relieve the pressure by opening the upstream valve.

## 6.5.2 MHP PRVs

The MHP PRVs are located up on the y-strainer flushing manifolds, as shown in Figure 6.5. They are fed from the hot manifolds in each MHP, and discharge into the y-strainer flushing manifold, which ultimately ends up in the condensate collection tank for that building.



**Figure 6.5** MHP PVR. Flow goes from bottom to top (into red manifold)

Position of these PRVs is critical. They need to be near the ceiling and discharge directly somewhere warm so that their discharge lines do not freeze. This can happen when they are located on the floor. Feeding them from the hot manifold keeps enough heat in their feed lines to prevent freezing there.

To set the MHP PRVs, start by removing all 4 MHP PRVs. They're installed with swivel JIC fittings, so install/uninstall is easy. Bring them to the SHOP where setting them can be done in a warm and convenient space. Prepare an adapter that allows you to install a 1/4" female swivel JIC hose fitting to the inlet of the PRVs.

Hook the proof pump up to the PRV and pressurize, holding the outlet of the PRV over a collection can. Eliminating all of the air is not critical here because the volume is so small. Slowly pump until the pressure will not rise and water spurts out, adjust setting as needed. Set each to nominal 1300 psig.

Reinstall the PRVs in MHPs, and make note that the settings have been made/verified in the logbook and on the valve itself.

### 6.5.3 HPP Torque Limits

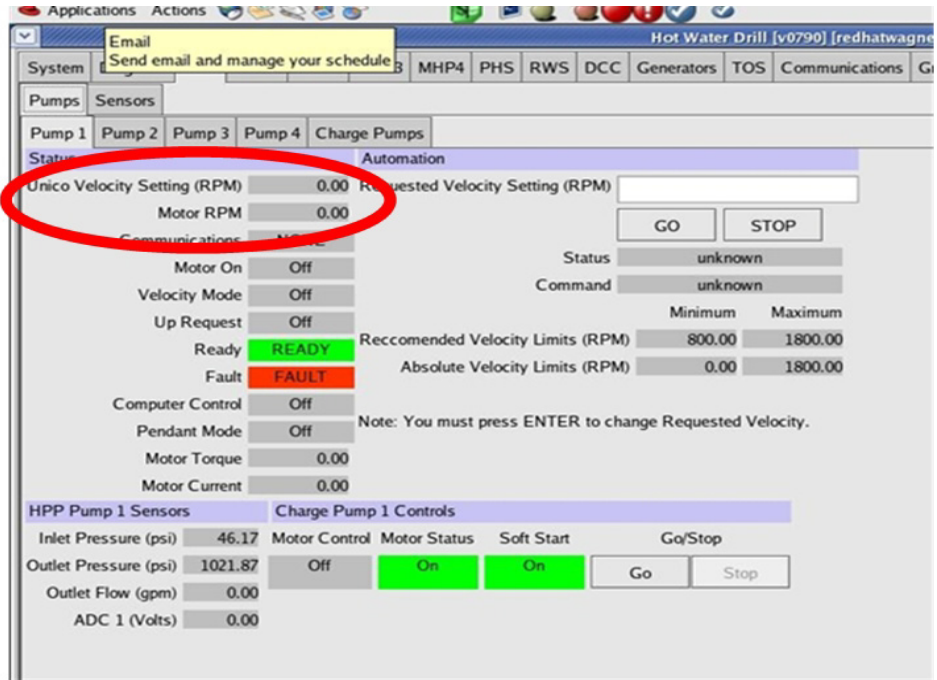
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Torque limits set in the motor drive of each HPP acts as a pressure limit by limiting the torque output of the motor, and is entered as a percentage of maximum torque. This is the first line of defense against overpressuring the system. The torque limit can be set and monitored at the Unico drive following this menu path:

1. Dictionary
  - 11.Man. Ctrl.
    3. torque limit [to set torque limit]
    4. torque cmd [to monitor torque command]

Due to system dynamics, the torque limit doesn't limit the pressure to a fixed value, but instead phases in over a range of about 100 psi.

The DCC operator can see an indication of torque limiting by comparing the commanded and actual motor RPMs on the individual pump tabs, shown in Figure 6.6. Consistent torque limiting throughout drilling of a hole should alert the operator that measures should be taken to reduce system pressure. The most common cause of this is excessive throttling of system flow through the heaters at the flow control throttling valves. This is why the standard procedure before start of drilling a hole is to flush y-strainers and completely open all flow control throttle valves. Note that during hole startup, torque limiting often occurs because the water in the system is on average cooler, which causes increased pressure drop. Pressure should settle and torque limiting should cease after about 15 minutes, when the hot water finally reaches the drill nozzle.



**Figure 6.6** Drill control system pump display tab

On pump tab, if Motor RPM (actual RPM) is consistently less than Unico Velocity Setting (commanded RPM), circled in Figure 6.6, torque limiting is probably occurring.

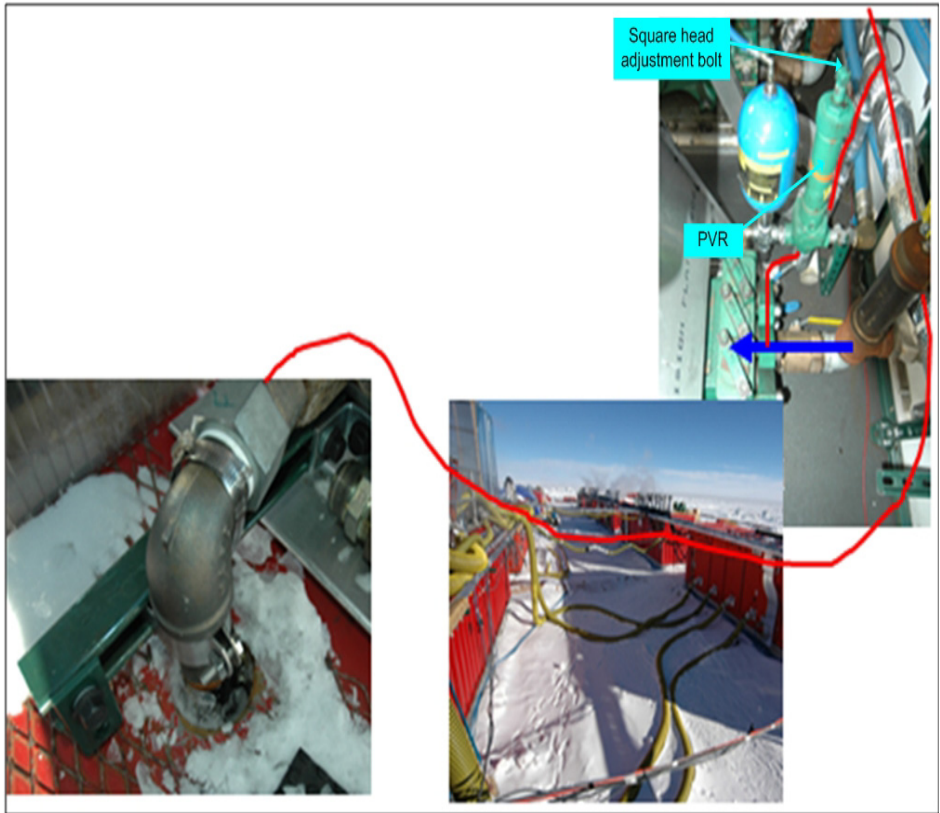
## 6.5.4 HPP PRVs

Each high pressure pump has its own PRV at the discharge, shown in Figure 6.7, which act as the second line of defense. These are spring operated lifters. Discharge water exits out the bottom and is routed back to Water Tank 2. The discharge water path to WT2 is shown in Figure 6.7. Adjustment is made by turning the square head bolt on top CW (to increase pressure setting) or CCW (to decrease pressure setting).

The most critical aspect of this pressure relief subsystem is keeping the discharge lines from freezing. This is accomplished in two (redundant) ways:

- 1 Continuous leak circuit.
- 2 Heat trace and heated hose.

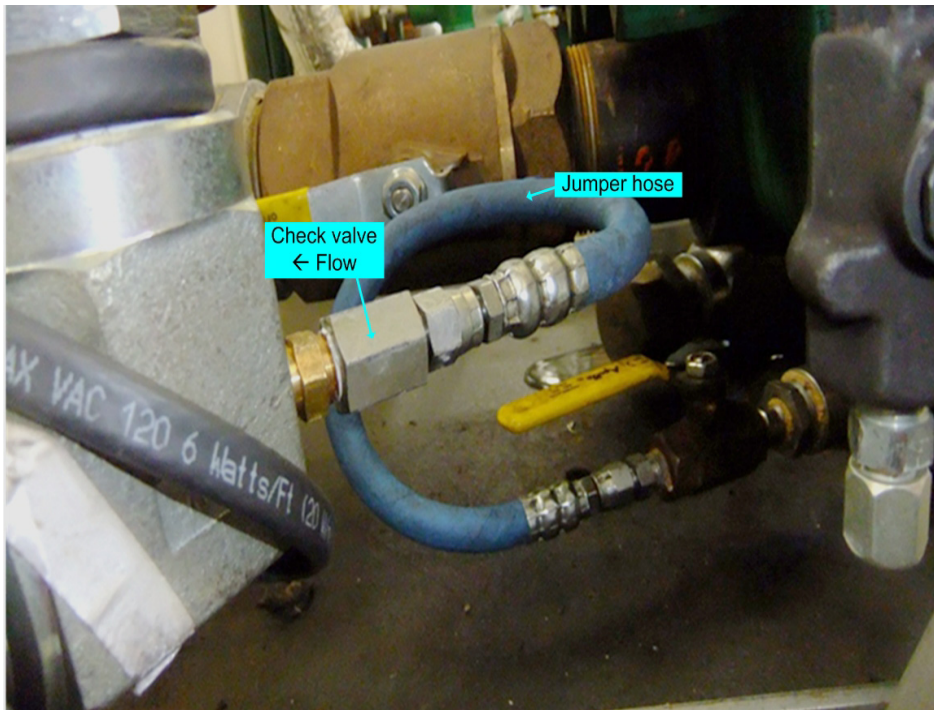
Proper operation of the leak circuit and heating must be checked initially during system commissioning and continuously throughout the season on a once-per-shift basis.



**Figure 6.7** HPP PVR location and discharge and leaker flow path from HPP to WT2

### **Continuous Leak Circuit.**

The leak circuit maintains continuous warm water flow through the PRV discharge plumbing. It is fed from the charge pump(s) via the HPP intake(s). The water ultimately returns to Water Tank 2. A small jumper line with check valve, shown in Figure 6.8, allows water in the high pressure pump intake to enter the bottom of the PRV at its discharge. The check valve prevents leak flow from back-flowing through pumps that are off (such as during idle when only one pump is running). There is also a shutoff ball valve (lower yellow handle in Figure 6.8) for maintenance. The combined flow from the discharge line dumps into Water Tank 2 inside the doghouse, and the discharge is plumbed so that flow can easily be seen exiting the end of this line, confirming that the line is not frozen. This is where a driller should check to confirm discharge flow once-per-shift, both during idle and drilling.



**Figure 6.8** Continuous leak circuit jumper line and check valve

### **Heat Trace and Heated Hose**

‘The discharge lines inside the HPP building are heated with four runs of heat trace fed by two dedicated circuits on the back wall. Each run has an end-light to give an indication that it is receiving power. The hose going from the HPP building back to WT1 is a heated hose and should also have an end-light of its own. All five end-lights should be verified to be on during rounds, at least once-per-shift.

#### **6.5.4.1 Setting HPP Torque Limits and PRVs**

Begin by cleaning the PRV discharge leaker check valves and setting proper valve configuration. The leaker check valves are small and become clogged over time, it's best to clean them right at the start. Remove the valves, clean with a poker tool, and reinstall. Make sure the leaker jumper ball valve is open for each pump. Once flow is established with charge pumps, verify leaker flow is coming out the end of the discharge line. Note this leaker circuit will be momentarily disabled during setting of the PRVs.

Make sure the four runs of heat trace in the HPP and the heated hose from HPP to WT1 all have end-lights, and that they are on.

Setting of the torque limits and PRVs requires 4 drillers with radios:

- 1** Driller in DCC to control pumps and RPM, monitor pressures and RPMs
- 2** Driller in HPP to make and monitor Unico settings, adjust PRV, and reconfigure pumps
- 3** Driller in MHP to make throttle adjustments to flow
- 4** Driller on WT2 to monitor discharge flow

Reconfigure SES flow so that all water from the HPP building goes through two heaters in one MHP building. System back pressure will be provided by throttling flow through the two heater flow control valves. Start with the valves fully open. These valves are rugged, and can easily be replaced if they become damaged. They are also upstream of the MHP PRVs, so it's certain adjustments won't be influenced by potential pressure relief from those valves. Note that this operation is now time critical since three buildings no longer have flow.

Close all the leaker jumper ball valves to stop leaker flow. This is so the driller monitoring discharge flow can easily tell if a PRV has opened or not.

For each high pressure pump, follow these steps:

- 1** Set torque limit artificially high.
- 2** DCC operator starts pump at minimum RPM.
- 3** MHP driller throttles flow until pressure in HPP reaches about 1000 psig.
- 4** Ramp up RPM in small increments so pressure creeps up on 1250 psig, the nominal PRV setting.
- 5** WT1 driller should start to see discharge in 1200-1250 psig range. If not, readjust PRV, drop RPM and creep back up again.
- 6** Continue increasing RPM. Discharge flow should increase, and pressure should be limited to about 1250 psig. PRV is set, make note in logbook noting actual setting.
- 7** Reset torque limit back to nominal 44%. There should be an audible drop in motor RPM and the DCC operator should see a difference between commanded and actual motor RPM. Observe pressure, it should be nominally 1150 psig. Make adjustments to torque limit if necessary.
- 8** Lower RPM until torque limiting stops, make sure there is also no discharge flow from PRV. Observe pressure.
- 9** Increase RPM again by a couple steps, watching motor RPMs and pressure. Pressure should be limited to a nominal 1150 psig by torque limit. Discharge from PRV should be minimal. Torque limit is set, make note in logbook about actual pressure and torque limit setting.
- 10** Lower pump RPM to minimum. Turn off pump.

Repeat these steps for the remaining pumps. The throttle valve settings need not be changed for subsequent pumps, but keep someone there in case an adjustment is needed.

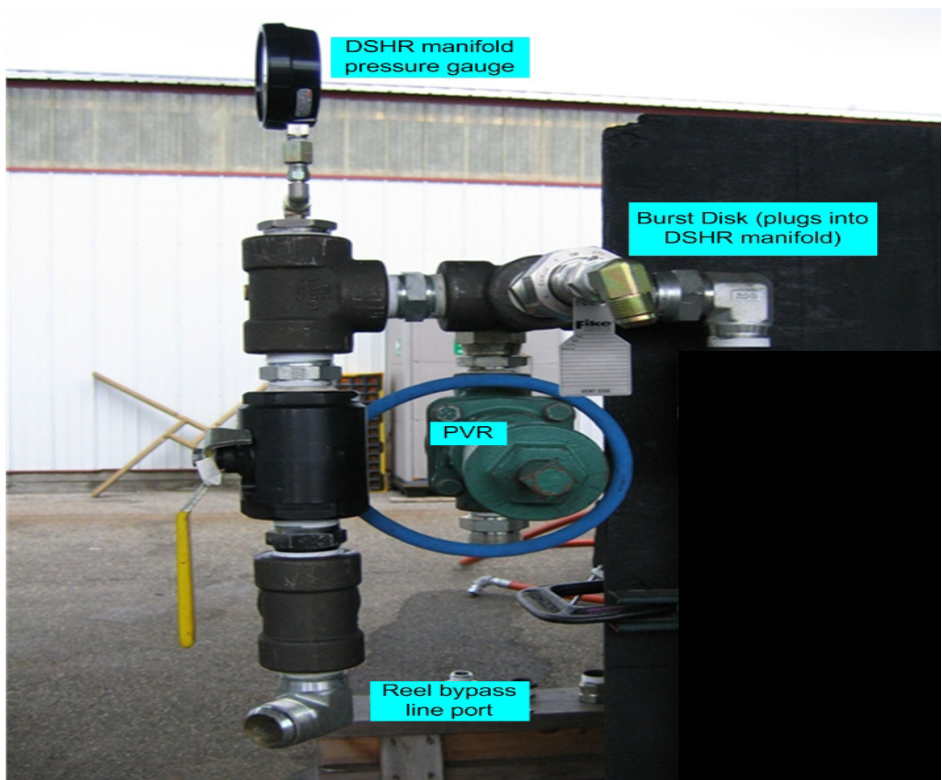
Finally, reestablish SES flow to all buildings, open all throttle valves, and open all leaker jumper ball valves to reestablish PRV leaker flow.

Click on the visdeo link below to play a video showing hoe the HPP pressure and torque limits are set.

## Setting HPP Press. and Torque.mp4

### 6.5.5 DSHR PRV and Burst Disk

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**Figure 6.9** DSHR PVR and Burst Disk

The DSHR PRV and Burst Disk, shown in Figure 6.9, are a part of the DSHR manifold. In addition to heat trace, warm water continually flows by these devices as it's being directed or leaked through the reel bypass port line. When installed on the DSHR, this manifold is completely covered in insulation.

The DSHR PRV and burst disk are a last line of defense. Their function is geared toward local protection of the TOS site and hose. The burst disk has the advantage of zero leakage, so its discharge remains free of water and will not freeze. If all the other safeties fail, this one should give out. However, rupture of a burst disk is a violent process, and time critical since flow needs to be shut down until a replacement disk can be installed. Therefore, a PRV is paired with the burst disk to provide a more suitable means of pressure relief local to the hose reel. The PRV is set lower than the burst disk rating.

**Note: Spare burst disks should be prominently displayed in the DCC where people can find them in a hurry.**

The settings at the DSHR can be lower than those farther upstream at the SES under normal flow conditions. Because of the pressure drop between the upstream safeties and the hose reel, a balance is needed to maintain proper protection but while allowing the upstream safeties to be the primary ones under these conditions. However, if the system is dead headed at the TOS or downstream from there, the DSHR PRV becomes the primary because it has a lower setting and there is no longer pressure drop between the SES and TOS.

Resetting the DSHR PRV isn't necessary each season, but the discharge plumbing needs to be inspected and its heat trace plugged in. Anything that suggests freezing should be remedied.

There is no setting involved with the burst disk, but its discharge plumbing should also be inspected.

It is very important that the heat trace for these safeties (and the overall DSHR manifold) be kept plugged in, especially immediately after hose reel moves. This manifold should also have an end-light so that power received can regularly be verified.

### **6.5.6 PHS heater PRV, PHS filter PRV, and RWS PRV**

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The PHS and RWS are full of "low" pressure plumbing, and therefore have pressure safeties that are set much lower. These are very critical safety valves because sometimes these buildings are integrated into the primary loop, which is fed by the HPP and protected to a much higher pressure limit.

The PHS PRV is upstream of the PHS heaters, and is a duel PRV design, as shown in Figure 6.10. This is because at the time of install, none of the available valves for the proper pressure range had enough capacity rating, so two are used in parallel.





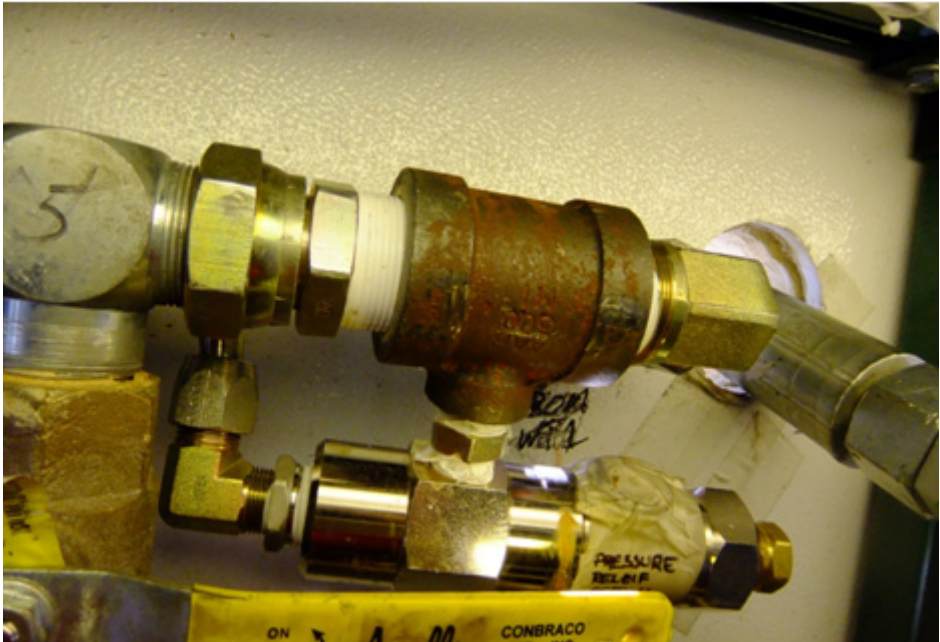
**Figure 6.10** PHS Heater PVR's

The PHS filter PRV is on the inlet manifold to the main filters, as shown in Figure 6.11.



**Figure 6.11** PHS filter PVR

The RWS PRV, shown in Figure 6.12, is at the idle inlet to the building. During idle, the RWS is fed through this line from the HPP via the MHPs and TOS, so this PRV is pretty important.



**Figure 6.12** RWS PVR

All of the PRVs in the PHS and RWS can be removed and set using the proof pump as described above for the MHP PRVs. Note the settings in the logbook and on the valves themselves.

## 6.6 Setting and Testing Heaters and Heater Safety Systems

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Heater setup and testing can be facilitated by using the checklist in Figure 6.13. Below that is a brief description of each bullet point in the checklist. Work heater by heater, and confirm with DCC what you are doing. You will need a heater with flow that can be adjusted over a wide flow range and one that can be cycled on and off for various amounts of time.

While doing heater setup, it is often handy to run the burner motor without having the heater fire. One easy way to do this is to turn the heater thermostat all the way down. Assuming the thermostat is in proper working order, this

allows the motor to run (to get fuel pressure for example) but will not allow the fuel solenoid to open nor the ignition to activate.

## Heater Checkout Checklist

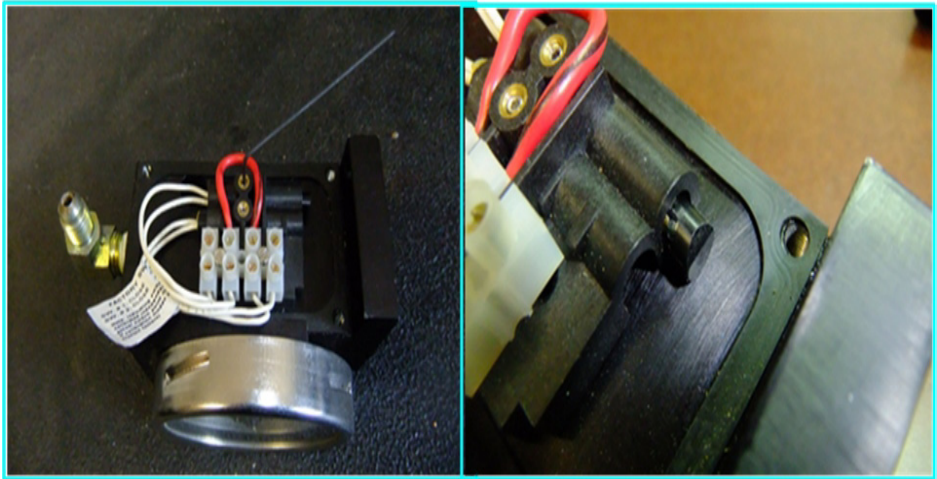
- Differential pressure switch set to 22 psid (Model 75) / 10 psid (Stinger)
- Differential pressure switch shuts down heater below set point, and yellow LED lights
- Thermostat set to 90 C
- Thermostat shuts down heater above set point, and red LED lights
- Computer shuts down heater for flow below software set point
- Computer shuts down heater for temp above software set point
- Holes sealed with aluminum tape
- No water leaks at 900 psi
- Condensate drain unplugged
- Burner fuel bled of air
- Combustion analysis, record in building logbook (nominal settings in parenthesis)
  - Excess Air (EA=40, adjust air bands as necessary)
  - CO<sub>2</sub>
  - O<sub>2</sub>
  - Ambient Temp
  - Stack Temp
  - Efficiency (Eff = 90% for Model 75)
  - Fuel pressure
  - Water flow (PDA)
  - Water temp in (DCC)
  - Water temp out (PDA)
- Air bands tightened
- Burner fires normally (no “puff”), and runs smooth
- Cycle heater on/off, allowing to cool between cycles, to shake it loose
- Y-strainer cleaned (note screen color in logbook)
- Y-strainer purgeable (purge line is not plugged)

**Figure 6.13** Heater checkout checklist

## Differential Pressure Switch set to 22 psid (Model75) / 10 psig (Stinger)

### Differential pressure switch shuts down heater below set point, and yellow LED lights

Refer to Section 2.7: Heaters for more detail and locations about these safety systems.



**Figure 6.14** Heater differential pressure switch

Figure 6.14 shows the inside of differential pressure gauge/switch. The photo on the left shows the reed switches on top and terminal strip beneath them. The image on the right shows the notch of reed switch is facing upwards.

For Model75 heaters, the reed switches are wired in series, so both must be properly set. The switches close when the pressure differential is at or above the set point, and a closed circuit satisfies this safety. If the heater is commanded ON and this safety is not satisfied, the yellow indicator light will illuminate.

For Stinger heaters, one of the switches provides local safety identical to the MHP heater configuration described above, but the other provides feedback to the network and acts as a safety/indicator via the control system software (LOW or FULL Flow). Setting both switches is important here too.

To set the switch, follow these steps:

- 1 Heater should be OFF, but have flow.
- 2 While getting feedback from the DCC, adjust the flow to desired minimum flow (5 gpm for Model75s, 2.2 gpm for Stingers).

- 3 Loosen set screw holding one of the switches with hex key.
- 4 Put a multimeter (continuity) on the terminals across the switch you're working on.
- 5 Make sure that the notch of the switch is facing UP.
- 6 Move the switch so that the switch is just open. Make very minor adjustments to flow to make sure it closes with a small increase in flow.
- 7 Tighten set screw.
- 8 Do step 6 again as the switches often get repositioned during tightening.
- 9 Repeat for the other switch.
- 10 Verify the switch point again against flow from the DCC, and make note in logbook. Typically at 5 gpm the differential pressure reads about 22 psid for the Model75s, and 10 psid at 2.2 gpm for the Stingers.
- 11 For the Stingers, in addition to the multimeter, get indication from the DCC that the LOW/FULL flow indicator is properly switching on screen as flow is adjusted around the set point.

‘To verify the differential pressure switch does its job, turn the heater ON while adjusting the flow up and down. The burner should stop (blower keeps running) and the yellow light should illuminate if the flow is adjusted below the set point.

### **Thermostat set to 90 C**

#### **Thermostat shuts down heater above set point, and red LED lights**

First check that the thermostat shuts down the heater if its set point is exceeded. Turn a heater on and adjust the thermostat up and down as the output water temperature ramps up. When the setting on the thermostat matches or goes below the indicated output water temperature, the burner should shut down (blower continues running) and the red light should illuminate.

If there's a discrepancy between the thermostat setting and the output water temperature, take measures to mitigate before moving on. The thermostat or sensor could be faulty, the thermostat knob could have rotated relative to the scale, or temperature readings on output water temperature could be off. If there's no discrepancy, set the thermostat to 90 C and move on.

Click on video link below to view a description of the heater thermostat.

Model 75 Thermostat.mp4

### **Computer shuts down heater for flow below software set point**

### **Computer shuts down heater for temp above software set point**

The easiest way to check the software safety is to reset the software set points to something below the current status of the heater in question. For example, for an OFF heater idling with 7 GPM of 17 C water, you might reset the software flow and temperature limits for heaters to 7 and 17, respectively. After confirmation, return the limits to normal.

Heater flow and temperature limits are set in software on the tab: System/Settings/Heaters. There are both warning and shutoff set points for temperature and flow for each building type (except RWS and PHS do not have flow sensors). Their normal values are shown in Figure 6.15 below. Perform the software check for both the warnings and shutoffs.

	<b>MHPs</b>	<b>RWS</b>	<b>PHS</b>
High Temp Warning (C)	89	89	89
High Temp Shutoff (C)	93	93	93
Low Flow Warning (gpm)	5.5		
Low Flow Shutoff (gpm)	5.0		

**Figure 6.15** Heater temperature and flow limit settings

The flow safeties for the RWS and PHS are tied to the differential pressure switches. When adjusting these switches (see above), the DCC should also be checking the software is preventing remote turn-on when the flow condition is LOW. Note there is no flow warning point for these buildings.

### **Holes sealed with aluminum tape**

Make sure any leaks in the heater enclosures and stacks are sealed with high-temp aluminum tape. Focus on penetrations and joints. Make a peel tab when taping over the diagnostic hole in the stack so it can be easily removed. Sealing leaks minimize CO concentrations in the buildings.

### **No water leaks at 900 psi**

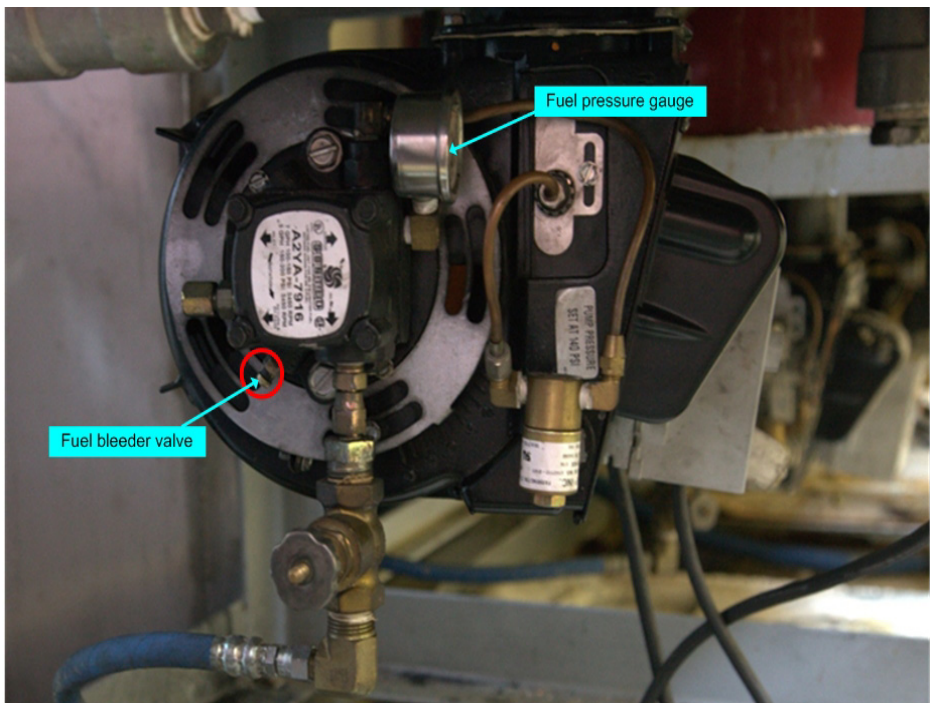
See Sections 6.2 and 6.3.

### **Condensate drain unplugged**

Often, the port and plumbing where condensate exits the heater becomes clogged up. A cross has been installed to assist in unplugging. Use a poker tool to access plumbing through the open cross ports and free the lines of gunk.

### **Burner fuel bled of air**

After hooking up the fuel system for the first time, each burner needs it's fuel feed bled of air. Find a small can to collect fuel and place it under the bleeder valve (if a can does not fit, Tygon tubing can be used between the bleeder and can). Turn the thermostat all the way down to prevent ignition of flame, and turn the heater ON. The fuel pump will prime the line, but there will be air trapped as well. This is indicated on the fuel pressure gauge by irregular or zero pressure. Crack open the bleeder valve and allow fuel to flow out. It should start out foamy. When the bled fuel turns from foamy to a solid stream, the air has been bled. Close the bleeder, reset the Honeywell controller, and turn up the thermostat to verify the heater fires and runs consistently for a minute or two. Fuel pressure should be stable. If not, or if the heater goes out (tripping the Honeywell), bleed again.



**Figure 6.16** Location of burner fuel bleeder valve

### **Combustion analysis**

A combustion analysis on each heater during startup is a good check that the heater is performing normally and efficiently. Although it's not necessary to record all of the following data (unrecorded confirmation is OK), it's nice to have a record of heater performance that can be referred to later on if needed. If a heater is out of tune, refer to the heater tuning section in Appendix E, page 19 to get it back to spec.

With help from the DCC operator and a Bacharach combustion analyzer inserted into the diagnostic port drilled into the heater stack, collect data on the parameters listed in Figure 6.17 (nominal range listed below is for Model 75 heaters only, Stinger numbers will be different, but still worth recording):

Variable	Nom. Range	Tool	Why?
<i>Excess Air (EA)</i>	35-45%	Bacharach	Critical tuning variable
<i>CO2</i>	4 – 8 ppm	Bacharach	Post combustion analysis
<i>O2</i>	8 – 12 ppm	Bacharach	Post combustion analysis
<i>Ambient Temp (TA)</i>	20 – 30 C	Bacharach	Post combustion analysis
<i>Stack Temp (TS)</i>	50 – 70 C	Bacharach	Post combustion analysis
<i>Efficiency (EFF)</i>	88 – 96%	Bacharach	Critical tuning variable
<i>Fuel Pressure</i>	125 – 150 psi	Fuel Pressure Gauge	To calculate true efficiency
<i>Water Flow</i>	6-7 gpm	DCC or PDA	To calculate true efficiency
<i>Water Temp In</i>	10 – 20 C	DCC	To calculate true efficiency
<i>Water Temp Out</i>	80 – 90 C	DCC, PDA, or Temp Display	To calculate true efficiency

**Figure 6.17** Model 75 heater parameters and nominal range

### **Air bands tightened**

If the air bands on the burner are not tight they can be bumped or vibrated to a different position and knock the heater out of tune. Whether or not adjustments have been made, it is a good idea to make sure the air bands have been tightened down.

### **Burner fires normally (no "poof"), and runs smooth**

The heater should not "poof" or "pop" when it fires up, and there shouldn't be excessive vibration, noise, smoke, smells, etc. If there is a "pop", it indicates the burner isn't firing as soon as it should, allowing fuel to collect in the chamber until it finally does ignite, violently. The most likely situation is that the heater is tuned for too much air, however it could be a number of other things. Refer to heater troubleshooting.



Monitor the heater for a few minutes until confident it is in good working order. If there are a few non-critical nuances about it, make note of them and come back to address during slow or down time.

### **Cycle heater on/off, allowing to cool between cycles, to shake it loose**

At the beginning of a season, the heaters and plumbing are fairly dirty. To clean them out, temperature cycling the heater expands and contracts the coils and acts to break loose more of the stuff that's attached itself to the inside walls of the coils. Do about 2-3 cycles.

### **Y-strainer cleaned (note screen color in logbook)**

Once the heater has been heat cycled, do a thorough cleaning of the y-strainer screen. The most effective way to clean the screen is to remove it and brush it clean. Refer to Section 2.7 in the heaters section for cleaning y-strainer screens, and remember to use a new compression sealing ring and dress the threads with anti-seize when putting it back together.

If the screen is damaged or very badly clogged, replace with a new one. Use the "yellow" screens.

The note about logging the screen color is just to help keep track of what screens are where, while generally working towards all heaters having "yellow" screens installed.

Screen color and mesh size:

022 mesh = No Color (standard size)

060 mesh = YELLOW (preferred)

100 mesh = BLUE

200 mesh = GREEN

300 mesh = RED

### **Y-strainer purge-able (purge line is not plugged)**

The y-strainer purge lines will plug over time if the flushing operation is not done for about 4 - 5 seconds or more. Plugged purge lines are difficult to immediately recognize, so preempt any issues now by testing the lines out while the buildings are relatively quiet.

Open the purge line and listen for flow emptying into the condensate tank. Get a visual if needed. There should be a healthy amount of flow (what you would expect for a ¼" line given the system pressure at the time). If any lines have little or no flow, clear them out.

To clean a flushing line, remove it and find a clog at either end. Clear it by using a long, small diameter drill bit to drill it out. Clogs in flushing lines can extend a considerable length into the hose, so a long drill bit is often necessary. If there is no clog in the hose, check the fittings and valves.

Click on the link below to view a description of the Y-strainer system.

Model 75 Y strainers.mp4

## 6.7 Providing Seed Water and Filling Water Tanks

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Seed water has to be provided from an existing supply. In the past the EHWD drill was always operated near the South Pole Station, which always was the source for the seed water. As the drill requires several thousand gallons of seed water it is always best to plan in advance for seed water.



**Figure 6.18** Seed water delivery tank tilted towards hose and delivering water

Be sure that there is a pump and hose that will connect to whatever water tank (the icetop water delivery tank is shown here is Figure 6.18) in which the seed water will be delivered.

1 At a minimum of twenty four hours before delivery of seed water start preheating the WT-1 with an external heat source, NGH style heater, large electric heater, bullet heater, etc.

2 After tank is preheated enter tank and install drain plugs.

**Warning: water tanks are confined spaces, follow all applicable rules before entering.**

3 Make sure that RWS and VT pumps one and two are operational.

4 Take delivery of water and park at bottom of ramp.

5 Connect pump and hose and fill WT-1 with approx. 2,000 gallons of seed water.

**Note:** If one load of seed water does not fill WT-1 enough to cover inlet of vertical turbine pumps another load of seed water will have to be added until water level is 3 inches above vertical turbine pump inlet. Keep external heat supplied to WT-1 while waiting for second load of seed water.

6 When water level is 3 inches above vertical turbine pump, have DCC start vertical turbine pump and monitor for flow, when flow between WT-1 and RWS is confirmed system is ready for heat.

7 Start circulating water from WT1, through the heaters in the RWS and back into WT1 in order to heat the water in the tank. At the same time, dump snow through the top of WT1 to fill the tank. Once the snow has melted, dump more snow and continue doing so until WT1 is almost full.

8 When necessary, transfer water from WT1 to WT2 and do this periodically until WT1 and 2 are both at capacity.



# Chapter 7

## **7: ROD WELL DRILLING AND DEVELOPMENT**

Click on the video link below to view the RWS pump installation process

Installing the Rodwell pump.mp4



# Chapter 8

## 8: TOWER OPERATIONS SITE SETUP

### 8.1 Introduction

---

Before any drilling can commence, the TOS and TWR needs to be set up. This chapter will outline how that is done.

To speed up the startup process on a drill season, part of the TOS could be heated during the off season. The TOS and DCC are in the off season normally used for storage of DNF equipment found throughout drill camp. If the TOS is not heated in the off season, other storage will have to be used for the DNF equipment.

This chapter will assume that the TOS has been winterized and has not been disassembled, with the Electrical Closet and Drill Control Room heated in the off-season and that no DNF equipment has been removed from the TOS.

### 8.2 De-winterizing Tower Operations Structure (TOS)

---

The electrical closet and the control room (deployment and drill control) contain motor drives, computers and UPS's that are DNF. Those rooms, as well as the rest of the TOS should have been sealed off and insulated for the off season. The side of the TOS that connects to the Tower, should have its sealing panel installed. The electrical closet and drill control room has been heated in the off-season.

The TOS is normally used for off-season storage of DNF equipment found elsewhere in drill camp, as only TOS and DCC are kept heated. This DNF equipment will need to be moved out and installed at its designated place. All off-season insulation in the TOS also needs to be removed. Check the equipment in the TOS is in place and operational condition.

### In the Drill Control Room:

- The two drill/deployment computers (one server/master, one client/slave) in the drill control room should be hooked up and tested. Each computer comes with a set of monitor, keyboard and a mice. Update the EHWD software with the most current release.
- Ethernet switch. Located in the computer rack.
- DDB (Deployment Data Box). Located in the computer rack.
- DCB (Drill Communication Box). Located in the computer rack.
- UPS (Auxiliary power). Check that the batteries are in operational condition.
- Communication radio, programmed and installed.
- Electrical space heater x1, verify function.
- AED, battery replaced and tested (by station medical personnel)
- Chemical fire extinguisher.
- Optional: There is a radio controlled level wind adjuster box located in the Drill Control Room. It is not a necessity for the operation of the drill, but can be useful when adjusting the level wind positions.

### Electrical closet:

- DSHR Drum Motor Drive,
- DSHR Level Wind Motor Drive,
- DSCR Drum Motor Drive,
- DSCR Level Wind Motor Drive,
- RWCR Drum Motor Drive,
- RWHR Drum Motor Drive,
- Tower Hoist Drum Motor Drive,
- Return Water Pump Motor Drive)
- Line Filter (for Return Water Pump communication)
- Modems x2 (for DSL communication with SES)
- E-stop Controller
- Chemical fire extinguisher
- And other equipment that's not DNF and should never have to be removed (transformers, breaker cabinets, relay cabinets, reel stop cabinet, furnace etc).



### Rest of TOS:

- Install DCM (Deployment Control Module), located below the window of the Drill Control Room.
- Install the motor drive pendants (to DSHR, DSCR, Tower Hoist, RWHR and RWCR). RWCR has a smaller, yellow pendant. The other pendants are the conventional, black style.
- Check E-stop slap buttons inside and outside the TOS as well as cables to and from the button to the electrical closet.

## 8.3 De-winterizing Tower

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The tower is not considered DNF. The tower should have been sealed for the off-season, to avoid snow accumulating inside the tower. Most likely some snow will have drifted inside that will have to be removed.

Remove the metal panel from the rear of the tower. This side connects to the TOS. Open up the top of the TWR, where the hoses and cables will exit.

Check that all equipment in the TWR is in operational condition and all mounts are ok. Specifically:

- Check the lower cable sheave for any damages; that bearings, rollers (x 3) and the wheel are in operational shape.
- Check both the crescent conveyor belts for damage and that they move a full rotation without problems. Ice has not cracked the belt, bearings are in shape etc.
- Check the fairlead assemblies for damage and that they tilt effortlessly.
- Install the load cells for the hose crescent and the cable sheave, both on top of the TWR.
- Check both the cable sheaves on top of the TWR; that they rotate without problems, bearings are in good shape, both rollers are in place.
- Install the load cell amplifier box inside the TWR, on the wall right above the weight stack and hook up the top mounted load cells to the amplifier box.
- As soon as the TOS/TWR has been powered up and the E-stop system is operational, check the tower hoist for any problems. Does it move as expected? Does the break engage? Is the entire wire rope in good shape, without evidence of straining or stranding?
- Check the manual winch mounted on the traverse in the ceiling of the TWR in the same fashion as the tower hoist.

- Check that the capstan rope winch in front of the TWR is operational.
- Check the E-stop slap buttons on the tower and cables leading to and from them. There's one slap button inside the door of the TWR, one outside the TWR at the cable sheave side and finally one on top of the TWR. Make sure they are reset.
- If not already in place, the weight stack will need to be secured on the wall of the TWR.
- Tools needed should be inventoried. Tools such as adjustable wrenches, 2 ¼" fixed wrench, 6 mm Allen key, 2000 - 6000 lb choke rated slings (different lengths: 2 ft, 3 ft, 6 ft), ropes, flow bypass fittings (for bypass flow inside and outside the TWR), hole covers (for deployment and drilling), weight stack elevators, weight stack installation clam shells, weight stack collars with screws and any other tools required for drilling.

## 8.4 Connecting Tower to TOS

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Move the TOS to the upcoming drill site. See Chapter 13 - "Preparing Site at Next Hole" and Chapter 14 - "Relocating TOS/TWR at Next Hole" for information on how the drill site is prepared and how to move and position the TOS at the drill site.

The TOS is now in place at the drill site, and is ready to be connected to the Tower. Power has been hooked up to the TOS, and heaters are running, keeping the electrical closet and drill control room warm.

Since it is the first time of the season coupling the TWR with the TOS, a couple of additional steps are taken.

- The panel (as described under "De-winterizing TWR") to the TWR has to be removed.
- The side panel covering the hole facing the TWR has to be removed.

Optimally put the two panels on top of the TOS roof, to make them easy to find at time for winterizing.

Back up the TWR to TOS as described in Chapter 14 - "Relocating TOS/TWR at Next Hole".

## 8.5 Powering and Heating TOS/ Tower assembly

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### 8.5.1 Powering the TOS

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The TOS is powered from the PDM located at SES. A single 100 A, 480 V, 3-phase cable runs from SES to TOS. Depending on the distance several serially connected power cables may be needed to reach the TOS. The power cable is hooked up to the power box on the short end of the TOS. The key in the Appleton connector at the power box is oriented 90 degrees differently than the surface power cable Appleton connectors. Therefore a pigtail cable is used as an adapter between the power box and the power cable. Make sure the power cable is de-energized before moving the power cable and connecting it by killing the power to the appropriate TOS at the PDM. Before connecting the power cable, turn off the main breaker inside the TOS electrical closet. Also make sure all other breakers are opened, such as the power breakers to the motor drives. When the power cable has been connected to the PDM and the TOS, first energize the cable at the PDM then close the main breaker at the TOS.

### 8.5.2 Electrical Heaters

---

There are four electrical heaters in the TOS. One in the drill control room, one in the electrical closet and the remaining two in the drill and deployment area. They supply heat to the TOS during the winter season and when the furnace is not running. Any time power is disconnected from the TOS, the heaters first have to be turned off and allowed to cool. Otherwise they will overheat and eventually burn out. Turn on the heaters to heat up the TOS. The heaters are mainly used when the furnace is not operational.

### 8.5.3 Furnace

---

A furnace is installed in the electrical closet. It can and will supply the TOS and TWR with all required heat. To get it running, hook up an external fuel tank (containing AN-8 or any diesel fuel). Two fuel hoses from the tank are needed to hook up to the two fuel fittings outside the TOS, on the short end closest to the electrical closet. One of the fuel lines is for supply, the other is used as a return line. This is to avoid that air/gases in the fuel line impair the function of the furnace. There is a manual ball valve inside the electrical closet that will need to be opened to supply the furnace with fuel flow. A breaker in the breaker box on the furnace side of the electrical closet is flipped to supply the furnace with power. There is also a breaker on the furnace itself to turn on the furnace. The Honeywell may pop before sufficient fuel flow has been established. The thermostat is located just outside the electrical closet. Note that the furnace will

not operate until the E-stop is operational. Check the section on E-stop to activate the E-stop.

Until the furnace is running and the TWR has been connected to the TOS, keep the electrical closet and the drill control room closed, to contain the heat for the DNF equipment.

## **8.5.4 Installing DNF**

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DNF (Do Not Freeze) in TOS includes motor drives, line filter, computers, UPS, modems, E-stop control box, communications radio, drill head, drill head communication box, DDB (Deployment Data Box), DCM (DOM Control Module) and AED.

Normally, since the TOS electrical closet and drill control room are heated in the off season, they are not removed. In case of a completely unheated TOS, the DNF equipment has to be removed and stored to be reinstalled the following drill season.

## **8.5.5 Check Equipment**

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- Check tower hoist.
- Install drill head.
- Check drill nozzle at weight stack.
- Check weight stack collars and bolts for cracks and other wear.
- Hook and power up drill head to verify communication.
- Check supply hose and return hose conveyor belt.
- Test E-stop.
- Test Reel-stop.
- Power up motor drives and verify reel function.
- Test limit switches on the reels, soft and hard limit switch.
- Check drum drive and level wind drive.
- Verify that the manual winch is operational and as no damage to the steel wire, hook or traverse.
- Check the steel wire for the tower hoist. Check that the hoist brake engages.

## 8.6 Positioning reels relative to TOS/Tower

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See Chapters 11 to 13, for description of site preparation and reel positioning.

## 8.7 Circulating Water through System at Start of Season

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### Assumption:

Water is already circulating through SES. Water is going through the heat recovery loop for the generators. The Rodwell has been started and a reservoir has been formed. Both water tanks are full and MHP/HPP have flow.

### 8.7.1 Preheating DSHR

---

The DSHR needs to be preheated before establishing flow through it. After the winter, the hose reel with hose will be cold, keeping ambient temperature. Any flow through the hose will be cooled fast, possibly freeze and block the hose (that is roughly 2600 m long). The hose reel should have a heating blanket on the inside, on the hub of the reel. It has been plugged in during the winter season. The outside of the reel is insulated to contain the heat. At the beginning of the season the reel is completely covered by a concrete tarp. Bullet heaters, space heaters and NGH may be used to heat the hub and the hose of the reel. The preheating will occur for as long as required to bring the temperature of the hose up to a level where confidence is felt that any flow will make it through the hose without complications. A warm hose is also less susceptible to damage than a cold hose.

### 8.7.2 Circulating Water through Surface Hoses

---

The surface hoses are installed. A supply hose is installed at the HPP, with the hose coming out from the HPP hot water supply. A return hose is installed coming into the return manifold at WT1. From the manifold is installed a heated hose leading to RWS for flow coming from the surface return hose to the Rodwell. The return manifold is heated with heat trace to avoid freezing. The heated hose is plugged in and thus heated.

Sufficient amount of surface hoses are installed to reach TOS and DSHR from SES. The surface supply hose and surface return hose are looped together. Circulate warm water through the surface hose.

### **8.7.3 Circulating Water through the Drill Supply Hose Reel**

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This is one of the most critical parts of season startup. Is the reel and hose warm enough to allow flow? Has any damage occurred to the hose during the off-season?

Prior to commencing water circulation through the main hose reel hose, it is important to get the water temperature as high as possible (up to 88 degrees Celcius) and circulating through the surface hoses first, until the surface hoses are hot and hot water is returning to water tank 1. At this point the main hose has to be fairly quickly placed in the loop as the water tanks can't be allowed to get too hot as this affects the submersible pumps and the high pressure pumps.

Once hot water has reached tank 1, Stop the flow. Once flow has stopped and system pressure is back down to 0 psi, disconnect the loop formed by the two surface hoses at the TOS site and connect the surface supply hose to the main hose reel inlet valve and the return surface hose to the main hose reel output. Restart water flow at 200gpm and 88 degrees Celcius and maintain a watch to make sure a steady flow is returning to water tank 1. This should take around 20 inutes at 200 gpm flow rate.

Once flow has been established through teh main hose reel and the hose is relatively warm, stop flow again adn place the return water hose reel in the water loop and recommence flow again. Once flow is fully established through the hose system, reduce the water temperature to around 35 degrees Celcius and a flow rate of say 35 gpm top maintain a water cilrculation loop in idle mode. See chapter 9 for placing teh ssystem in idle mode.

## **8.8 Setting up Local E-Stop System**

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The E-stop system is used for emergencies, to stop all hazardous equipment. A triggered E-stop will at the TOS halt all reels and engage the brakes. It will also halt the furnace and the tower hoist.

The E-stop buttons are located at each reel and at numerous places in the TOS and TWR. In order for the E-stop to be operational a number of cables have to be hooked up. One cable leading from the drill control room end to the E-stop button inside the TWR has to be hooked up. There is one cable leading from the DOM side of the TOS that is to be hooked up to the outside E-stop button on the cable sheave side of the TWR. The octopus/communication cables from the reels have to be hooked up to the E-stop inside the electrical closet.

Finally the E-stop control box has to be hooked up. The E-stop breaker on the wall of the electrical closet has to be in the "local" position. To activate the E-stop, turn the key to start on the E-stop control box. Make sure all E-stop buttons are released before starting the E-stop.

The reel stop is independent of the E-stop. Being triggered, the reel stop only halts the movement of the reels and activates the reel brakes. The reel stop buttons are yellow and are found on the reels and inside the TOS. To activate the reel stop, hook up the octopus/communication cables from the reels to the control box inside the electrical closet.

Once all reel stop buttons are released and all cables are hooked up, the reel stop is operational. The reset button at the control box can be pressed. If a yellow light comes on, the reel stop system is activated.

## **8.8.1 Switching from Local to Global E-Stop**

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### **8.8.1.1 Difference between Local and Global E-stop**

The E-stop is an emergency shutdown system in place over all drill camp. It is a closed loop system that consists of serially connected slap buttons located at and inside each MDS containing hazardous equipment. The E-stop is controlled by E-stop controllers located in DCC and at each TOS. If an E-stop is triggered, all hazardous equipment will shut down. That includes high pressure pumps, heaters and reels. Low pressure pumps, generators etc are not affected. The generators have their own dedicated E-stop system. The E-stop controller supplies the E-stop loop with a current. If a slap button is hit, the current will be broken which will trigger the controller to halt the hazardous equipment motion.

The E-stop can be in either local or global mode. In global mode the E-stop in SES is in series and connected to the E-stop in either TOS. That means that if an E-stop is pressed at SES or in the TOS, all potentially hazardous equipment in SES and the TOS hooked up to and controlled by the E-stop will halt. A TOS in local mode will not cause or be impacted by a global E-stop. If an E-stop in a TOS in local mode is triggered, the only equipment affected will be the local equipment in the TOS that is in local mode.

### **8.8.1.2 Going from Local to Global E-stop and Vice Versa**

In DCC and at each TOS are located E-stop controllers. The controller in DCC handles the E-stop in SES and also the TOS E-stop when the system is in global mode. The controllers in each TOS controls the E-stop locally when the TOS E-stop is isolated and thus is in local mode. The controller in the TOS is bypassed when the E-stop is in global mode.

In the electrical closet of DCC is located a switch box that allows the E-stop in SES to be serially connected to the E-stop in either TOS or to bypass the TOS' entirely. The E-stop can be in series with only one TOS at the time; the other TOS will be in local mode. The switch box has a flip switch which reads TOS1/Bypass/TOS2. If in the TOS 1 or TOS 2 position, the E-stop in SES will be globally connected to the E-stop in TOS 1 or TOS 2. If in the Bypass position, SES will be in local E-stop not connected to either TOS. The E-stop in SES cannot be globally connected to both of the TOS'es at the same time.

In the electrical closet of the TOS is located a switch box that reads Local/ Global. If the switch is in the Local position, the TOS will be in local mode. If the switch is in the Global position, the E-stop in the TOS is connected to SES. If in the global position, the E-stop controller in the TOS is bypassed. If in the Local position, the local controller is controlling the TOS E-stop.

Assuming the system is in local mode, do the following to go to global mode:

- 1** The E-stop at the TOS to go into global mode is operational. There is no break in the circuit and the TOS E-stop controller is not triggering an E-stop. I e, all cables are hooked up and no slap switches are depressed. The E-stop at SES is also operational.
- 2** The E-stop/Communications cable is hooked up to the TOS and at the other end DCC.
- 3** Flip the switch in the TOS electrical closet to Global. This will bring down the TOS, as the TOS E-stop controller is bypassed and the E-stop loop is broken.
- 4** Call the DCC operator to go to global mode, informing the operator what TOS to go into global with.
- 5** The DCC operator will press the bypass button on the switch box in the DCC electrical closet. While depressing the bypass button, the switch will be moved to the TOS to go global with.
- 6** If done correctly, no E-stop will be triggered and all equipment will keep running. The TOS is now up and running again as the SES E-stop controller is supplying the TOS E-stop loop with a current. If a mistake was made and the E-stop loop is somewhere broken, an E-stop will be triggered. Find out what is causing the E-stop and after resolving the issue, restart the E-stop at the E-stop controller. Turn the key at the SES E-stop controller to the Start position, which will restart the E-stop.

Going from Global to Local E-stop the process is reversed.

- 1** The DCC operator presses the bypass button in the DCC electrical closet and moves the switch to either the other TOS to go global with or to the bypass position if SES is going local.



- 2 At this time, the TOS has gone down, as the SES E-stop controller has stopped supplying the TOS E-stop loop with a current. To remedy this, move the switch in the TOS electrical closet to Local.
- 3 Restart the TOS E-stop by moving the TOS E-stop controller knob to the Start position. If everything has been done correctly, a light on the controller will show that the local E-stop is operational.

## **8.8.2 Testing E-Stop/Reel Stop System**

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Before drill operation can start, the E-stop and Reel Stop system has to function tested.

### E-stop test:

- Verify the E-stop at the TOS is in Local mode.
- Start the local E-stop system by turning the E-stop Controller Box operating knob to "Start".
- Verify that the E-stop system is running. A green light "Run" should be lit on the E-stop Controller Box. If the E-stop is not operational, verify that all E-stop slabs are released, that all E-stop cables are hooked up with no interruption, that the E-stop communication cables from the reels have been installed at the Reel Control Box.
- Depress every E-stop slab individually and verify that the E-stop is triggered. The E-stop status can be checked at either the EHWD software or at the E-stop Control Box. Repeat for each slab, including all external and Reel slabs.
- Reset the E-stop slab after every test by rotating the knob clockwise. The E-stop Controller has to be restarted after every test.

### Reel Stop Test:

- Start Reel Stop by pressing "Reel Start" at the Reel Control Box. When Reel Stop is operational, a green light at the Reel Control Box will be lit.
- Depress every Reel-stop slab (after which the slab is reset) and verify that the Reel-stop is engaged. The Reel-stop status can be checked at either the EHWD software or at the Reel Control Box (green light is out).
- Reset the Reel-stop slab after every test. Reset the Reel stop by pressing "Reel Start" at the Reel Control Box.
- Test the reel trip wires at the DSHR and DSCR. If triggered they will engage Reel stop. Check that all wires are hooked up. Each reel has one wire in the front of the reel and one in the back of the reel. Engage reel stop by pulling each trip wire individually. Verify that Reel Stop is engaged.

- Reset the trip wire after each test by depressing a button at one end of the trip wire. Reset Reel Stop by pressing Reel Start at the Reel Control Box.

## 8.9 Calibrating Load Cells

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See Appendix “R” for a description of the load cell calibration procedure using an independant load cell.

The link below is to a spreadsheet program used to calculate the calculate the slope and offset of the calibration curve to be used.



TowerCalibration  
Spreadsheet\_0909

Click on the video link below to view the process of load cell calibration.

Load Cell Calibration.mp4





# Chapter 9

## 9: DEEP HOLE DRILLING

### 9.1 Introduction:

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This chapter will describe the procedure for preparing the drill for commencing drilling at a new site. It will cover the following topics:

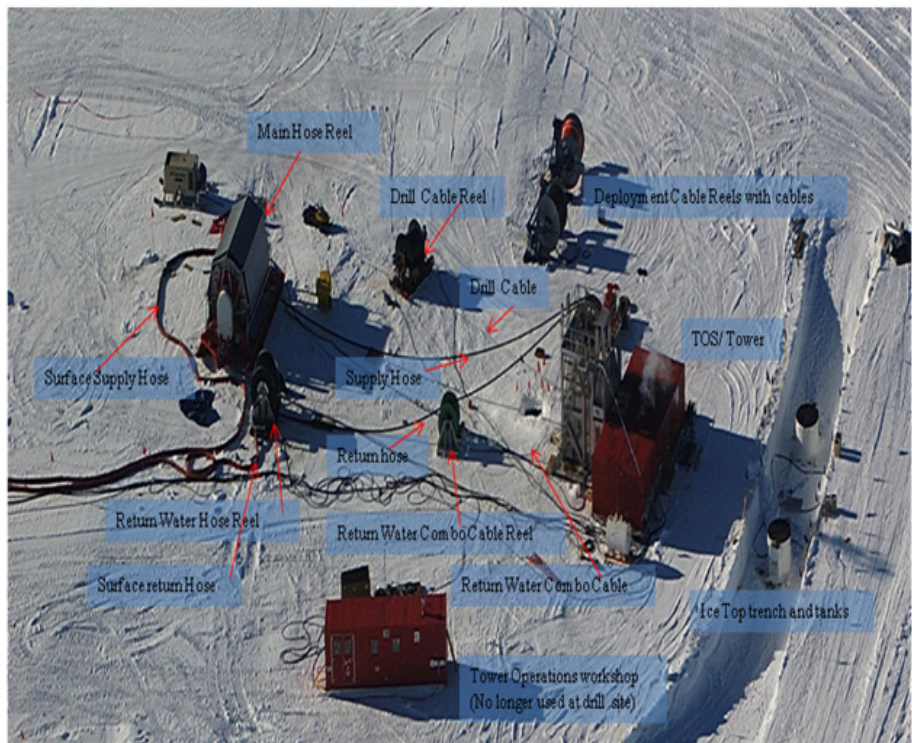
- Routing hoses and cables into the tower and re-establishing water flow through the system in idle mode.
- Assembling the weight stack and attaching the drill head to the weight stack and to the hoses and cables.
- Preparations immediately prior to commencing deep drilling and the actual commencement of drilling.
- Preparing and deploying submersible pump.
- Reaming of the hole.
- Retrieving the submersible pump, extracting the hoses from the tower and re-establishing water loop in idle mode with hoses outside the tower.
- Disconnecting the drill head, disassembling the weight stack and cables from the tower and preparing the reels for relocation to the next site.
- The following assumptions are made in the descriptions to follow:
  - The TOS/ Tower have already been relocated to the new site and all the reels are in position with all wiring and cabling connected to them.
  - The main drill and return water hoses are looped together outside the tower via the yellow heat traced and insulated hose.
  - Water is circulating through the hoses and the system is in idle mode.
  - Firm drilling at the hole has been completed.
  - Both water tanks are full or near full.

- The E-Stop system is in "global mode".

Note: **Idle mode** refers to the mode the system is placed in when no drilling is taking place. In this mode, all the hoses are connected in such a way that they form a loop and water is pumped through the hoses at about 40gpm and about 25°C. This is done to keep water flowing in the system and prevent freezing.

**Bypass mode** refers the mode where the bypass hose is connected between the bypass valves of the main and return hose reels during drilling, in order to bypass the water from the main and return hoses and maintain water circulation in the surface hoses. This would be required when flow has to be disrupted to the main hose for whatever reason or the return water pump is not yet in a position to recover water from the hole.

**Intermediate Idle Mode** refers to the mode where the hoses are in the tower and looped together and the bypass hose is connected between the bypass valves of the main and return hose reels. This is an intermediate step in preparation for drilling. It maintains water flow through all the hoses while some flow is still maintained through the bypass line in order to prevent the line from freezing.



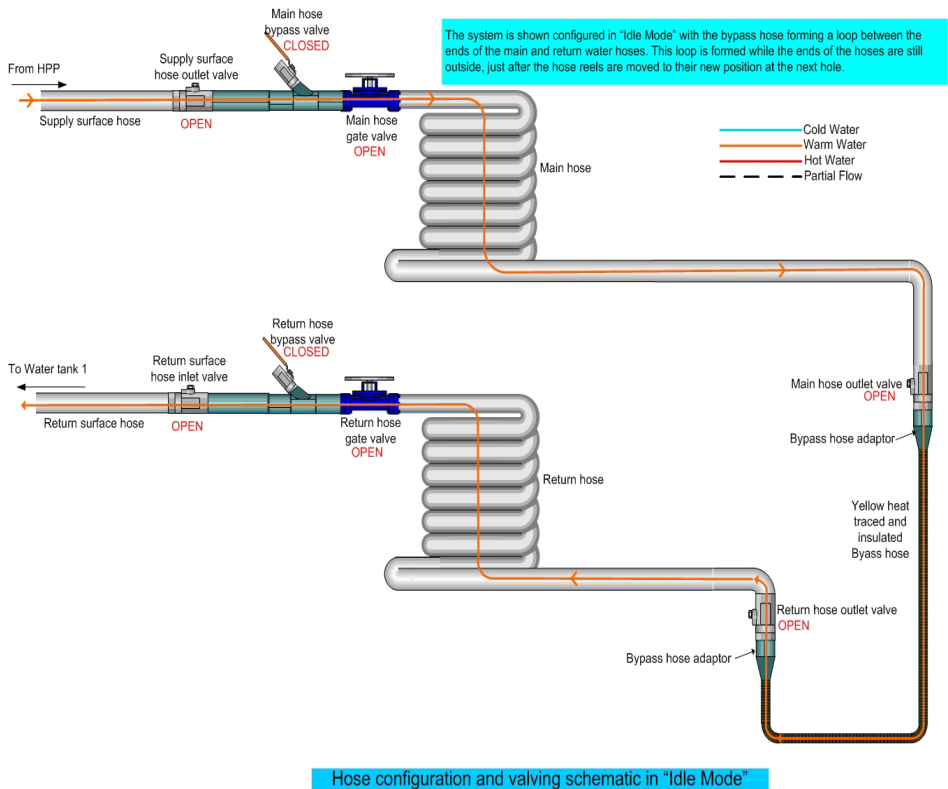
**Figure 9.1** View of Tower Operations Site showing main components

Figure 9.1 above shows a photo of the Tower Operations site, giving an overview of the main components in position and all cables and hoses already routed into the tower.

## 9.2 Routing Hoses and Cables Inside Tower and Placing System in Idle Mode:

**Caution:** The following step requires that water flow through the hoses be stopped. To prevent freezing, water flow must be restored within 60 minutes.

When the TOS/ Tower and the reels are moved to a new location, they are normally configured in idle mode with the hoses and cables outside the tower, as shown in Figure 9.2. This is done in order to reheat the hoses and water in them after a period of no flow when the system is being moved from the previous hole to the new location. This move can take up to an hour, so it is important to reheat the system as soon as possible after the move. Once the system is warm again the hoses can be brought inside the tower and joined together to reform the loop. Water circulation is then restored in idle mode.



**Figure 9.2** Plumbing and Valving Arrangement with hoses connected outside tower in "Idle Mode"

In order to move the hoses inside the tower and re-establish flow in idle mode, carry out the following steps.

- 1 Ask the DCC operator to stop water flow through the system and wait for the flow and pressure to drop to zero.
- 2 Once it's confirmed that flow has stopped and there is no pressure in the system, close the main hose and return hose outlet valves as shown in Figure 9.3 below.



**Figure 9.3** Main and return hose outlet valves being closed for routing into tower

- 3 Disconnect the bypass hose which is connecting the main and return water hoses together, then remove the bypass hose adaptors from the ends of both the main and return water hoses, shown in Figure 9.4.



**Figure 9.4** Bypass hose being disconnected from main and return water hoses

- 4 Move the bypass hose and reconnect to the bypass valves of the main and return water hose reels, as shown in Figure 9.5.





**Figure 9.5** Bypass hose being connected to main and return water hose bypass valves

- 5 Attach the tapered end cap to the end of the main hose, as shown in Figure 9.6 below.



**Figure 9.6** Tapered end cap fitted to end of main hose

- 6 Attach a 60m static rope to the end of the drill supply hose and sling the rope over the drill supply hose crescent, down into the drill tower, through the pulley anchored to the tower floor, then back out through the hole in the tower and wrap 3 turns around the capstan winch, as shown in the series of photos in Figure 9.7.



**Figure 9.7** Rope setup for hauling the main hose into the tower

- 7 Using the main hose reel pendant, unwind the main hose reel while another driller is operating the capstan winch at the same time to pull the main hose through the fairlead assembly on the tower, over the main hose crescent and into the tower.
- 8 Once the hose is at the required level inside the tower, anchor the hose off to the crescent via the Yale grip attached to the hose, as shown in Figure 9.8.



**Figure 9.8** Anchoring the main hose on the tower via the attached Yale Grip

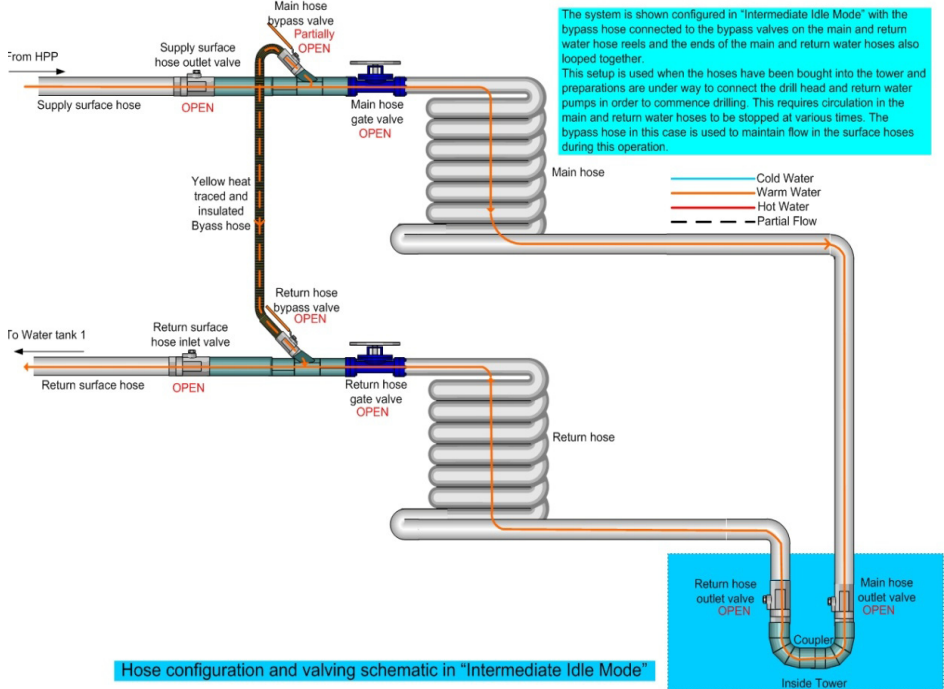
- 9 Repeat steps 5-7 to bring the return water hose inside the tower.

10 Once inside the tower, tie off the return water hose to an anchor point inside the tower and connect the main and return water hoses together using the coupler, as shown in Figure 9.9.



**Figure 9.9** Hoses coupled together inside tower

11 The hoses should now be configured as shown in Figure 9.10. Open the main and return water hose valves and make sure all the other valving is re-arranged as shown in the figure below.



**Figure 9.10** Schematic showing the hoses in "Intermediate Bypass Mode"

**12** Ask the DCC operator to restart water flow at 35gpm and about 25C while carefully monitoring system pressure to make sure there are no blockages in the system.

**13** As a final check, have a driller check to make sure water from the return hose is flowing back into the water tank. Once flow has been re-established in the system, the drill cable and return water pump combo cable can be brought into the tower.

**Caution:** **It's important that the cable is gently handled and only pulled with the attached Yale grip; never with the connector. The cable must never be reeled out through the sheaves and guide rollers under tension, in case it catches. It must always be gently guided through by hand.**

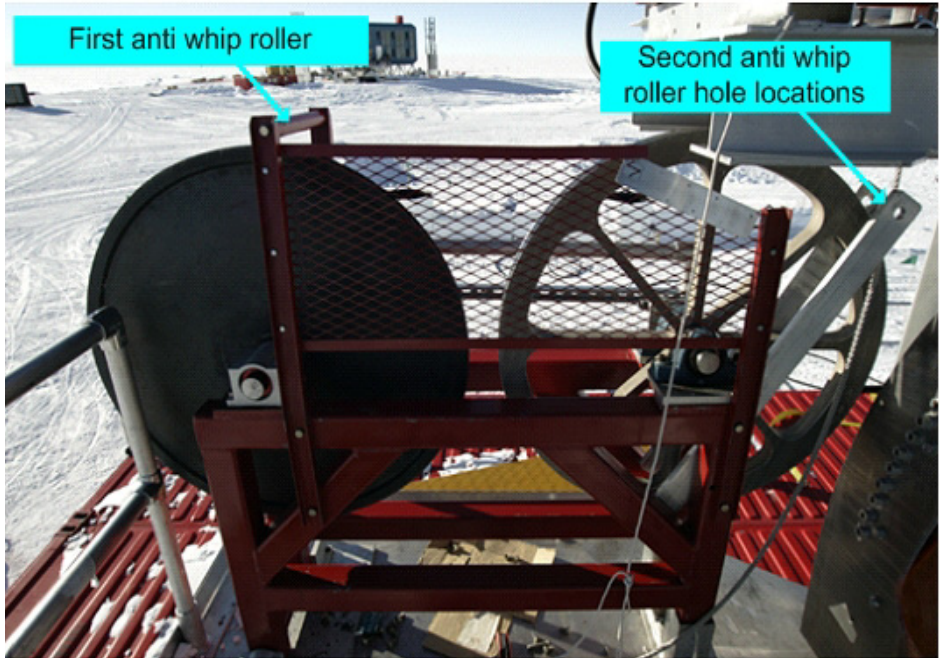
**14** Using the drill cable reel pendant, unwind the cable while someone “walks” the end of the cable over to the cable sheave on the side of the tower.

**15** Remove all the guide rollers (shown in Figure 9.11) from the cable sheave at the bottom of the tower and thread the end of the cable through the sheave. Replace all the guide rollers.



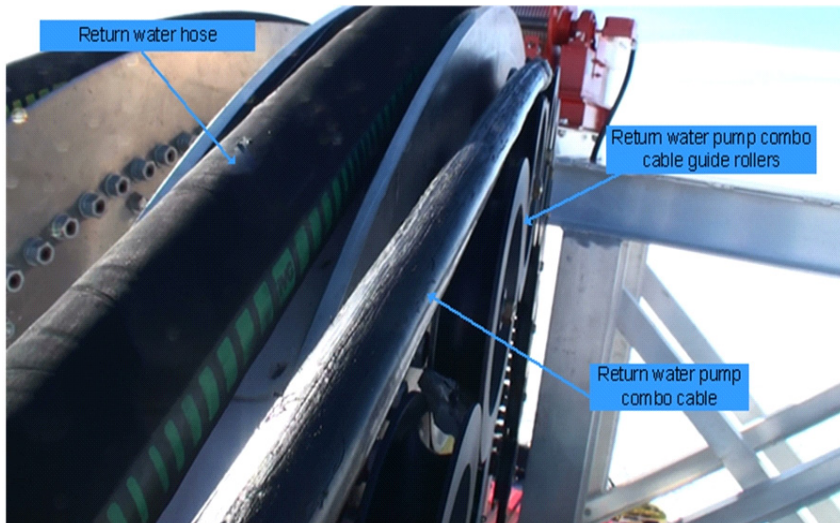
**Figure 9.11** Tower floor cable sheave showing guide rollers

- 16** Lower a rope from the top of the tower and attach to the end of the cable.
- 17** Using the cable reel pendant, unwind the cable off the reel while someone hauls the cable to the top of the tower.
- 18** Once at the top of the tower, disconnect the rope from the cable. Remove the two “anti whip” rollers (shown in Figure 9.12) from the top sheaves and guide the cable onto these sheaves while continuing to unwind the cable off the cable reel.



**Figure 9.12** Tower cable guide sheaves showing one anti whip roller in place and one removed

- 19** Re-install the “anti whip” rollers onto the top sheaves and continue to unwind the cable and feed it into the tower.
- 20** Once at the cable is about 5 feet from the tower floor, stop unwinding and tie the cable off to the side of the tower.
- 21** Lower a rope from the top of the tower, through the return water hose fairlead assembly and attach to the return water combo cable. Lower the other end of the rope over the combo cable guide (near the return water hose crescent as shown in Figure 9.13) and lower into the tower.



**Figure 9.13** Return water hose crescent and return water pump combo cable guide

**22** With one person at the top of the tower guiding the cable through the fairlead assembly and over its guide, operate the return water combo cable reel to unwind the cable while someone in the tower is pulling on the rope to haul the cable into the tower.

Click on the video link below to view the cables and hoses being routed into the tower and the submersible pump being installed ready for deployment.

[Installing Return Pump-hose-cable.mp4](#)

## 9.3 Assembling Weight Stack

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The weight stack is made up of 7 sections and is a total of approximately 78 feet in length. The bottom two sections of the weight stack are tapered, with the drilling nozzle attached to the bottom section. Each weight stack section has a collar welded to it about a foot from the top of the weight stack. This provides a means for the pipe elevator to clamp underneath the collar and lift the weight stack into position.

As discussed previously, the weight stack needs to be the length it is for two reasons;

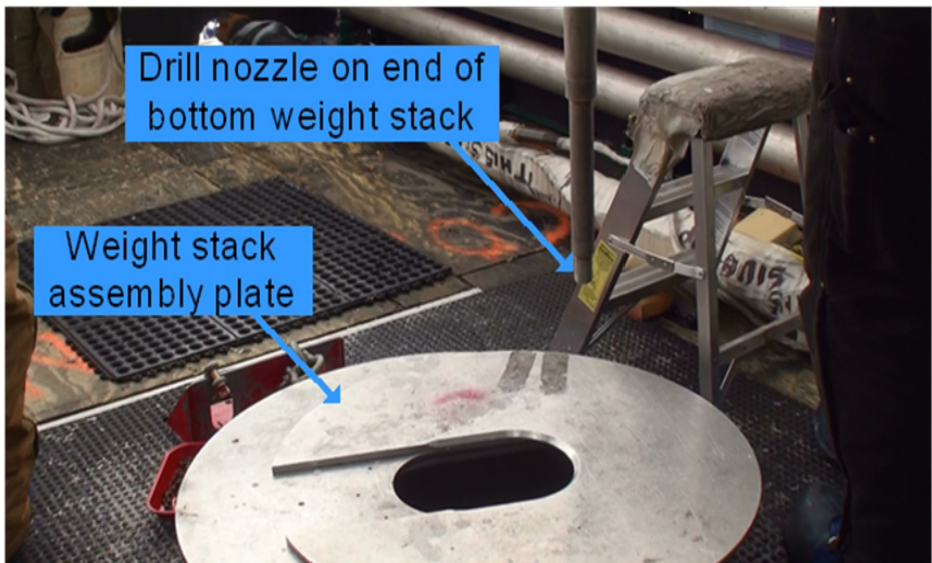
- One is to provide enough weight at the end of the drill hose that the drill hose is always hanging straight in the hole and moves down without any slack.
- The second reason is to allow the drill nozzle to deposit the hot water far enough away from the drill head that the continued melting action of the water has enough time to widen the hole sufficiently for the larger diameter drill head to pass through the hole.

**Note:** Given the tower is only about 15 feet high, the weights stack needs to be assembled inside the hole, in sections. The hole is around 38m (~120') deep and has previously been drilled by the firm drill prior to the TOS/ Tower being placed in position over the hole.

**Caution:** **At all times there must be two independent means of securing the weight stack section and drill head during the assembly and disassembly process.**

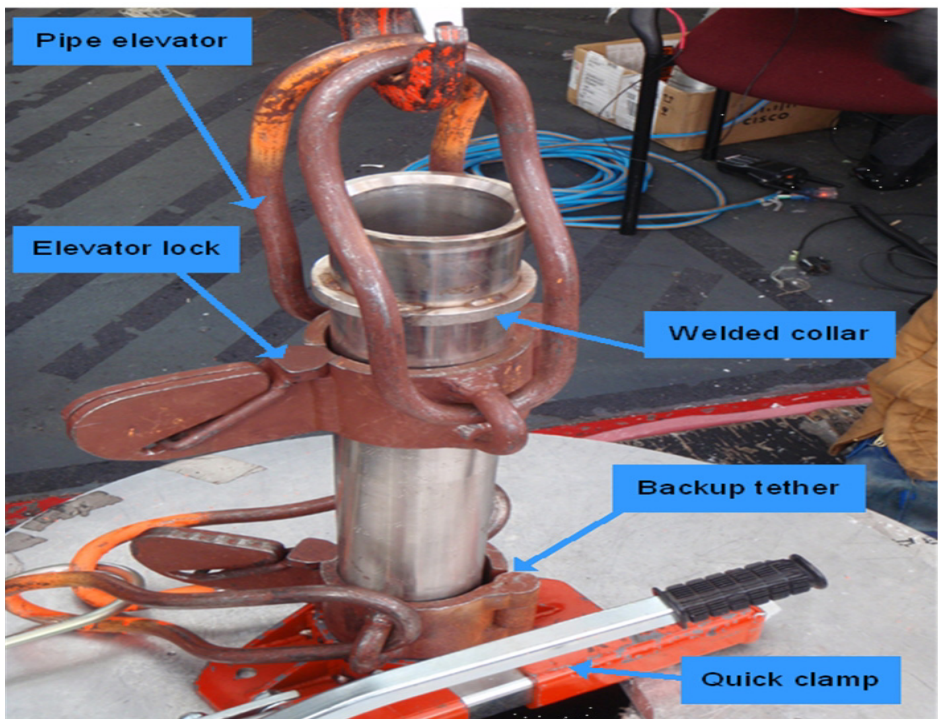
To assemble the weight stack:

- 1 Check to make sure the correct spray nozzle is attached to the bottom most stack section and that it is securely screwed in place. The nozzle type should generally be a zero angle spray pattern nozzle and the nozzle diameter should be such that the “normal” drilling system pressure of approximately 850psi is not exceeded.
- 2 Position the weight stack assembly plates over the hole as shown in Figure 9.14.



**Figure 9.14** Weight stack assembly plate in position over hole

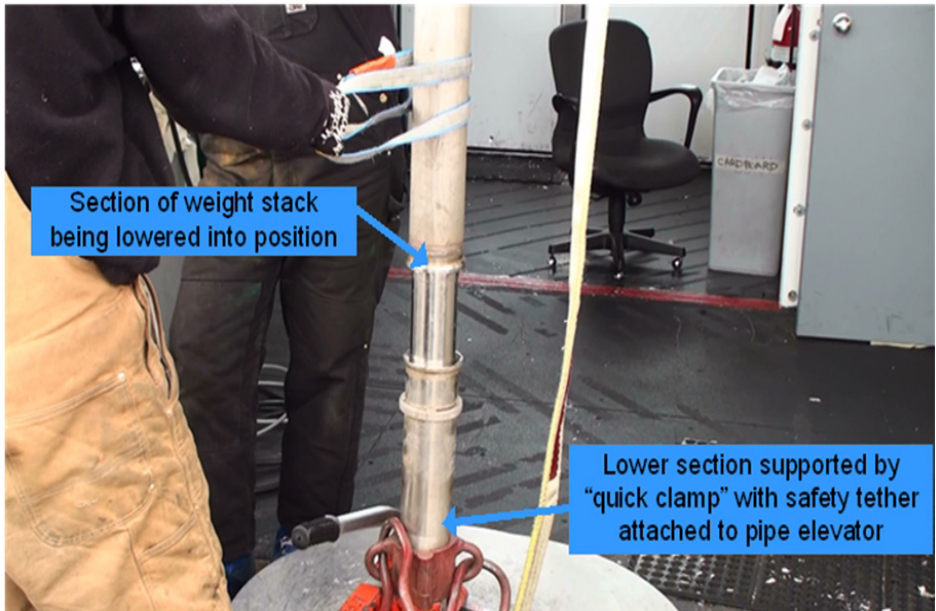
- 3 Move the bottom (tapered) weight stack off its storage rack and position it at a comfortable working level on the tower floor, but not over the hole)
- 4 Place the 4” pipe elevator below the welded collar on the bottom (tapered) weight stack and lock it into place. Attach a second pipe elevator below the first one.
- 5 Connect the tower winch to the top pipe elevator and then attach a safety strap to the second pipe elevator. Anchor the strap to an anchor point at the top of the tower. The strap should be long enough that it will allow the weight stack section to be winched up over the hole then lowered into the hole until the top of the weight stack section is at a convenient working height.
- 6 Using the tower winch, lift the weight stack and lower it into the hole until the top of the weight stack is at a convenient working height.
- 7 Attach a “quick clamp” to the weight stack beneath the second pipe elevator and just above the weight stack assembly plate. Lock the quick clamp handle down and apply the safety lock.
- 8 Continue to lower the weight stack until the weight is supported by the quick clamp and the tower hoist cable is slack, as shown in Figure 9.15.



**Figure 9.15** First weight stack section inside hole and resting on quick clamp



- 9 Disconnect the tower winch from the top pipe elevator and remove the top elevator from the weight stack, while making sure the safety strap remains attached to the second pipe elevator.
- 10 Move the next weight stack section to a convenient working position and attach a 5" pipe elevator to this section, below the welded collar.
- 11 Attach the tower hoist to the pipe elevator and lift this segment and insert it into the segment sitting over the hole as shown in Figure 9.16. Note the two independent anchors still in position on the lower section.



**Figure 9.16** Section of weight stack being mated with lower section

- 12 Clamp the two sections together using a weight stack collar clamp as shown in Figure 9.17, after inspecting the clamp to make sure it's not cracked or otherwise damaged.
- 13 Once the two sections are clamped together, the safety tether can be removed from the lower weight because the weights are now held by the tower hoist and the "quick clamp". Remove the pipe elevator with the safety strap from the lower weight stack and attach it to the top weight stack. This will now be the safety for the all the weight sections when the "quick clamp is released in order to lower the whole section further down the hole.



**Figure 9.17** Weight stack collar clamp being attached to two weight sections.

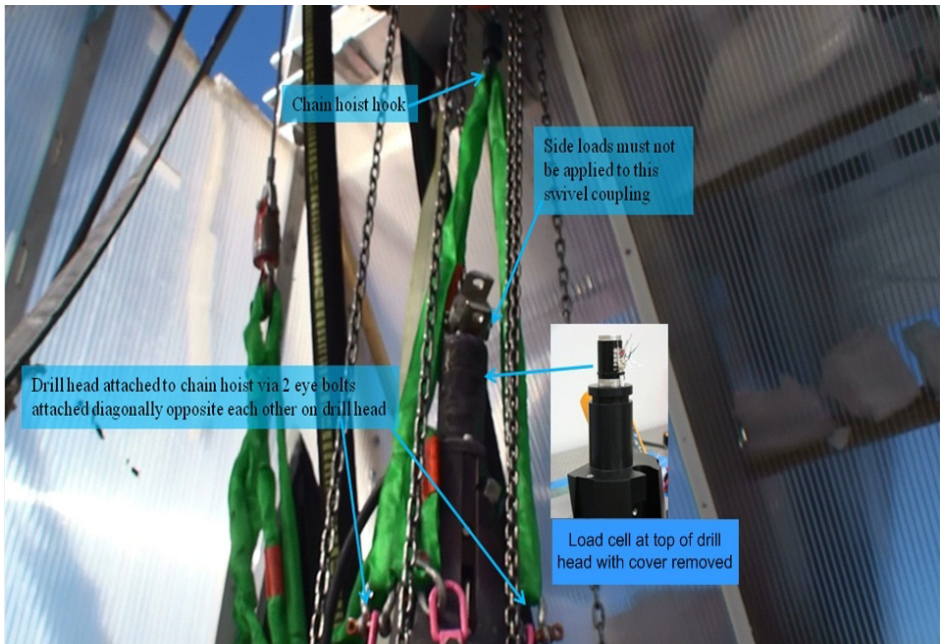
- 14** Using the tower winch, lift the stack sections until the winch has taken the load from the quick clamp. Remove the quick clamp from the lower section and winch the weight stack assembly down until the top of the stack is at a convenient working height.
- 15** Once the weights are at a convenient working height, attach the quick clamp to the weight stack below the pipe elevator, as before. Again, as before, lock the quick clamp handle down and apply the safety lock. The setup should now look like Figure 9.15 again.
- 16** Lower the weight stack until the weight is supported by the quick clamp and the tower hoist cable is slack. After confirming the "quick clamp" is holding the weight, disconnect the pipe elevator connected to the tower hoist, while making sure the pipe elevator connected to the safety strap remains attached to the weight stack.
- 17** Repeat steps 10-16 for the remaining weight stack sections. Once all weight sections are in place, make sure the "quick clamp" remains attached and taking up the weight load, while a safety tether is in place, before disconnecting the tower hoist and moving to the next step.

Click on video link below to view the weight stack assembly procedure.

[Installing the weight stack.mp4](#)

## 9.4 Attaching Drill Head to Weight Stack

**Caution:** Do not apply side loads to the drill head load cell, shown in Figure 9.18. Application of side load can damage this load cell.

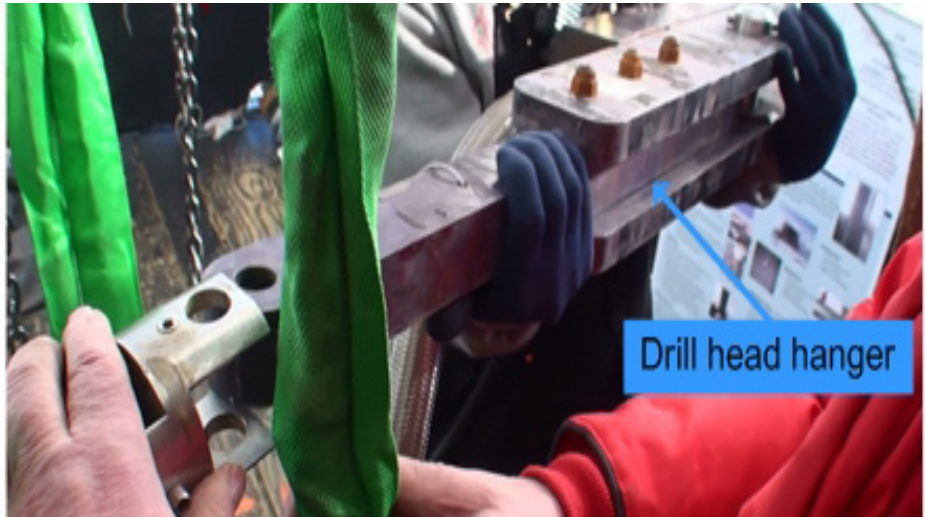


**Figure 9.18** Drill head attached to chain hoist and inset showing load cell and housing.

The drill head is normally attached to the chain hoist which runs along the ceiling of the drill tower. After a hole is drilled, the drill head is attached to the chain hoist via eye bolts attached to the top of the drill head, moved along the chain hoist rail and stored out of the way near the tower front wall.

Before attaching the drill head to the weight stack, inspect the drill head to make sure all the caliper arms are securely attached the drill head. Apply "Loctite" to any loose screws and retighten. Check the drill head to weight stack adaptor to make sure it is securely attached to the drill head.

In order to attach the drill head to the weight stack, the drill head weight must be transferred from the chain hoist to the tower hoist before being lowered onto the weight stack. Once the drill head is attached to the weight stack the "drill head hanger" (shown in Figure 9.19) can then be attached to the drill head before the whole drill/ weight stack assembly can be suspended by the drill cable.



**Figure 9.19** Drill head hanger

To attach the drill head to the weight stack:

- 1** Move the drill head along the chain hoist track until it's as close to the hole as possible.
- 2** Attach two slings to the two empty eye bolts on the drill head and attach the other end of the slings to the tower hoist, as shown in Figure 9.20. At this stage the drill head is still being supported by the chain hoist.



**Figure 9.20** Drill head attached to chain hoist and tower hoist.

- 3 Slowly take up the drill load with the tower hoist while at the same time unwind the chain hoist to release the load from the chain hoist, until all the load has been taken up by the tower hoist, as shown in Figure 9.21. At this stage leave the chain hoist slings attached to the drill head as a safety precaution.



**Figure 9.21** Tower hoist supporting drill head weight with chain hoist slings slack.

- 4 Continue to slowly raise the drill head with the tower hoist until the bottom of the drill head can be slotted into the top of the weight stack, as shown in Figure 9.22.



**Figure 9.22** Drill head about to be mated with the weight stack.

- 5 Slot the drill into the weight stack and allow it to sit firmly on top of the weight stack. Once properly seated, clamp the drill head to the weight stack using the collar, as shown in Figure 9.23.



**Figure 9.23** Drill head clamp collar attaching drill head to weight stack

- 6 Once the drill head clamp collar is attached, slowly take up the weight of the drill head with the tower hoist until the weight has come off the "quick clamp". Once all the weight is on the tower hoist, disconnect the "Quick clamp" and pipe elevator safety tether, but keep the chain hoist safety in place, then remove the weight stack assembly plate from the hole entrance as shown in Figure 9.24.



**Figure 9.24** "Quick clamp", safety tether and weight stack assembly plate being removed

**Danger:** At this point the hole is open and extra care must be taken to make sure people are always facing the hole and aware of it while working around it.

- 7 Lower the drill head and weight stack assembly slowly down the hole until the top of the drill head is at a comfortable working distance above the tower

floor as shown in Figure 9.25. Notice that the chain hoist tether is still in place as a safety.



**Figure 9.25** Drill head positioned at comfortable working distance above tower floor.

- 8 Insert the drill head hanger into the swivel bracket at the top of the drill head and insert the retaining bolt. Make sure the "cotter pin" is properly installed and splayed out as shown in Figure 9.26.



**Figure 9.26** Drill head hanger being attached to drill head swivel bracket

- 9 Once the drill head hanger is securely attached to the drill head, attach the drill cable to the other end of the drill head hanger by inserting the retaining

bolt through the drill cable eyelet, then insert the locking pin to lock the drill cable retaining bolt in place, as shown in Figure 9.27.



**Figure 9.27** Connecting drill cable to drill head hanger

**10** Once the drill head hanger has been properly connected to the drill head and the drill cable properly connected to the drill head hanger, use the drill cable reel pendant to slowly take up the weight of the drill head and weight stack, as shown in Figure 9.28, until the weight is completely transferred from the tower hoist to the drill cable reel.



**Figure 9.28** Drill head being raised by drill cable reel

**11** Once the weight has been completely taken up by the drill cable reel, disconnect the sling attaching the drill head to the tower hoist, but retain the sling attaching the drill head to the chain hoist, as a safety.



Apply some copper anti seize compound to the mesh covered adaptor hose hanging off the end of the drill head hanger and connect this hose to the fitting on the drill head, as shown in Figure 9.29. Note that the connector swivel is at the drill head end, not the hose end and can be counterintuitive when attaching. This hose allows water to be directed from the main hose through a cavity in the drill head, out to the weight stack and through the nozzle to the ice.



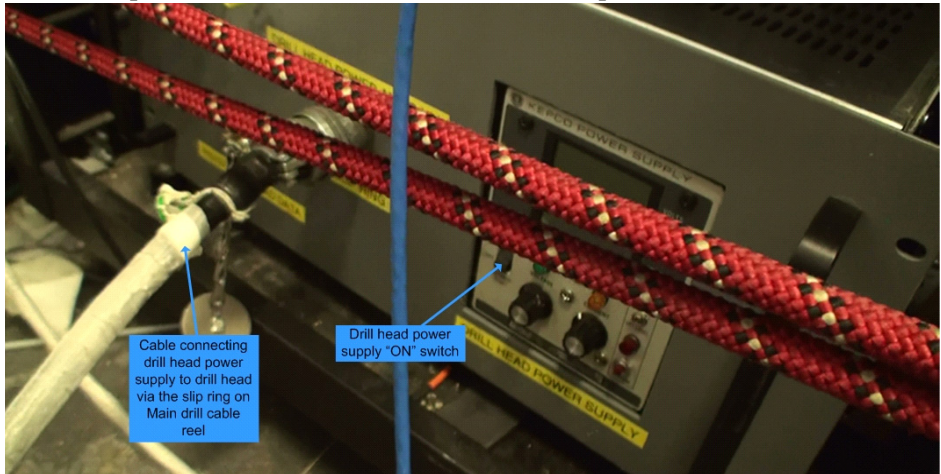
**Figure 9.29** Preparing and connecting adaptor hose to drill head

**12** Attach the drill cable electrical connector to the drill head as shown in Figure 9.30, after making sure there is no ice or debris in either end of the connectors. Note that the connector does not need any silicone or other compounds to aid in waterproofing the connector. Each pin on the connector has its own water proofing.



**Figure 9.30** Attaching the drill cable to the drill head

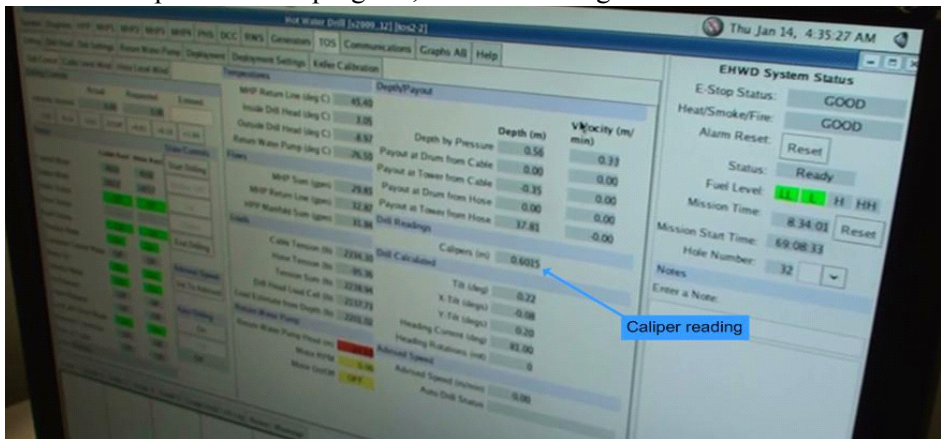
13 Once the drill cable is connected to the drill head, turn on the drill head power supply, shown in Figure 9.31. This supply is located at the bottom of the computer rack in the corner of the TOS computer room.



**Figure 9.31** Drill head power supply

The drill head power supply provides a constant 75V to the drill head. The voltage setting does not need to be changed. It is preset and the voltage knobs on the power supply have no effect on the power supply output.

To confirm the drill head is working, check the voltage reading on the power supply. It should read about 75V and the current draw by the drill head should be around 200mA. Once that's confirmed, check the output of the drill head on the drill computer control program, as shown in Figure 9.32.



**Figure 9.32** Computer program showing TOS display screen

The drill head should be sending data that is continuously being updated. A good check is to look at the caliper data on the screen. Move the calipers in and out on the drill head and confirm the changes on the display.

- 14 Once it's confirmed the drill head is functioning correctly, apply some tape around the top of the drill head and drill head hanger to securely hold the adaptor hose and drill cable connector against the drill, as shown in Figure 9.33.



**Figure 9.33** Tape applied to drill head adaptor hose and connector.

This holds the hose and connector against the drill head and prevents them accidentally catching on anything in the hole, such as the submersible pump. Taping around the retaining bolts, cotter pins and locking pins also adds an extra safety measure against them falling out.

Click on the video link below to view the drill head installation procedure.

[installing the drill head.mp4](#)

## 9.5 Commencing Main Hole Drilling

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At this stage the drill head is hanging in the hole but has no water hose connected to it yet. The drill and return hoses are still connected in "intermediate" bypass mode inside the drill tower. Water is still flowing through the hoses at about 35gpm and at about 20°C. At this point we need to bypass the water flow from the main and return hoses before disconnecting them from bypass mode and connecting the main hose to the drill head.

- 1 Inform the DCC that valving changes are about to take place and that they should keep an eye on the drill system pressure. Fully open the main hose winch bypass valve, as shown in Figure 9.34, and watch the system pressure to make sure it remains stable. This valve opening allows water to be bypassed from the main hose reel. This allows the outlet valve of both the

main hose and bypass hose to be closed in order to remove the hose coupler connecting the ends of those hoses without "dead-heading" the pumps.



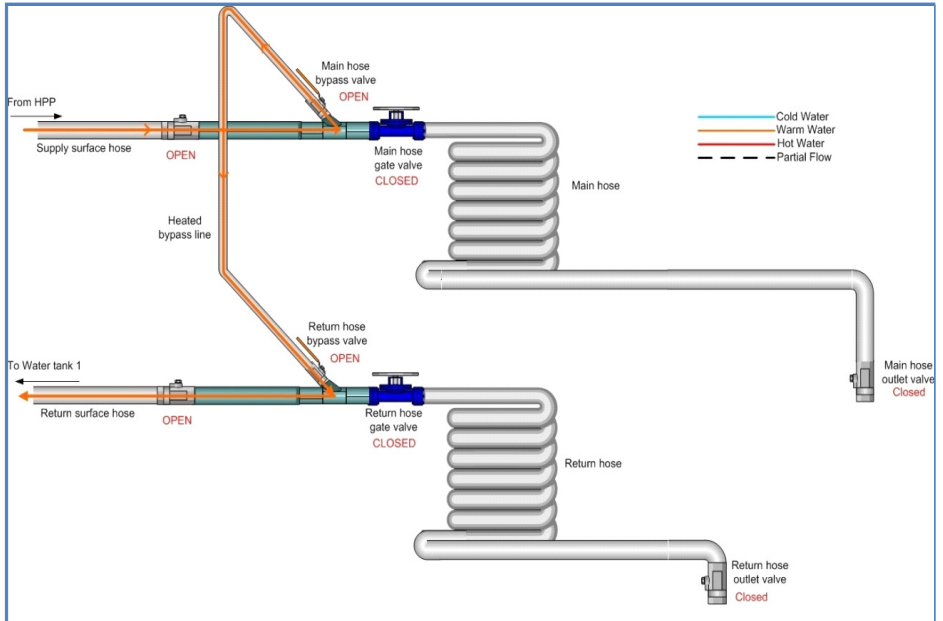
**Figure 9.34** Main hose bypass valve being opened to connect main hose to drill head

- 2 Close the outlet valves of both the main hose and the return water hose, as shown in Figure 9.35, prior to disconnecting the hose coupler. Confirm with the DCC that system pressure is still stable then disconnect the hose coupler connecting the two ends of the hoses together.



**Figure 9.35** Closing main and return hose outlet valves to disconnect the coupler

Once the coupler is disconnected, the hose and valving arrangement and water flow should look as shown in Figure 9.36. The gate valves on the main and return water reels may be closed or left open for this step.



**Figure 9.36** Hose and valving arrangement and water flow while preparing to connect drill head for main hole drilling

- 3 Connect the main hose to the drill head as shown in Figure 9.37. The figure shows one half of the "clam shell" hose coupler attached between the drill head and hose outlet valve with the other half of the coupler about to be attached before the two halves are screwed together.



**Figure 9.37** Main drill hose being connected to drill head

- 4 Once the hose has been attached to the drill head remove the safety tether attaching the drill head to either the chain or tower hoist.
- 5 Before the main hose winch can be operated, the strap tying the hose off at the top of the tower (shown in Figure 9.8) must be removed and the end of the Yale grip taped to the hose, as shown in Figure 9.38.



**Figure 9.38** Taping main hose Yale grip anchor to hose

- 6 Once the hose has been released at the top of the tower use the hose reel pendant controller to slowly winch up with the main hose reel to take up the slack on the main hose. At the same time have the TOS operator monitor the control screen to inform the operator when a nominal load of 650lbs is on the main hose. With 650lbs of tension on the hose, viewed from inside the tower the hose slack visually should look as shown in Figure 9.39. The hose tension value is read from the TOS/ Drilling screen, also as shown in Figure 9.39.



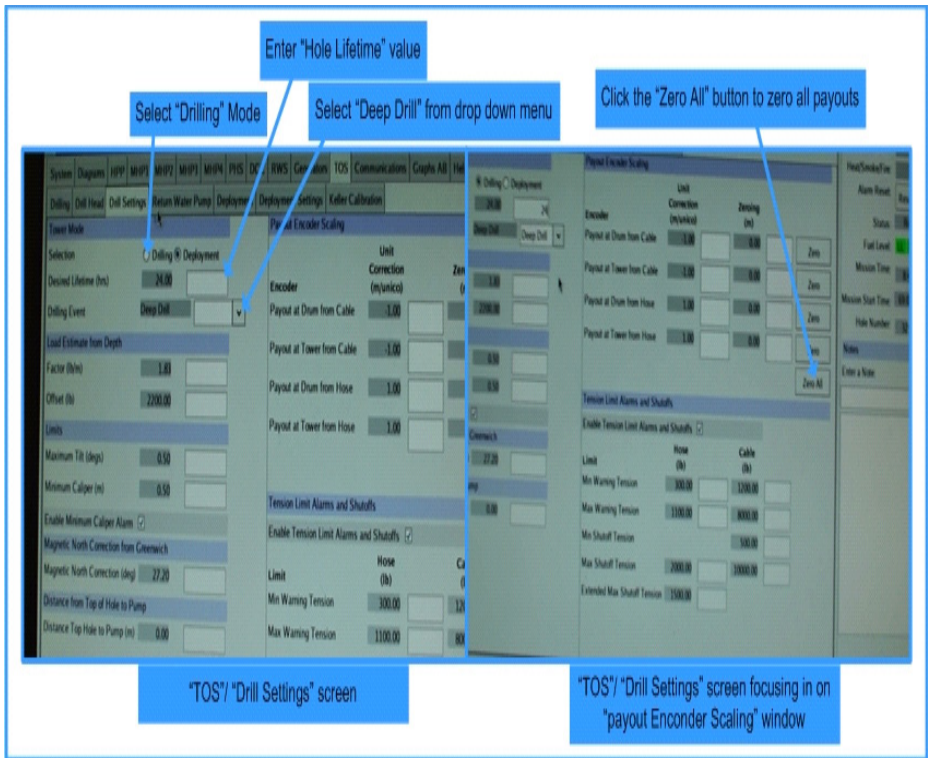
**Figure 9.39** Hose tension at 650lbs load and screen where hose tension is displayed

- 7 Move the drill head so the calipers are level with the snow surface, as shown in Figure 9.40.



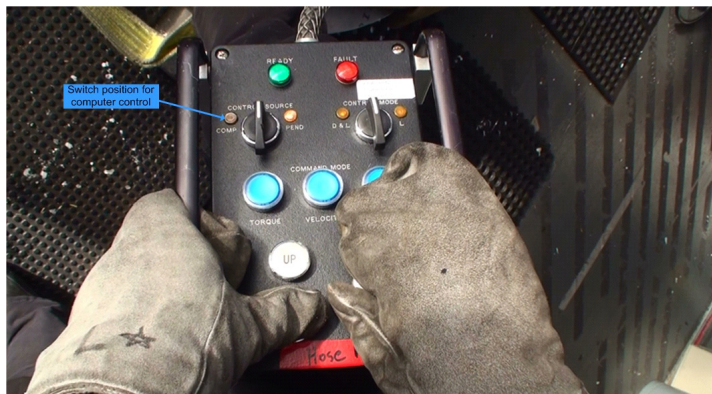
**Figure 9.40** Drill Head position prior to "zeroing" payouts

- 8 Once the drill is in position, in the drill control program go to the "TOS"/ "Drill Settings" screen and perform the following actions (in no particular order), as shown in Figure 9.41.
  - a Under "Tower Mode" Heading, select "drilling" mode.
  - b Enter the hole lifetime in hours. This is the length of time in hours from the end of drilling until the hole diameter has closed to 45cm. This is considered the smallest diameter at which IceCube instruments can be safely deployed in the hole without risk of getting stuck. In general, the holes have been drilled to 24 or 27 hours. The selection value is confirmed in the grayed box to the left of the entry box. The value entered here is used by the drill control program to automatically adjust drill speed based on water flow rate and temperature to drill a hole of the correct lifetime.
  - c Select "Deep Drill" from the drop down menu. Again the value selected is confirmed in the grayed box to the left of the selection box.
  - d Confirm that the drill head is at the "zero" mark in the hole then move to the right of the screen and under the "Payout Encoder Scaling" heading, click "zero All" to zero all the payouts. This resets all the counters to zero.



**Figure 9.41** TOS Drill Settings Screen showing the selections to be made prior to drilling.

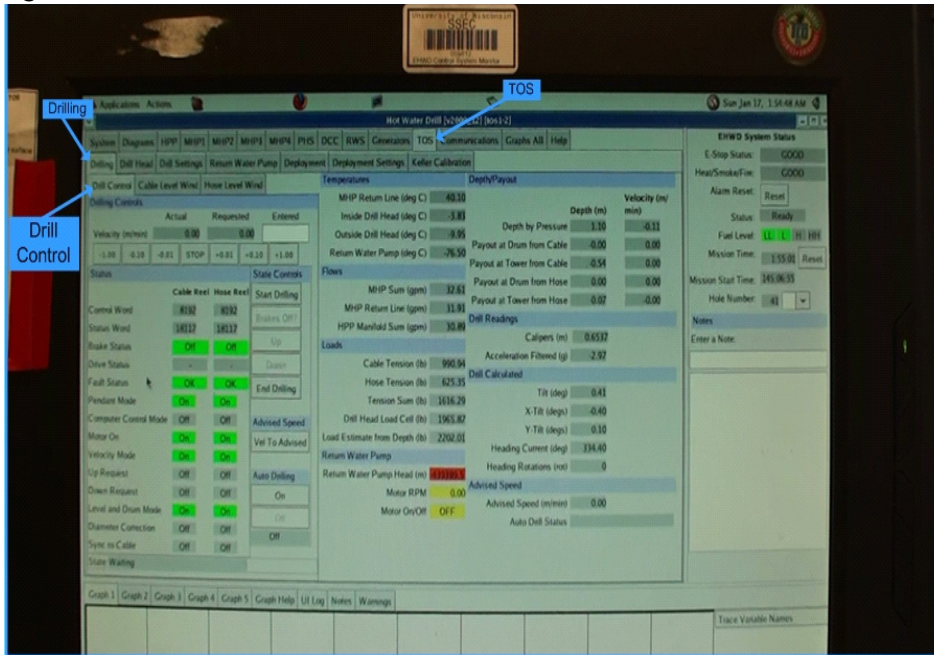
- 9 Drilling is now ready to commence. Allow the computer to take control of the main hose and cable reels by turning the "control source" switch of the respective pendants left to "COMP" mode, as shown in Figure 9.42.



**Figure 9.42** Pendant controller showing switch position to allow computer control of winch



The next step is to place the main hose and cable reels in computer control mode. This is done in the "TOS"/ "Drilling"/ "Drill Control" screen, shown in Figure 9.43.



**Figure 9.43** "TOS"/ "Drilling"/ "Drill Control" Screen prior to starting drilling

Figure 9.43 shows the TOS/ Drilling/ Drill control screen with the drill in “Pendant Control” mode with the brakes on the cable and hose reels de-energised and the motors energized and in velocity mode. For obvious reasons, the motor controllers won’t allow the brakes to be de-energised (whether in pendant or computer control mode) without the motors first being energized and applying holding torque to the reels.

An explanation of each item on the “Drill Control” screen follows, starting from the top of the screen:

#### 9.5.0.0.1 “Drilling Controls” section:

“Velocity (m/min)”

Once the system is running in computer control mode, a speed is entered in “m/min” in the white “Entered” box to the right of the screen. The “Requested” box should confirm the request by the entered value appearing in the “Requested” box. Once the motor controllers have received the request and sent confirmation of set speed back to the program, the same entered speed should appear in the “Actual” box.

The tabbed buttons below the speed entry boxes allow the operator to increment or decrement the speed by the value on the button. Note that these buttons only increment or decrement the speed. They do not change the motor direction, as may be incorrectly inferred by the “+” and “-” prefixes on the buttons. The direction change is accomplished by the “Up” and “Down” buttons further down the screen.

#### **9.5.0.0.2 “Status “section:**

“Control Word” and Status Word”:

These are values communicated between the control program and the motor controllers to ascertain the state of communications of the system and are not used by the operator in controlling the drill.

“Brake Status”:

This indicator gives the state of the brakes on the winches. Green and “Off” means the brakes have been energized (released) and the winches can be operated. Red and “On” means the brakes are de-energised (engaged).

Note that the motor controllers won’t allow the brakes to be released unless the motor on the respective reel is energized and is applying holding torque to the reel. However, once the motor on the reel is energized, it is possible to rotate the reel with the brakes still applied. So it is very important in order not to overload the controller and motor and damage the brake, that the brake be released before rotating the reel.

The brakes are fail safe, in that power needs to be available to the hydraulic dump valve and a status signal sent from the motor controller to the dump valve to shut the valve and allow the brakes to be released. The brakes are then released by manually pumping hydraulic pressure to a piston which acts on the brake pads and opens them out from the brake disk. If power is lost, the dump valve de-energises and dumps the hydraulic fluid to a holding reservoir, thereby releasing the pressure in the system and forcing the brake pads closed against the brake disk. Likewise, if the motor for that reel isn’t energized, the status signal from the controller keeps the dump valve open and prevents the hydraulic system from being pressurized to release the brakes.

“Drive Status”:

“Fault Status”:

This is a control signal sent from the controller. If there is a fault on the controller this indicator turns red and the word changes to “Fault”. The fault needs to be cleared in the drive before this status will reset.

“Pendant Mode”:

This status indicator turns green and “On” when the pendant has control of the motor controller. When the computer has control the indicator turn grey and “Off”.

“Computer Control Mode”:

This status indicator turns green and “On” when the computer has control of the motor controller and changes to grey and “Off” when the pendant has control.

“Motor On”:

This status indicator turn green and “On” when power has been applied to the motor by the controller and the motor is applying holding torque to the reel. When this is the case, the brakes can be released as the motor is now able to stop the reel from spinning freely.

“Velocity Mode”:

The motor controller can be programmed to operate in various modes, including “velocity mode”, “Torque mode” and “Position mode”. In “Computer Control Mode” the only mode the controller can be operated in is “Velocity Mode” which allows the controller to control the motor by applying a speed setting. When the controller has initiated velocity mode, this indicator turns green and “On”. While the other modes of operation are possible in pendant mode, in general the reels are only operated in “velocity Mode”.

“Up Request”:

Pressing the “Up” button in the “State Controls” section causes this indicator to change to “green and “On” and once a speed is set, the drill will start moving up at the entered speed.

“Down Request”:

Pressing “Down” button in the “State Controls” section causes this indicator to change to “green and “On” and once a speed is set, the drill will start moving down at the entered speed.

“Level and Drum Mode”:

This mode indicator turns green and “On” when the level wind motor and the drum motor on each reel are energised and synched to run together to allow the level wind to track with the reel rotation.

This mode is automatically set when the reels are running in “Computer Control” mode but the drum motor or level wind motor can be operated independently in “Pendant” mode.

“Diameter Correction”:

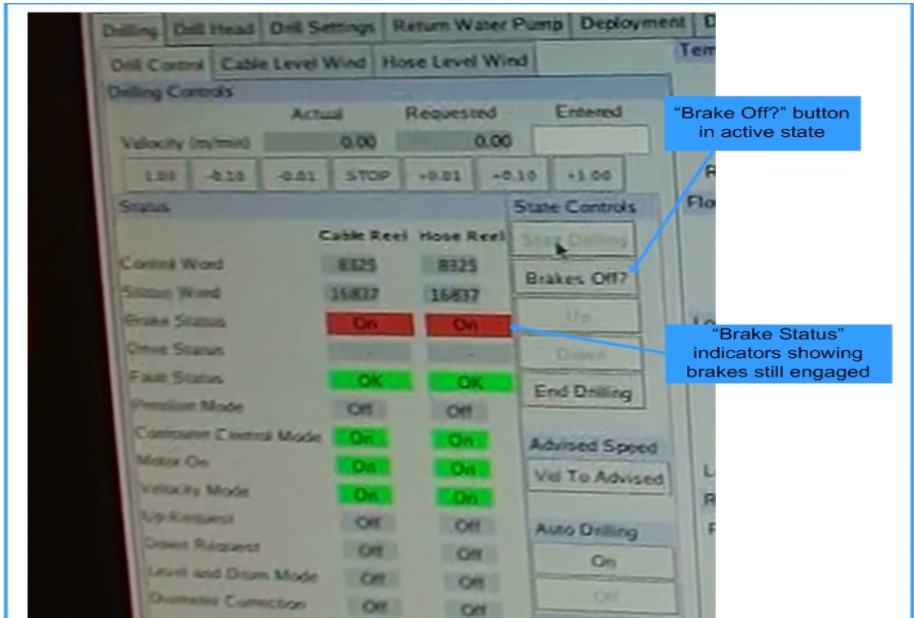
This mode turns green and “On” when the motor controllers are in “Diameter Correction” mode. This mode is applied automatically when drilling in “Computer Control” mode.

“Sync to Cable”:

This indicator turns green and “On” when the hose reels speed is synched to the cable so that it moves at the same rate as the cable. In this mode, an algorithm in the motor controller senses the load on the hose crescent load cell and while keeping the speed of the cable reel at the set speed, adjusts the speed of the hose reel to maintain a nominal 650lbs of load on the hose. This, combined with taping the hose to the cable every 15 feet ensures a constant 850lbs of tension is applied to the hose.

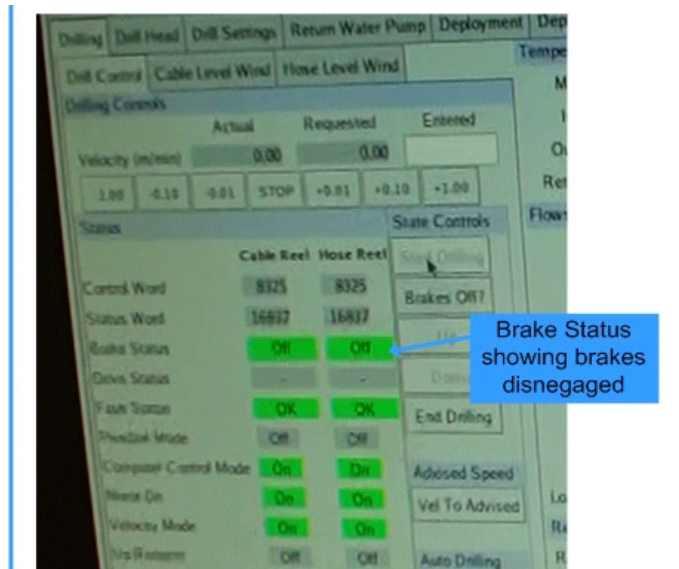
**10** To start both the hose and cable reels in Computer control mode for drilling, in the “state Controls” section of the “drill Control” screen, click on the “Start Drilling” button. This initiates the following sequence of steps:

- a** Sets the speed of both reels to Zero if the reels were running in “pendant” mode.
- b** De-energises (engages) the brakes of both reels which changes the "Brake Status" indicators to red and "On".
- c** Removes power from the motors of both reels.
- d** Places the controllers of both reels in “Computer Control” mode.
- e** Re-energises the motor (turns it on) to allow it to apply holding torque to the reel.
- f** Places the motor controller in "Velocity" mode.
- g** Once the motor controller is in velocity mode, the "Brakes Off?" button directly under the "Start Drilling" button becomes "ungrayed"; i.e. becomes active and ready to be pressed. This button is asking a question and waiting for an action to be performed before it is pressed. It is asking if the brakes on both the hose and cable reels have been energised (released). The "Drilling Controls"/ "Status" screen will look as shown in Figure 9.44.



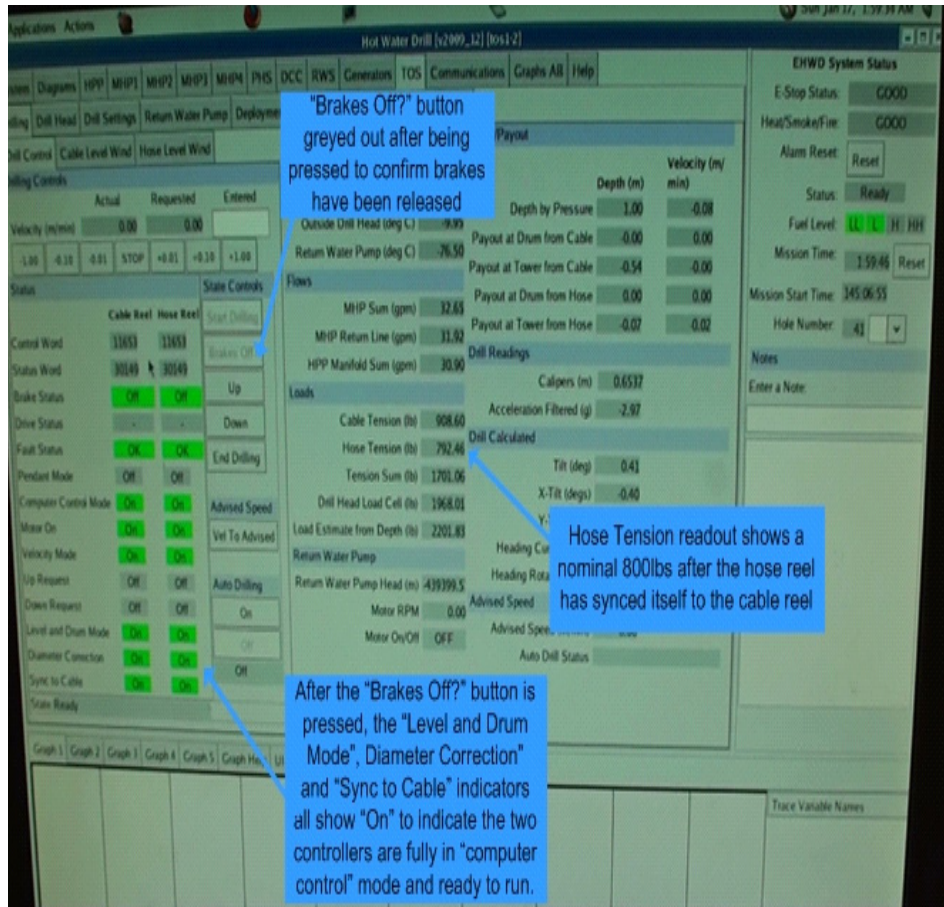
**Figure 9.44** Drilling controls status screen just after the "Start Drilling" button is pressed

11 At this point an operator pumps the brake hydraulics on the hose and cable reels to release the brakes. Once the brakes are released, the status screen will look as shown in Figure 9.45 below.



**Figure 9.45** Drilling controls status screen just after brakes have been released.

12 At this point, the answer to the "Brakes Off?" question is yes and the button can be clicked to move to the next step in the startup sequence. Once the "Brakes Off?" button is pressed, the start up sequence continues and the "level and drum mode", "diameter Correction" and Sync to Cable" indicators all eventually turn green and "On" and the hose winch starts slowly turning to slowly bring the tension on the hose to the nominal 800lbs, as shown in Figure 9.46 below.

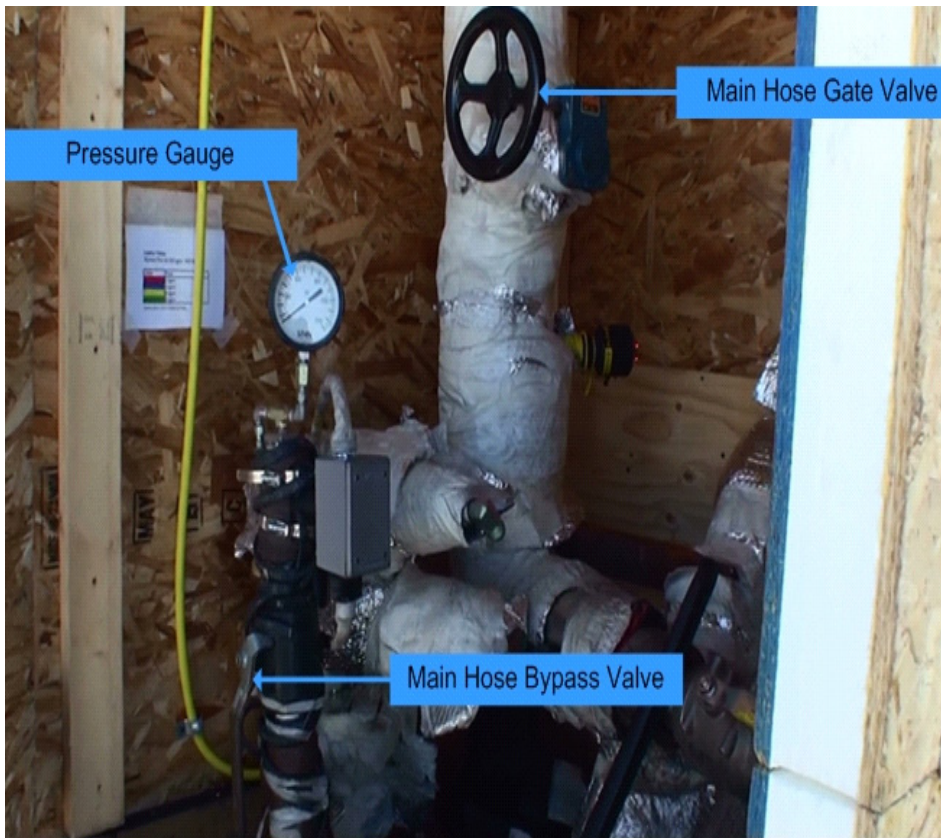


**Figure 9.46** TOS Drill control and display screen after the reels have been energised and synched.

13 Water flow down the drill head can now be started. Ask the DCC operator to keep an eye on system pressure as valves are about to be opened and closed.

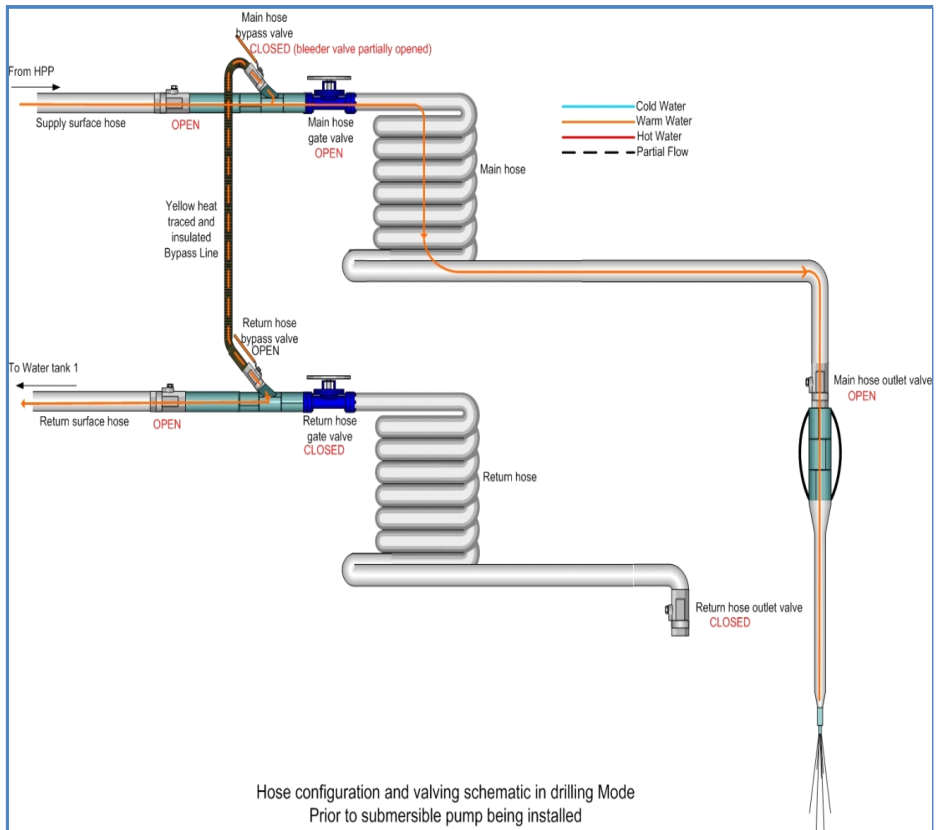
- a Open the main supply hose outlet valve, located just above the drill head.
- b Open the main hose gate valve, as shown in Figure 9.47

- c While keeping an eye on the pressure gauge directly above the main hose bypass valve fully close the main hose bypass valve, again shown in Figure 9.47, but make sure the bleeder valve associated with the bypass valve is partially opened to allow some flow through the bypass hose to prevent it from freezing.
- d Until water flow is detected coming out of the drill nozzle, indicated by steam coming out of the hole, Keep an eye on the pressure gauge just above the bypass valve and check that the DCC operator does not see a change in system pressure. Any change in the gauge pressure or the system pressure would indicate a blockage either in the main hose or possibly an ice plug in the drill head or weight stack.



**Figure 9.47** Main hose reel inlet valves located inside dog box.

The hose configuration and valving arrangement should now look as shown in Figure 9.48 below.

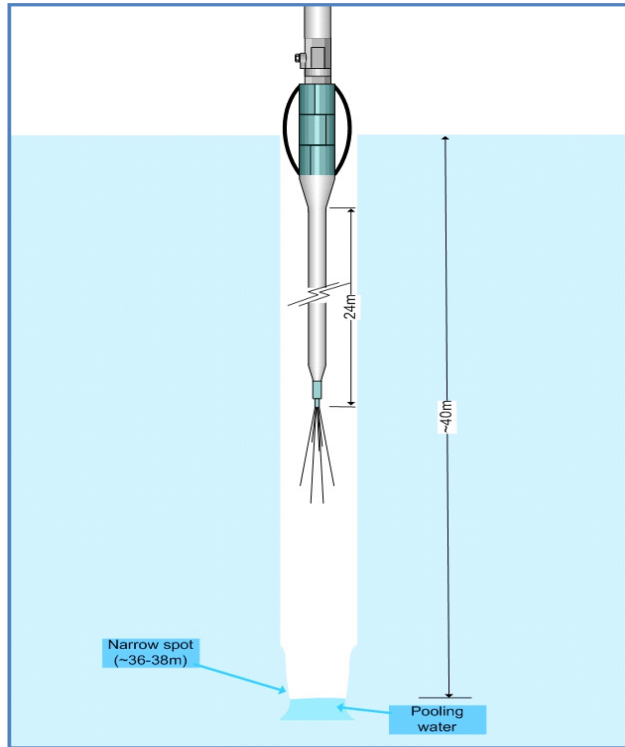


**Figure 9.48** Hose and valving arrangement with drill head attached and testing for blockage

The above diagram shows water flow being directed down to the drill head with some bleed water flowing through the bypass hose back to the return line to prevent freezing. Once flow has been confirmed through the drill head, drilling can commence.

**14** The next step is to ramp up the water flow and temperature to commence drilling. Have the DCC operator ramp up water flow to 200gpm and commence turning on heaters to bring up the water temperature to just below boiling point. It's important that water temperature does not reach boiling point. This is a safety measure. Because the system is pressurised, if the temperature is at boiling point and we have a leak in the system, the resulting leak would result in steam being ejected at high pressure and flow, potentially causing serious injury. If drilling at South Pole, the boiling point of water is 88°, so keep the water temperature at around 86-87°C.





**Figure 9.49** Top 40m of hole showing dimensions and some features

Figure 9.49 shows a graphic of the top of the hole, where it has been drilled with the firm drill, and the drill with the calipers sitting at the snow surface about to commence drilling. The drill weight stack is around 24m and the firm drilled hole is around 40m. Note that the firm hole is dry, except towards the bottom where water is pooling. Also note the narrow spot at around 36-38m. This narrow spot is a common feature of pretty much every firm hole that's been drilled. One theory is that the narrow spot results from the surface water pooling at the top of the hole starting to freeze from the outside in, as it is in contact with the cold air. This results in a narrowing of the hole and is an area that needs to be closely monitored when drilling commences and when reaming is about to be completed and the drill retrieved from the hole. This spot might need to have extra reaming applied to it in order to make it wide enough for the instruments to be deployed.

The main hose reel has around 9800 feet of hose wrap and there is about 1200 feet of surface supply hose delivering water from the SES to the main hose reel. This is a total of about 11000' (3437m) of 3" (0.0762m) I/D hose, with a resultant volume of 15.7m<sup>3</sup>.

At 200gpm (760l/m) flow rate, it would require about 20 minutes for the water entering the surface supply hose at the SES to make it all the way to the nozzle at the end of the drill.

This is important because what it means is that when the water flow rate is turned up and the temperature is brought up to 87°C, that is the temperature appearing at the output of the SES. It will take another 20 minutes for that temperature water to make it to the nozzle. So ideally we want the nozzle to reach the ice surface at 40m, at about the same time as the 88°C water reaches the nozzle. From Figure 9.49, we can see that we need to travel about 16m. Therefore if we start the drill moving down about the same time as the water flow and temperature is brought up to 200gpm and 88°C, we will need to set the drill speed to 0.8m/m to make it to the ice face at the time water temperature at the nozzle is at a maximum.

15 Assuming the reels motor controllers are still in computer control mode, motors are still powered up and brakes are released, press the down button (under "State Controls"). The Cable reel "Down Request" indicator should turn green and "On", as shown in Figure 9.50 below. Note that only the Cable reel "Down Request" indicator turns green and "On". The hose reel indicator remains grayed out. This is because the hose reel has been synched to follow the cable reel and maintain a constant load on the hose. In order to do that it can automatically move up or down as needed to maintain that constant load.

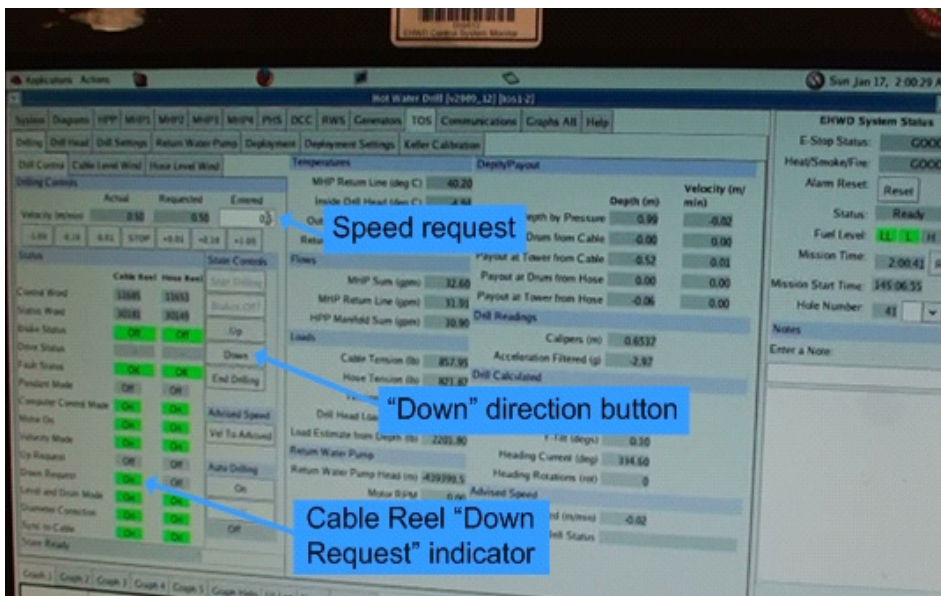


Figure 9.50 Display showing "Down" request button and "Down Request" indicator

- 16** Once the "Down Request" indicator on the cable reel has turned green, set the drill speed to 0.8m/min in the speed request "Entered" box shown above. Note that the entered speed is shown in the "requested" box and once the controller has received the speed setting it reports the speed back to the program and the entered speed is shown in the "Actual" speed box.
- 17** From this point on someone must be standing near the hole taping the drill cable to the drill hose every 15 feet. It's important to tape the hose onto the cable properly to prevent tape sections slipping and resulting in more load on the hose than necessary and maybe even exceeding the hose load limit. The proper taping procedure is 3 tight overlapping wraps, as shown in Figure 9.51

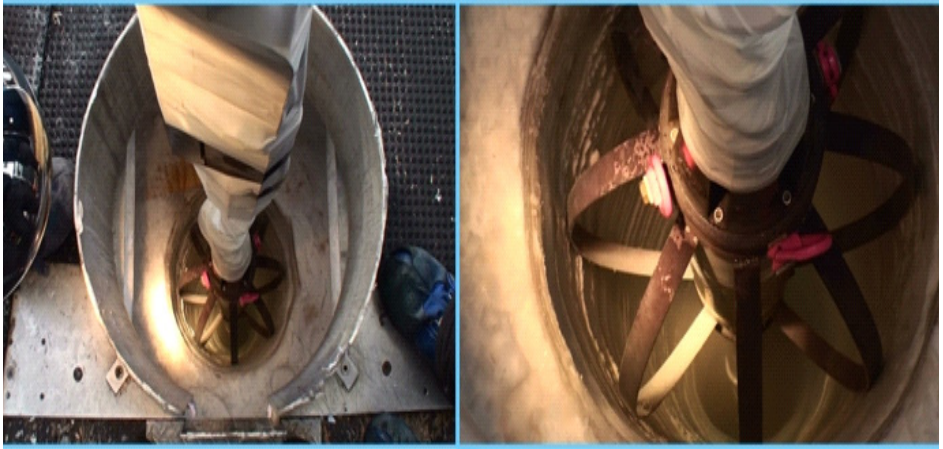


**Figure 9.51** Proper taping Procedure

Click on the video link below to view the proper hose/ cable taping technique.

## Taping main hose and cable.mp4

The drill should now be moving slowly down the hole and steam should be visible in the hole, as shown in Figure 9.52.



**Figure 9.52** Drill moving down hole and steam evident from the bottom of drill  
Click on the video link below to see a video of the drill startup procedure.

[Drilling Start up at the Tower.mp4](#)

## 9.6 Deploying Submersible Pump.

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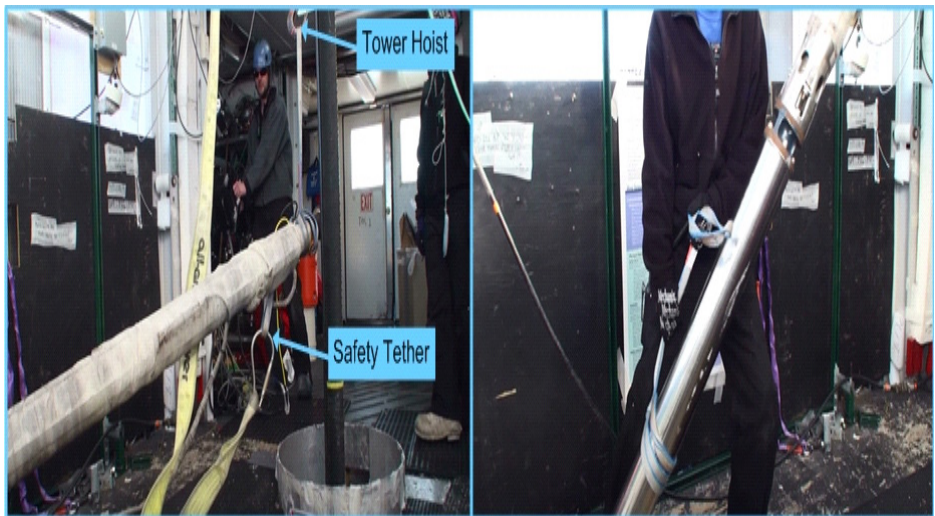
Once the drill is moving slowly down the hole, it becomes important to try and get the pump deployed as quickly as possible in order to recover the water that is being pumped down the hole. The water tanks are 10000 gallons each. However at 200gpm flow rate, the tanks will be fully drained in about 1.5 hours. However not all the tank level is useable due to the fact that the pumps have their inlet above the tank floor. Even with make up water being pumped from the Rodwell during the initial phase of drilling, in practice we only have about an hour of useable water in the tanks before flow rate has to be reduced until water recovery from the hole can take place.

This obviously can't happen until the top of the drill has gone passed the water level in the hole. However by preparing the submersible pump and commencing lowering so it's "chasing" the drill head down but staying a safe 5m away from the top of the drill, the pump can be positioned in place as quickly as possible as soon as the drill head is a safe distance away from the

pump "parking spot". In practice the pump should be lowered so it has at least 10m of head and if time permits, around 15-20m is better.

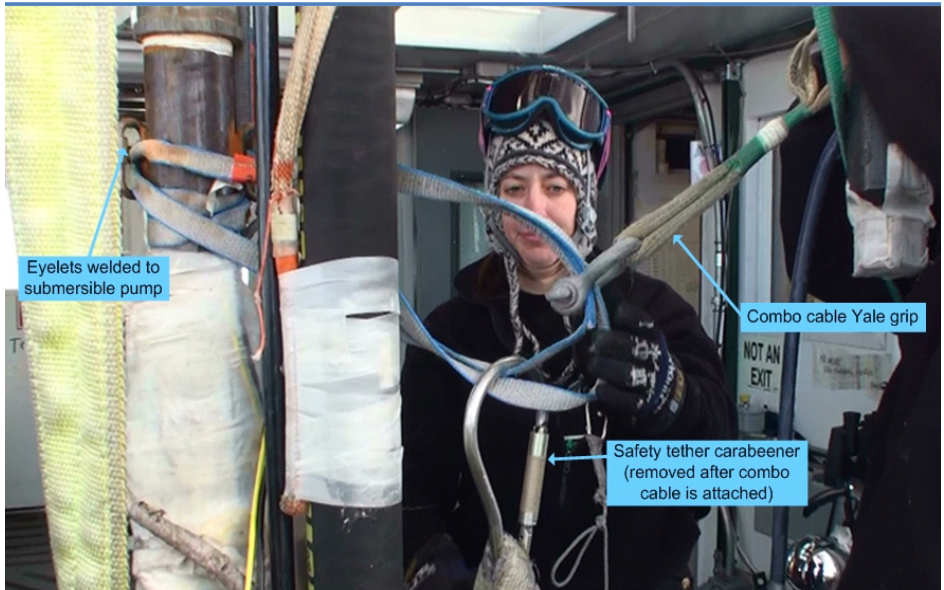
#### 9.6.0.0.1 To Deploy the submersible pump:

- 1 Wrap a sling under the eyelets welded to the top of the pump and connect this sling to the tower hoist.
- 2 Attach another sling through the eyelets and connect this sling via a safety strap to an anchor point at the top of the tower. The sling that's passed through the eyelets will eventually attach to the Return water combo cable. It's therefore important that this sling be the right length so the combo cable strength member takes up the load before the connectors on the combo cable which attach to the pump go taught.
- 3 Slowly hoist the pump up using the tower hoist while another person with a sling around the lower part of the pump motor section slowly maneuvers the pump into position, as shown in Figure 9.53.



**Figure 9.53** Submersible pump being maneuvered into hole with safety tether attached.

- 4 Position the pump over the hole then remove the hole covers before lowering the pump to a convenient working position in the hole. Then using a D-shackle, attach the combo cable Yale grip eyelet to the sling that has the safety tether attached, as shown in Figure 9.54, then remove the sling.



**Figure 9.54** Attaching combo cable to submersible pump

- 5 Attach the return water hose to the top of the pump using the clamshell coupler, as shown in Figure 9.55.



**Figure 9.55** Attaching return water hose to pump.

- 6 Lower the pump with the tower hoist until the combo cable is taught and taking the pump weight. Take up the return water hose slack so it's taught but not taking any pump weight.
- 7 Once the combo cable has the weight, disconnect the tower hoist from the pump.
- 8 Attach the pressure and temperature sensors to the combo cable connectors after making sure the O-rings in each connector are in place prior to mating, as shown in Figure 9.56. Failure to do this will likely lead to communications problems with the sensors.



**Figure 9.56** Connecting pump pressure and temperature sensors to combo cable

- 9 Make sure the return water pump motor controller is switched off. Check the pump power connector and the mating connector on the combo cable to make sure the O-rings are in place, then attach the pump power connector to the combo cable connector, as shown in Figure 9.57.



**Figure 9.57** Inspecting pump power and combo cable mating connectors for O-Rings

- 10 Once all connectors are properly mated, open the main outlet valve at the end of the return water hose, as shown in Figure 9.58.



**Figure 9.58** Opening return water hose outlet valve prior to lowering pump

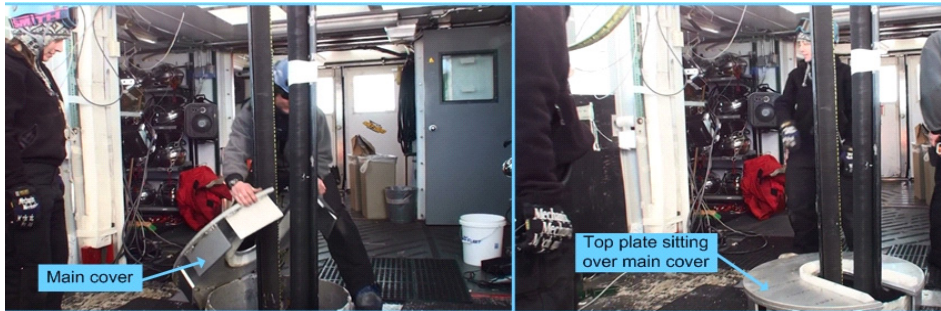
**11** Tape all the cables, connectors and slings tightly against the pump body, as shown in Figure 9.59, to prevent any cables accidentally catching on the way down the hole.



**Figure 9.59** Taping submersible pump cables, connectors and slings against pump body.

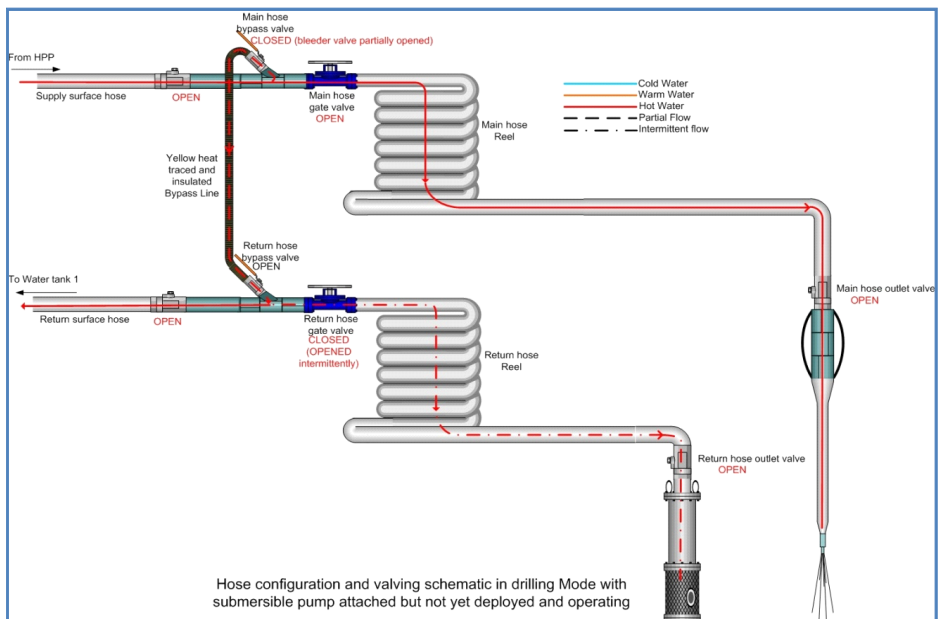


**12** Lower the pump until it's just below the hole tower and place the hole covers back over the hole, as shown in Figure 9.60. Note the tapered guides on the bottom of the main cover and the top of the top plate. These guides are designed to guide the hose connectors into the opening in the covers rather than catching on the plates, either on the way down or up. The pump is now ready to be lowered into position.



**Figure 9.60** Installing hole covers after submersible pump has been lowered into hole

**13** While waiting for the drill head to go past the spot at which the pump will be positioned, it is a good idea to periodically reverse flow some water into the pump hose and down to the pump to prevent freezing. This is done as follows. Refer to Figure 9.61.



**Figure 9.61** Valving arrangement and water flow when back flushing water to pump

While the submersible pump is connected but before it's in position and running, every 5 minutes or so open the "return hose gate valve" for about 30 seconds to flush some water back down through the return water reel and through the pump to prevent the pump or the hose from freezing.

Click on the video link below to view a video showing the submersible pump being installed, lowered and started.

Installing and Starting the return water pump.mp4

## 9.7 Main Hole Drilling.

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While the pump was being set up for deployment, the drill head has been slowly descending into the hole. Hopefully in the time the pump was being prepared the drill head has now reached the ice face and it's now time to set the drilling speed for the current depth at the given water flow and temperature.

Thermal modeling has been done which give drill speed vs depth for a given temperature and flow rate and ream speeds vs depth for a given temperature, flow rate and hole diameter in order to produce a hole of the required lifetime. The drill software has these models incorporated which automatically adjust the speed to produce the required hole lifetime once automatic drilling is selected.

An excel program has also been put together to calculate the required speed when current parameters (required hole lifetime, depth, water temp, water flow rate and hole diameter (for reaming) are entered). A link to this program is given below.

		<b>Start Calculator</b>			
Date	Note				
15/12/2005	This is a version of Ted's drill and ream speed calculator.				
	Heavily based on work by Lee Greenler. Help from TerryB				

**Figure 9.62** Drill and Ream calculator

In addition a chart has been produced for drill speed vs. depth for a required hole lifetime as well as a set of charts which will give ream speed vs. depth and hole diameter for a required hole lifetime. These charts assume a 190gpm flow and 87°C and are used as follows:

## 9.7.1 Drill Chart.

The drill chart is a simple chart showing graphs of drill speed versus depth to produce a given hole lifetime. To drill a hole to a lifetime not shown in the graph, extrapolate to the lifetime required.

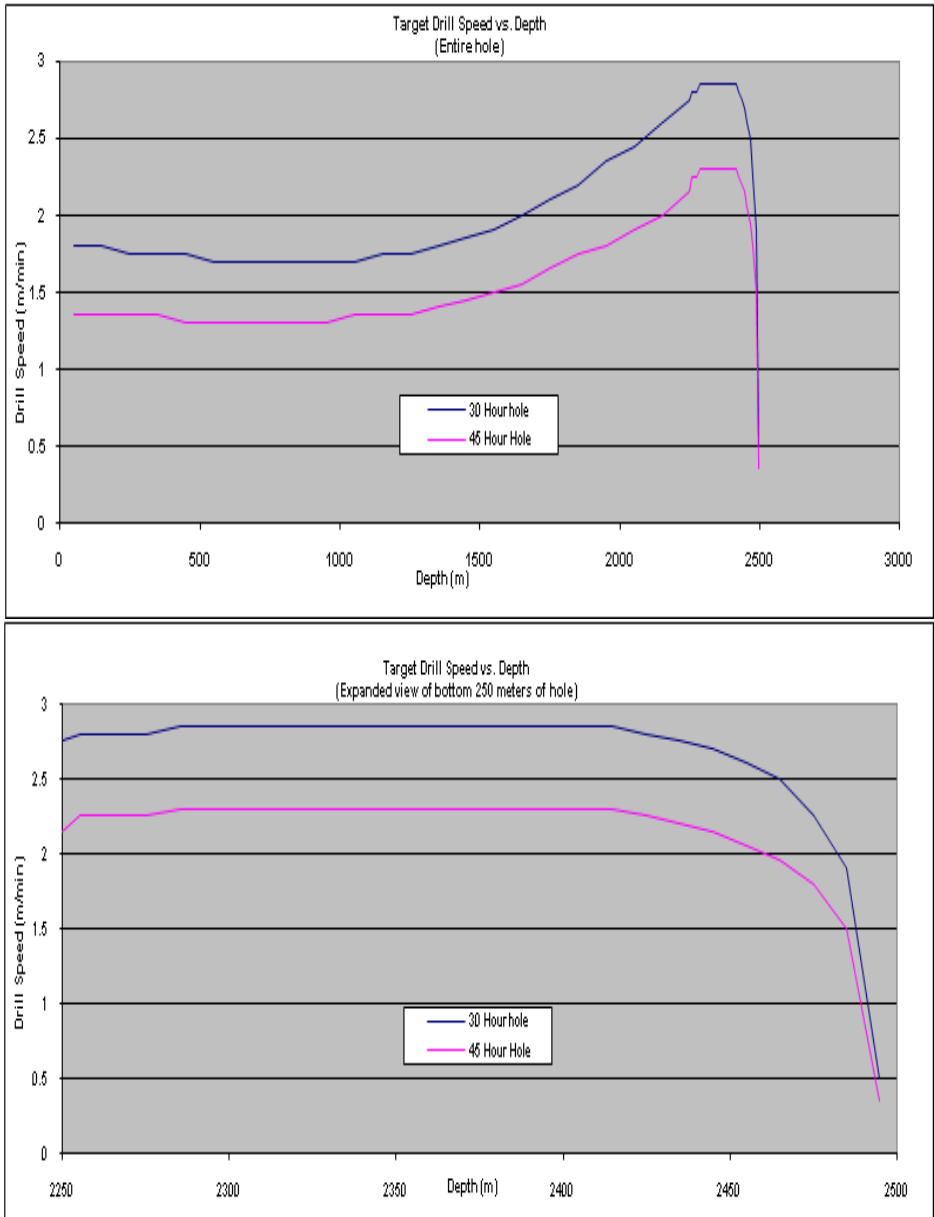


Figure 9.63 Drilling speed Vs Depth plots 30 hour and 45 hour lifetime holes

The above graphs show drill speeds Vs depth for both a 30 hour and a 45 hour hole. The bottom graph shows an expanded plot of the bottom 250m to aid in reading.

To use the above graphs, decide what hole lifetime the hole is going to be drilled at. That decision partly depends on what else is being deployed in the hole besides the DOM string and partly on what other issues or problems there may be with the drill system at the time and needs to be made on a hole by hole basis. Once a decision about hole lifetime is made, on the drill charts above look up the speed at which the hole should be drilled at the given depth. If the hole lifetime is between 30 and 45 hours, simply extrapolate between the two values above.

For example, for a 33 hour hole lifetime, at 1500m depth, the drill speed should be about 1.95m/ min.

The above graphs are based on a water flow of 190gpm at 87°C. If either the flow or the temperature drops, the drill speed needs to be scaled accordingly.

It is possible to correct for incorrect drill speed during the ream process. It is however important to concentrate on the caliper diameter during drilling to make sure the drill speed is not so fast that the hole is too small for the drill head and calipers to fit through. The calipers should not read less than 0.34m when drilling down the hole. If they do, the drill speed should be reduced until the diameter exceeds 0.34m.

**Note: It has been determined from experience that the drill will begin to oscillate in the hole when the drilling speed exceeds 2.1m/ min. Therefore it is very important that this drill speed is never exceeded, even when the drill plots suggest that a faster speed is possible.**

Given the above note regarding drill oscillations, in practice if a hole of 27 hour or less hole lifetime is being drilled, the modelling would suggest a drill speed of faster than 2.1m/min for a significant proportion of the drilling time, which we are not allowed to exceed. However, because the hole lifetime is determined by both the drill and ream speeds, any speed reduction during drilling can be made up for when reaming.

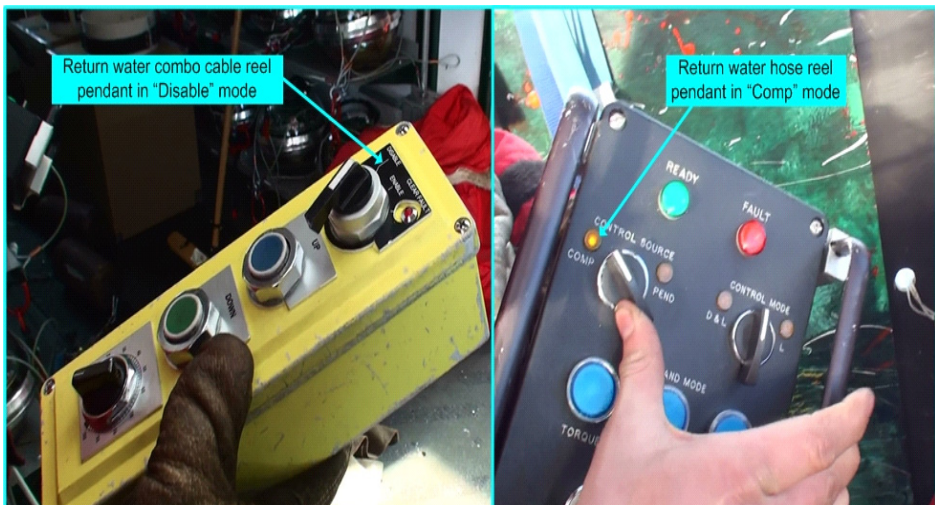
- 1 If drilling manually, assuming 190gpm and 87°C, set the drill speed according to the depth for the required hole lifetime. If either the flow or temperature are different from the above values, scale the speed accordingly. In practice, unless the flow or temperature is significantly different from above, then the speed can be maintained according to the chart.
- 2 Continue to lower the pump while making sure the pump load is taken by the combo cable and the pump remains at least 5m above the drill head. Continue to periodically backflush water down the return hose to the pump until the pump is in position

- 3 Once the pump is about 10-5m below the water surface, stop the pump, set the brakes on both the combo cable and return water hose reels by "dumping" the fluid from the hydraulic cylinders using the bleeder valves, as shown in Figure 9.64.



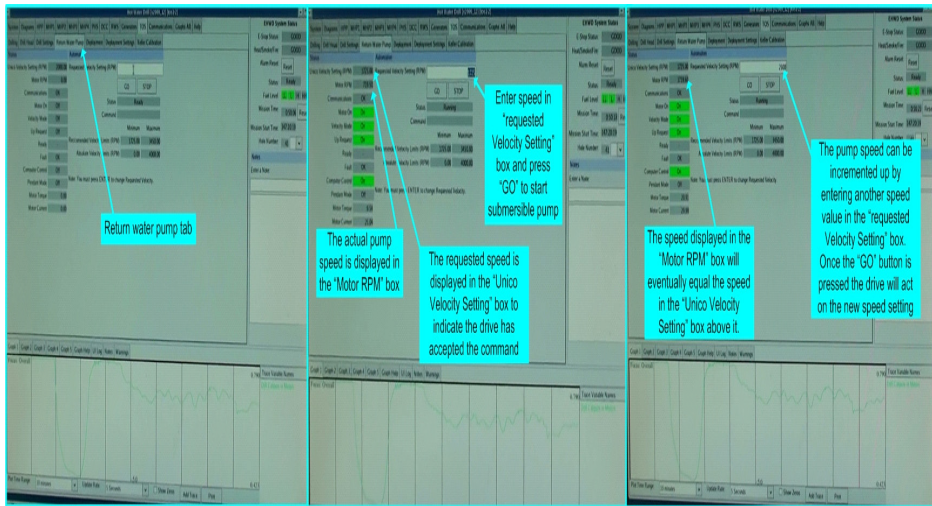
**Figure 9.64** Return water pump reel and Combo cable reel brakes being applied

- 4 Disable both the return water combo cable reel and the return water hose reel motor controllers by placing the cable reel pendant into "Disable" mode and the return water hose reel pendant into "Comp" mode, as shown in Figure 9.65.



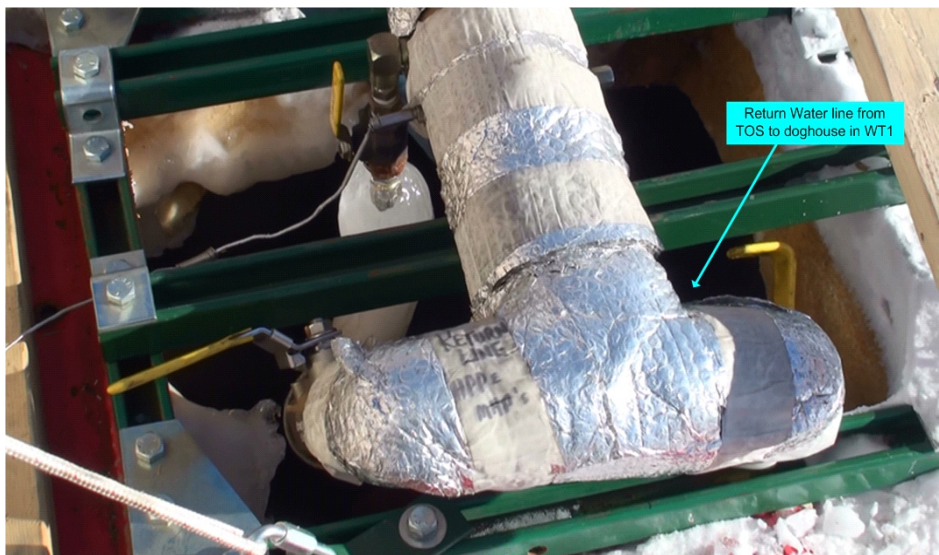
**Figure 9.65** Return Water Reel Pendants being placed in mode to disable corresponding motor controllers

- 5 Inform the DCC operator the return water pump is about to be turned on and turn on the motor controller driving the return pump.
- 6 Turn the pump on as shown in Figure 9.66 and bring up the pump speed in increments until the pump is set at the 3400rpm.



**Figure 9.66** Return water pump control on software screen

- 7 Check the return water hose at tank 1 to make sure water flow is returning back to the tank from the pump, as shown in Figure 9.67.



**Figure 9.67** Return water hose outlet at Water tank 1.

- 8 Once return water flow has been established, the system is now in stable drilling mode. Inform the DCC operator that he now has control of the return water pump.
- 9 Keep a close watch on the following drilling parameters, which are highlighted in Figure 9.68 below, to make sure drilling is proceeding smoothly:

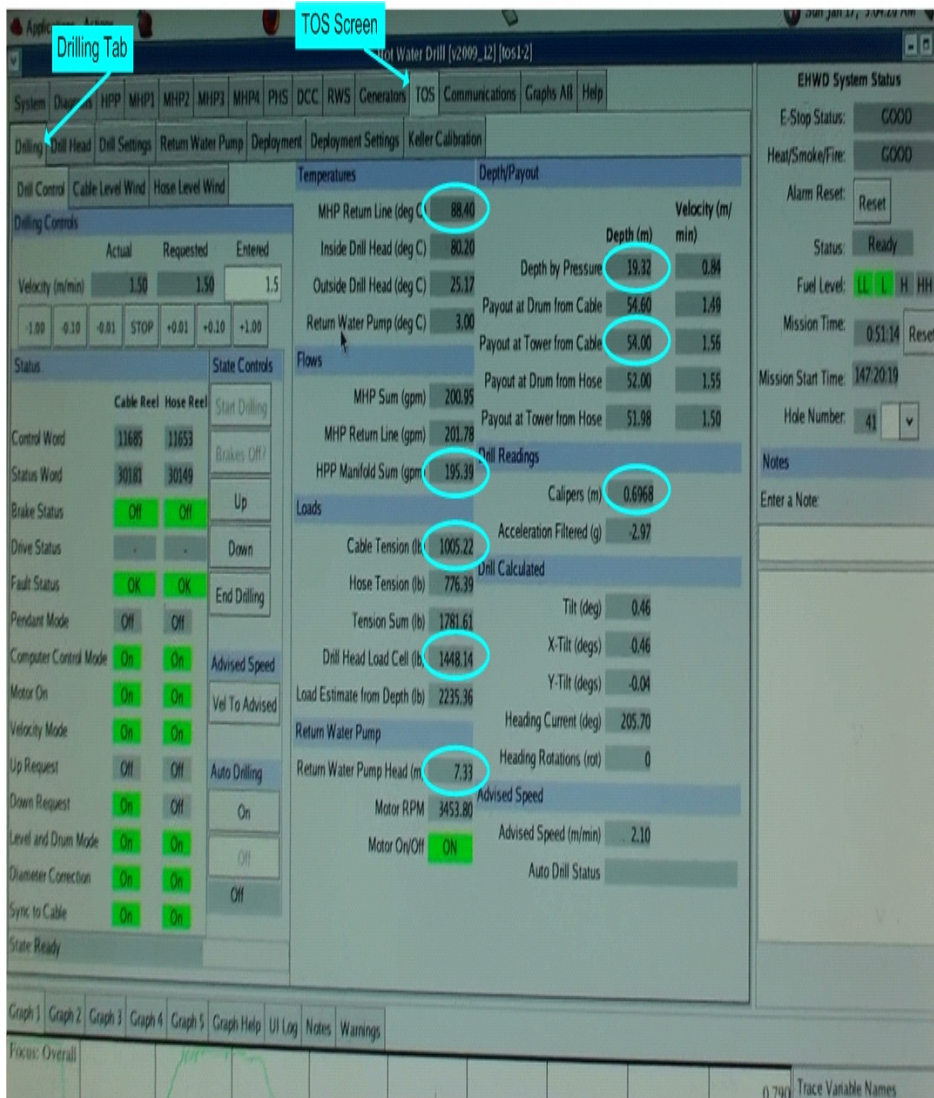


Figure 9.68 Drill parameters to watch while drilling.

- a System pressure shown as "MHP Return Line Pressure" in the "system/ General tab (Not to exceed 1100psi)
- b "MHP Return Line" temperature (Should be between 86-87°C. Not to exceed 88°C)
- c HPP outlet water flow rate shown as "HPP Manifold Sum" (Should be around 190-200gpm)
- d Hole diameter displayed as "Calipers" (Not to be less than 0.34m)
- e "Payout at Tower from Cable" (Should be tracking pressure depth but be less than pressure depth. The difference is the depth of the water level from the surface).
- f "Depth by pressure" (Should be constantly increasing by the set speed/ min. If not, the drill may be stuck in the hole)
- g "Cable Tension" ( Should be increasing constantly with depth)
- h "Drill Head Load Cell" (Should be constant with no oscillations. If oscillating, drill head may be bouncing off the bottom of the ice)
- i "Return Water Pump Head" (should always be above zero when pump is on. In practice try to maintain around 8m or more of water head above the pump).

## 9.8 Main Hole Reaming.

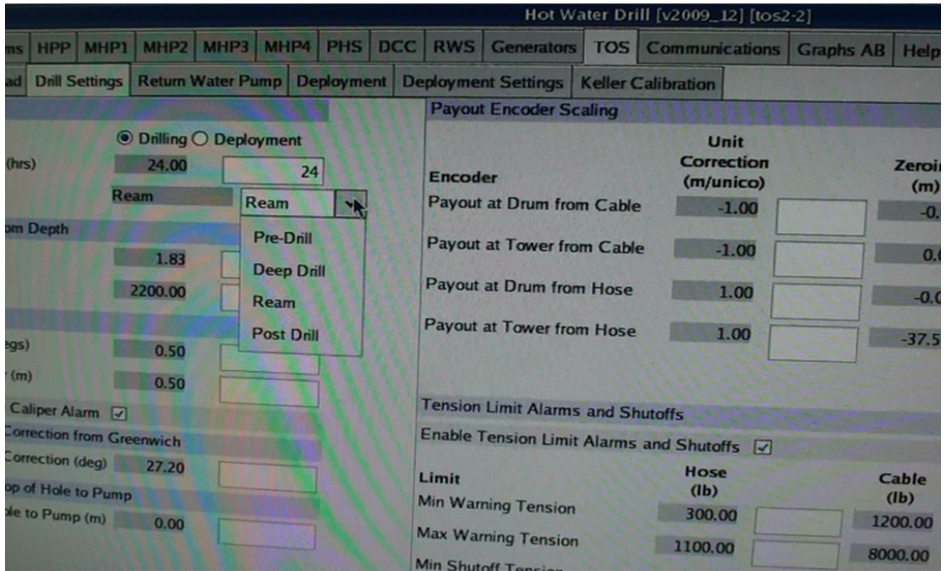
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About 2m before the drill has reached the required depth, allow the drill to dwell at the bottom of the hole by slowing the speed down to about 0.1m/min and leaving it to run for about 20 minutes to deposit enough water at the bottom of the hole to allow it to properly develop to the required diameter.

The reason the drill is slowed down rather than stopped is to prevent the possibility of any part of the drill, specifically the calipers, from freezing against the hole wall.

While dwelling, change the software mode to reaming as shown in Figure 9.69. This lets the software know that reaming is taking place so that software "Auto Drilling" mode can be implemented if required. It also allows the software to report an accurate "advised Speed" setting while reaming.





**Figure 9.69** Changing the drill direction.

Once dwelling is completed, set the drill speed to "zero", change the drill direction to "Up" and set the ream speed.

The ream speed on the way back out of the hole needs to be set according to the ream charts, to allow the hole to be properly reamed to the right diameter to give the required hole lifetime. This is done as follows.

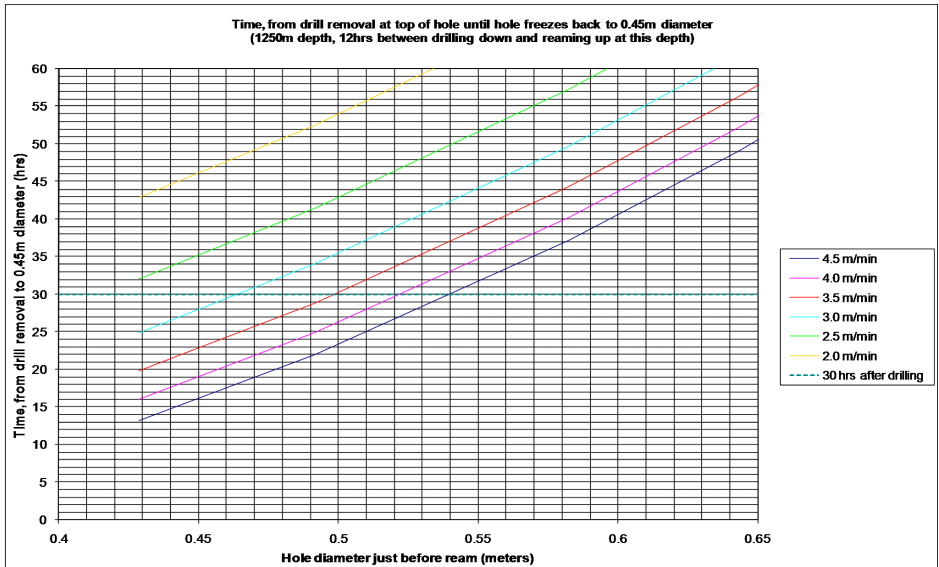
### 9.8.1 Ream Charts.

Reaming is the process of depositing hot water in the hole while bringing the drill back up to the surface at a predetermined speed, after drilling to the bottom of the hole. The speed at which the hole is reamed at depends on the water flow and temperature, as well as the diameter of the hole at the depth the drill head caliper is measuring just prior to the hot water being deposited. The hot water deposited in the ream process continues to work on the surrounding ice to widen the hole and give the hole its target lifetime.

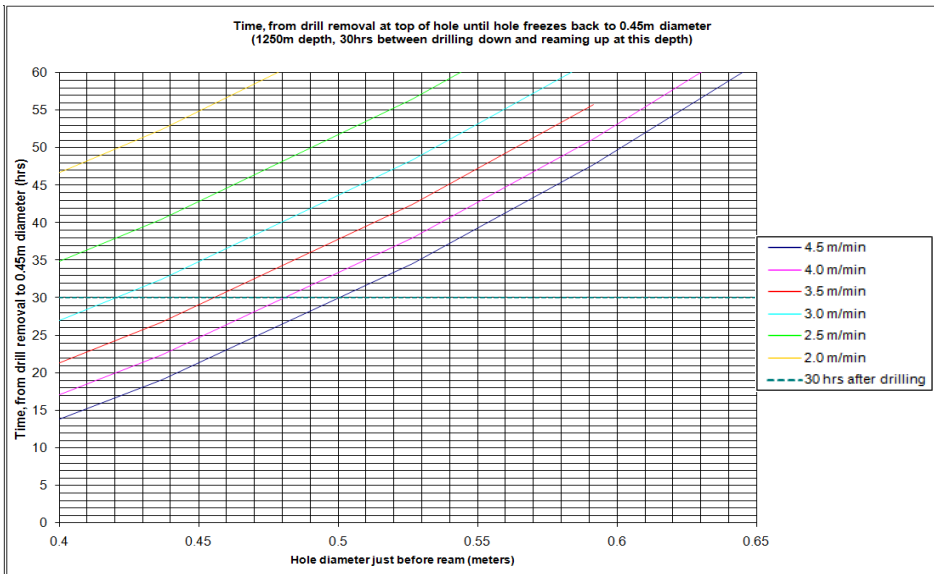
The ream charts are a little more complicated than the drill charts. There are a series of ream charts produced for each 500m section of hole and centered in the middle of the 500m section, detailing reaming speed in that 500m section for a given hole lifetime and a given hole diameter. There are also two sets of these

ream charts produced, one set assuming steady drilling with no delays during the drilling process and another set to be used in case there were problems during the drilling process, resulting in delays.

Figure 9.70 and Figure 9.71 below are two ream charts for the 500m section of hole centered on 1250m depth.



**Figure 9.70** Ream chart for 1250m region assuming normal delay between drilling and reaming



**Figure 9.71** Ream chart for 1250m region assuming 30 hour delay between drilling and reaming

Notice the chart in Figure 9.70 gives the ream speeds for various borehole diameters for a range of hole lifetimes, assuming it has taken 12 hours after drilling down past this spot and then reaming back up to this same spot. This is the expected time interval, assuming drilling and reaming are proceeding normally, between when the drill passes this spot on the way down and when it comes back up to this spot on the way up.

The chart below it in Figure 9.71 is a ream chart for the same section of hole, assuming it has taken 30 hours between first passing this spot on the way down then coming back to this spot on the way up. This chart gives the longest time that can be reasonably expected between drilling down to this spot, and reaming back up to the same spot. This chart would be used when there have been problems and drilling or reaming has proceeded slower than normal. For delays somewhere between the two time intervals, some extrapolation would be required.

If you look at ream charts for other sections of hole, you will notice that the time intervals for the two charts for that section are different to the time interval for the 1250m section, or any other section of hole. This reflects the fact that for each section of hole the time it takes to come back to that spot again after first reaching it is different to any other section. The second plot for each section is always the longest time interval that can be expected between drilling down to that location and reaming back up to that same spot.

A couple of paragraphs up it is stated that some extrapolation may be required between these charts if the time intervals are different to that given in the charts. In practice, there is not a lot of difference between the two sets of plots for each section and therefore it is not critical that precise extrapolation be done if the time intervals are not as shown in the charts. The first set of charts (with the short time interval) should be used if drilling is proceeding smoothly. The second set of charts should only be used if there have been very significant delays during the drilling or reaming operations. If the delays are only of the order of a few hours, then the first set of charts should be used. These charts are produced assuming a flow rate of 190gpm at a temp of 88°C, and extrapolation will be necessary to compensate for changes in flow or temperature.

#### **9.8.1.0.1 Using Ream Charts:**

- 1** Determine the borehole diameter at the current depth from the caliper reading on the screen.
- 2** Locate the ream chart which covers the depth of interest.
- 3** Determine which of the two charts for that depth to use based on the past history of the hole; i.e. have there been major delays during the drilling/

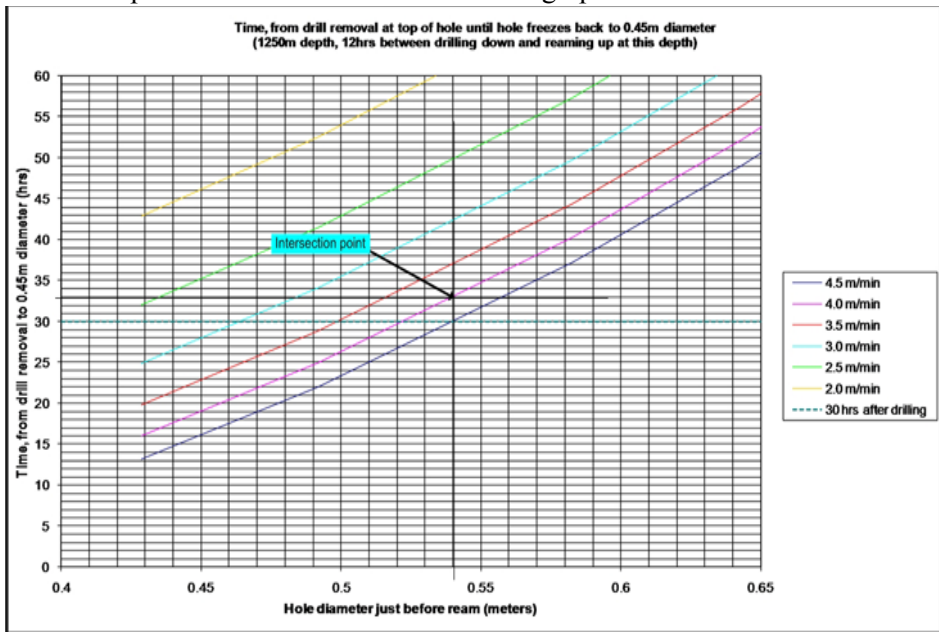
reaming operation. If the delays are only of the order of a few hours, use the chart with the smaller time interval.

- 4 From that chart, look along the X-axis to find the caliper diameter and draw a line straight up from this point.
- 5 Look up along the Y-axis to locate the hole lifetime figure the hole is been drilled to and draw a straight line along the graph from this point.
- 6 Find the point where these two lines meet. If the point where these two lines intersect sits on one of the coloured lines on the chart, read the legend on the right hand side of the chart to determine the ream speed the drill should be moving at for that section of hole.
- 7 if the intersect point falls between two of the coloured lines, extrapolate to a ream speed figure somewhere between these two lines.

**Example 1:**

Assuming we are drilling a 33 hour lifetime hole and this has been proceeding smoothly. We are currently reaming at 1400m and the caliper diameter is reading 0.54m. The 1400m location in the hole is covered by the 1250m ream chart, which covers the depth from 1000m to 1500m.

From Figure 9.72, if we draw a straight line up from 0.54m, it meets the straight line across from the 33 hour hole lifetime mark precisely on the pink line. From the colour legend on the right of the graph, the pink line corresponds to a ream speed of 4.0m/ min as shown in the graph below.

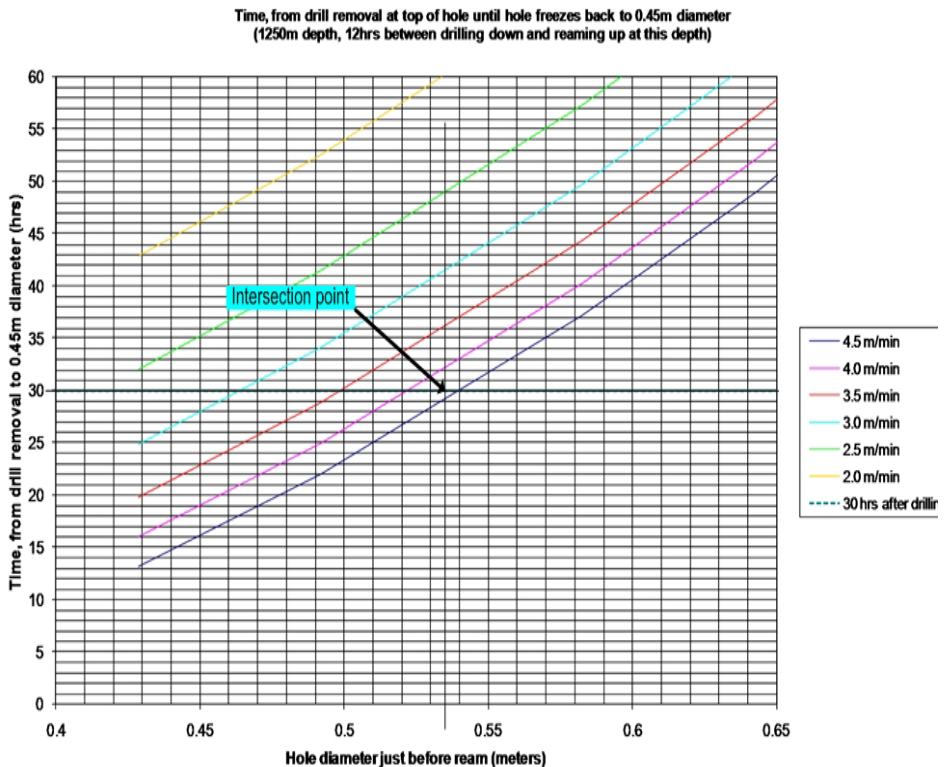


**Figure 9.72** Reaming speed calculation example 1.

## Example 2:

Assuming we are drilling a 30 hour lifetime hole and drilling is proceeding smoothly. We are currently reaming at 1200m and the caliper diameter is 0.535m. Here again, we use the chart centered on the 1250m section of hole.

Again, from Figure 9.73, drawing the straight lines from the X and Y axis corresponding to these two values, we find the intersection point is between the blue and the pink line. Extrapolating between the two, we see that the intersect point is a little closer to the blue line and we should therefore be reaming at 4.3m/ min, as shown in the graph below.



**Figure 9.73** Reaming Speed calculation example 2.

### Adjusting for changes in caliper Diameter:

The drill nozzle is some 77 feet below the caliper, where the borehole diameter is being read. Therefore it is important to remember that there will be a delay between when the reading takes place and when the change to speed should be made. A table of these speed up/ slow down time should be displayed on the wall in the TOS near the drill operator seat.

Click on the link below to view a video describing the reaming process.

## Reaming.mp4

### 9.9 Submersible Pump Retrieval

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The drill must not be brought out of the hole while the submersible pump is still in position, so when the drill head is approximately 20m from the submersible pump, the pump needs to be turned off and retrieved from the hole before the drill head can be retrieved.

- 1** While the drill head is still about 150m below the submersible pump, lower the pump as far as it can be safely lowered and set the pump speed to maximum to recover as much water from the hole as possible.
- 2** Once the drill head is approximately 20m below the submersible pump, reduce the drill ream speed to about 0.1m/m and request the DCC operator reduce water flow rate to around 50gpm in order to conserve water while the pump is being retrieved.
- 3** Turn off the submersible pump in software and turn off the pump controller. Set the hose reel valving arrangement as shown in Figure 9.62. This prevents water in the return water hose from siphoning back down the hole while intermittently opening the return hose gate valve allows water to be backflushed back down to the pump to prevent freezing while the pump is retrieved.
- 4** While retrieving the submersible pump, periodically open the return hose gate valve for 30 seconds every five minutes to keep the pump and return hose from freezing.
- 5** When the pump inlet is at around 40m, half open the main hose bypass valve and fully open the return hose gate valve and slowly raise the pump past the constriction in the hole at around 38m. This will backflush some hot water in the hole and hopefully widen the narrow spot at around 36-38m.
- 6** Once just above the narrow spot, stop raising the submersible pump and continue backflushing hot water down the hole for about 5 minutes while slowly moving the return pump hose around the hole to try and deposit water evenly over the hole wall near the narrow spot.

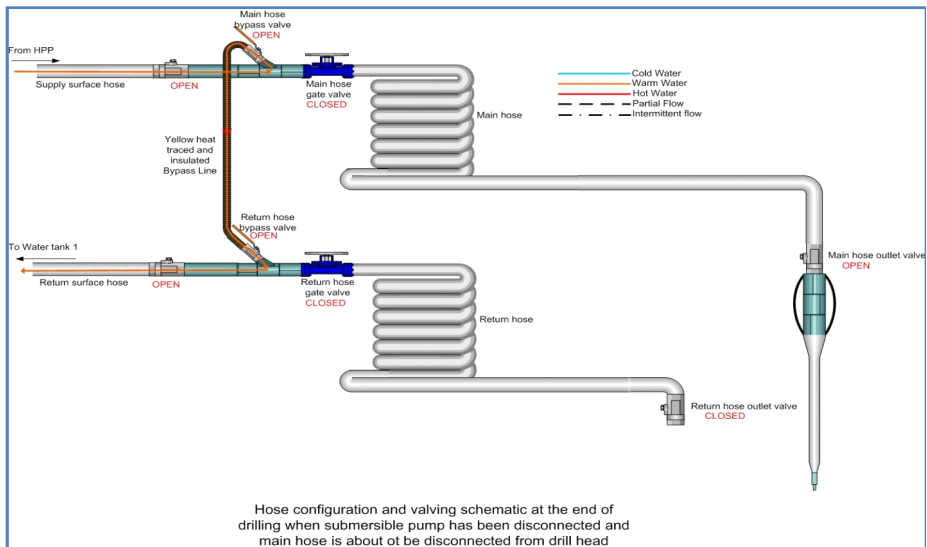
- 7 After backflushing the narrow spot, continue winching the pump up to the surface. Once at the surface disconnect the pump combo cable power connector and the two sensor connectors from the pump. Attach covers to all connectors or tape the ends to protect the connectors.
- 8 Shut off the return water hose outlet valve and disconnect the hose from the pump.
- 9 Tie off the pump combo cable and the return water hose to the side of the tower while removing the pump from the hole.
- 10 Pump removal is the reverse of pump installation, again making sure the pump has two tethers attached to it at any one time while over the hole.

## **9.10 Extracting hoses from Tower and Forming Water Loop**

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At this point there is no water circulating in the return water hose and the hose has to be reconnected to the water loop as soon as possible. This can however wait until after the main hose reel has been disconnected from the drill head and both hoses have been extracted from the tower and wound onto their respective reels. If this process looks like it will take much longer than an hour, then the return water hose should be placed in a temporary water loop in order to re-warm the water in the hose.

- 1 Once the pump is out of the hole, increase the drill head speed to 0.5m/min and continue reaming until the drill nozzle is out of the water.
- 2 Once the nozzle has cleared the water at the top of the hole (at around 38m), ask the DCC operator to turn the heaters off but continue water flow at around 35gpm. At this point flow to the drill head is about to be diverted to conserve water while the drill head is being winched to the surface. This is done because the drill nozzle is now out of the water and the straight jet on the end of the nozzle has minimal impact on widening the hole in the firm layer. So water flow is diverted back to the tanks in order to conserve water.
- 3 Divert all water flow from the drill head to the surface hoses by first making sure the return hose bypass valve is open and the return hose outlet valve is closed. Then fully open the main hose bypass valve before closing the main hose gate valve. It is important that the sequence above is followed so as not to "dead head" the pumps. The valving arrangement should look as shown in Figure 9.74 below.



**Figure 9.74** Valving arrangement in bypass mode with pump disconnected and drill head still connected

- 4 Continue to winch the drill head up to the surface.
- 5 While the drill head is being winched up, extract the submersible pump combo cable and return hose from the tower. Wind the combo cable fully onto its reel and wind the return water hose almost fully on; leaving the valve at the end of the hose sitting on the winch base plate (as shown in Figure 9.3) so as to allow the bypass line to be connected later on. Extracting the hose and combo cable from the tower is the reversal of the process for bringing them into the tower.
- 6 Once the drill head is at the surface, apply a safety tether to the drill head, close the main hose outlet valve and disconnect the main hose from the drill head.
- 7 Extract the main hose from the tower and wind back onto the main hose reel until just before the main hose outlet valve enters the level wind (as shown in the first slide of Figure 9.4). Extracting the main hose is the reversal of the process to bring the hose into the tower.
- 8 Connect the bypass hose adaptors to the end of the main and return water hoses (as shown in Figure 9.4).
- 9 Ask the DCC operator to stop water flow and wait for confirmation that system pressure is zero.



- 10** Once the system pressure is zero, close the main hose and return hose bypass valves, disconnect the bypass hose from these valves and connect to the main and return water hose outlet valves (via the adaptors, as shown in Figure 9.4).
- 11** Open the main hose and return hose gate valves, then open the main hose and return hose outlet valves. The hose and valve arrangements should now be in "bypass" mode and be as shown in Figure 9.2.
- 12** Ask the DCC operator to reestablish water flow at 35gpm and around 25°C, and watch to make sure the system pressure doesn't spike. Check to make sure water is returning to tank 1.
- 13** At this point the system is in stable idle mode and work can commence on extracting the drill head and weight stack from the hole and preparing the reels for relocation.

Click on the link below to view a video showing the drill system being placed in idle mode at the drill camp (SES).

[Changing from Drill Mode to Idle Mode at Drill Camp.mp4](#)

## **9.11 Disconnecting Drill Head and Main Drill Cable.**

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Drill head disconnection storage is a reversal of the process for attaching it to the weight stack. Similarly with removing the drill cable from the tower. The important things to keep in mind are:

- 1** Always have two independent tethers attached to any equipment sitting over the hole.
- 2** Make sure to switch power off to the drill head prior to disconnecting the cable electrical connector from the drill head. Cover the drill cable electrical connector after disconnecting it from the drill head.
- 3** Make sure the weight stack quick clamp and pipe elevator (with a safety tether) is attached to the weight stack prior to disconnecting the drill head from the weight stack.
- 4** Make sure the drill head is lifted by the eye bolts so as not to damage the load cell located at the top of the drill head.
- 5** It is very important that all guide rollers and anti whip rollers are removed from the sheaves prior to the drill cable being pulled through the sheaves.

- 6 It is especially important that the cable is never pulled through the sheaves by operating the winch. The drill cable must only be extracted from the sheaves by hand. The main cable winch must not be operated until the connector at the end of the cable is well clear of the sheaves. Failure to do this can severely damage the drill cable if the connector snags on any part of the sheaves as it is being extracted.
- 7 Once the cable connector is well clear of the sheaves, the winch can be operated carefully to wind the cable back onto the winch while an operator is holding the cable taught to allow it to properly wrap onto the reel.
- 8 It is critical that the reel is stopped before the cable connector is anywhere near the cable level wind guide. Failure to observe this can cause the connector to jam in the guide and rip the connector from the cable. In practice stop the winch with about 2m of the cable still unwound and manually "drape" the cable back over the reel and tie off loosely.

At this point, all the cables and hoses have been wound onto their respective reels, the drill head has been packed away, but the weight stack is still being removed from the hole and the system is still in a global E-Stop state.

The next step is to prepare the site for deployment and prepare the reels for relocation to the next site. This is covered in the next chapter.

Click on the video link below to view the process of removing the drill and weight stack, main hose and drill cable from the hole.

## Removing the Drill.mp4

The video link below shows the process of removing the submersible pump from the hole.

## removing the return water pump.mp4

# Chapter 10

## 10: PREPARING TOS/ TOWER SITE FOR DEPLOYMENT.

### 10.1 Introduction:

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The aim of this chapter is to describe the tasks that remain to be completed immediately after drilling has concluded and the processes involved in preparing the drill site for deployment.

This chapter assumes all the cables and hoses have been removed from the tower and wound onto their respective reels, the system is in "idle" mode with water circulating through all the hoses, the drill head has been disconnected but the weight stack has only been partially removed from the hole and work is still continuing on its dismantling. A further assumption is that the system is still in a global E-stop state and all the electrical and signal cables are still connected to their respective reels.

Once the system is in stable bypass mode and the cables are out of the tower, weight stack disassembly can begin or continue, free from the interruption of the drill head and other activity in the tower.

As well as completing the weight stack removal from the hole, the reels have to be prepared for the move to the next hole and the Tower site has to be prepared for the deployment reel to be positioned in place. In order to do this without accidentally triggering E-stops which will shut down the Seasonal Equipment Site (SES), the E-Stop system needs to be placed in "local" mode and all the winch E-stops and Reel stops have to be bypassed.

## 10.2 Switching to Local E-Stop and Bypassing Reels.

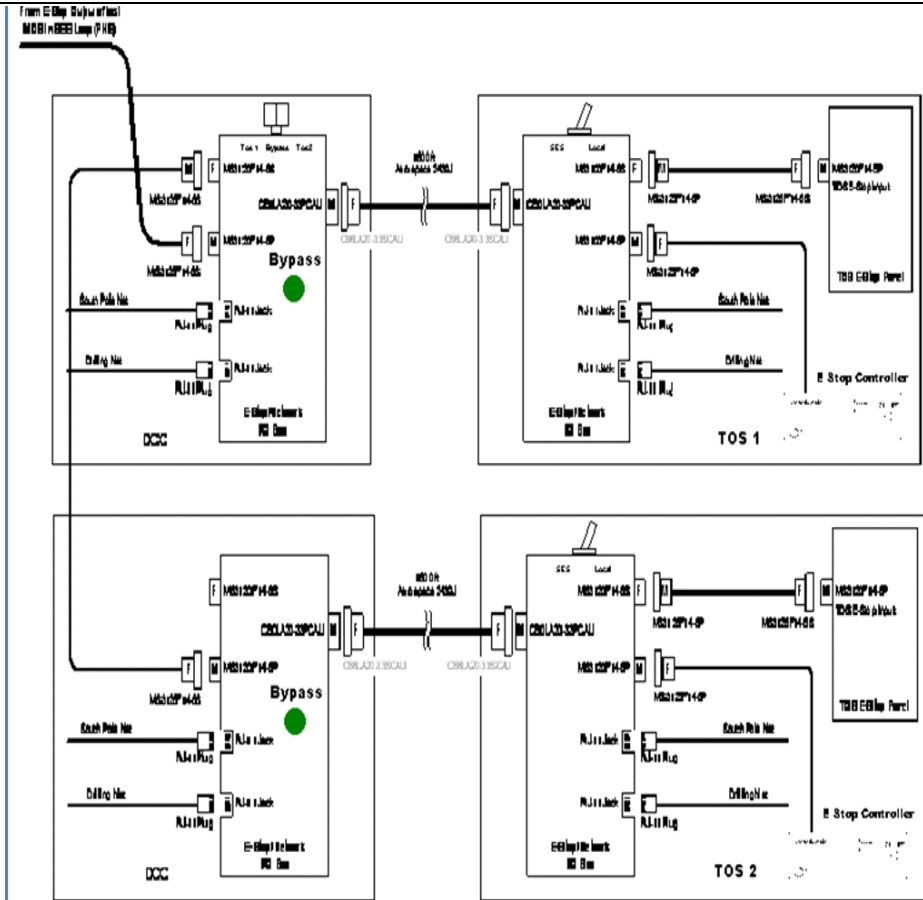
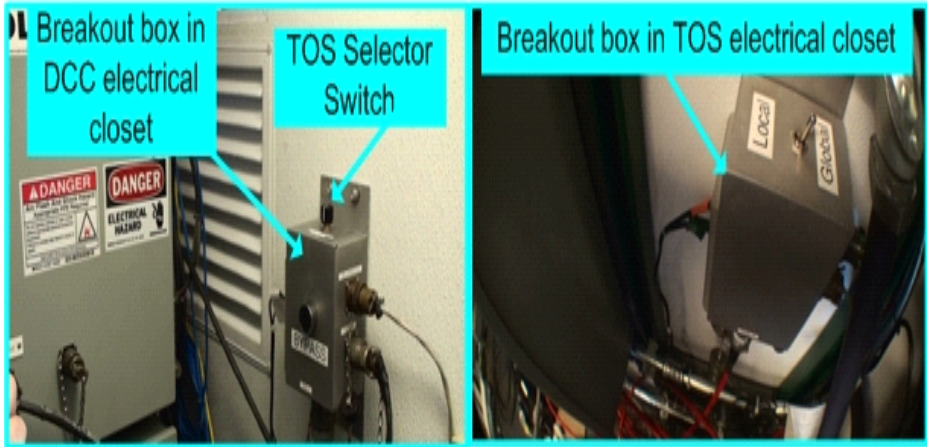


Figure 10.1 SES-TOS E-Stop Diagram

Figure 10.1 above shows the E-stop connection setup from the SES to each of the TOS'. The setup consists of two breakout boxes in the DCC (one for each TOS) with a TOS selector switch on one of the breakout boxes as shown in Figure 10.2 below.

The selector switch allows the E-Stop system to be placed in "global" mode by selecting one of the TOS' to be in the "global" E-Stop system, or in "Bypass" mode which puts the SES in a "local" E-stop mode.

At the TOS end, each TOS has a breakout box with a selector switch, as shown in Figure 10.2 below, to allow each TOS to be placed either in "Local" E-Stop mode or in "Global" mode by toggling the breakout box selector switch in that TOS.



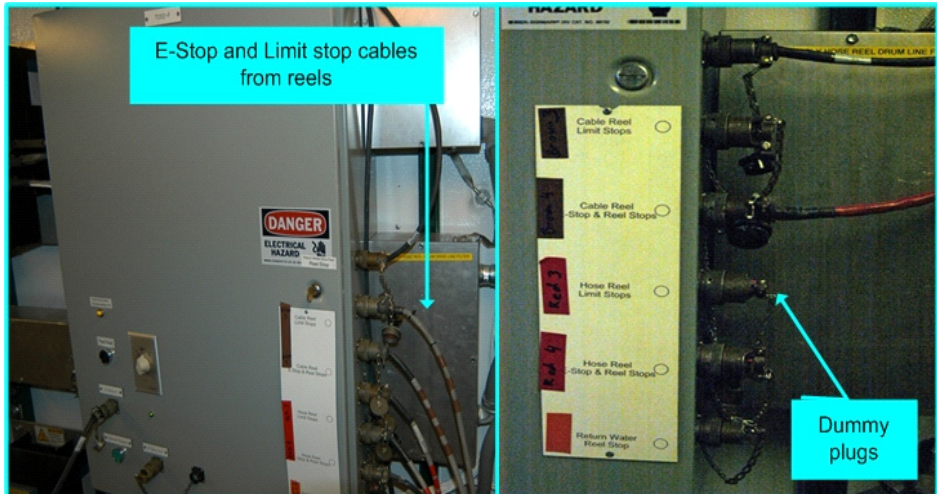
**Figure 10.2** E-Stop Breakout Box Locations in the DCC and TOS Electrical Closets

**To change over from Global to Local E-Stop and bypass the reels:**

Click on the video link below to view the proces of changing from local to global E-stop.

### E-Stop local and Global.mp4

- 1 Press and hold the "bypass" button on the breakout box in the DCC electrical closet.
- 2 Turn the TOS selector switch to "Bypass"
- 3 Release the "bypass" button
- 4 At the TOS breakout box, switch the "Local/ Global" selector switch to "Local"
- 5 Restart the TOS E-Stop controller by turning the key to "START/RUN" then releasing it.
- 6 Once the system is in "Local" E-Stop, bypass all the hose and cable reel E-Stops/ Reel Stops and limit stops by disconnecting the respective winch reel "Limit Stop" and "E-stop/ Reel Stop" cables from the electrical panel and replacing them with the dummy plugs hanging off the sockets, as shown in Figure 10.3 below.



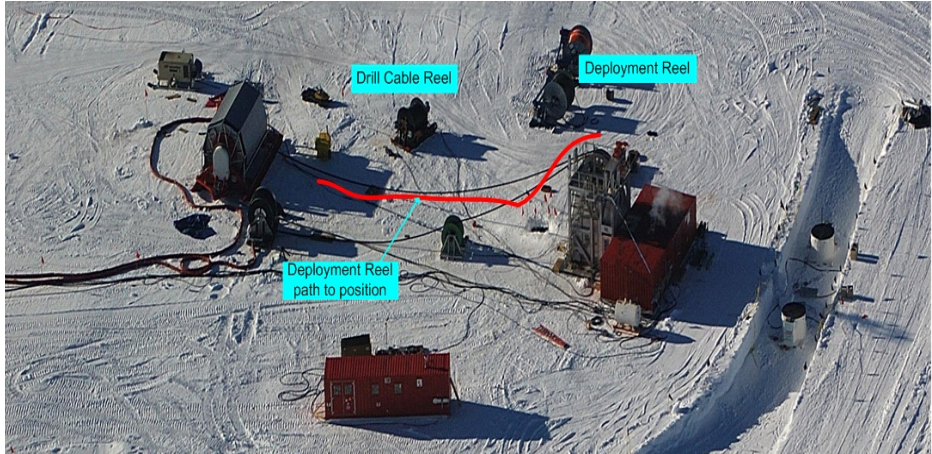
**Figure 10.3** Replacing winch E-Stop/ Reel Stop and Limit stop cables with Dummy plugs

Placing the E-Stop system in local mode and bypassing any unconnected reel E-stop cable with a dummy plug allows work to go on at the tower site without disrupting the SES with accidental E-stops.

Bypassing all the reels except the tower hoist, allows all the reel electrical cables to be disconnected without triggering a local E-Stop, which would prevent the tower hoist from operating.

- 7 Once the E-Stop system is in local mode and the reels bypassed, continue disassembling the weight stack, This is a reversal of the assembly process, keeping in mind the need for two independent tethers at all times on any weights over the hole.
- 8 While weight stack work is progressing, make sure all the motor controllers to all reels (except the tower hoist) have been turned off. Disconnect all the power and signal cables from all the reels, except the drill cable reel, and store the cables on the respective reels ready for relocation to the next hole.
- 9 With the drill cable, make sure the motor controllers driving this reel have been turned off and disconnect and pack away only the level wind power cable. All the other cables need to be disconnected from the drill cable reel, but not from the TOS. These cables can be moved away from the cable reel and out of the path the deployment reel will take as it is being moved into position.

The path the deployment reel takes to be moved into position is shown by the red line in Figure 10.4. So all cables, hoses and other items needs to be moved from this path. The Drill Cable Reel will also need to be moved away to give the dozer room to maneuver out of the way once the deployment reel is in position.



**Figure 10.4** Deployment reel Path into position

**10** Using a heavy lift vehicle, such as a fork lift or a dozer, move the deployment reel into position, as shown in Figure 10.5 below. As can be seen from the photo, the vehicle needs to get very close to the main hose reel in order to position the deployment reel properly. Once the reel is in position, some delicate maneuvering work is required in order to move the vehicle away. The anchors for the deployment reel should already be in position, just in front of the main hose reel.



**Figure 10.5** Moving deployment reel into position

11 Once in position, the deployment reel should be located approximately as shown in Figure 10.6 below. The exact distances aren't critical and are given as a guide.

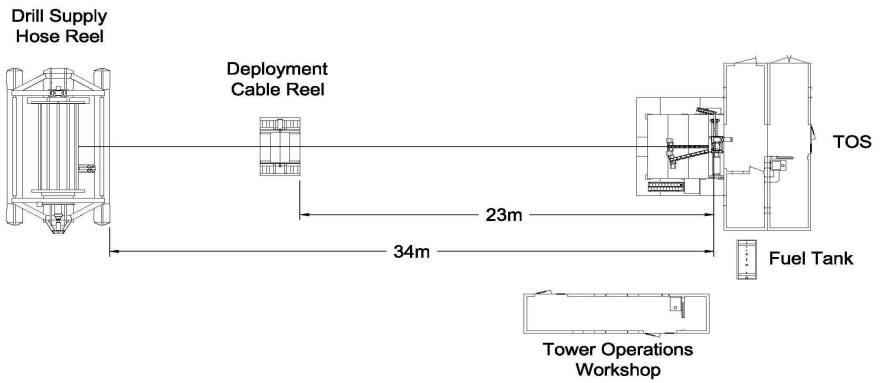


Figure 10.6 Deployment reel location with respect to tower and main hose reel

11 Anchor the deployment reel to the anchors located just in front of the main hose reel.

12 Check to make sure the spool is properly mounted on the winch shaft, the shaft collar is clamped tightly and the spool drive pins are properly locked in place, as shown in Figure 10.7.

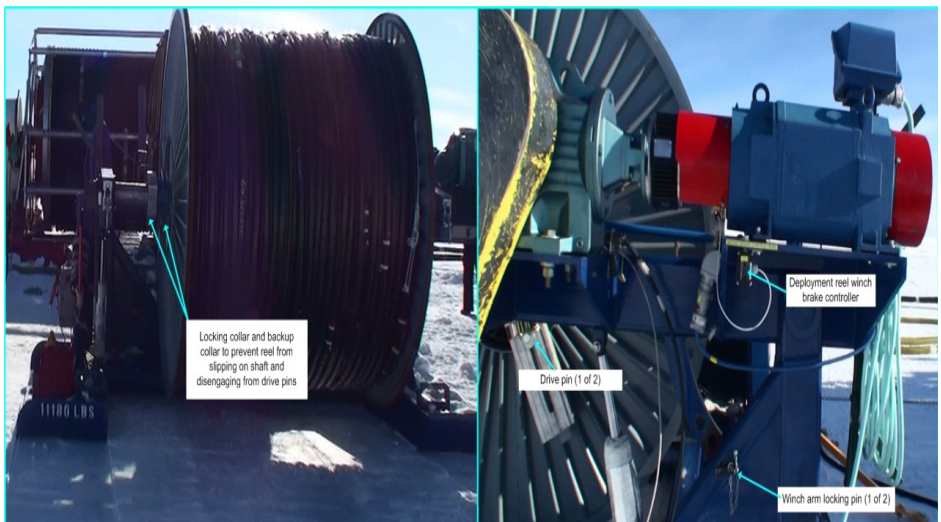
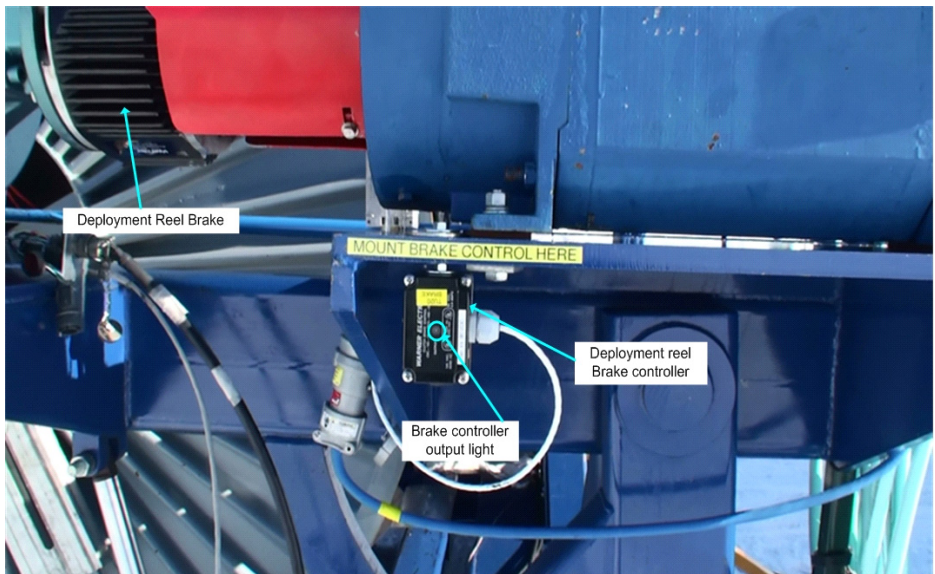


Figure 10.7 Deployment reel showing the reel locking collars, drive pins, arm locking pins and brake controller



- 13** Install the emergency brake pads to the reel. These are plates with a "brake pad" bonded to the plates and positioned under each rim of the deployment reel. In an emergency, as a last resort the hydraulic fluid is dumped from the pistons holding the winch arms up, resulting in the cable reel dropping to the ground with the rims hitting the brake pads and hopefully stopping the deployment cable from running away down the hole.
- 14** Remove the winch arms locking pins (shown in Figure 10.7 above).  
Removing these pins allows the winch arms to drop down once the hydraulic fluid is released (as described in step 13 above).
- 15** Connect the drill cable reel power cable, encoder cable and brake cable to the deployment reel.
- 16** Replace the cable reel E-Stop/ Reel Stop dummy plug with the deployment reel E-stop/ reel stop cable.
- 17** Turn on the drill cable reel motor controller. The motor controller should recognise that the deployment reel is now connected to the controller and the controller will change some of its setting to allow it to properly drive the deployment reel. no manual operator changes to the controller should be necessary.
- 18** Check the operation of the deployment reel brake controller by making sure the "output" light on the controller (shown in Figure 10.8 below) is on. An "on" output light indicates the brake controller is working and has disengaged the brake, allowing the drive shaft to rotate freely. This light should always be on when the E-stop/ reel stop system is not activated.



**Figure 10.8** Deployment reel brake components

**19** Test the operation of the deployment reel by slowly driving the reel "up" and "down" and checking that the brake is disengaged during these tests by listening for any 'screeching sounds coming from the brake, which is an indication the brake is not releasing the drive shaft when it's supposed to.

Once the weight stack has been removed from the hole and put away, the tower should be ready for deployment activities. The only thing that remains to be done by the drillers at this site is to properly tidy up all the power and signal cables for all the other drives and move them across to the next location in preparation for drilling at the next hole. This topic will be covered in another chapter.

# Chapter 11

## 11: RELOCATING REELS

### 11.1: Introduction:

---

This chapter describes the process for relocating the hose and cables reels to the next drilling location. The assumption is that drilling has been completed at the current location, the system has been reconfigured in idle mode and the current drill location has been configured for deployment (see chapter 10).

The move also assumes the anchors for all the reels have been installed at the new drill site, the second TOS and tower have already been relocated to the site and the power and network cables have been connected.

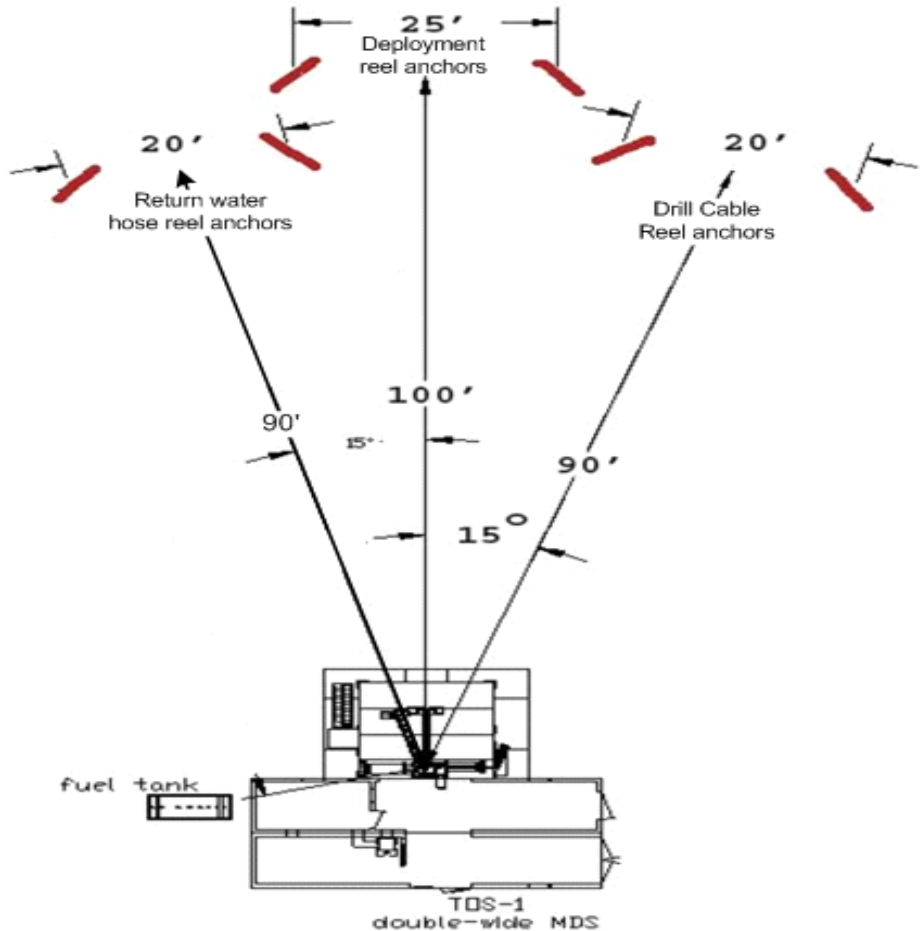
#### 11.1.1: Reel Anchors:



**Figure 11.1** Anchors being installed in anchor trenches.

Prior to locating the reels to the next drill site, the anchor locations for each reel should already have been marked out, the anchor trenches drilled and the anchors placed in position with the chains visible at the surface, as shown in Figure 11.1 above.

Figure 11.2 below is a diagram of the various reel anchor locations with respect to the hole centre. Note that there are no anchors for either the return water pump combo cable reel or the drill supply hose reel. The return water pump combo cable reel is anchored to the return water hose reel, while the main supply hose reel weighs around 100000lbs when the hose is full of water and does not need to be anchored in position.



**Figure 11.2** Reel anchor locations with respect to hole to be drilled.

Click on the video link below to view a video showing the anchors locations being marked.

# Anchor Locations.mp4

## 11.2: Reel Relocation Sequence

When the time comes to move the reels into position at the next drill site, it is very important to have the move planned in advance, and to have all tools and required equipment on hand for the move. Some things to consider prior to the move are the location of the next hole relative to the current drill location, what obstacles are in the way that the surface hoses have to negotiate, is the location far enough away from the current one that extra surface hose has to be added in order to make the hose reach the new location?

These considerations are important prior to the move because during the move, water circulation through the system has to be stopped and it is important that the circulation is disrupted for the minimum time necessary and no longer than an hour before circulation is restarted.

Figure 11.3 below is a diagram of the location of each reel and reel anchor at the tower operations site with respect to the hole to be drilled.

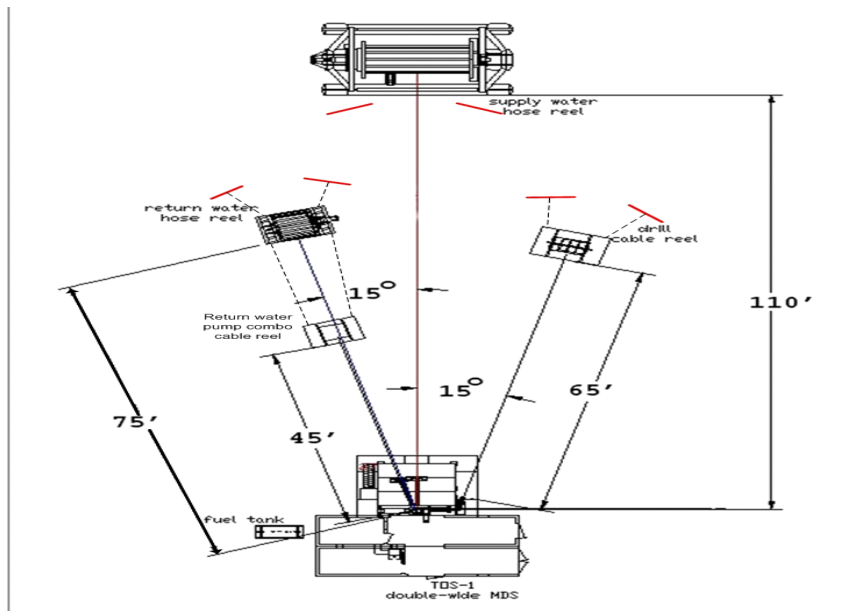


Figure 11.3 Locations of each reel and anchor relative to hole to be drilled

Note, as previously discussed above that there is no anchor for the return water combo cable reel. This reel is anchored directly to the return water hose reel. Note also that the anchors in front of the supply water hose reel are not for that reel but are for the deployment cable reel, which will be located in front of the supply water hose reel and attached to those anchors once drilling is completed.

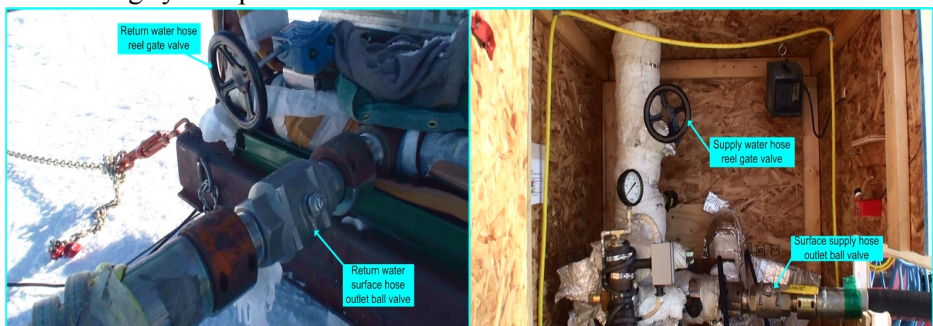
In general, it has been found easier to concentrate on moving the supply water hose reel and the return water hose reel into position first, then bring the two surface hoses across and configure the system in idle mode. Once that's done and water flow is established, the rest of the reels can be brought across, accurately positioned in place and reconnect all the power and signal cables to the reels.

Please note that a bulldozer is required to move the supply water hose reel and that the reel must remain on a prepared and compacted path during the move. The reel weighs around 100000lbs when the hose is full of water and if an attempt is made to move it with anything other than a dozer and on a prepared path, the vehicle will bog in the unconsolidated snow.

### **11.2.1: Stopping water circulation for move:**

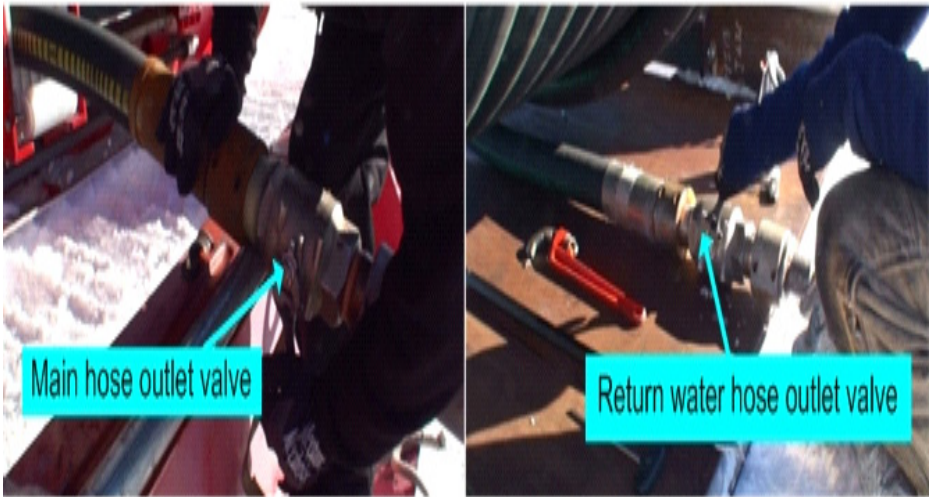
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- 1 Make sure all the tools necessary to complete the move are on hand prior to commencing the move. This includes things such as Allen keys and crescent wrenches to undo fittings, surface hose moving equipment and snatch straps.
- 2 Once the bulldozer that will move the hose reel is at the drill site, prepare the supply water hose reel and surface hoses for the move.
  - a Ask the DCC operator to stop water flow and confirm system pressure has dropped to 0 PSI.
  - b Once the system pressure is at 0 PSI, slowly close the ball valves on the outputs of both the supply and return hoses, then the gate valves on both reels (shown in Figure 11.4), while asking the DCC operator to keep monitoring system pressure.



**Figure 11.4** Return and surface supply hoses ball valves and reel gate valves

- c Once the valves are closed, disconnect the two surface hoses from their respective reels and move them clear of the reels.
- d Close the outlet valves on both the main hose and return water hoses, as shown in Figure 11.5 below.



**Figure 11.5** Main and return outlet hose valves being closed

- e Disconnect the bypass hose connecting these two hoses and drag it across to the next site.

At this point all water circulation in the system and the reels has stopped and it is critical that the hose reels and surface hoses are moved to the next site and water circulation re-established as quickly as possible.

The time circulation is stopped should be noted down by the DCC operator and circulation should be restarted within an hour of it being stopped.

At this point 3 crews; one working on the supply hose reel, one on the return water hose reel and one on the surface hoses, should be working to move the hose and reels and surface hoses into position and re-establish flow as quickly as possible.

- 3** Connect the supply hose reel to the dozer tow hitch then drag the reel over the compacted path and accurately position at the new site.

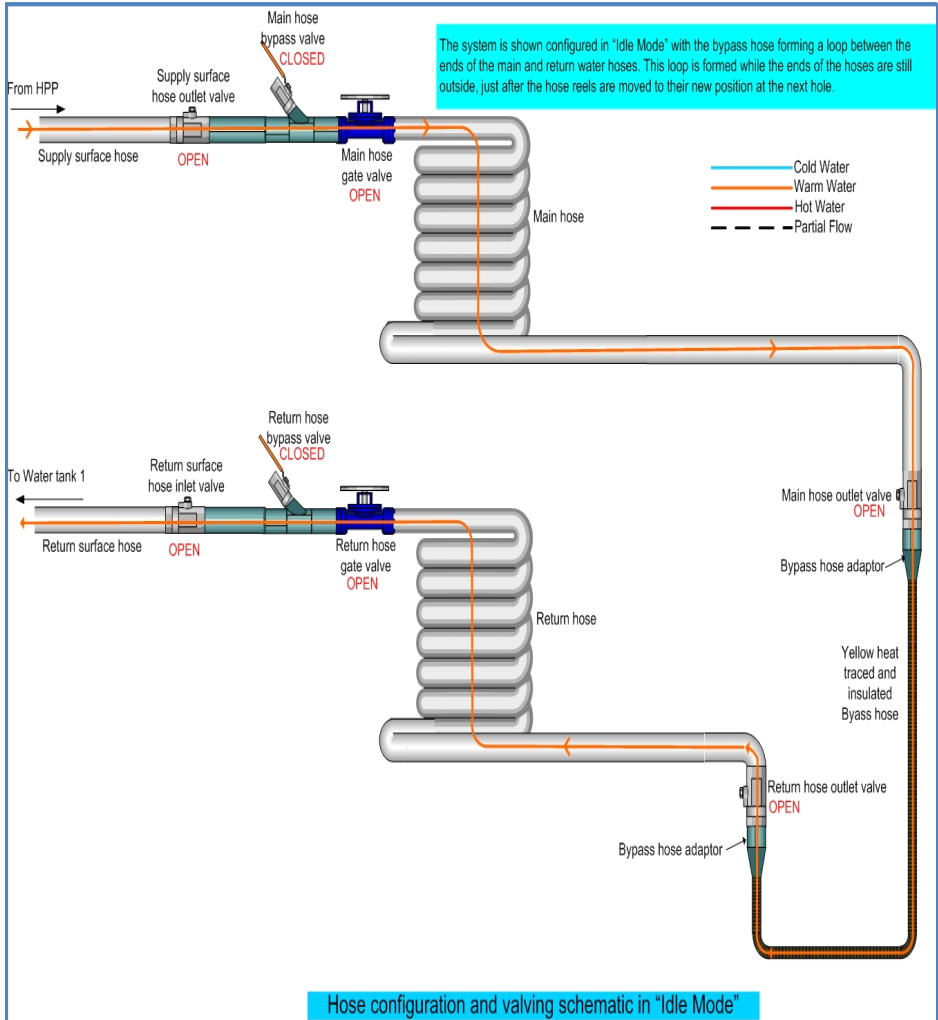
- 4 At the same time, do the same with the return water hose reel using the 953 loader.
- 5 While the reels are being moved into position the third crew drags the surface hoses to the site using a combination of sling attached to Skidoos and a 287 loader with a hose relocation attachment, as shown in Figure 11.6 below.



**Figure 11.6** Hose relocator connected to 827 loader relocating hose to new hole.

- 6 As soon as both hose reels are in position and the two surface hoses have been relocated, reconnect the two surface hoses to their respective reels.
- 7 Reconnect the bypass hose between the outlet of the supply water hose and the end of the return water hose and then open the main hose outlet valve on the supply water hose and the return water hose outlet valve, shown in Figure 11.5 above.
- 8 Open the gate valves on both the supply hose reel and return water hose reel and the ball valves on the ends of both surface hoses, as shown in Figure 11.4 above. At this point the system should be set up to run in idle mode and configured as shown in Figure 11.7 below.





**Figure 11.7** Plumbing and valving arrangement for system configured in "Idle Mode".

- 9** Confirm the plumbing and valving arrangement is as shown in the diagram above by having a second person check the plumbing.
- 10** Once the system configuration has been confirmed, ask the DCC operator to recommence water flow at around 35gpm and 25C while carefully monitoring system pressure to make sure there are no blockages in the system and the pumps aren't being dead headed. Confirm that water flow is returning to tank 1 via the return water surface hose.

Once flow has been re-established and the flow is stable, the rest of the reel move can be undertaken at leisure without having to worry about hoses freezing.

**11** Move the drill cable reel and return water combo cable reel approximately into the position shown in the diagram in Figure 11.3. In the case of the drill cable reel it is fairly important that the reel is lined up as centrally and as perpendicular as practical to the sheave on the tower floor through which the drill cable will pass through. This cable carries the drill and most of the hose load down hole and keeping kinking of the cable to a minimum helps to prolong the cable life.

**12** Once all the reels are in position, commence connecting the power and signal cables to all the reels as detailed in the table in Figure 11.8 below.

Cable Type	Reel End Connector ID	Reel end cable ID	TOS end cable ID	TOS connector ID
<b>Drill Supply Hose Reel (DSHR)</b>				
Drill Supply Hose Reel Drum Motor	HR1-CD1	HR1-CD1/C	TOS1(2)-CD5/C	TOS1(2)-CD5
Drill Supply Hose Reel Level Wind Motor	HR1-CD2	HR1-CD2/C	TOS1(2)-CD6/C	TOS1(2)-CD6
Drill Supply Hose Reel Brake	HR1-CD3	HR1-CD3/C	TOS1(2)-CD4/C	TOS1(2)-CD4
Hose Reel Drum Motor Encoder	Connects to Hose Reel Drum Motor Encoder Connector			Connects to "Hose Reel Drum Motor Encoder" Connector on TOS Reel I/O Box
Hose Reel Level-Wind Motor Encoder	Connects to Hose Reel Level Wind Motor Encoder Connector			Connects to "Hose Reel Level Wind Motor Encoder" Connector on TOS Hose Reel I/O Box
Hose Reel E-Stop and Reel-stop	Connects to "E-Stop/ Reel-Stop" Connector on Hose Reel Safety Enclosure			Connects to "Hose Reel E-Stop & Reel-Stops" Connector on TOS E-Stop Panel
Hose Reel Limit-Stop	Connects to "Limit Stop" Connector on Hose Reel Safety Enclosure			Connects to "Hose Reel Limit Stops" Connector on TOS E-Stop Panel

Drill Cable Reel (DCR)				
Drill Cable Reel Drum Motor	DH1-CD1	DH1-CD1/C	TOS1(2)-CD9/C	TOS1(2)-CD9
Drill Cable Reel Level Wind Motor	DH1-CD2	DH1-CD2/C	TOS1(2)-CD10/C	TOS1(2)-CD10
Drill Cable Reel Brake	DH1-CD3	DH1-CD3/C	TOS1(2)-CD11/C	TOS1(2)-CD11
Cable Reel Drum Motor Encoder	Connects to Cable Reel Drum Motor Encoder Connector			Connects to "Cable Reel Drum Motor Encoder" Connector on TOS Cable Reel I/O Box
Cable Reel Level Wind Motor Encoder	Connects to Cable Reel Level Wind Motor Encoder Connector			Connects to "Cable Reel Level Wind Motor Encoder" Connector on TOS Cable Reel I/O Box
Cable Reel E-Stop and Reel-Stop	Connects to "E-Stop/Reel-Stop" Connector on Cable Reel Safety Enclosure			Connects to "Cable Reel E-Stop & Reel Stops" Connector on TOS E-Stop Panel

Return Water Hose Reel				
Return Water Reel Motor	RW1-CD1	RW1-CD1/C	TOS1(2)-CD12/C	TOS1(2)-CD12
Return Water Reel-Stop Reel Motor Resolver	Connects to Return Water Reel Motor			Connects to TOS Return Water Reel Vector Drive V4
Return Water Reel Reel-Stop	Connects to Return Water Reel Safety Enclosure			Connects to "Return Water Reel Stop" Connector on TOS E-Stop Panel
Return Water Combo Cable Reel				
Main motor power	?????????			?????????
Main motor resolver	?????????			?????????
E-stop/Reel Stop	?????????			?????????

**Figure 11.8** Reel Cables connection Matrix.

At this point the system is configured in idle mode with all the hoses and cables outside the tower and hoses connected in a loop with water circulation through the complete hose system. The next stage of the operation would be to bring the hoses and cables inside the tower to commence drilling. This is covered in Chapter 9 which picks up from where this chapter left off.



# Chapter 12

## 12: PREPARING TOS/TOWER FOR RELOCATION

### 12.1 Overview:

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This chapter describes how to prepare the Drill Tower (towertower) and Tower Operations Structure (TOS) for relocation.

Preparing the TOS for relocation is fairly straight forward. All equipment has to be powered down and connections between the tower and TOS have to be severed. All connections to SES and surrounding equipment also have to be disconnected and loose objects have to be secured.

This chapter will describe the steps taken. Parts of the discussion in this chapter may seem redundant, as the steps will already have been taken when performing another part of the operation. Nevertheless, it's all part of the process of preparing the TOS/tower for relocation.

### 12.2 Cable Drag:

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Before preparation of the TOS/tower for relocation, the StD (Surface to DOM) Cable has to be moved out of the way. After deployment, the StD cable is mainly in the hole, attached to the DOM's in the hole and secured to a dead man anchor at the surface, near the hole opening, as shown in Figure 12.1. The top portion of the cable is still spooled up on the Deployment Reel. This portion of the cable will eventually connect to the SJB (Surface Junction Box). This

remaining cable will be unspooled and lifted over the tower to the far side of the TOS.

- 1 Double check that the cable is attached to the anchor.
- 2 Disconnect the military connectors at the deployment reel slip ring.
- 3 Unspool the cable from the reel. Be sure not to overspool and end up winding the cable back onto the reel, possibly damaging the end connector in the process.
- 4 The end of the cable is fed out from inside the reel drum. Feed this out carefully, making sure the connectors is not damaged in the process.
- 5 Protect the connectors and attach a rope to the end of the cable.
- 6 Remove the plastic wall between the tower and TOS, to allow the cable through (otherwise the cable will be trapped inside the tower).
- 7 Feed the cable up over the tower. Be careful not to damage it.
- 8 Feed all the cable over to the opposite side of the TOS.
- 9 Put the cable out of the way, optimally flagging it.

The cable is heavy. Optimally there are a couple of people on top of the tower, one or two on top of TOS, one or two below the TOS and one feeding the cable below the tower.



**Figure 12.1** Deployment cable shown anchored to deadman

## 12.3 Preparing Electrical Equipment:

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All electrical and signal cables between the TOS and Reels and SES have to be disconnected.

### 12.3.1 Motor Drives:

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Before disconnecting any output cables from the motor drives, the associated motor drives have to be de-energized.

Turn off or make sure that all Motor Controllers are turned off by opening the corresponding breaker, shown in Figure 12.2.

Before turning off the tower hoist motor controller, check that the hook is secured to the tower and that it is in no way attached to the TOS, deployment cable or anything that will not move with the Tower.



**Figure 12.2** TOS electrical closet and main circuit breaker

The Motor Controllers are:

- Drill Supply Hose Reel Drum
- Drill Supply Hose Reel Level Wind
- Drill Cable Reel Drum
- Drill Cable Reel Level Wind
- Return Water Pump
- Return Water Hose Reel
- Return Water Cable Reel

- Tower Hoist



**Figure 12.3** Motor drives in TOS electrical closet

After turning off the drives, wait a while for the drives to de-energize before removing any power cables. The large capacitors in the drives may take minutes to discharge.

### 12.3.2 Reels:

---

The reels are normally already in use at the other drill site, and the preparation of the reels for a move has already been performed. See Ch 11 “Relocating Reels to Next Site” for detailed instructions on reel moves. Here is a brief description of how to prepare the reels for a move, and what cables need to be disconnected.

**Warning:** **Under no circumstances should the motor drives be energized when disconnecting the power cables.**

Disconnect all cables leading from the TOS to the reels. The cables are typically spooled up on the reels, but some may be spooled up on the TOS, or on a separate pallet.

All power cables except the Tower Hoist cable are spooled up on their respective reel. The reason for this is to keep the cables with their respective piece of equipment, avoiding match making at the new drill site, as well as minimizing the potential of damage to the cable. The DSHR and DSCR communication cables are either spooled up on the TOS or a pallet.



The Tower Hoist Cable goes with the TOS. The DSCR octopus cable is typically left for the TU-20 deployment reel. Once the deployment is done, the octopus cable is spooled up on a pallet and is moved with the TOS to the subsequent drill site. The DSHR drum power cable has been considered too bulky to spool up on the DSHR, so it is spooled up on a separate pallet and moved to the subsequent drill site.

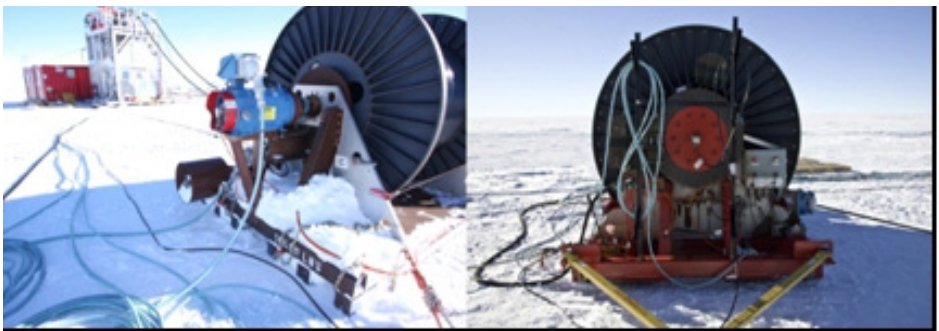
Following is a short summary on reel cables that need attention before a move at the site.

The Drill Supply Hose Reel (DSHR) has three associated power supply cables. One drum power cable, one level wind power cable and one brake power cable. There is also one octopus cable used for communication, such as motor encoder, e-stop and reel stop, as shown in Figure 12.4.



**Figure 12.4** DSHR cable connectors (network, level wind, drum and brake cables)

The Drill Supply Cable Reel (DSCR), shown in Figure 12.5, also has three associated power cables. One drum power cable, one level wind power cable and one brake power cable. There is also one octopus cable used for communication, such as motor encoder, e-stop and reel stop.



**Figure 12.5** DSCR cable connectors (drum, level wind, brake, octopus and drill head)

The Return Water Hose Reel (RWHR), shown in Figure 12.6, has two power cables and one network cable. One power cable is for the drum and one for the brake. The network cable is for e-stop and reel-stop.



**Figure 12.6** RWHR cable connectors (drum, brake and network cables)

The Return Water Cable Reel (RWCR), shown in Figure 12.7, has three power cables and two communication cables. One power cable for the reel drum, one for the reel brake and one pump power supply cable. One network cable and one return water pump (RWP) sensor communication cable. The network cable is for e-stop and reel-stop. The pump sensor cable communicates with the pressure and temperature sensor by the pump.



**Figure 12.7** RWCR cable connections (drum, brake, network and RWP comms)

The Deployment Reel (DR), shown in Figure 12.8, has two power cables, one octopus cable and a sensor cable. The power cables supply the reel drum and reel brake with power. The octopus cable is for e-stop, reel-stop etc. The sensor cable communicates with pressure sensors etc at the end of the Surface to DOM cable.



**Figure 12.8** Deployment reel cables (drum, brake, octopus and sensor cables)

The Hoist has one drum power cable and one brake cable connected on the door side of the tower, as shown in Figure 12.9. They have to be disconnected before a move. The cables move with the TOS.



**Figure 12.9** Tower hoist drum and brake cables

The reel side of the cable is seldom disconnected. The TOS side of the cables, shown in Figure 12.10, is almost always disconnected instead.

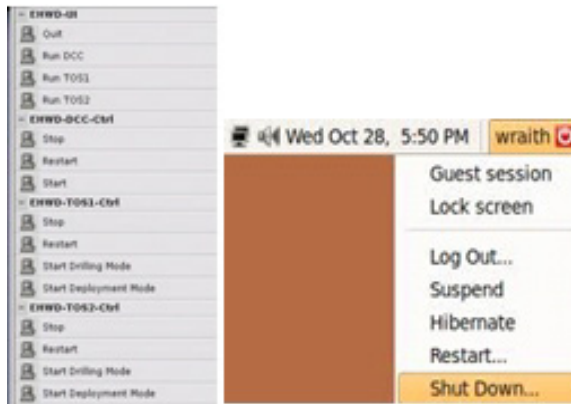


**Figure 12.10** Power and network cables connections at the TOS end

## 12.4 Preparing Electronics Equipment:

### 12.4.1 Computers:

Exit all running software on both master and slave drill/deployment computers, including but not limited to the EHWD UI Software and EHWD Control Server.



**Figure 12.11** EHWD software and OS shutdown

Log out and shut down the computers. Shut down the communications radio. Make sure the drill head power supply and deployment data box (DDB), shown in Figure 12.12, are powered down.



**Figure 12.12** Drill head power supply and DDB

As the move of the TOS can be bumpy, all equipment will need to be secured from movement. Eg. lie down computer monitors and secure them to the table. Secure keyboards, mice, auxiliary power (UPS) and computer rack. The easiest way to secure the equipment is using straps.



**Figure 12.13** Improperly secured drill control room

## 12.4.2 Communication and E-stop Network:

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There are a few cables between the TOS and tower, and between the TOS and SES. These cables have to be disconnected before a move.

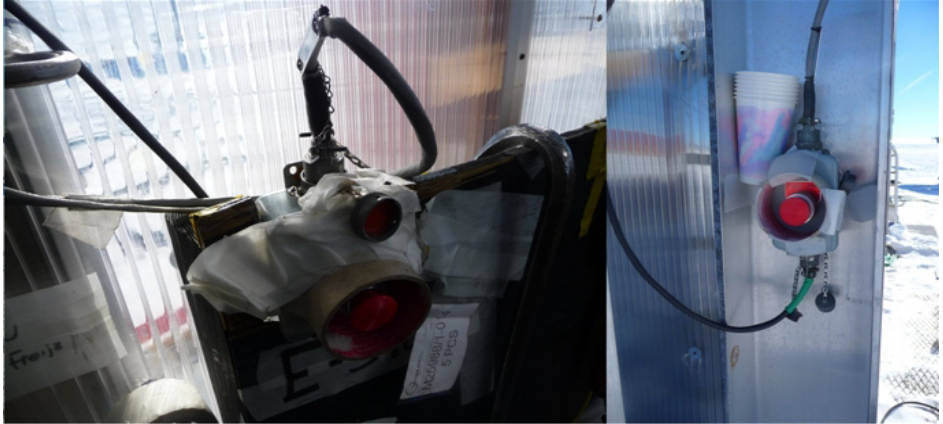
After drilling is completed and before deployment starts, the E-stop will be changed from global to local mode. Local mode means the TOS is isolated from SES and runs on its own E-stop. A triggered E-stop will not affect SES. Global means the TOS and SES are interconnected. An E-stop at the SES will stop operation at the TOS and vice versa.

The E-stop should at this point be in local mode. Verify that before disabling the E-stop. Instructions on how to go between local and global E-stop can be found in Chapter 8 – Tower Operations Setup.

Disabling the E-stop system is one of the last things to do, as this makes motor drives inoperable and disables the furnace etc.

Disconnect the following cables between the tower and TOS, shown in Figure 12.14.

- 1- E-stop cable from TOS to the E-stop inside the tower.
- 1- E-stop cable from TOS to the E-stop outside the tower.



**Figure 12.14** E-stop cables between TOS and Tower which need to be disconnected

- 1- cable from TOS to the Load cell amplifier box. shown in Figure 12.15.



**Figure 12.15** Load cell amplifier box with cable to be disconnected at bottom of box

- 1- Network/E-stop cable. This is disconnected at network box next to the DSL modem inside the electrical closet, shown in Figure 12.16. This network cable connects TOS to SES. Remember, if the E-stop is in global mode when disconnecting the cable, an E-stop affecting both SES and TOS will be triggered. The network cable is spooled up on a portable spool.

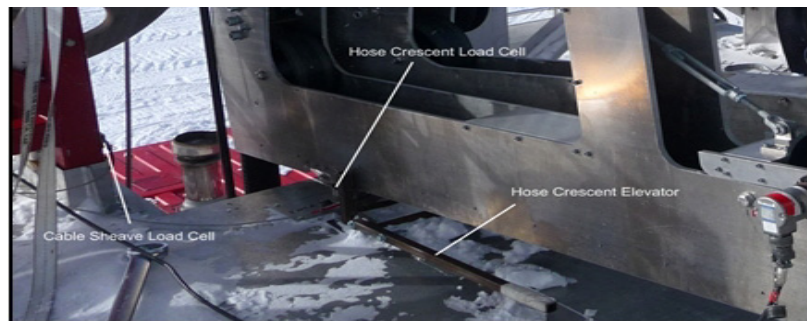


**Figure 12.16** Network cable and TOS network junction box

### 12.4.3 Load cells:

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To avoid forces on the load cells during the move, remove any load on them. By elevating the front end of the drill hose crescent (the load cell end), the crescent load cell is not exposed to any forces. The crescent can be elevated by using a leveraged lift device installed under the crescent, shown in Figure 12.17. When the crescent has been elevated, a 4x4 in piece of wood can be put under the crescent to keep it elevated. Don't forget to lower the crescent before pulling the cable and hoses inside the tower after the move. The weight of the drill cable sheave on the drill cable load cell cannot be removed, but is smaller than the crescent load.

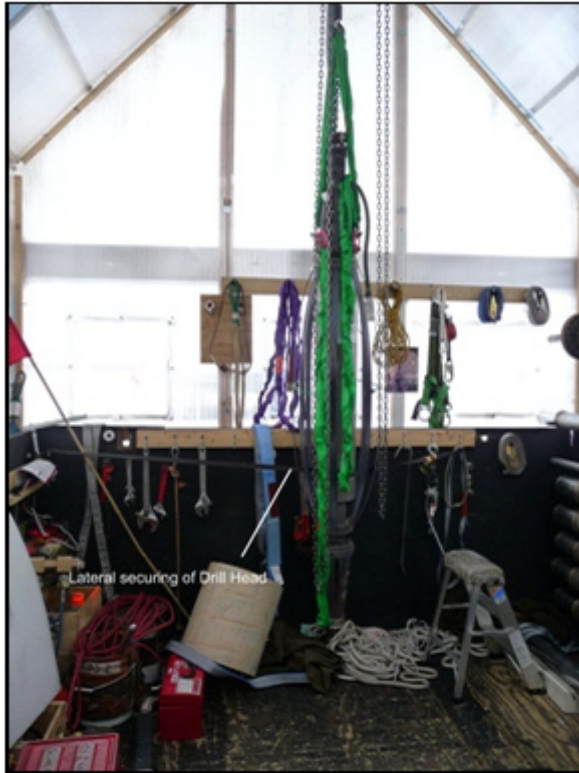


**Figure 12.17** Hose crescent and cable sheave load cells and crescent elevator

## 12.4.4 Drill Head:

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The drill head would typically hang from the manual winch or the I-beam when not in use. Secure the drill head to the tower, as shown in Figure 12.18, to prevent it from swinging and hitting objects during the move.



**Figure 12.18** Storage and securing of drill head for Tower move

## 12.4.5 Drill Head and Deployment Communication Boxes:

Check that no external cables are connected to the DDB (Deployment Data Box) or the drill head power supply box. Both are located in the computer rack in the drill control room, as shown in Figure 12.12.



## 12.5 Preparing Mechanical Equipment:

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### 12.5.1 Lose Objects:

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Secure any movable objects inside the TOS and tower, including but not limited to chairs, tools, weight stack, hoist cable and hook.

Put away all lose objects on the ice in the TOS area.

Remove and store landings in the TOS.

### 12.5.2 Attachments:

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Disconnect all cargo straps holding the tower attached to the TOS. There are two low cargo straps + chains and two cargo straps + chains on top of the TOS, as shown in Figure 12.19 and Figure 12.20.



**Figure 12.19** Securing of lower section of TOS to tower



**Figure 12.20** Securing upper section of TOS to tower

### 12.5.3 Insulation:

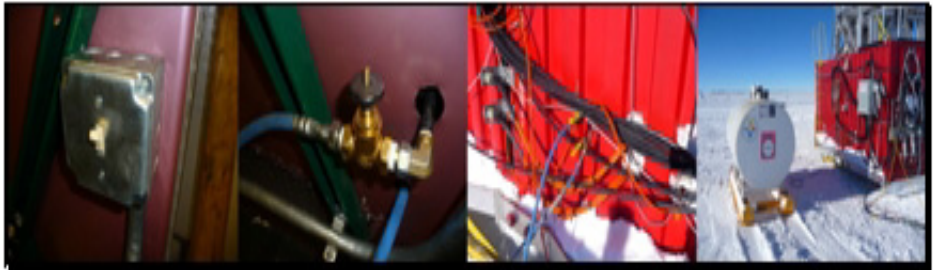
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Remove insulation between tower/TOS, including the wood panel on top of TOS interfacing the tower.

### 12.5.4 Furnace:

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Turn off the furnace with the switch on the side of the furnace. Close the valve on the fuel line inside the electrical closet. Disconnect the fuel lines outside the TOS and put the ends in the fuel tank to avoid leaks. Prepare the fuel tank for moving to the new drill site. These steps are shown in Figure 12.21.



**Figure 12.21** TOS furnace off switch, fuel valve and fuel tank and fuel line entry

### 12.5.5 Heat Conservation:

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Close the doors to electrical closet and control room to keep the electronics warm during the move. The computers, UPS and motor drives are DNF.

Only turn off the electrical heaters, shown in Figure 12.22, right before the move, when power to the TOS is to be killed and the power cable is removed. Let the heaters cool down before turning off the power.



**Figure 12.22** Electric heater thermostat control

## 12.5.6 Surface to DOM Cable:

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The surface to DOM cable should have been tied off to an anchor chain in the hole. Nothing else should be used to secure it. Before a move of the TOS, the cable has to be positioned so as not to interfere with the move and where the cable cannot be damaged.

See Chapter 14 for instructions on how to move the tower/TOS.

## 12.5.7 Towing Preparations:

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Attach a tow bar to the side of the TOS most suitable, as shown in Figure 12.23. Which side is most suitable is dependant on such things as the compacted roads and how the TOS will be oriented at the next drill site. A tow bar attached appropriately will avoid reconnecting and/or backing up the TOS at the next drill site.

Attach a tow bar to the front of the tower.



**Figure 12.23** Tow bar attached to tower in preparation for move

## Hole Cover

Locate the grate, shown in Figure 12.24, that will cover the drill hole after the tower has been pulled out. It will be put in place over the hole right after pulling out the tower.



**Figure 12.24** Hole grate cover

**Danger:** The person placing the hole cover over the hole must be wearing a safety harness and anchored to a safe anchor point on the TOS before attempting to position the cover over the hole.

# Chapter 13

## 13: PREPARING SITE AT NEXT HOLE

### 13.1 Introduction

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Preparing the next drill site in advance makes the move smoother and drilling can be resumed faster. The preparation is normally done well in advance of moving the drill to the drill site. This chapter describes the steps taken in the preparation process.

### 13.2 Hole Location Preparation

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#### 13.2.1 Surveying

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The location should be checked and marked by a surveyor. The hole location should be flagged and labeled. Any potential complications and hazards in the drill area should be investigated by the surveyor. Any cable trenches, buried equipment or structures etc should be hazard analyzed, clearly communicated as well as marked on site. Optimally a GPR (Ground Probing Radar) would be used to check the area for anything that could pose a drill obstruction. The dark sector at the South Pole has plenty of hidden objects covered by snow and ice. If there are complications, there may be a need to alter the drill location. The drill itself needs unobstructed ice, as it is designed to melt ice and not to penetrate objects. The DSHR (Drill Supply Hose Reel) is the heaviest piece of equipment on the drill site next to the bulldozer pulling it. Any cavities may give way due to the weight. Any cables may be cut when making anchor trenches etc. All this has to be clear before starting the preparation at the hole site. Surveying is

normally done at the beginning of the season, before commencing drill operation.

### 13.2.2 Drill Site Surface Preparation

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The drill site needs to be level, compacted and flat, as shown in Figure 13.1. A compacted surface is essential for the equipment not to sink in and get stuck in the soft surface layer of snow. Especially the Drill Supply Hose Reel (DSHR) and the caterpillar will be heavy and will easily get stuck in the snow. The tower needs to sit flat to allow the drill head to be lowered vertically into the ice. A level area is needed for the reels to be able to spool up cable and hose without complications. The drill cable could be damaged if the reel sits lower than the tower, with the cable touching the sharp edges of the tower while moving and under tension.

The drill site should be prepared well in advance to allow the snow to settle. Typically this is performed at the beginning of the season, with all drill locations prepared at the same time.



**Figure 13.1** Groomed drill sites and roads

A drill plan should already have been prepared for the coming season, as shown in Figure 13.2. This plan should show the hole numbers and drill sequences, as well as the roads and drill sites marked for compaction. Any

buried cables or other equipment to avoid, as well as hazards of any kind, should also be well known and marked out.

Nevertheless, when arriving to a groomed drill site, the first thing is to identify all possible complications. If everything is as described by the site map, go ahead with preparing the site. If there are problems, if possible reorient the drill in such a way as to avoid any complications.

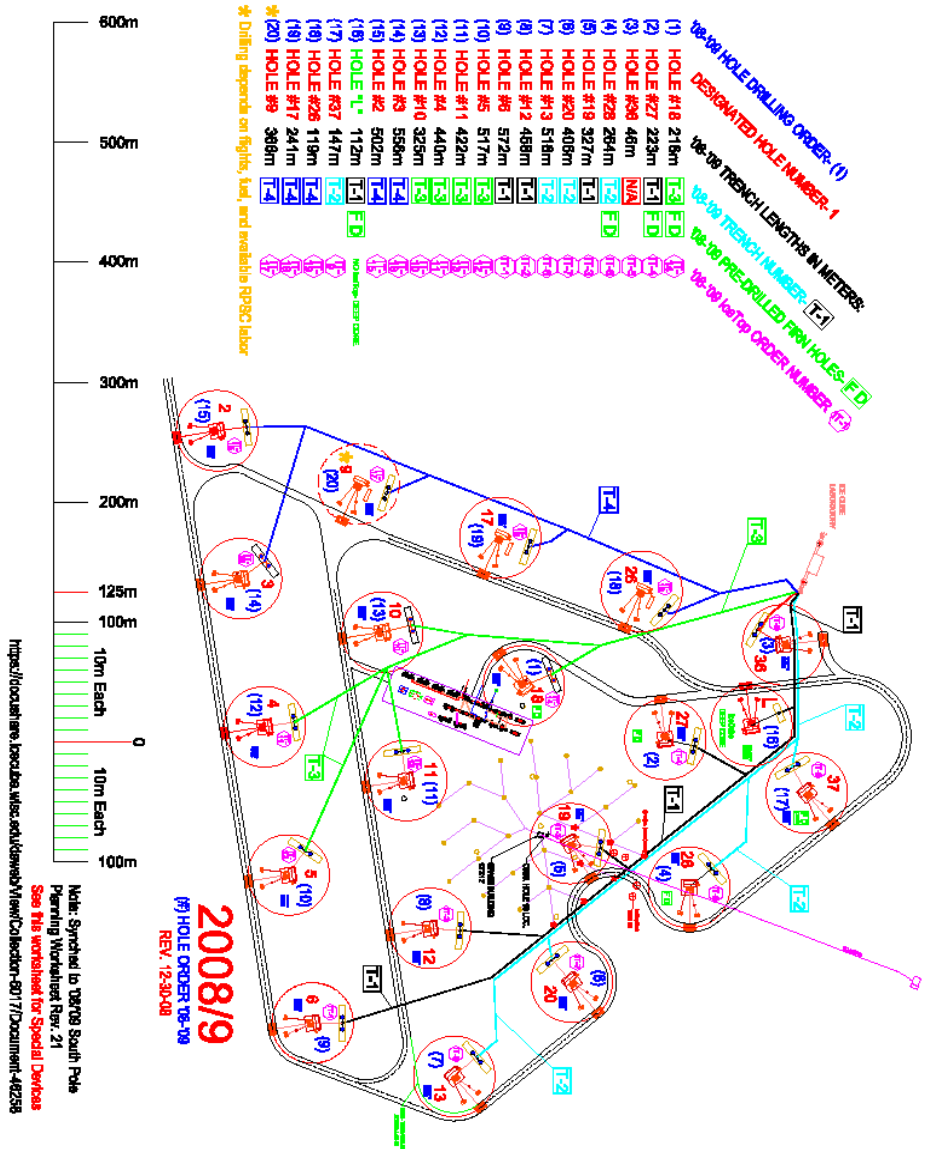
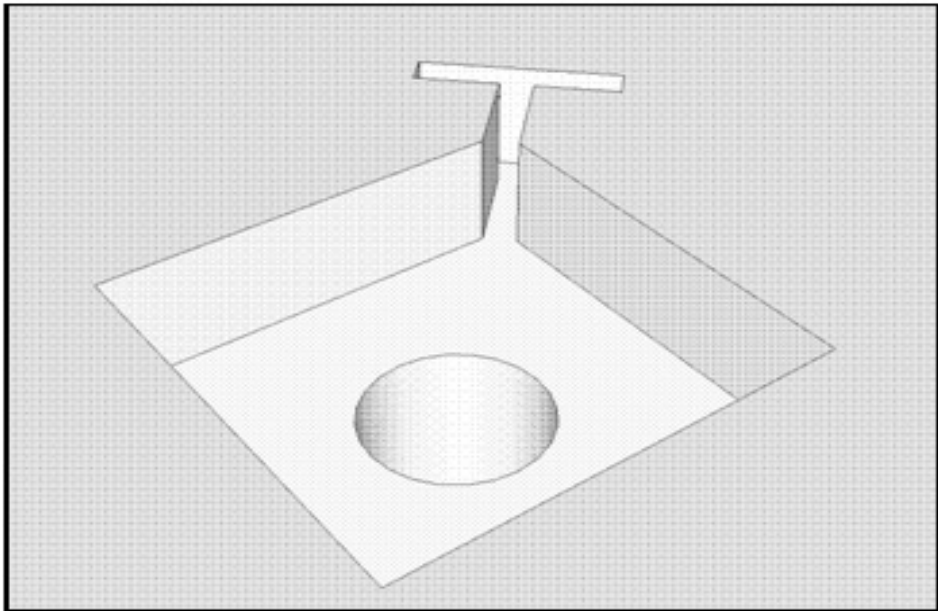


Figure 13.2 Season drill map

### 13.2.3 Hole preparation

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A square 6x6 ft (2x2m) and 2 ft (0.6m) deep hole should be dug out and centered around the surveyed hole location, as shown in Figure 13.3. This pit will house a fall prevention security grate and keep the surface to DOM cable exit level with its future cable trench. The pit should be flagged in each corner. In the pit is put a sheet of plywood with a 1.0 m square (or round) hole cut out in the middle. The opening should be centered over the hole to be. On top of the plywood is placed a plastic or metal grate that will serve as a hole fall prevention. To avoid accidental removal of the grate after the hole has been drilled, the grate should be secured to the plywood sheet.



**Figure 13.3** Hole pit and cable anchor trench

A T-trench should be dug out outside one corner of the pit, as shown in Figure 13.3, to house an anchor used to secure the surface to DOM cable. A dedicated anchor chain is attached to the anchor. After deployment the anchor will be attached to the Surface to DOM cable (using a yale grip) to prevent the cable from slipping into the hole. Put the chain in the pit, under the plywood sheet, but with the end of the chain clearly visible on top of the plywood sheet. This procedure will make it easy to grab hold of the chain after deployment is completed and with the tower still in place. If the chain is buried or hidden under the plywood sheet, the only way to recover the chain is to climb into the pit, with the hole still open. This is a safety hazard and should be avoided.



## 13.3 Firn drilling

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The next activity in the site preparation sequence is drilling the firn hole. A firn hole is to be drilled after the hole pit has been dug out, but before moving the TOS into place. At the South Pole, the firn hole needs to be drilled to about 40m.

The top 35-40 m of the ice sheet is porous and water will not pool but percolate into the firn. The deep water drill will not function in this layer, as it requires pooling water. i.e a different way of drilling the top layer of the firn will have to be used. At 35-40 m the ice is dense enough to allow the water deposited into the hole to pool, and the deep water drill can be used.

The current and recommended method of drilling the firn hole is using the Independent Firn Drill (IFD). It is an autonomous drill using a closed loop system for drilling. By using the IFD time is saved, as the drill tower is used strictly for deep drilling.

After the firn hole has been drilled, secure the fall prevention grate over the hole. This is an important safety measure, as falling into a firn hole is a definite death sentence.

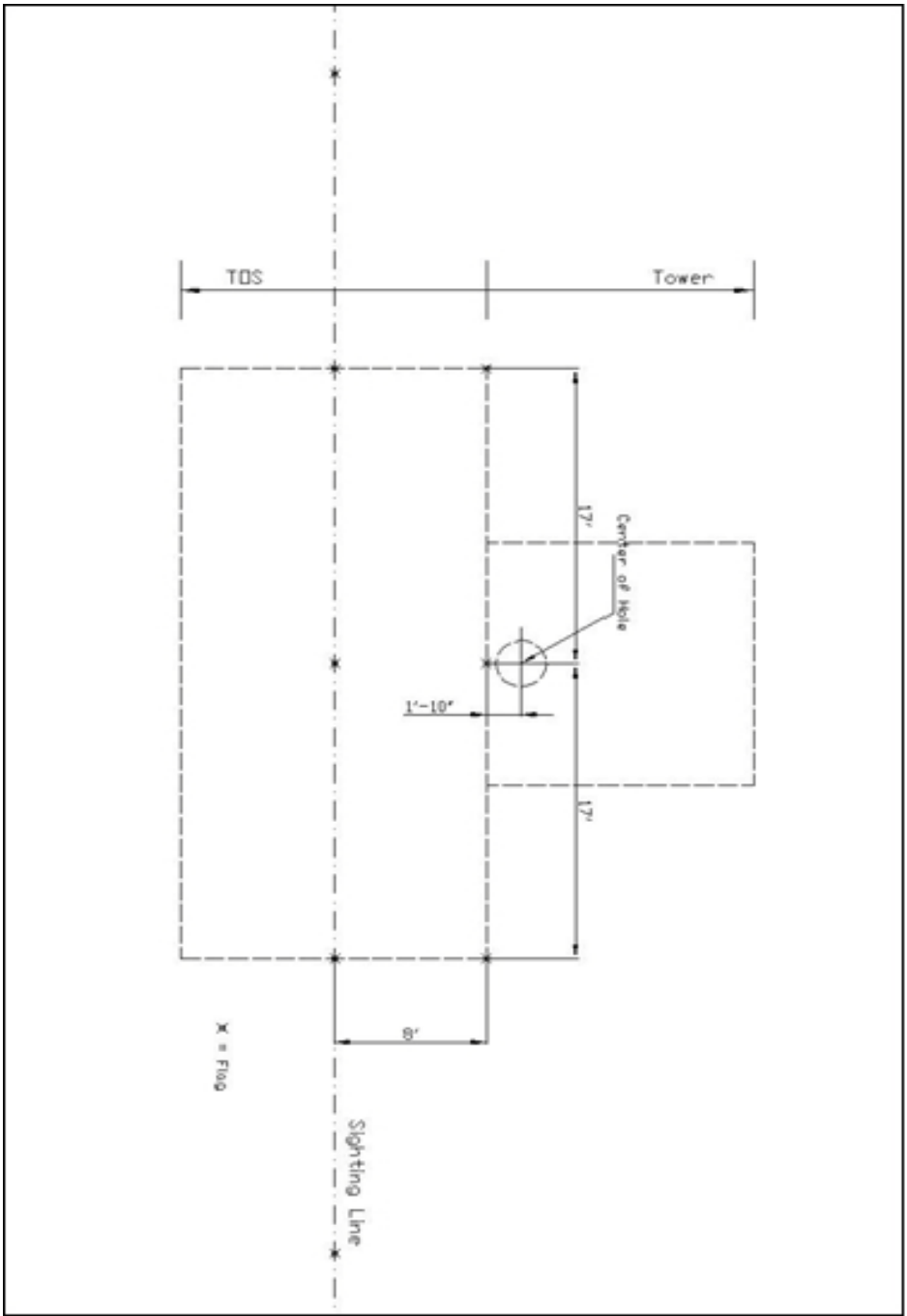
Detailed instructions on the IFD and firn drilling are found under chapter 16 & 17.

## 13.4 Marking the TOS/Tower Location

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The towertower (and TOS) has to be in the exact right position above the hole. Misalignment of an inch or a few is acceptable, but more should be avoided. Drill assembly and return water pump must fit in the hole, and a misalignment of the tower will complicate their fit. How to align the tower and TOS is a matter of personal preference, but here follows a suggestion.

Experience has taught us that moving the TOS and tower into position is greatly aided by the erection of sighting flags along the path the dozer driver needs to take to position the TOS. To this end, a method has been arrived at for marking out the TOS location and dozer path which simplifies the relocation process. The diagram for the flag positioning is shown in Figure 13.4.



**Figure 13.4** TOS move flag positioning diagram

The flags indicate the corners of the TOS, as well as the center point of the TOS. The flags are intended to function as aiming points for the Caterpillar driver. The line with three flags closest to hole is symbolizing the corners of the TOS and the center line of the TOS. The line with three flags furthest away from the hole is a sighting line for the Caterpillar driver symbolizing the center of the TOS/Caterpillar. Additional flag/s can be put as an extension to this center line, giving the driver a longer sighting line. If the TOS is positioned according to the flags, the tower can readily be backed up against the TOS and positioned correctly.

Remember that the flags are on the opposite side of the hole relative to the Tower and the reels.

Before flagging the drill location, make sure the orientation of the TOS/tower is optimal. Remember that the reels with their anchors are coming in after the TOS/tower has been relocated there. Are there any obstructions, hazards or danger of damaging other equipment?

If the area is not level, try to orient the TOS/tower in a way that the reels will be at a higher elevation than the tower. If there are pits, buried cables etc in the way of the reels, reorient the TOS/tower.

## **13.5 Setting up Reel Anchors**

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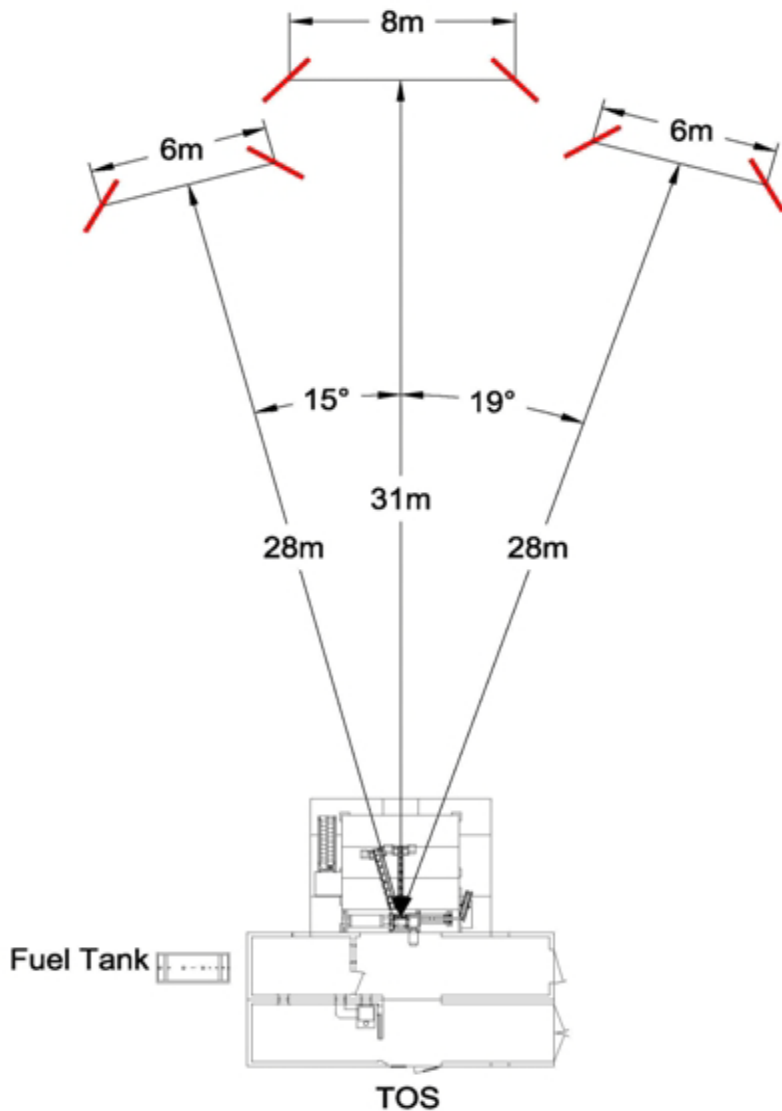
### **13.5.1 Marking the Anchor Locations**

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Marking of the anchor locations is done after the TOS and tower have been relocated to the drill site.

All reels except the DSHR needs to be anchored. A reel that starts to move under load can be very dangerous. Anchors prevent them from moving. The DSHR is so heavy that it requires no anchors. Four reels need to be secured, but only three reels are secured with dead man anchors. The Drill Supply Cable Reel, Return Water Hose Reel and Deployment Reel are secured to dead man anchors. The Return Water Cable Reel is secured to the Return Water Hose Reel.

Figure 13.5 shows how the anchors are positioned. The left position is for the Return Water Hose Reel. The mid position is for the Deployment Reel. The right position is for the Drill Supply Cable Reel.



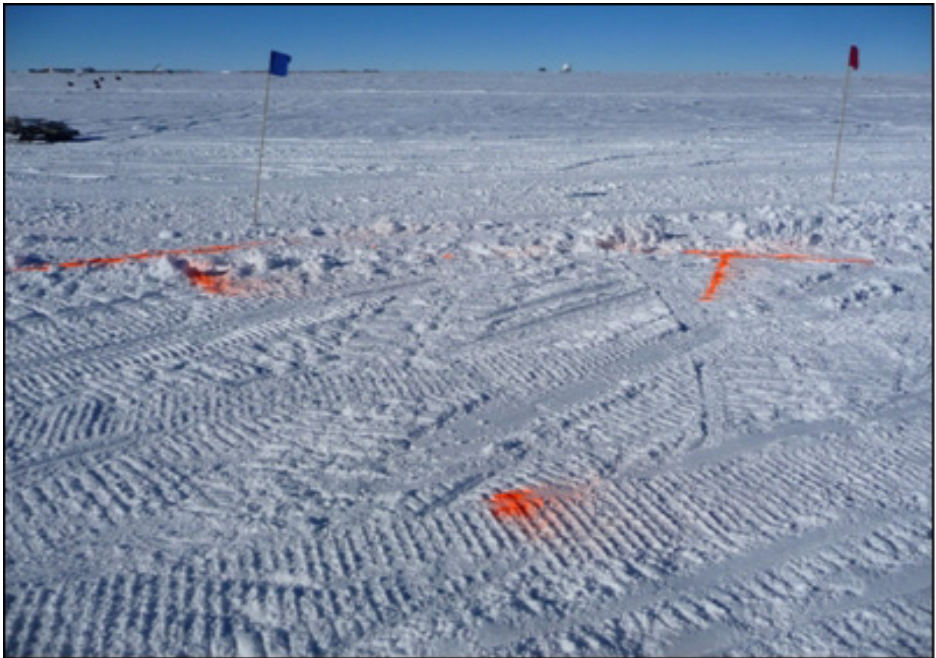
**Figure 13.5** Anchor locations

The closer the reels are to the tower, the greater the angle becomes between the reel and the tower. High angles may damage the drill cable and more force is exerted on the level wind. If necessary to avoid obstructions etc, the reels can be moved slightly closer to the tower, but use caution as the risks increase. The

reels should be positioned so the center of the reel is aligned with the sheaves and fairleads. Graph 13.5 gives a rough outline how to position the anchors. It is not a definite schematic. The most important thing is to make sure the reels are aligned with sheaves and fairleads, with the anchors symmetrically positioned behind the reels. Adjust the position of the anchor trenches with this in mind.

Trenches are in the shape of a “T”. The “T” should point towards the corners of the reels. That means a 30-45 degree angle towards the centerline. A suggestion is to aim for a point 5 m away on the centerline.

Mark the trenches in a “T” pattern with biodegradable marking paint, as shown in Figure 13.6. The paint is used as a guide when doing the trenching.

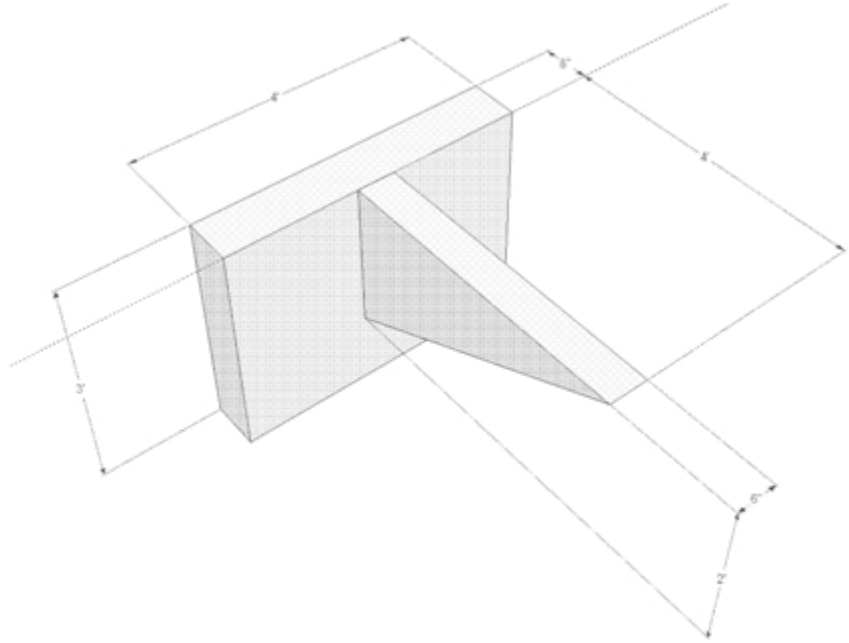


**Figure 13.6** Anchor trench marking and aiming point

## 13.5.2 Trenching and Installing Anchors

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Normally a mechanical trencher is used to dig the trenches, but a water trencher or shovels can be used as well. The trench of the top part of the “T” should be 3-4 ft deep, while the leg portion of the “T” is inclined. The width of the trench should be twice that of the width of the anchor, about 8 inches, to have the anchors fit and to make the installation easy. This is illustratively shown in Figure 13.7.



**Figure 13.7** Reel anchor trench layout

After all the trenches have been dug out, the anchors can be installed, as shown in Figure 13.8. Before putting the anchors in the trench, verify that all chains are in place. One long chain comes out the center of the anchor. This chain is used to secure the reel. It needs to be long enough to reach the reel. There are two short chains attached to the top of the anchor. These chains are intended to simplify the process of getting the anchor out of the snow after use.

The dead man anchor will sit in the top part of the “T”, with a chain coming out of the leg of the “T”. When dropping the anchors into the trench, the pointed edge should be at the bottom. The long reel chain goes into the inclined leg of the “T”. The trench is completely filled with snow, with no holes remaining that can pose a safety hazard. The entire anchor is to be covered. The two top mounted short chains are allowed to remain uncovered by snow. By attaching these supplemental chains for the anchor, the anchor can be lifted out of the trench after use by a 287 loader, without the need for digging them out. They are optimally flagged to make them easy to locate. These flags can also be used as guidelines when positioning the reels.



**Figure 13.8** Installing reel anchors

## 13.6 Marking the Reel Locations

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The flags marking the anchors are good markers to use for setting up the reels. To improve the work of positioning the reels, additional optional measures can be taken.

### **Flag a center line for the reels**

For the RWHR (Return Water Hose Reel) and RWCR (Return Water Cable Reel), the center line will be with the fairlead in line with the return water crescent on top of the tower. There are two rollers on the crescent. One is for the return water hose, the other for the return water cable. Both should be visible from the center line that is set up. Flags can be used to mark the center line, or the heavy equipment conductor creates a mental center line when guiding the reel in place.

The center line for the DSCR (Drill Supply Cable Reel) should be in line with the bottom drill cable sheave. The center line could be flagged or a mental center line created. The cable reel is the single most important reel with respect

to alignment, since high tension will occur in the cable and on the sheave if misaligned. Besides being in line with the sheave, the reel needs to be level with the tower. If the reel is below the tower, the cable will be in contact with the tower floor, potentially harming it. If the reel cable output is below the tower floor, either the TOS/TWR has to be repositioned or the cable reel elevated.

The DSHR (Drill Supply Hose Reel) has no anchors assigned to it, since its pure weight will prevent it from shifting. The alignment of the reel is not quite as important as for the DSHR, but an aligned reel will make the conditions for the equipment easier. An aligned reel will minimize bending and torsion of the hose, as well as forces on the level wind and fairlead, and finally make leveling when spooling up the hose easy. Torsion in the hose is to be avoided at all cost, as it can cause the cable and hose inside the tower to shift and the main cable to derail.

To make it easy for the heavy equipment operator to maneuver the hose reel into position, a center line can be flagged here as well. The center of the reel should be aligned with the center crescent on top of the tower, the main hose crescent, and the fairlead. This center line could be flagged or a mental center line created when moving the reel into position. A sighting line can be flagged for the heavy equipment operator that is perpendicular to the center line. It is either a sighting line that is outlining the ends of the reel, or better, a center sighting line for the heavy equipment operator to aim for. Make sure the main hose reel is positioned plenty away from the deployment reel anchors. The reel should at least be positioned with the close edge of the hose reel 2-3 m from the flags indicating the deployment reel anchors (4-5 m from a center line for the reel). This is to create a margin as well as allowing for maneuvering the deployment reel into position at the end of drilling.

Check that the snow has been compacted for the reel and that no obstructions are visible. If the snow is not compacted, the reel may sink into the snow when moved in place. If the snow is more compact closer to the tower, all reels could be moved closer to the tower, keeping in mind what has earlier been said about distances between the tower and reels.

The deployment reel is secured to the mid anchors. The reel should be aligned to the center crescent on the tower. As the reel will in most cases be pulled in from the tower side, a center line could be flagged. The reel will not be pulled in until the drilling has finished and the main cable reel has been moved to allow for the deployment reel to get into place. The reel needs to be centered to avoid the cable jumping.



# Chapter 14

## 14: RELOCATING TOS/TOWER TO NEXT HOLE

### 14.1 Introduction

---

Normally drilling is alternated between two TOS'. While one is being used for drilling, the other is moved and set up for the subsequent drill operation. This chapter will describe how the TOS and Tower are moved from one drill site to the next.

#### **Prerequisites**

See chapter 13 “Preparing Site at Next Hole” and chapter 12 “Preparing TOS/tower for Relocation”. Below is a short summary of these two chapters.

The new drill site should already have been prepared as follows:

- The drill area and a road leading to the area should have been compacted.
- The drill area is level and flat.
- A predrilled firm hole should already exist at the drill site.
- The firm hole is covered and marked.
- The firm cavity is clear of drift snow.
- An anchor for the surface to DOM cable is in place and is clearly visible beside the hole.
- The positions for the TOS and tower have been marked and flagged.

Prior to the move perform the following checks on the TOS and tower to be moved:

- Check that there are no cables connecting the tower to the TOS, such as communication cables and power cables (for instance reel cables, hoist cable, E-stop cables, network cables, load cell cables).
- Check that the TOS and tower are not secured to each other. Both the two lower and the two upper cargo straps should have been disconnected.
- Cable drag has been performed and the StD (Surface to DOM) cable is clear of the tower.
- In no way can the StD cable be attached to the tower or TOS. The only thing to be connected to the cable should be the anchor chain.
- All equipment that is likely to move in the tower and TOS have been secured from movement.
- All insulation between the tower and TOS has been removed.
- All electric and electronic equipment has been powered down.
- The Drill Hose Crescent has been elevated and there is no load on the load cell.
- The fuel lines to TOS are detached.
- tower is an autonomous structure, with nothing preventing it from a move. The only thing connected to the TOS is the power cable from SES.
- Locate the hole grate and stage it next to the tower.
- Make sure the slot leading from the tower hole is open, as shown in Figure 14.1, allowing the cable to exit the tower.
- If the deployment cable is still on the tower side of the insulating wall, the centre wall section needs to be slid out and the cable moved to the outside of the tower, as shown in Figure 14.1, before the tower move.



**Figure 14.1** Hole slot cover being removed and tower insulating wall centre section

Right before the move, do the following:

- 1 Acquire logistic support for the move. As long as the area is compacted, a Crawler Loader has no issues moving the tower. When the surface layer is compacted, it can normally move the TOS as well. Otherwise a D7 or D8 Bulldozer has been used for the TOS move during the IceCube project.
- 2 The Fuel tank can be pulled away from the TOS and moved over to the next drill site. This can be done anytime after the tank has been detached from the TOS.
- 3 Turn off all electrical heaters in TOS, and allow them to cool down. If not, they will eventually burn out and will need to be replaced.



**Figure 14.2** Heater thermostat control

- 4 Kill power in the TOS by opening (turning off) the main breakers, shown in Figure 14.3.



**Figure 14.3** TOS main circuit breakers at the top of the breaker panel

- 5 Turn off the power to the TOS at the circuit breaker at the PDM, shown in Figure 14.4. Open (shut off) the breaker to the TOS to be moved. There is only one breaker to each TOS. Do NOT turn off the power to the other, active TOS! Each TOS is labeled, TOS 1 and TOS 2. At the PDM each breaker is labeled accordingly. There is only one power cable per TOS. Due to legacy reasons there may be breakers labeled TOS 1 A and TOS 1 B, TOS 2 A and TOS 2 B, and TOS 1/2. Ignore any that do not state TOS 1, TOS 1 A or TOS 2, TOS 2 A.

**Caution:** Always double check to make sure power is being turned off to the correct TOS.



**Figure 14.4** TOS circuit breaker at PDM

- 6 Unplug the power cable to the TOS. It has been found to be easier to unplug the power cable where the pigtail meets the first surface cable and keep the pigtail connected to the power interface box.



**Figure 14.5** TOS power interface box

**Note:** A surface cable can typically not be directly be plugged into the power box without using a pigtail, as the connector key is oriented 90 degrees differently.

- 7 Move the power cable and the already disconnected TOS to SES network cable out of the way for the move.

## 14.2 Moving the Tower

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- 1 Hook up a tow bar to the front end of the tower.
- 2 A crawler loader or similar connects to the tow bar. By hooking up the front of the loader, as shown in Figure 14.6, the driver has better control of the tower maneuvering.



**Figure 14.6** Hooking up tower tow bar to front of loader

- 3 One person dresses up in harness and secures himself/herself to the TOS or tower using a lanyard.
- 4 Pull out the tower away from the TOS 5-6ft. While the tower is being pulled out, the harnessed person inside the tower checks that the StD cable exits the tower without being damaged.
- 5 The harnessed person installs the staged grate on top of the hole, as shown in Figure 14.7. A slot may have to be dug out to allow the Surface to DOM cable to exit the hole under the grate. The grate is fastened to the underlying plywood, to remove any possibility of accidental removal of the grate.



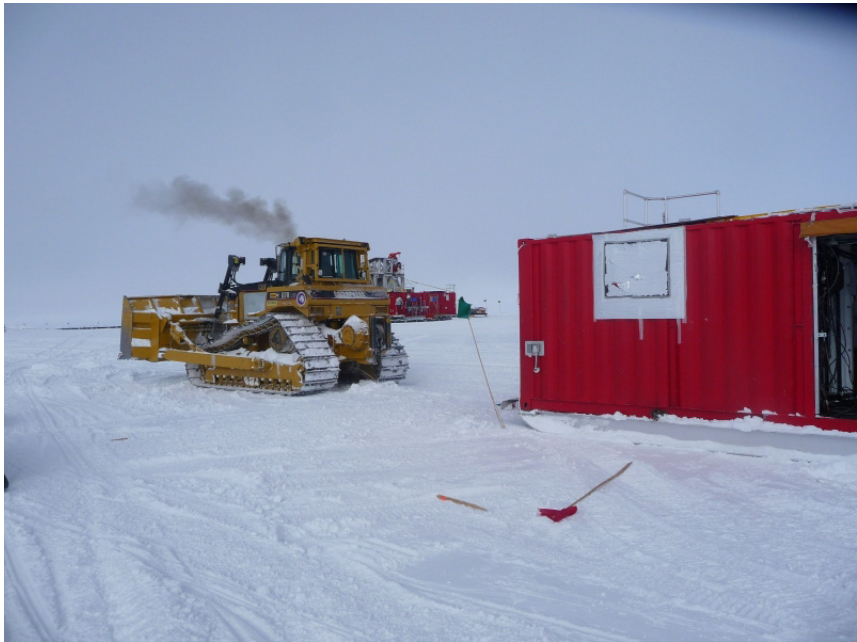
**Figure 14.7** Grate covering hole

- 6 Checking that nothing is obstructing the path for the tower, the tower can be moved to the next drill site.

## 14.3 Moving TOS

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- 1 Move the Surface to DOM cable over the TOS roof to the side of the TOS. Which side depends on what is optimal with respect to the Surface Junction Box (SJB) and in what direction the TOS is to be pulled.
- 2 Hook up a tow bar to the appropriate side of the TOS.
- 3 Hook up heavy machinery to the TOS.
- 4 After double checking nothing is in the way of the move and that the StD cable is well out of the way, the TOS can be pulled away to the next drill site. The heavy machinery and the TOS will need to stay on prepared, compacted roads as the TOS (and heavy machinery) will easily dig into the surface snow and get stuck.



**Figure 14.8** D8 Hooking up to TOS

## 14.4 Positioning TOS at New Drill Site

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- 1 Check that there are no obstructions for the TOS, tower and Reels. If necessary, reorient the tower/TOS to avoid any complications.
- 2 Pull in the TOS using the previously set up flags, marking the drill site, as shown in Figure 14.9. The flagged line closest to the hole marks the perimeter of the TOS and the center point of the TOS. The flag line furthest away from the hole is the center line for the TOS, used by the heavy equipment operator as a sighting line when guiding the TOS into place. When moving the TOS into place, make sure the open end of the TOS (where the tower connects) is oriented towards the hole.

**Caution:** When moving the TOS, avoid making sharp turns. The skis will bulge causing the brace to break and the skis will be deformed. A bulged ski will create a larger gap between the TOS and tower, as the tower cannot be moved close enough to the TOS.



**Figure 14.9** Flagging TOS location and TOS move

- 3 The center of the TOS to tower opening should be aligned with the hole center, as shown in Figure 14.10. There is a mark on the TOS defining the proper position. The TOS should be 22 inches from the hole center.



**Figure 14.10** Tower position relative to TOS

### 14.4.1 Removing Hole Cover

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The pre-drilled firm hole is around 40 m deep and is wide enough to fit a grown person. Therefore a grate is always covering the hole when drilling or deployment is not taking place. Before backing up the tower to the TOS, the hole has to be exposed. Optimally the grate is removed when the tower is being backed up to the TOS. A safety harness and lanyard is used to secure the person removing the grate. The lanyard is hooked up to either the TOS or tower. Any person approaching the hole from now on, will need to be secured by fall protection.



**Danger:** **If not absolutely necessary to keep the hole open, as here, keep the hole covered (grates) and flagged for hazard.**

**Caution:** When moving the TOS, avoid making sharp turns. The skis will bulge causing the brace to break and the skis will be deformed. A bulged ski will create a larger gap between the TOS and tower, as the tower cannot be moved close enough to the TOS.

At the time the grate is removed, the person in fall restraint checks that the cable anchor chain is in the right place, clearly visible and recoverable once the tower is in place. The anchor chain should go under the plywood sheet, but the hook easily recoverable on top of the sheet.

The grate is moved out of the way of the tower. Place it next to the tower, where it will be easily found once it is time for the next relocation.

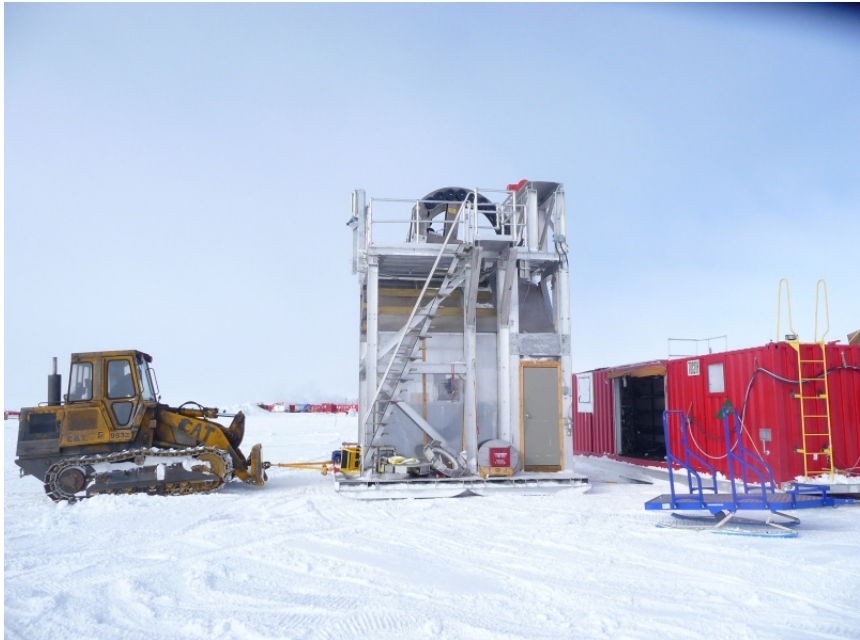
## 14.5 Positioning tower at New Drill Site

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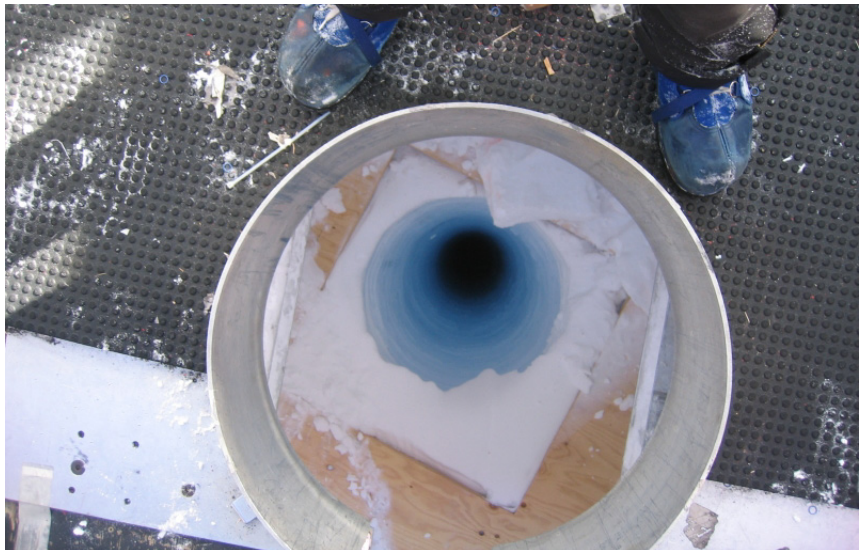
When the TOS is in place, the tower can be moved into position.

- 1 Position the tower for backing up to the TOS. Optimally a front mounted hitch point is used for the Crawler Loader, as shown in Figure 14.11, will make positioning of the tower easier for the equipment operator.
- 2 A person using fall protection guides the equipment operator from inside or outside the tower or TOS. The tower is backed up to the TOS (check that nothing is in the way). The alignment has to be checked inside the tower. The tower hole opening should be centered right above the firm hole. A pendulum can be used to make the positioning easier, if unsure. The hole should be centered fairly accurately, as a misalignment, shown in Figure 14.12, may complicate drilling and/or deployment. An inch or two off from the center line is acceptable.
- 3 If the tower is in the right place, but the TOS is not aligned correctly, the TOS has to be moved. The more care is taken when moving the TOS into place, the less is the risk of having to make adjustments when the tower is in place. A Crawler Loader can be used to push the TOS into place. The opening of the TOS should be centered to the tower opening. An alignment of  $\pm\frac{1}{2}$  ft is ok, but more should be avoided. The reason for this is multifold. The cargo straps securing the tower to the TOS are only offset to allow some

misalignment. The insulation of the interface between TOS and tower may also be more awkward to install if the misalignment is greater.



**Figure 14.11** Tower being backed up to TOS



**Figure 14.12** Positioning of tower over Hole

- 4 After verifying that the tower and TOS are in their proper location, put a metal cover over the hole opening, to serve as fall prevention.

### 14.5.1 Anchoring TOS to Tower

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When the TOS and tower are in place, secure the two structures to each other using heavy duty cargo straps and chains. There are two attachment points at the low end of the tower and TOS, and two on top of the TOS. Keep the straps plenty taut, with no slack.



**Figure 14.13** Securing tower to TOS using cargo straps and chains

Click on the link below to view a video showing the TOS and tower being relocated to the next drill site.

[Moving the TOS and Tower.mp4](#)

### 14.5.2 Cable Move

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While the TOS and tower are being moved, the power cable and network cables are rerouted to connect at the new drill site. The TOS can be without power and heat for normally a few hours as long as the electrical closet and drill control room are closed to contain the residual heat.

## **Relocating Electric Feeder cables to New Site**

The power cable has to be de-energized when performing the rerouting and hook up. A section may have to be removed or added to reach the new drill site. Plan ahead to avoid conflicts when making the next move. The power cable and network cable will easily get twisted with each other and/or the surface hose. By planning ahead and clearing any complications, the next move will go more smoothly. Check that no twists occur and route the cables to minimize impact on the next hose move and cable move. The power cable is hooked up to the TOS power box. After checking that there are no interruptions in the cable routing, power may be turned on at the PDM. Flip the main breaker in the TOS to bring power back to the TOS.

## **Relocating Communications Cable to New Site**

The network cable is wound up on a spool. The spool can be used to spool in and out network cable according to need and to make the move easier. The end at SES is fixed and will not have to be disconnected. The TOS end is disconnected and reconnected after the rerouting of the cable. After the power has been switched on, the modems in the electrical closet will connect to SES and establish a network connection.

Check that no twists occur between the network cable, power cable and surface hose. Once relocated, flag the network cable and power cable to mark it as a no crossing area.

# **14.6 Preparing TOS/ Tower at New Hole for Drilling**

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To get the TOS and tower ready for drilling, basically the reverse of what is described in Chapter 12 – “Preparing TOS/tower for Relocation”. Here is a brief discussion of what to do.

## **14.6.1 Heat Restoration**

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Turn on the electrical heaters in TOS.

Move the furnace fuel tank to sit next to the TOS. Hook up the fuel lines. Turn on the furnace breaker. Turn on power breaker at the furnace. Check the thermostat and that the furnace fires up (for the furnace to start up, local E-stop needs to be up and running; check section below).

## 14.6.2 E-stop and Network Hookup

---

Connect all cables between the tower and TOS.

- 1 E-stop cable from TOS to the E-stop inside the tower.
- 1 E-stop cable from TOS to the E-stop outside the tower.



**Figure 14.14** E-stop cables connected to tower inside and outside slap buttons

- 1 cable from TOS to the Load cell amplifier box, shown in Figure 14.15.



**Figure 14.15** Cable needs to be reconnected to bottom of load cell amplifier box

- Communication cable between TOS and SES:

The network/E-stop cable connecting TOS with SES is connected at the network box next to the DSL modem inside the electrical closet, as shown in Figure 14.16. Verify that the TOS is in local E-stop mode. If not, the furnace and drives in the TOS will be rendered non operational.



**Figure 14.16** Network cable attached to network box inside TOS electrical closet

Restart the E-stop by rotating the E-stop control box knob to Start. If the E-stop system does not start, check cables and E-stop slabs at the TOS and tower. Also check that the Reel Network Box (inside the electrical closet) has its E-stop dummy connectors installed. Press reel start at the Reel Network Box.



**Figure 14.17** E-stop controller, reel start and slap button reset

The Reel Network Box requires dummy connectors installed in place of the reel cables in the TOS E-stop controller box, as shown in Figure 14.18, in order for the E-stop system to work. The dummies maintain the continuity loop in the E-stop network that would otherwise be interrupted since the reel E-stop cables are not yet hooked up.



**Figure 14.18** Dummy plugs installed in place of reel cables in TOS E-stop box

## 14.6.3 Electronics

---

Remove all the tie downs securing the equipment in the TOS computer room and position all equipment for operation, as shown in Figure 14.19. Monitors should be standing and plugged in. Keyboards and mice should fully functional. The communication radio turned on, set to the proper channel and function verified.

Turn on the computers. Start the EHWD UI on both computers and the control server on TOS(1/2)-2 computer.

Verify that the UPS is operational.



**Figure 14.19** TOS drill control room in operational state

## 14.6.4 Preparing Tower

---

- 1 Put landings in front of the entrances of the TOS and lower the landing grates.



**Figure 14.20** TOS landing



- 2 Insulate between the TOS and tower. The better the interface is insulated, the better work environment is accomplished and better fuel economy.
- 3 Remove any equipment restraint that was put in place for the move, including restraints for drill head, weight stack etc.
- 4 Make sure there is a metal cover, shown in Figure 14.21, on top of tower hole. This piece is important as it serves as a fall prevention as well as preventing heat leakage from the MDS'.



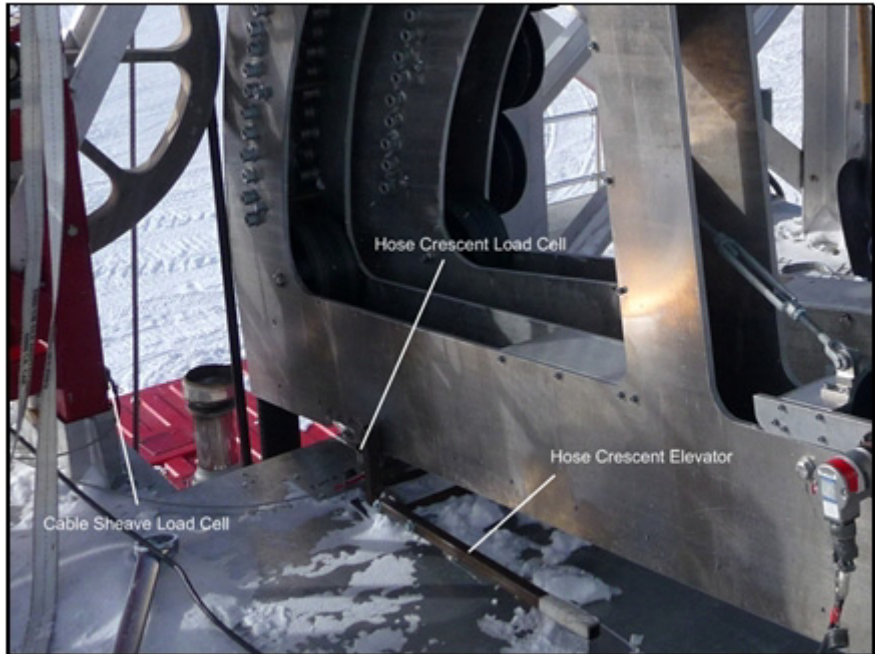
**Figure 14.21** Tower hole covers

- 5 Put hole slot cover in place, as shown in Figure 14.22.



**Figure 14.22** Hole slot cover

- 6 Remove the separation piece at the drill hose crescent and lower the crescent onto its load cell, as shown in Figure 14.23.



**Figure 14.23** Crescent and elevator

- 7 Hook up the power cable to the tower hoist, as shown in Figure 14.24. Verify the functionality of the hoist and inspect the hoist wire rope for any damage.



**Figure 14.24** Tower hoist power connectors



**Figure 14.25** Tower hoist

## 14.6.5 Marking Reel Anchors

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Once the TOS and tower are in place, the reel anchor locations can be marked. For instructions on how to mark and trench the anchor locations, see Chapter 13 – “Preparing Site at Next Hole”.

The anchors at the previous drill site can be removed and relocated. The most efficient way is to use a skid steer to lift the anchors by the short lifting chains. Move them to the new drill site to be buried there. See Chapter 13 - “Preparing Site at Next Hole” for further instruction.



# Chapter 15

## 15: WINTERISING EHWD SYSTEM

### 15.1 Introduction:

---

At the end of each drilling season, all water needs to be purged from the system. After purging, the system needs to be flushed with glycol in order to dilute any remaining water that may be trapped in fittings and valves as well as at low points in the system. Flushing with glycol is very important, as any undiluted water will freeze and rupture any fittings and valves it is trapped within.

Once the system has been flushed and water diluted, all “Do Not Freeze” (DNF) equipment will need to be removed from any buildings that will not remain heated over winter. This equipment needs to be stored at room temperature.

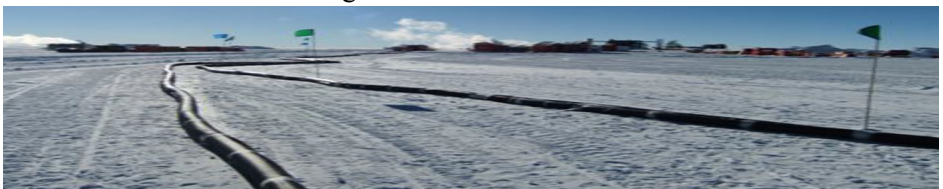
Finally, all buildings need to be secured against the elements by plugging any holes and sealing any vent and exhaust openings before the system is moved to its winter storage site.

### 15.2 Purging Water from the System

---

The EHWD is made up of four main plumbing components that require flushing with air and glycol. These are:

- 1 Surface hoses shown in Figure 15.1.



**Figure 15.1** Surface hoses

**2** The main hose reel and return water reel shown in Figure 15.2



**Figure 15.2** Main and return water hose reels

**3** The Rod Well reel system

**4** The Seasonal Equipment Site (SES) consisting of the RWS, PHS, WT1, WT2, MHP1-4 and the HPP

Upon completion of drilling removing water from the system should occur in the following order;

- 1** Surface hoses and hose reels concurrently.
- 2** Rodwell
- 3** SES

The equipment needed to purge the system of water and to dilute any remaining water with glycol include:

- 1** Large Air Compressor of 175 CFM capacity or larger, as shown in Figure 15.3



**Figure 15.3** Air compressor

- 2 A 800 gallons or larger tank that can be used as the glycol tank, as shown in Figure 15.4



**Figure 15.4** 800 gallon glycol tank with 3 way valve

- 3 Three way valve, as shown in Figure 15.4 for quick switching between air compressor and glycol pump.

- 4 Submersible pump capable 30 gpm at 100 foot of head (40 psi).
- 5 Misc hoses for connecting MDS's, glycol tank, compressor, WT-2.
- 6 A “287” skid loader with the hose roller attachment, shown in Figure 15.5



**Figure 15.5** Hose roller attachment for “287” skid loader

In order to purge the system, the drill needs to be in an operational state, so that pumps, heaters and hose reels can be operated.

#### **Prepping drill system for purging:**

- 1 Have drill system in a closed loop state, with the surface hose and supply hose reel and return water reel in the loop.
- 2 Heat loop up to minimum of 100F/37.8C degrees
- 3 Recommended shift size for purging the drill of water is 7 people and 1 equipment operator.

### **15.2.1 Purging water from surface hoses and drill reels**

---

- 1 Shutdown and cool off all MHP heaters.
- 2 When MHP heaters are cooled down shut down the HPP and charge pumps stopping flow in surface loop to the Hose reels.
- 3 When line pressure has bled to zero, disconnect the surface hoses from the HPP and the hose reels. Install jumper from HPP to WT 2 and resume flow through the SES



- 4 Move surface hoses out in the open. With the hose roller attached to the 287 forks, sling the hoses over the roller, raise the forks and move along the length of the hose to drain it. Alternatively, make a snow mound and drag each hose section over the mound, making two passes per hose.
- 5 Remove any jumper hoses from the outlet end of the main hose and return water hose. Spool each hose onto it's respective reel and secure the outlet end of each hose onto the rest of the hose on the reel, such that each reel can be freely rotated without the end of the hose catching on any part of the reel.
- 6 Attach a jumper hose onto the inlet end of each hose reel and direct the end of the jumper away from the each hose reel. Commence rotating the return water hose reel and main hose reel backwards for one hour and up to eight hours, respectively. This will "corkscrew" the water out of the hose reels. Make sure the end of the jumper hoses where the water is being flushed out is properly flagged and the area is not a danger to personnel or equipment.
- 7 Using an adaptor fitting and a jumper hose, connect the air compressor to the surface hoses with and blow out the surface hoses for approximately 10 minutes each to assure there are no water pockets in the surface hose. After blowing out surface hoses, move them to winter storage site. When all hoses are in storage, tape the ends and mark and flag the storage area as shown in Figure 15.6.



**Figure 15.6** Surface and jumper hoses laid out and flagged for winter storage

- 8 After approximately one hour of back spinning of the return water reel, stop spinning. Attach hose to the air compressor, using an adaptor and jumper hose. Blow out the reel and all ports until all mist has quit, or for approximately 30 minutes. When done, weather proof hose ends and move return water reel to winter storage.

- 9 Continue back spinning the main hose reel until all water has quit coming out (up to 8 hours) then using an adapter and jumper hose, blow out the main hose reel with compressed air until all mist has quit coming out of the hose. When done weather proof all hose connections and move to winter storage site.

Click on the video link below to view a video of the surface hoses being purged of water.

Blowing out the Surface hose.mp4

## 15.2.2 Removing water from Water Tanks

---

- 1 Pump the water level in each tank down to approx 13 inches.
- 2 Shut down any pumps running. Remove submersible pumps from tanks and store in a warm area.
- 3 Open all valves and drain manifolds on Vertical Turbine Pumps.



**Figure 15.7** Vertical turbine pumps and filter

- 4 Drain WT-1's Bag filter and discard filter bag
  - 5 Drain Centrifuge filter in the doghouse of WT-1
  - 6 Lower a submersible sump pump into each tank and drain tanks down as low as sump pump will allow.
  - 7 Remove sump pump and check that no electrical devices are in the tanks.
  - 8 Enter into WT-1&2 and remove the drain plugs.
- Warning:** check with safety officer on any training and permits required for working in confined spaces.
- 9 When water flow has stopped from drain plug, enter tanks and use wet/dry vacuum to finish water removal.
  - 10 Replace drain plugs, and seal all opening in tanks.

## 15.2.3 Flushing MHP's, PHS, RWS, and Generators

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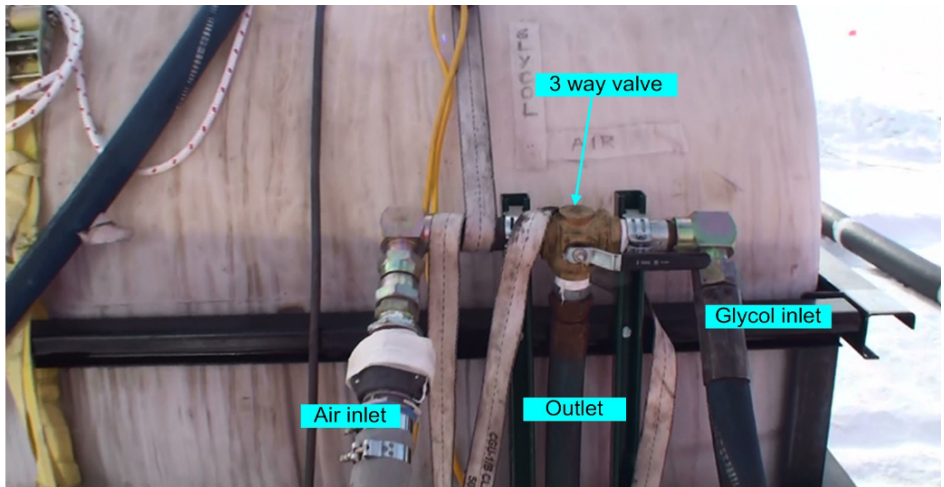
### 15.2.3.1 RWS

- 1 Stop all water flow to and from the Rod Well. Using the Rod Well reels, pull the Rod Well pump to the surface, being careful to layer the hoses properly on the internal hose reel.



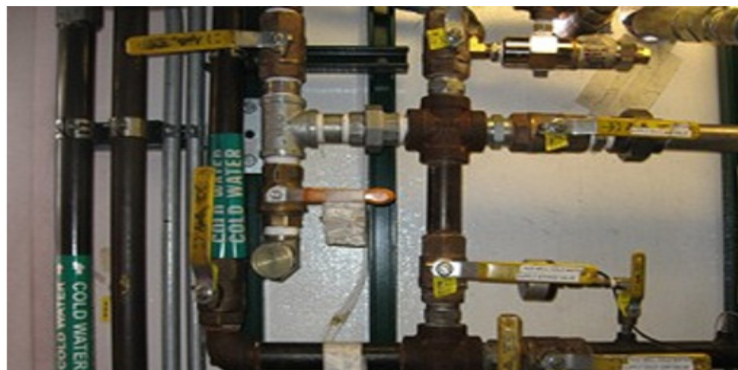
**Figure 15.8** Rod Well surface hose and cable support

- 2 Disconnect Rodwell pump and spray nozzle and place the pump in a warm location.
- 3 Spool up the two hoses to the edge of the RWS building and connect them hoses together to make a loop. Once looped, continue spooling until the hose ends are inside the RWS.
- 4 Remove the RWS water inlet line from WT-1 and using a jumper hose, connect this line to the air compressor/glycol tank 3 way valve on the glycol tank, as shown in Figure 15.9.



**Figure 15.9** Glycol tank 3 way valve showing inlets and outlet

- 5 Have the DCC valve all heaters in the RWS so their outputs are directed to the Rodwell.
- 6 Valve the manifold wall in the RWS for drilling, as shown in Figure 15.10.



**Figure 15.10** RWS “manifold wall” set for drilling

- 7 Check to make sure that the return line from the RWS to WT1 is fastened securely.
- 8 Select air as the inlet to the 3 way valve on the glycol tank. Open the supply valve from the air compressor and blow the water from the RWS until water quits coming out of the return line to WT1.
- 9 When water quits coming out of the return line to WT1, have the DCC valve all RWS heaters to the WT1 position and purge until water quits coming out of the return line.
- 10 Go through the RWS and valve off all but one of the RSW heaters. Purge the individual heater for approximately one minute then move to the next heater shutting off the previous one and repeat. Do this until all RWS heaters have been purged.
- 11 While purging the heaters, open up the drain valves on all manifolds in the RWS and briefly open to purge water from drain valves.
- 12 Continue blowing water out of the RWS and back to water tank 1 for approximately 1 hour.
- 13 After all water is blown out of RWS, remove the return line that runs from the RWS to water tank 1 and run a new water line from the outlet of the RWS to the glycol tank.

**WARNING: Make sure that is the return line is fastened securely to the glycol to avoid the hose coming lose and whipping which could cause severe injury!!**

- 1 Have the DCC valve all heaters in the RWS back down to the Rodwell.
- 2 Switch the 3 way valve on the glycol tank from air to glycol and start the glycol pump.
- 3 Continue pumping glycol until steady stream is arriving back to the glycol tank.
- 4 Switch the 3 way valve back to air and open the compresor valve to blow the glycol out of the RWS. Continue blowing until glycol stops arriving back at the glycol tank.
- 5 When glycol quits coming out of the return line to glycol tank have the DCC valve all RWS heaters to the Water tank one position. Change the 3 way valve back to glycol and turn on the glycol tank pump until a steady stream of glycol is coming back to the glycol tank.
- 6 Switch the 3 way valve back to air and open the compresor valve to blow the glycol out of the RWS. Continue blowing until glycol stops arriving back at the glycol tank
- 7 Go through the RWS and valve off all but one of the RSW heaters. Purge individual heater for approximately one minute then move to the next heater

shutting off the previous one and repeat. Do this until all RWS heaters have been purged.

- 8 Remove all hoses used for purging and seal openings in RWS building to keep snow out.

### 15.2.3.2 HPP and MHP's

This part of winterization of the system works best if you do the HPP and MHP's while they are plumbed together.

**Note:** Before blowing out MHP's, turbine flow meters need to be removed from every model 75 heater and jumpers installed in order to avoid damage to the flow meters. See video link below.

#### Removing MHP Flow Meter .mp4

- 1 Discontinue flow from HPP by stopping any high pressure pumps.

**Warning:** Be sure to also stop all charge pumps before disconnecting feed lines from WT-1 to HPP.

- 2 Connect the air compressor/glycol line to HPP-4 with an adapter fitting that goes from 4" male cam lock to 1.5" MJIC.

3. Install a 1.5" bypass line on drill hose outlet in HPP to WT-2

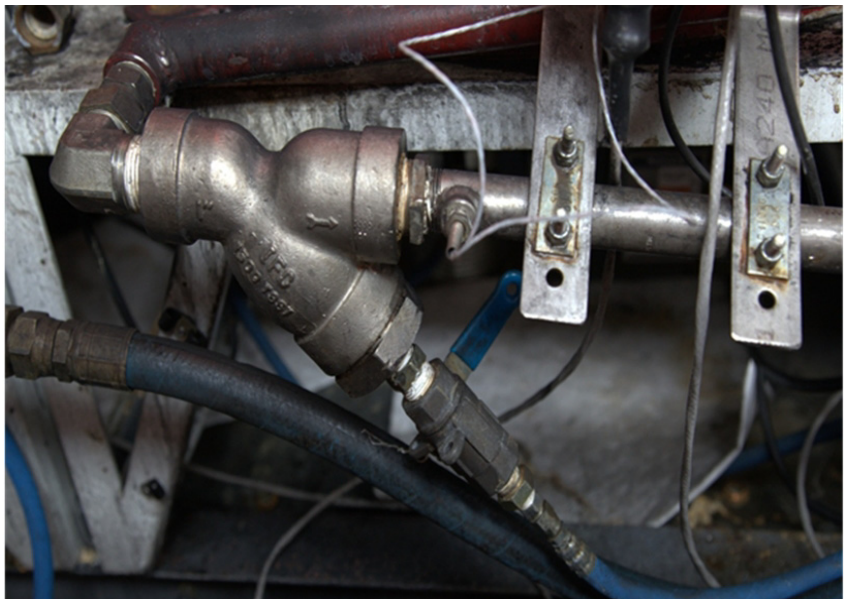
**Warning:** secure tank end of line securely due to chance of extreme whipping if hose gets loose.

- 4 Close all inlet valves on the HPP except for HPP-4. Close supply valves on wall manifold, shown in Figure 15.11, for HPP's 1-3, leaving HPP- 4 open.



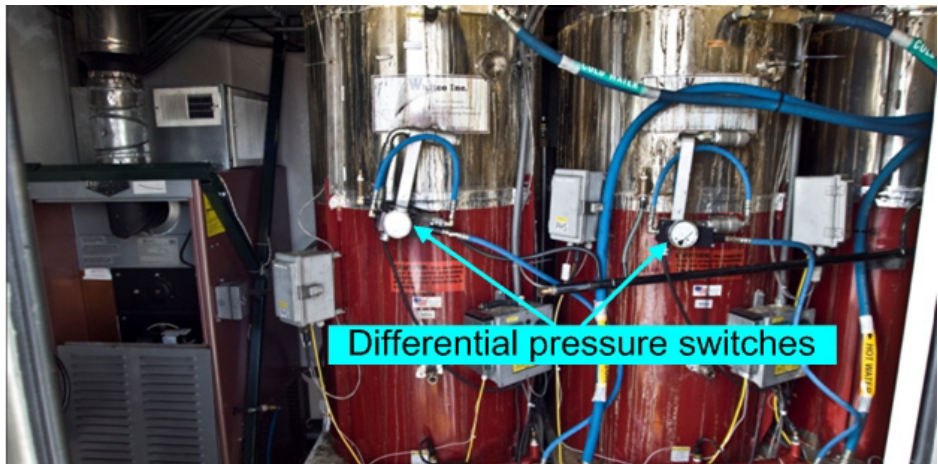
**Figure 15.11** HPP pump manifold

- 5 Make sure all heaters have their inlet and outlet valves open for flow through all MHP's
- 6 Open supply valve from compressor and start air flow through HPP-4 and all MHP's.
- 7 After 15 minutes, stop air flow. Make sure there is no residual pressure in air line, then move air hose over to HPP 3.
- 8 Open inlet and outlet valves on HPP-3, and shut inlet and outlet valves on on all other HPP's.
- 9 Start air compressor and run for 15 minutes.
- 10 After the 15 minutes, shut down air and move to HPP-2 following steps 8-10.
- 11 Moving to HPP-1, follow steps 8-10 again.
- 12 Once all the high pressure pumps are blown out, go to MHP's-1,2,3&4 and shut the inlet and outlet valves to all heaters. Then starting at the far end of MHP-4, open up two heaters at a time. Turn on air flow and leave open for 5 minutes. After 5 minutes, shut down the first two heaters and move to the next two heaters and repeat, continue this until all heaters have been blown out by pairs.
- 13 When done open all heaters and go back through the MHP's and open all the Y-Strainers, shown in Figure 15.12, one at a time to purge of liquid.



**Figure 15.12** Y strainer

- 14** Remove hoses on pressure differential switches, shown in Figure 15.13. Drain hoses and drain pressure differential switches by tipping them on their side. When confident that water is out, reattach and tighten hoses.



**Figure 15.13** Differential pressure switches

- 15** When finished, shut off air flow and move the bypass line from WT-2, to the Glycol tank to prepare for Glycol flushing, making sure to firmly secure the bypass line to the glycol tank to prevent the hose from whipping.

- 16** Move the air compressor/glycol line from HPP-1 to HPP-4. Valve the 3 way valve on the glycol tank to glycol and start the Glycol pump. Repeat steps 4 thru 12, but this time flushing glycol through the system instead of air.

**Note:** Make sure that glycol is flowing from the return line before doing individual heaters.

- 17** Once all heaters have been flushed with glycol, stop glycol pump. Move the air/glycol line back to HPP-4. Valve the 3 way valve back to air and repeat steps 4-12, this time flushing air through the system again in order to remove as much glycol from the system as possible.

At this point all the MHP's have been flushed except for their condensate collection system. This will be done as part of the PHS flushing in the next section.

Click on the video link below to see video of MHP lines being purged of water.

[Blowing out the lines with Air.mp4](#)



The following video link shows a video of the MHP's being flushed with Glycol

Flushing out the MHPs with Glycol.mp4

### 15.2.3.3 PHS

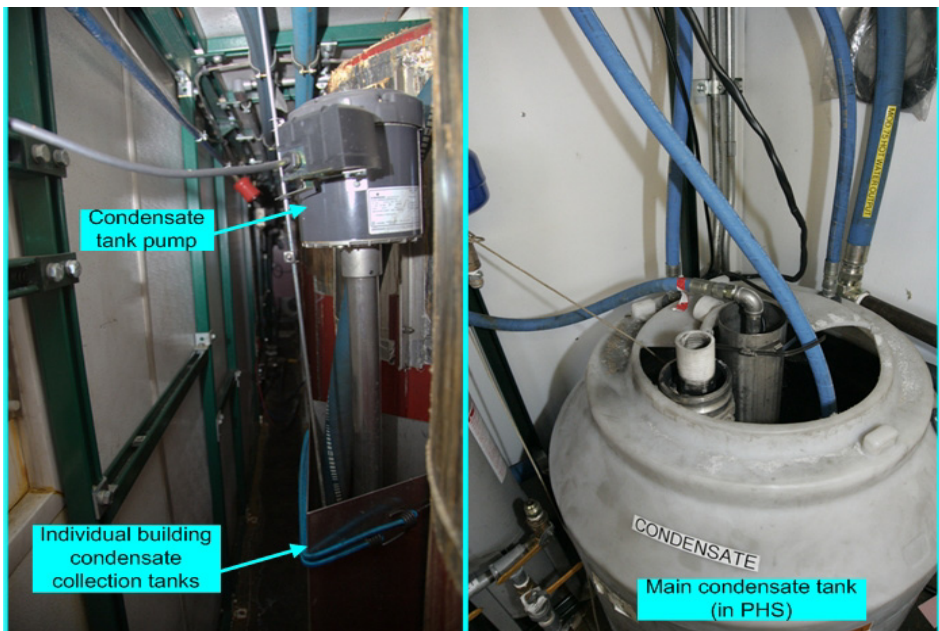
The PHS consists of three subsystems,

The PHS heating system

The condensate system (including the MHP's condensate system)

The WT2 filter system

- 1 Go through PHS and MHP's and manually start condensate pumps, shown in Figure 15.14, until they lose prime. Unplug pump and remove drain plug on condensate tanks, shown to the left in Figure 15.14 and finish draining condensate tanks into bucket. Dump condensate bucket into the main PHS condensate tank (shown to the right in Figure 15.14) for disposal.



**Figure 15.14** Condensate collection tank and pump and main condensate collection tank

- 2 Drain all condensate lines from the MHP's to the PHS main condensate tank.
- 3 In PHS go to main condensate tank and manually start condensate pump and drain down main condensate tank, when pump loses prime, unplug the main condensate pump and drain main condensate tank and dispose of condensate through approved methods.
- 4 When main condensate tank is empty, connect  $\frac{3}{4}$  inch hose to bottom of condensate filters, open vents on top of filters, and drain condensate filters into a container and dispose of in a approved method.
- 5 Shut down booster pump if running and stop flow to PHS by Shutting down vertical turbine pump in WT-2
- 6 Remove 4 inch inlet line from WT-2 to PHS and install the air/glycol line using the 4 inch male cam lock and 1.5 inch male JIC adapter.
- 7 Make sure all PHS heaters have their inlet and outlet valves open.
- 8 Make sure all WT-2 filters are open.
- 9 Start airflow through PHS. After 15 minutes close off valve to WT-2 filter.
- 10 Flow air through the four PHS heaters for 15 minutes then close the inlet and outlet valves on two of the heaters. After five minutes open the other two heaters and close the first two. After a further five minutes open all heaters. open valves to the booster pump and close the booster pump bypass valve, shown in Figure 15.15.



**Figure 15.15** Booster pump bypass valve

- 11** Open valve to WT-2 filters and close valves to PHS heaters. Blow air through WT-2 filters for 5 minutes.
- 12** Stop airflow to PHS, remove output line from model 75 heaters to WT-2 and replace with a jumper from the outlet of the model 75 heaters to the glycol tank.
- 13** Valve off WT-2 filters and drain filters.
- 14** Turn on Glycol pump and flow glycol through PHS model 75 heaters. After glycol return flow is established, pump glycol through individual model 75 heaters by isolating all but one heater and running glycol through individual heaters for 5 minutes then switching to the next one. When all model 75 heaters have been flushed with Glycol, open valves to all model 75 heaters.
- 15** Stop Glycol flow and reestablish air flow. Let air flow until glycol quits coming out the return line to the glycol tank.
- 16** After glycol has stopped flowing, valve open the booster pump and flush with air for 5 seconds.
- 17** Isolate the booster pump and flush the model 75 heaters with air, one at a time for 5 minutes each.
- 18** After all heaters have been flushed, stop air flow and open all drains.
- 19** Remove hoses on pressure differential switches (shown in Figure 15.13), drain hoses and drain pressure differential switches by tipping them on their side. When confident that water is out, reattach and tighten hoses.
- 20** Remove jumper air/glycol line and seal openings in building.

#### **15.2.3.4 Generator cooling system**

The generator heat recovery system is part of the EHWD system and the only part of the power generation system we winterize with the EHWD drill. The only equipment needed to winterise the system is:

A large air compressor, 175 CFM or larger.

Adapter, 2inch male cam lock by 1-1/2 inch MJIC

1-1/2 jumper hose long enough to reach all three generators.

The procedure for winterising the generator coolant/ heat recovery system is as follows:

- 1** In doghouse of WT-1 valve off the feed line to the generator heat recovery system.
- 2** Remove and walk out the cooling lines between the three generator and WT-1, making sure all water has been drained from the lines.

**Warning:** **3** Connect the jumper line from air compressor to the inlet of generator one, **Make sure the cam locks are secured on the jumper line to avoid hose whipping.**

- 4** Purge with air for 5 minutes or until all water is removed.
- 5** Remove the hose and move to generator two.
- 6** Repeat steps 3,4,
- 7** Remove hose and move to generator three and repeat steps 3,4
- 8** Remove jumper line from last generator and cap all openings on the generator's heat recovery system.

### **15.2.3.5 Submersible and sump style pumps**

- 1** Stand pumps up in heated area and let drain for 4 hours or more.
- 2** Pump Glycol from main Glycol tank to an open top tank of suitable size to totally submerge pump.
- 3** Dip pumps into Glycol until totally submerged.
- 4** Leave for 5 minutes then hang above Glycol tank until all Glycol has drip dried.
- 5** Move pumps into storage.

## **15.2.4 Removing DNF and Winterizing Buildings**

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### **15.2.4.1 Winterizing Generators**

Generators historically have been the responsibility of the logistics contractor, so this will be a brief, incomplete non thorough procedure and assumes the waste heat recovery system has already been winterized.

- 1** After Generator has been shutdown turn ther control switch on generator control panel to off , then turn generator circuit breaker that is located on side of generator to the off position. These are shown in Figure 15.16.



**Figure 15.16** Generator control switch and circuit breaker locations

- 2 Disconnect the fuel line at the dry disconnect connectors, shown in Figure 15.17, from outside of the generator building.



**Figure 15.17** Generator fuel lines dry disconnects

- 3 Have electrician disconnect main power supply to PDM and seal any external electrical connectors.

**Warning:** Make sure that the electrical feed line from the generator, shown in Figure 15.18, to be disconnected is not energized at the PDM end back feeding the power line back to the gen set!



**Figure 15.18** Generator feed cable

- 4 Disconnect any control and e-stop cables.
- 5 Drain glycol and store for future use.
- 6 Remove engine batteries and store as DNF.
- 7 Disconnect CO-2 fire suppression cylinders and leave in place, capping the cylinders..
- 8 Seal all vent openings, doors, and engine exhaust stack.

### 15.2.4.2 Winterizing PDM

The PDM historically has been a responsibility of the logistics contractor, so this will be a brief, non complete non thorough procedure.

- 1 Make sure all power is off to PDM.
- 2 Turn all Main and branch circuit breakers to the off position.
- 3 Turn all generator selector levers to off, and check to be sure all generator circuit breakers are in the off position.
- 4 Disconnect CO-2 fire suppression cylinders and leave in place, capping the cylinders.
- 5 Disconnect any control and e-stop cables.
- 6 Remove system batteries and store in DNF location.
- 7 Disconnect all feeder cables to the different MDS's
- 8 Disconnect the feeder power cables from the generators to the PDM.

- 9 Seal all vent, doors and cable entry points.

### **15.2.4.3 PHS Winterization**

Note: This procedure is a continuation of the winterization of the PHS after the water part of the system has been flushed of water and backflushed with glycol.

- 1 Remove all motor drives and DNF sensors to a DNF area.
- 2 Seal all vent opening and roof stacks.
- 3 Turn all circuit breakers to off position.
- 4 Make sure that breaker in the PDM is in the off position.
- 5 Remove the power cable and make sure that power receptacle is sealed.
- 6 Disconnect the dry disconnect fuel lines after shutting the valves at the dry disconnect and day tank, storing fuel line in building.
- 7 Put wooden landings inside of building, seal doors and lift landing and secure to building.

### **15.2.4.4 RWS Winterization**

Note: This procedure is a continuation of the winterization of the PHS after the water part of the system has been flushed of water and backflushed with glycol.

- 1 Remove all motor drives and DNF sensors to a DNF area.
- 2 Seal all vent opening and roof stacks.
- 3 Turn all circuit breakers to off position.
- 4 Make sure that breaker in the PDM is in the off position.
- 5 Remove the power cable and make sure that power receptacle is sealed.
- 6 Disconnect the dry disconnect fuel lines after shutting the valves at the dry disconnect and day tank, storing fuel line in building.
- 7 Put wooden landings inside of building, seal doors and lift landing and secure to building.

### **15.2.4.5 HPP Winterization**

Note: This procedure is a continuation of the winterization of the PHS after the water part of the system has been flushed of water and backflushed with glycol.

- 1 Remove all motor drives and DNF sensors to a DNF area.
- 2 Remove high pressure accumulators, shown in Figure 15.19, from plumbing circuit and store in DNF.



**Figure 15.19** HPP accumulator

- 3 Seal all vent opening and roof stacks.
- 4 Turn all circuit breakers to off position.
- 5 Make sure that breaker in the PDM is in the off position.
- 6 Remove the power cable and make sure that power receptacle is sealed.
- 7 Disconnect the dry disconnect fuel lines after shutting the valves at the dry disconnect and day tank, storing fuel line in building.
- 8 Put wooden landings inside of building, seal doors and lift landing and secure to building.

#### **15.2.4.6 MHP1-4 Winterization**

Note: This procedure is a continuation of the winterization of the PHS after the water part of the system has been flushed of water and backflushed with glycol.

- 1 Remove all motor drives and DNF sensors to a DNF area.
- 2 Seal all vent opening and roof stacks.
- 3 Turn all circuit breakers to off position.
- 4 Make sure that breaker in the PDM is in the off position.
- 5 Remove the power cable and make sure that power receptacle is sealed.
- 6 Disconnect the dry disconnect fuel lines after shutting the valves at the dry disconnect and day tank, storing fuel line in building.



- 7 Put wooden landings inside of building, seal doors and lift landing and secure to building

The video link below shows the SES camp being winterised.

## Winterizing the SES.mp4

### 15.2.4.7 7 Moving Drill to Winter Storage Site

Moving the drill to its winter storage site is an operation that requires the logistic contractor support with mid to large size bull dozers for moving the MDS'. If there is future drilling the SES has been moved to the future drilling location and staged in its basic drill configuration, as shown in Figure 15.20, with the notable exception of the DCC, and TOS's which are moved to a location with continuous electrical power for the winter storage of drill DNF. The Hose reels, towers and miscellaneous equipment traditionally are stored in separate locations, crates and miscellaneous equipment (such as the day tank) are stored between the MDS containers at the future drill site.

All surface hoses are laid out in in a location away from teh SES, lined up in the direction of the prevailing wind, with their ends capped and flagged along their length and at the ends, as shown in Figure 15.21.



**Figure 15.20** SES at winter storage site



**Figure 15.21** Surface hoses in their winter storage configuration

# Appendix A

## ACRONYM LIST

The following list of acronyms is a standard list of acronyms used by the project as a whole. It covers all aspects of the IceCube project, including drilling, science and logistics. Some of the acronyms may not be used in this manual, but the complete list is reproduced here for reference.

<b>A3RI</b>	UW Antarctic Astronomy and Astrophysics Research Institute
<b>AMANDA</b>	Antarctic Muon and Neutrino Detector Array
<b>AN-8</b>	Fuel (Also JP-8)
<b>ATWD</b>	Analog Transient Wave Digitizer
<b>CAT</b>	Caterpillar
<b>CDC</b>	Clothing Distribution Center
<b>CDR</b>	Critical Design Review
<b>CHC</b>	Christchurch, New Zealand
<b>DAQ</b>	Data Acquisition
<b>DCC</b>	Drill Control Center
<b>DFL</b>	Dark Freezer Lab
<b>DNF</b>	Do Not freeze
<b>DOM</b>	Digital Optical Module
<b>DOME</b>	“Old” South Pole Station
<b>DOMMB</b>	DOM main boards
<b>DOR</b>	DOM readout
<b>DSHR</b>	Drill Supply Hose Reel
<b>EHWD</b>	Enhanced Hot Water Drill
<b>ERD</b>	Engineering Requirements Document
<b>E-Stop</b>	Emergency Stop
<b>FAT</b>	Final Acceptance Test
<b>FMEA</b>	Failure Mode and Effect Analysis
<b>GRB</b>	Gamma Ray Burst

<b>GUARD</b>	National Air Guard – Flies the Planes
<b>GEN</b>	Generator
<b>HA</b>	Hazard Analysis
<b>HPP</b>	High Pressure Pump
<b>ICD</b>	Interface Control Document
<b>ICDS</b>	Ice Coring and Drilling Service
<b>ICDS</b>	UW Ice Coring & Drilling Services
<b>IV&amp;T</b>	Inspection, Verification & Testing
<b>JP-8</b>	Fuel (Also AN-8)
<b>KRC</b>	Kegonsa Research Center (Also PSL)
<b>MCM</b>	McMurdo
<b>MDS</b>	Mobile Drilling Structure
<b>MDS</b>	Modular Deployment Structure
<b>MDS</b>	UW Materials Distribution Services
<b>MECC</b>	Mobile Expandable Container Configuration
<b>MHP</b>	Main Heating Plant
<b>NPT</b>	National Pipe Thread – Type of Fitting
<b>NPX</b>	South Pole Station
<b>NSF</b>	National Science Foundation
<b>OML</b>	Optical Module Lab
<b>PAP</b>	Project Advisory Panel
<b>PDM</b>	Power Distribution Module
<b>PDR</b>	Preliminary Design Review
<b>PEP</b>	Project Execution Plan
<b>PHS</b>	Pre-Heater System
<b>PMP</b>	Project Management Plan
<b>PMT</b>	Photomultiplier Tube
<b>PSL</b>	Physical Sciences Lab in Stoughton (Also KRC)
<b>PSL</b>	UW Physical Sciences Lab
<b>RPS</b>	Raytheon Polar Services Corporation
<b>RPSC</b>	Raytheon Polar Services Corporation
<b>RWCR</b>	Return Water Cable Reel (or Rod Well Cable Reel)
<b>RWHR</b>	Return Water Hose Reel

<b>RWS</b>	Rodriguez well system
<b>S/W</b>	Software
<b>SDP</b>	Software Development Plan
<b>SEMP</b>	System Engineering Management Plan
<b>SES</b>	Season Equipment Site
<b>SEW</b>	Seasonal Equipment Workshop
<b>SSEC</b>	Space Science and Engineering Center, a UW center
<b>STF</b>	Simple Test Framework
<b>TOS</b>	Tower Operations Site
<b>TOS</b>	Tower Operations Structure
<b>TOW</b>	Tower Operations Workshop
<b>TWR</b>	Tower
<b>USAP</b>	US Antarctica Program
<b>VC</b>	Verification Coordinator
<b>WBS</b>	Work Breakdown Structure
<b>WG</b>	Working Group
<b>WT1</b>	Water Tank 1
<b>WT2</b>	Water Tank 2



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
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1	15	<b>Antarctic Astronomy &amp; Astrophysics Research Institute</b>					
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3	17	TITLE					
4	18	<b>ICECUBE</b>					
5	19	<b>TOS EVACUATION AND MUSTER</b>					
6	20	<b>ENHANCED HOT WATER DRILL</b>					
7	21	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
8	22	SC	10/27/05	JC/FF	10/27/05	HL	10/27/05
9	23	DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
10	24	AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05
11	25	FILENAME	8510-0341.0510.doc		PROJECT NO.	8510	
12	26	DRAWING NO. 8510-0341		SCALE	SIZE	SHEET	
13	27			NA	A		
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## Tower Evacuation and Muster

### References:

Search Sequence For Missing Staff

### Requirements:

Personnel: All personnel in and around the Tower or TOS

#### 1. Clearing the TOS and Tower

### Warning

Failure to follow this procedure can result in severe injury.

- 1.1 Upon hearing "Clear the TOS" all personnel must exit the TOS by the quickest available exit.

Grab a radio if you pass one while leaving.

If you pass an un-depressed Reel Stop or button on the way, press the button.

If there is uncontrolled water flowing, and you pass an un-depressed E-Stop button while leaving, press the E-Stop button.

- 1.2 The senior member of the team should contact any team members who happen to be in the TOW, and inform them that they are to muster with the rest of the team.
- 1.3 Once outside, proceed quickly to the muster location. Do not go between the TOS/Tower and any reels with hoses or cables run into the Tower to reach the muster point. If you exit on the side opposite the muster point, go behind the TOS to reach the muster point.

The muster point is shown in Figure 1.1. It is located 10 meters to the right of the TOS, when looking from the TOS to the Tower.

- 1.4 Do not re-enter the TOS or Tower for any reason until cleared to do so by the Shift Lead.
- 1.5 The senior member of the team present must take roll, and make sure that all team members are present. If a TOS evacuation is called for, and someone is missing, notify the On-Ice Manager immediately.

When all are accounted for, notify the On-Ice Manager.



# Tower Evacuation and Muster

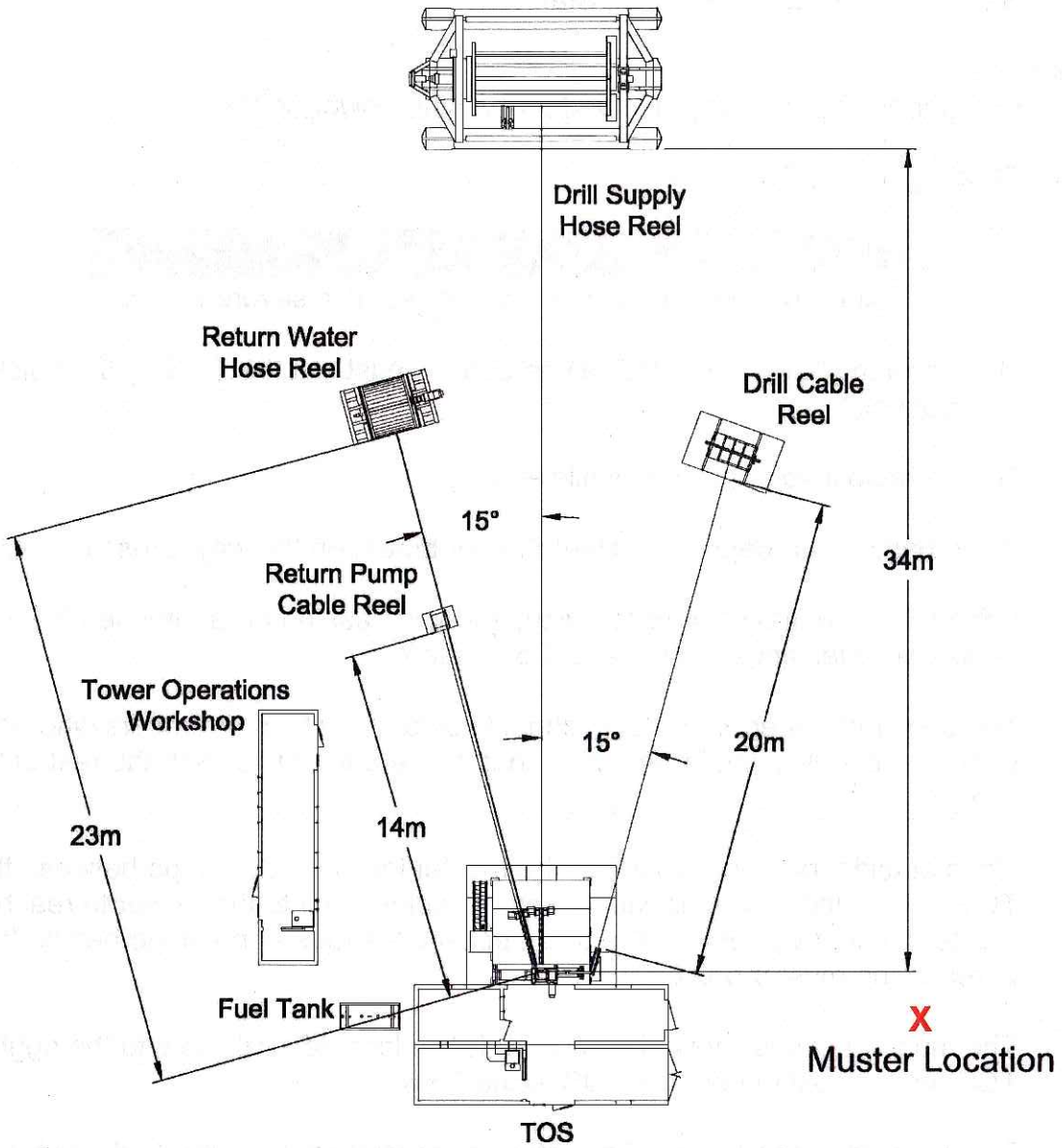


Figure 1.1 – Tower Operations Site Muster Location

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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<b>SES EVACUATION AND MUSTER</b>							
<b>ENHANCED HOT WATER DRILL</b>							
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE		
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DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE		
AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05		
FILENAME	8510-0342.0510.doc			PROJECT NO.	8510		
DRAWING NO.	8510-0342		SCALE	SIZE	SHEET		
			NA	A	1 of 9 <b>13</b>		

## SES Evacuation and Muster

### References:

Search Sequence For Missing Staff

### Requirements:

Personnel: All personnel in and around the DCC or SES location

#### 1. Clearing the SES

### Warning

Failure to follow this procedure can result in severe injury.

- 1.1 Upon hearing "Clear the SES" all personnel must egress whatever building they are in by the quickest available exit.

Grab a radio if you pass one during while leaving.

If you pass an un-depressed E-Stop button on the way, press the button.

- 1.2 Once outside, proceed quickly to the muster location via the most direct safe route.

The muster point is shown in Figure 1.1. It is located ~10 meters from the Tank 1 snow ramp.

- 1.3 Do not re-enter any part of the SES for any reason until cleared to do so by the Shift Lead.

- 1.4 The senior member of the team present must take roll, and make sure that all team members are present. If an SES evacuation is called for, and someone is missing, notify the On-Ice Manager immediately.

When all are accounted for, notify the On-Ice Manager.

# SES Evacuation and Muster

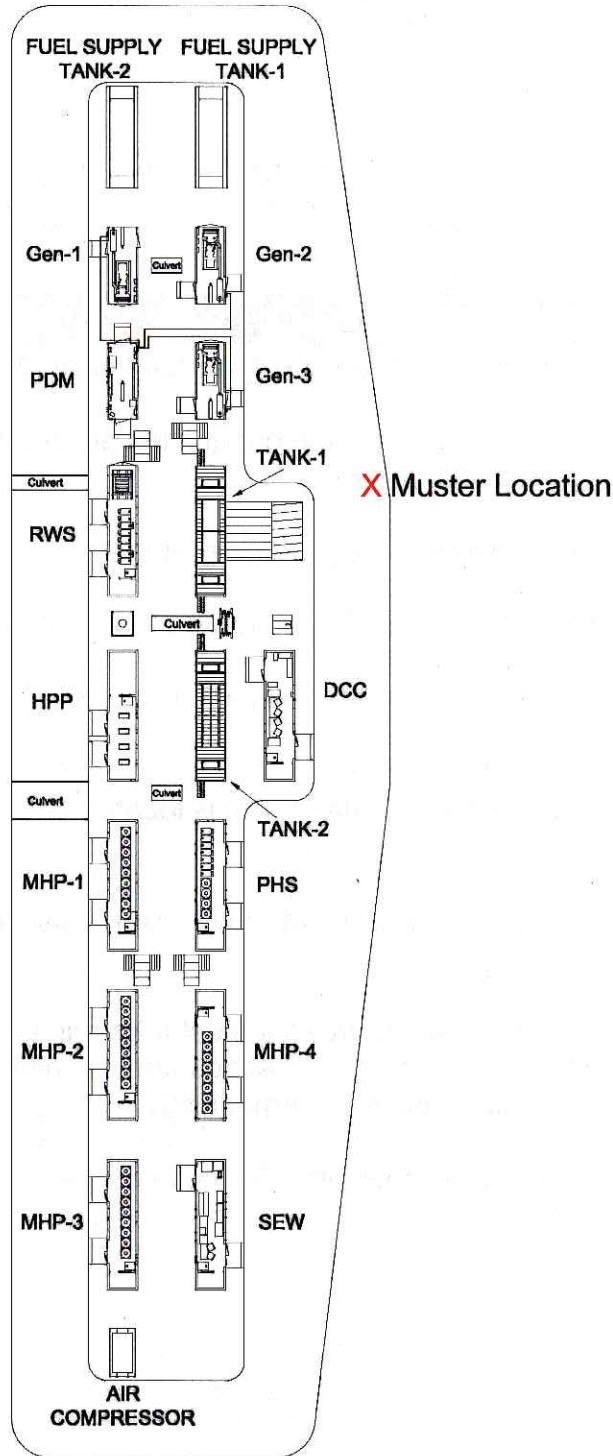


Figure 1.1 – SES Muster Location

**REVISIONS**

LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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<b>TOS REEL STOP TEST</b>			
<b>ENHANCED HOT WATER DRILL</b>			
<b>ORIGINATOR</b>	<b>DATE</b>	<b>ENGINEER</b>	<b>DATE</b>
SC <i>[Signature]</i>	10/27/05	JC/FF <i>[Signature]</i>	10/27/05
<b>DRILL MGR</b>	<b>DATE</b>	<b>QUALITY ASSURANCE</b>	<b>DATE</b>
AA/TH <i>[Signature]</i>	10/27/05	MAZ <i>[Signature]</i>	10/27/05
<b>SAFETY MGR</b>	<b>DATE</b>	<b>PROJECT APPROVAL</b>	<b>DATE</b>
HLP <i>[Signature]</i>	10/27/05	RJP <i>[Signature]</i>	10/27/05
<b>FILENAME</b>	8510-0343.0510.doc		<b>PROJECT NO.</b> 8510
<b>DRAWING NO.</b>	8510-0343	<b>SCALE</b>	<b>SIZE</b>
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		<b>SHEET</b>	1 of 9 <i>14</i>

**TOS Reel Stop Test**

## References:

8510-0114	Cable Reel Hazard Analysis
8510-0122	Drill Control System Hazard Analysis
8510-0107	Drill Hose Reel Hazard Analysis
8510-0124	Drilling Operations Hazard Analysis
8510-0219	Return Water Cable Reel Hazard Analysis
8510-0115	Return Water Hose Reel Hazard Analysis
8510-0108	Tower Hazard Analysis
9400-0061	DOM Deployment Hazard Analysis

## Requirements:

Personnel: 3 Drillers with radios

## Assumptions:

The TOS has just undergone a reconfiguration that included changes in the E-Stop or Reel Stop wiring.

The Return Water Combo Cable Reel is included in the TOS Reel Stop network.

2 Triggers for the Drill Cable Reel Protection Cable	2 Triggers for the Drill Supply Hose Reel Protection Cable
Drill Cable Reel Stop Button	Deployment Reel Button
Return Water Hose Reel Stop Button	Drill Supply Hose Reel Stop Button
2 Triggers for Limit Switches on Drill Cable Reel Level Wind	2 Triggers for Limit Switches on Drill Supply Hose Level Wind
Inside Tower	

Table 1.1 – TOS Reel Stop System Triggers

<b>Note</b>
This procedure tests only the TOS-based Reel Stop function. The RWS Reel Stop is dealt with in "RWS Reel Stop Test."

1. Testing First Button Comprehensively
  - 1.1 Verify that no Unico drives connected to the Reel Stop system are faulted. This requires a visual check of each Unico drive.
  - 1.2 Press one Reel Stop button identified in Table 1.1.
  - 1.3 Verify that a Reel Stop indication is received in the TOS Control Center.

**TOS Reel Stop Test****Note**

The Return Water Combo Cable Reel is not included in the Reel Stop System. Triggering a Reel Stop will not cause the Return Water Combo Cable Reel Brake to engage.

- 1.4 Verify that brakes have been applied to all TOS Reels, with the exception of the Return Water Combo Cable Reel.
- 1.5 Check that all Unico drives connected to the Reel Stop system, including the drives for the Level Wind motors, are faulted. This requires a visual check of each Unico drive.
- 1.6 Try to rotate each Reel through Pendant or Computer commands. Verify that no rotation takes place.

**2. Testing Additional Buttons and Triggers**

- 2.1 Reset the Reel Stop button.

Press the Reel Start button.

**Note**

When activating additional Reel Stop triggers, it is sufficient to verify that the Reel Stop system has activated, as the specific functions of the Reel Stop system were tested in Step 1.

Step 2 only tests the Reel Stop Buttons and other triggers to make sure that they correctly activate the system. The verifications outlined in Steps 1.3-1.5 are not required after the first activation.

- 2.2 Activate each additional Reel Stop trigger listed in Table 1.1.

Verify that a Reel Stop indication is received in the TOS Control Center.

Reset the trigger and the Reel Stop system.

8510-0343  
**TOS Reel Stop Test**

**Warning**

Operating without a properly functioning Reel Stop system poses a severe safety hazard. If the Reel Stop system is called upon to stop a rotating Reel, and does not do so, injury to members of the Drill or Deployment teams is possible.

- 2.3 If any trigger for the Reel Stop system fails to activate the system, or if the Reel Stop system does not fully perform its safety functions, then the TOS is not in a safe configuration, and workers must stand down from Drilling and Deployment activities until the Reel Stop system is repaired and fully operational.
- 2.4 Configure the TOS back to a fully operational state.



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
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<b>E-STOP TEST</b>							
<b>ENHANCED HOT WATER DRILL</b>							
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE		
SC	10/27/05	JC/FF	10/27/05	HL	10/27/05		
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE		
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FILENAME	8510-0345.0510.doc			PROJECT NO.	8510		
DRAWING NO.	8510-0345		SCALE	SIZE	SHEET		
			NA	A	1 of 9		

8510-0345  
**E-Stop Test**

References:

8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-1017 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0123 Fuel System Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0112 Rodriguez Well Hazard Analysis  
8510-0108 Tower Hazard Analysis  
8510-0109 Mobile Drilling Structure & Contained Equipment Hazard Analysis  
9400-0061 DOM Deployment Hazard Analysis

Requirements:

Personnel: 3 Drillers with radios

Assumptions:

For Step 1, the SES has recently been brought fully online, and a comprehensive system test is required. The TOS is not included in this initial test. The Surface Hoses are configured in a loop.

For Step 2-3, the TOS has just undergone a reconfiguration that broke and remade some E-Stop cable connections. The system must be retested.

**Note**

Step 1 is used only for a full test of the SES E-Stop system. A full test is performed only at the start of the season, or when a significant reconfiguration warrants a confidence re-test.

1. Testing the Full SES E-Stop System

1.1 Notify the DCC Operator that the E-Stop system test is about to start.

Request that the DCC Operator activate as much of the SES equipment as practical, but that at least one heater in each MHP and at least one HPP must be operating.

8510-0345  
**E-Stop Test**

**Note**

The Generators have two E-Stop buttons. One is for a “generator only” local E-Stop, and the other is for the integrated SES E-Stop. For purposes of this test, press only the buttons for the integrated SES E-Stop. Do not press the “generator only” E-Stop buttons.

DCC	2 Locations
Generator 1	1 Location
Generator 2	1 Location
Generator 3	1 Location
PDM	1 Location
RWS	3 Locations
HPP	2 Locations
PHS	2 Locations
MHPs 1-4	2 Locations

Table 1.1 – SES E-Stop Button Locations

- 1.2 Verify that all Unico drives connected to the SES E-Stop system are unfaulted. This requires a visual check of each Unico drive.

**Caution**

Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 1.10. If Step 1.10 cannot be completed within 60 minutes, interrupt the E-Stop test to restore water flow through the hoses for 60 minutes before picking up again where the procedure left off.

- 1.3 Activate one of the E-Stop buttons identified in Table 1.1.

Have one person standing by at an MHP fuel solenoid. When the E-Stop button is depressed, there should be an audible “click” when the fuel system is cut off.

Verify that an E-Stop indication is received in the DCC.

8510-0345  
**E-Stop Test**

<b>Note</b>
-------------

Activation of the E-Stop system does not engage the brakes on the Rod Well Combo Cable and Return Water Combo Cable Reels.
--

1.4 Verify that the active Heaters are no longer operating.

On the DCC computer screens, verify that there is no fuel flow and that fuel pumps are shut down.

Verify that the active HPPs are no longer operating.

Verify that the Transfer Pumps are no longer operating.

Verify that all MDS Furnaces are no longer operating.

Verify that RWS Vane and Submersible Pumps are no longer operating.

Verify that PHS Circ Pumps are no longer operating.

Verify that each Unico drive connected to the SES E-Stop system has faulted. This requires a visual check of each Unico drive.

If any Charge Pumps were active before the E-Stop, verify that they are still active.

8510-0345  
**E-Stop Test**

- 1.5 Request that the DCC Operator check hardware to verify that it cannot be reactivated.

Attempt to activate each Heater in each MHP, the RWS, and the PHS. Verify that the Heater will not activate.

For each Heater in each MHP, the RWS, and the PHS, move the Heater switch to "Manual" and verify that the Heater Fan does not start up. Switch the Heater back to "Computer."

Attempt to activate each HPP. Verify that the HPP will not activate.

Attempt to activate each Transfer Pump. Verify that the Transfer Pumps will not activate.

Attempt to operate the RWS Hose Reel. Verify that the RWS Hose Reel cannot be commanded to rotate.

Attempt to activate the RWS Vane and Submersible Pumps. Verify that the Pumps will not activate.

Attempt to activate the PHS Circ Pump. Verify that the Pump will not activate.

- 1.6 Attempt to activate the Furnace in each MDS. Verify that the Furnace will not activate.
- 1.7 Reset the E-Stop system.

8510-0345  
**E-Stop Test**

**Note**

When activating additional E-Stop buttons, it is sufficient to verify that the E-Stop system has activated, as the specific functions of the E-Stop system were tested in Step 1.3-1.7

Step 1.8 only tests the remaining E-Stop Buttons to make sure that they correctly activate the system. The verifications outlined in Steps 1.3-1.7 are not required after the first activation.

- 1.8 Verify that all equipment deactivated by the E-Stop system is still Off.
- Sequentially trigger each remaining E-Stop button identified in Table 1.1.
- Verify that the E-Stop condition is shown on the DCC Computer screen.
- Reset the E-Stop button. Reset the E-Stop system after resetting the E-Stop button.

**Warning**

Operating without a properly functioning E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to make safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

- 1.9 If any trigger for the E-Stop system fails to activate the system, or if the E-Stop system does not fully perform its safety functions, then the SES is not in a safe configuration, and workers must stand down from preparing for Drilling and Deployment activities until the E-Stop system is repaired and fully operational.

**Note**

Step 1.10 restores water flow through the hoses, ending the hazard of freezing established in Step 1.3.

- 1.10 Request that the DCC Operator return the SES to full operation, and restore flow through the hoses.

8510-0345  
**E-Stop Test**

<b>Note</b>
Steps 2 and 3 are executed after the "E-Stop Reconfiguration" procedure is executed or at any other time a significant reconfiguration is made at the TOS.

<b>Note</b>
Step 2 should be performed before the TOS E-Stop cable is connected at the HPP.

2. Testing the TOS E-Stop System as a Remote Island

Drill Supply Hose Reel	1 Location if connected
Drill Cable Reel	1 Location if connected
Deployment Cable Reel	1 Location if connected
TOS	2 Locations
Tower	3 Locations

Table 2.1 – TOS E-Stop Button Locations

- 2.1 Verify that all Unico drives connected to the TOS E-Stop system are unfaulted. This requires visual verification at each drive.

<b>Note</b>
The Return Water Combo Cable Reel brake is not activated by the E-Stop system, and should not be the reel rotated in Step 2.2.

- 2.2 Turn a reel connected to the TOS E-Stop system slowly, and hit any E-Stop switch.

- 2.3 Observe that all reel brakes engage.

Verify that the reel set rotating stops rotating.

Verify that the E-Stop registers in the TOS Computer Screen.

Verify that every Unico drive connected to the TOS E-Stop system shows a fault condition. This requires visual verification at each drive.

- 2.4 Reset the E-Stop switch that was depressed for the test.

8510-0345  
**E-Stop Test**

2.5 For each additional E-Stop switch

**Action:** E-Stop Controller Key → Start  
**Action:** E-Stop Controller Key → Run

Depress the E-Stop switch. Verify activation of the E-Stop, either by listening for relay switching, or visually on the TOS computer screen.

Reset the E-Stop switch.

Perform any required debugging.

<b>Note</b>
The Tower E-Stop system has been checked out, and is safe for use.

<b>Warning</b>
Operating without a properly operating Reel Stop system poses a severe safety hazard. If the Reel Stop system is called upon to stop a rotating Reel, and does not do so, injury to members of the Drill or Deployment teams is possible.

2.6 Restore hardware at the TOS to an operational state.

3. Testing the Integrated E-Stop System

<b>Caution</b>
Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.
To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 3.4.

3.1 Request that the DCC Operator turn off hardware that will be automatically turned off when an E-Stop occurs. This list includes:

MDS Furnaces  
Any pumps other than the Charge Pumps  
All heaters in MHPs, the RWS, and the PHS



8510-0345  
**E-Stop Test**

3.2 On DCC Operator Go, depress any TOS-based E-Stop button.

Verify with the DCC Operator that the E-Stop registers on DCC Computer screens.

3.3 Reset the E-Stop button and the E-Stop system.

3.4 Request that the DCC Operator recover from the E-Stop by restoring the SES to its configuration immediately before the E-Stop test.

**Warning**

Operating without a properly functioning E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

3.5 If the E-Stop system fails to activate when the TOS E-Stop button is depressed, then the TOS is not in a safe configuration, and workers must stand down from Drilling and Deployment activities until the E-Stop system is repaired and fully operational.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/27/05	
	A	Annual review	10/23/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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**ICECUBE  
E-Stop Test**

ORIGINATOR	DATE	ENGINEER	DATE	ENGINEER	DATE
Alan El-Cheikh	9/24/07	Terry Benson	10/22/07	Jeff Cherwinka	10/22/07

CHECKER 2	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
Tim Brenner	10/23/07				

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<b>DRAWING NO.</b>	8510-0345	<b>SCALE</b>		<b>SIZE</b>		<b>SHEET</b>	1 of 9
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8510-0345  
**E-Stop Test**

References:

8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-1017 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0123 Fuel System Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0112 Rodriguez Well Hazard Analysis  
8510-0108 Tower Hazard Analysis  
8510-0109 Mobile Drilling Structure & Contained Equipment Hazard Analysis  
9400-0061 DOM Deployment Hazard Analysis

Requirements:

Personnel: 3 Drillers with radios

Assumptions:

For Step 1, the SES has recently been brought fully online, and a comprehensive system test is required. The TOS is not included in this initial test. The Surface Hoses are configured in a loop.

At least one High Pressure Pump (HPP) and one heater are operating prior to the test and water is circulating through the system.

For Step 2-3, the TOS has just undergone a reconfiguration that broke and remade some E-Stop cable connections. The system must be retested.

Note
Step 1 is used only for a full test of the SES E-Stop system. A full test is performed only at the start of the season, or when a significant reconfiguration warrants a confidence re-test.

1. Testing the Full SES E-Stop System

1.1 Notify the DCC Operator that the E-Stop system test is about to start.

Request that the DCC Operator activate as much of the SES equipment as practical, but that at least one heater in each MHP and at least one HPP must be operating.

8510-0345  
**E-Stop Test**

<b>Note</b>	
The Generators have two E-Stop buttons. One is for a “generator only” local E-Stop, and the other is for the integrated SES E-Stop. For purposes of this test, press only the buttons for the integrated SES E-Stop. Do not press the “generator only” E-Stop buttons.	

DCC	2 Locations
Generator 1	1 Location
Generator 2	1 Location
Generator 3	1 Location
PDM	1 Location
RWS	3 Locations
HPP	2 Locations
PHS	2 Locations
MHPs 1-4	2 Locations

Table 1.1 – SES E-Stop Button Locations

- 1.2 Verify that all Unico drives connected to the SES E-Stop system are unfaulted. This requires a visual check of each Unico drive.

<b>Caution</b>
Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.
To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 1.10. If Step 1.10 cannot be completed within 60 minutes, interrupt the E-Stop test to restore water flow thro the hoses for 60 minutes before picking up again where the procedure left off.

- 1.3 Activate one of the E-Stop buttons identified in Table 1.1.

If the fuel shutoff solenoids have been installed, have one person standing by at an MHP fuel solenoid. When the E-Stop button is depressed, there should be an audible “click” when the fuel system is cut off.

Verify that an E-Stop indication is received in the DCC.

8510-0345  
**E-Stop Test**

Note
Activation of the E-Stop system does not engage the brakes on the Rod Well Combo Cable and Return Water Combo Cable Reels.

- 1.4 Verify that the active Heaters and HPP's are no longer operating.

On the DCC computer screens, verify that there is no fuel flow and that fuel pumps are shut down.

Verify that the active HPPs are no longer operating.

Verify that the Transfer Pumps are no longer operating.

Verify that all MDS Furnaces are no longer operating.

Verify that RWS Vane and Submersible Pumps are no longer operating.

Verify that PHS Circ Pumps are no longer operating.

Verify that each Unico drive connected to the SES E-Stop system has faulted. This requires a visual check of each Unico drive.

Verify that the charge pumps that were on prior to the E-Stop activation are still on.

Note
When an E-Stop has been activated, the charge pumps that feed the high pressure pumps should still be running. This is a safety measure to make sure that cool water continues to flow through the heaters to help cool them down in case the E-Stop was pressed because of an overheating heater.

8510-0345  
**E-Stop Test**

- 1.5 Request that the DCC Operator check hardware to verify that it cannot be reactivated while the E-Stop button is still engaged.  
Attempt to activate each Heater in each MHP, the RWS, and the PHS.  
Verify that the Heater will not activate.

For each Heater in each MHP, the RWS, and the PHS, move the Heater switch to “Manual” and verify that the Heater Fan does not start up. Switch the Heater back to “Computer.”

Attempt to activate each HPP. Verify that the HPP will not activate.

Attempt to activate each Transfer Pump. Verify that the Transfer Pumps will not activate.

Attempt to operate the RWS Hose Reel. Verify that the RWS Hose Reel cannot be commanded to rotate.

Attempt to activate the RWS Vane and Submersible Pumps. Verify that the Pumps will not activate.

Attempt to activate the PHS Circ Pump. Verify that the Pump will not activate.

- 1.6 Attempt to activate the Furnace in each MDS. Verify that the Furnace will not activate.
- 1.7 Reset the E-Stop button that was originally triggered then rest the E-Stop system via the E-Stop controller in the DCC.

<b>Note</b>
When activating additional E-Stop buttons, it is sufficient to verify that the E-Stop system has activated, as the specific functions of the E-Stop system were tested in Step 1.3-1.7
Step 1.8 only tests the remaining E-Stop Buttons to make sure that they correctly activate the system. The verifications outlined in Steps 1.3-1.7 are not required after the first activation.

- 1.8 Verify that all equipment deactivated by the E-Stop system is still Off.

Sequentially trigger each remaining E-Stop button identified in Table 1.1.

8510-0345  
**E-Stop Test**

Verify that the E-Stop condition is shown on the DCC Computer screen and the E-Stop controller in the DCC indicates the E-Stop has been tripped.

Reset the E-Stop button. Reset the E-Stop system via the E-Stop controller in the DCC after resetting the E-Stop button.

**Warning**

Operating without a properly functioning E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to make safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

- 1.9 If any trigger for the E-Stop system fails to activate the system, or if the E-Stop system does not fully perform its safety functions, then the SES is not in a safe configuration, and workers must stand down from preparing for Drilling and Deployment activities until the E-Stop system is repaired and fully operational.

**Note**

Step 1.10 restores water flow through the hoses, ending the hazard of freezing established in Step 1.3.

- 1.10 Request that the DCC Operator return the SES to full operation, and restore flow through the hoses.

**Note**

Steps 2 and 3 are executed after the “E-Stop Reconfiguration” procedure is executed or at any other time a significant reconfiguration is made at the TOS.

**Note**

Step 2 should be performed before the TOS E-Stop cable is connected at the Pre Heat System (PHS) building.

2. Testing the TOS E-Stop System as a Remote Island

Drill Supply Hose Reel	1 Location if connected
Drill Cable Reel	1 Location if connected
Deployment Cable Reel	1 Location if connected
TOS	2 Locations
Tower	3 Locations

Table 2.1 – TOS E-Stop Button Locations

8510-0345  
**E-Stop Test**

- 2.1 Verify that all Unico drives connected to the TOS E-Stop system are unfaulted, the drives are powered up and the brakes are disengaged. This requires visual verification at each drive.

<b>Note</b>
The Return Water Combo Cable Reel brake is not activated by the E-Stop system, and should not be the reel rotated in Step 2.2.

- 2.2 Turn a reel connected to the TOS E-Stop system slowly, and hit any E-Stop switch.

- 2.3 Observe that all reel brakes engage.

Verify that the reel set rotating stops rotating.

Verify that the E-Stop registers in the TOS Computer Screen.

Verify that every Unico drive connected to the TOS E-Stop system shows a fault condition. This requires visual verification at each drive.

- 2.4 Reset the E-Stop switch that was depressed for the test.



8510-0345  
**E-Stop Test**

2.5 For each additional E-Stop switch

**Action:** E-Stop Controller Key → Start  
**Action:** E-Stop Controller Key → Run

Depress the E-Stop switch. Verify activation of the E-Stop, either by listening for relay switching, or visually on the TOS computer screen and the E-Stop controller box in the TOS electrical closet.

Reset the E-Stop switch.

Perform any required debugging.

Note
The Tower E-Stop system has been checked out, and is safe for use.

Warning
Operating without a properly operating Reel Stop system poses a severe safety hazard. If the Reel Stop system is called upon to stop a rotating Reel, and does not do so, injury to members of the Drill or Deployment teams is possible.

2.6 Restore hardware at the TOS to an operational state.

3. Testing the Integrated E-Stop System

Caution
Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.
To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 3.4.

3.1 Request that the DCC Operator turn off hardware that will be automatically turned off when an E-Stop occurs. This list includes:  
MDS Furnaces  
Any pumps other than the Charge Pumps  
All heaters in MHPs, the RWS, and the PHS

8510-0345  
**E-Stop Test**

- 3.2 On DCC Operator Go, depress any TOS-based E-Stop button.

Verify with the DCC Operator that the E-Stop registers on DCC Computer screens.

- 3.3 Reset the E-Stop button and the E-Stop system.

- 3.4 Request that the DCC Operator recover from the E-Stop by restoring the SES to its configuration immediately before the E-Stop test.

**Warning**

Operating without a properly functioning E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

- 3.5 If the E-Stop system fails to activate when the TOS E-Stop button is depressed, then the TOS is not in a safe configuration, and workers must stand down from Drilling and Deployment activities until the E-Stop system is repaired and fully operational.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/27/05	
	A	Annual review	10/11/07	TCB
	B	Annual review		
	C	Annual review	6/19/2009	TR

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	C	C	C	C														

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1	15	Antarctic Astronomy & Astrophysics Research Institute			
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4	18	ICECUBE			
5	19	DCC PREP			
6	20				
7	21	ORIGINATOR	DATE	ENGINEER	DATE
8	22	Terry Matt	4/28/08		
9	23	CHECKER 2	DATE	QUALITY ASSURANCE	DATE
10	24				
11	25	FILENAME	PROJECT NO.8510		
12	26	8510-0346.RevB			
13	27	DRAWING NO.	SCALE	SIZE	SHEET
14	28	8510-0346			1 of 4

References:

8510-0122Drill Control System Hazard Analysis  
8510-0123Fuel System Hazard Analysis  
8510-0120Power Distribution System Hazard Analysis  
8510-0109Mobile Drilling Structure Hazard Analysis  
Drill Computer Setup/Upgrade Process – Matt Newcomb

Requirements:

Personnel: Full team of 8 Drillers

Equipment: Hardware and discs for computer hardware and software upgrades

Assumptions: Electricity and fuel are available at the SES.

DCC Computers are still in their racks.

DNF equipment is still in the DCC, and it cannot be moved until the other modules are warmed up to receive it.

1. Preparing the DCC Building

1.1 Set up the landing and entry steps for the building.

**NOTE: Front entry only. Back entry blocked by DNF storage.**

1.2 Enter the building.

Though none is expected, because the DCC has been kept warm during the Winter, look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

1.3 Replace the battery in the Smoke/CO Detector.

1.4 **Verify:**PDM DCC Power Breaker → Open

**Verify:**DCC Main Breaker → Open

Plug in the DCC main building power cable.

**Action:**PDM DCC Power Breaker → Closed

**Action:**DCC Main Breaker → Closed

## Warning

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 1.5 **Action:**Electrical Heater 1 → On
- Action:**Electrical Heater 2 → On
- Action:**Electrical Heater 3 → On

1.6 Check that the South Pole network hardware is set up. If it is not, set up the network hardware.

1.7 Install an E-Stop network terminator on the E-Stop panel.

**Action:**E-Stop Controller Key → Start

**Action:**E-Stop Controller Key → Run

## 2. Setting Up Computers

2.1 Set up the UPS.

2.2 Set up window shades to prevent computer overheating.

## Caution

When working on internal components of the computers, failure to take proper anti-static precautions can result in damage to computer components.

2.3 Perform any required hardware upgrades.

2.4 Turn on all computers, and perform required software upgrades.

2.5 Power up the printer.

## 3. Setting Up Communications (Shared Activity with RPSC)

3.1 Hook up and check out the telephone.

3.2 Set up the radio base station.

3.3 Set up the radio battery chargers for temporary use. Permanent season placement will be in MECC. Do not plug into UPS power circuits (red outlet boxes).

4. DNF

4.1 Coordinate with drill manager and electrical specialist to start removal of DNF equipment stored in the DCC over the winter.

NOTE: Some DNF equipment will stay stored on the racks in the DCC during the summer season. Most of this equipment is stored in racks along outside walls.

4.2 Remove insulation from windows and doors, mark and store for use at end of season.

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
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4	18	<b>ICECUBE</b>					
5	19	<b>RWS PREP</b>					
6	20	<b>ENHANCED HOT WATER DRILL</b>					
7	21	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
8	22	SC	10/27/05	JC/FF	10/27/05	HL	10/27/05
9	23	DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
10	24	AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05
11	25	FILENAME	8510-0347.0510.doc		PROJECT NO.	8510	
12	26	DRAWING NO. 8510-0347		SCALE	SIZE	SHEET	
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14	28						

8510-0347  
**RWS Prep**

References:

8510-0121 Anti-Freeze and Water Tanks Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0123 Fuel System Hazard Analysis  
8510-0120 Power Distribution System Hazard Analysis  
8510-0112 Rodriguez Well Hazard Analysis  
8510-0109 Mobile Drilling Structure Hazard Analysis  
  
8510-0348 Tank 1 Prep

Requirements:

Personnel: Full shift of 8 Drillers with radios  
Equipment: Portable heater

Assumptions:

Electricity and fuel are available to the SES.  
  
All SES buildings are in place.  
  
Seed water is available for Tank 1.  
  
DCC Prep is complete.

1. Preparing the RWS Building

1.1 Set up the landing and entry steps for the building.

1.2 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

1.3 Remove from DNF storage, and install, the Smoke/CO Detector, and change its battery.

1.4 **Verify:** PDM RWS Power Breaker → Open  
**Verify:** RWS Main Breaker → Open

Plug in the RWS main building power cable.

**Action:** PDM RWS Power Breaker → Closed

**Action:** RWS Main Breaker → Closed



**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 1.5 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On
- 1.6 Connect the RWS building network cable.
- 1.7 Connect the RWS building E-Stop network cable.
- 1.8 Check that the furnace exhaust is not covered. If it is, remove the cover.  
Remove all heater chimney stack covers.  
Verify that the Makeup Air Vents are open and Fans are installed.
- 1.9 Hook up the fuel hose to the RWS building.  
Bleed the furnace fuel line.

**Note**

Warming the furnace with the portable heater should take approximately 3-4 hours.

- 1.10 If necessary, use a portable heater to warm the furnace to above freezing.
- 1.11 When the furnace temperature reaches approximately 0 °C, activate the furnace.  
Set the furnace thermostat to 21 °C (70 °F).  
Place the electrical heater thermal setpoint at approximately 15.5 °C (60 °F).

**Warning**

The CO<sub>2</sub> bottle is extremely heavy. Two or more people are required for lifting, when weighing the bottle. Exercise care when lifting or moving the bottle.

8510-0347  
**RWS Prep**

- 1.12 Verify that the Fire Suppression System is in good order. Weigh the CO<sub>2</sub> bottle to verify that there is CO<sub>2</sub> remaining in the bottle.

Reconnect the CO<sub>2</sub> bottle to its hose.

- 1.13 Direct the output of a portable heater toward the Vane Pumps for approximately 2 hours. This should raise their temperature to within the 10 – 21 °C range.

2. DNF Installation

- 2.1 Apply lockouts to the circuit breakers that supply the Unico drives.

Once the wall temperature in the RWS Electrical Closet has reached -7 – -1 °C, install the Unico drives in the Electrical Closet.

- 2.2 A person other than the one who performed Step 2.1 should check the installation.

Remove the circuit breaker lockouts applied in Step 2.1.

- 2.3 Install Flow Meter Assemblies for each heater.

Install a Differential Pressure Switch for each heater. Installation requires connection of two hoses and two wires per heater.

- 2.4 Install Manifold Pressure Transducers. There is one upper, and one lower manifold. One transducer is installed for each manifold.

3. Component Testing

- 3.1 Once all metal plumbing components are above 0 °C, and all electrical components are above 4.5 °C, proceed with component testing.

- 3.2 **Action:** RWS Network Panel → ON

**Action:** RWS Unico 1 → ON

**Action:** RWS Unico 2 → ON

**Action:** RWS Unico 3 → ON

8510-0347  
**RWS Prep**

- 3.3 Coordinate with the DCC Operator to sequentially check all 21 Three-Way Solenoid Valves. Each valve must be commanded to the three available positions, and visual verification of solenoid valve operation must be performed.
- 3.4 Coordinate with the DCC Operator to sequentially check all 10 Solenoid Valves. Each valve must be commanded to both available positions, and auditory verification of solenoid valve operation must be performed.

**Caution**

The Vane Pumps can be damaged by extended operation at low speeds. Operate the Vane Pumps only long enough to verify rotation.

- 3.5 **Action:** RWS Vane Pump 1 → 10 RPM  
**Verify:** RWS Vane Pump 1 movement in correct direction  
**Action:** RWS Vane Pump 1 → 0 RPM  
  
**Action:** RWS Vane Pump 2 → 10 RPM  
**Verify:** RWS Vane Pump 2 movement in correct direction  
**Action:** RWS Vane Pump 2 → 0 RPM

4. Placing the RWS In A Minimally Active Configuration

- 4.1 Bleed the RWS fuel system.
- 4.2 Connect the water hoses between the RWS and Tank 1.  
Connect the Gen Set heat exchanger hoses.
- 4.3 Configure the RWS flow path to be "From Tank 1 To Tank 1."  
Configure the RWS so that no water flows to the Generator Heat Exchanger.  
Configure the RWS so that no water flows down the Rod Well.
- 4.4 Close the Vacuum Break Vents.
- 4.5 Verify that caps have been placed on the Rod Well Supply and Return Hoses.
- 4.6 Request that RPS provide seed water for Tank 1. Coordinate the seed water request with the team performing "Tank 1 Prep."

8510-0347  
**RWS Prep**

- 4.7 Perform an electrical motor test for each heater:  
**Action:** Main Heater Control Switch → Manual (Position 1)
- Verify that the fan motor comes on. The fan should be audible.
- Action:** Main Heater Control Switch → Off  
**Action:** Main Heater Control Switch → Computer
- 4.8 Request that the DCC Operator turn the RWS Vane Pumps ON, and that they be set with a low flow rate.
- 4.9 Request that the DCC Operator ramp the RWS Vane Pump speed higher until flow through the Tank 1 Manifold Bypass Flow Meter is detected.
- 4.10 Request that the DCC Operator turn on one Heater. He should start with the first Heater and if that one will not activate, he should move to the next.
- Make sure that the active Heater has sufficient water flow.
- If an unsuccessful attempt is made to activate a Heater, close the Heater's valve to prevent water flow.
- 4.11 If at least one heater is on, then the RWS is active, and troubleshooting on any failed heaters can proceed.

**REVISIONS**

LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

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SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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<b>ICECUBE</b>					
<b>TANK 1 PREP</b>					
<b>ENHANCED HOT WATER DRILL</b>					
<b>ORIGINATOR</b>	<b>DATE</b>	<b>ENGINEER</b>	<b>DATE</b>	<b>SAFETY MGR</b>	<b>DATE</b>
SC <i>He Conroy</i>	10/27/05	JC/FF	<i>Chunta</i> 11/27/05	HL <i>He Conroy</i>	10/27/05
<b>DRILL MGR</b>	<b>DATE</b>	<b>QUALITY ASSURANCE</b>	<b>DATE</b>	<b>PROJECT APPROVAL</b>	<b>DATE</b>
AA/TH <i>He Conroy</i>	10/27/05	MAZ <i>Michael Remedios</i>		RJP <i>RJP</i>	10/27/05
<b>FILENAME</b>	8510-0348.0510.doc		<b>PROJECT NO.</b>	8510	
<b>DRAWING NO.</b>	8510-0348		<b>SCALE</b>	<b>SIZE</b>	<b>SHEET</b>
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8510-0348  
**Tank 1 Prep**

References:

8510-0121 EHWD Anti-Freeze and Water Tanks  
9000-0002 IceCube Safety Manual – Confined Space Entry Procedure

RWS Prep

Requirements:

Personnel: 2 Drillers  
Equipment: Front end loader, portable heater, ladder, safety harness,  
O<sub>2</sub>/Combustable Gas Analyzer, Seed water

Assumptions: Raytheon has constructed a snow ramp up the side of Tank 1.

1. Preparing Tank 1

1.1 If not already done, install Tank 1 Ladders.

1.2 Place a portable heater on the lid of Tank 1, blowing hot air inside the tank.

Wait until the temperature in Tank 1 exceeds 0 °C.

1.3 Air out the Tank 1 volume.

**Warning**

Failure to follow the Permit Required Confined Space  
Entry procedure can cause suffocation.

1.4 Enter the Tank 1 volume, inspect the liner, and repair any damage.

Use the Permit Required Confined Space Entry Procedure.

1.5 Install the Tank 1 Transfer Pumps.

Connect their power lines to the PHS.

Run their hoses to Tank 2.

1.6 Install Temperature and Depth gauges, and connect them to the RWS. Verify with the DCC Operator that the gauges are operating properly.

1.7 Install all hoses to the RWS building.

8510-0348  
**Tank 1 Prep**

2. Filling Tank 1

**Caution**

Adding Seed Water to Tank 1 before "RWS Prep" has reached Step 4.5 can lead to the seed water freezing in the Tank.

- 2.1 Wait for seed water, which is provided by Raytheon. Seed water should not be added to Tank 1 until the "RWS Prep" activity has reached Step 4.5 of that procedure.

**Warning**

Adding snow to Tank 1 usually requires one person on the Tank with a shovel to guide snow from the front end loader's bucket into the Tank.

Footing on the Tank can be precarious. Exercise caution.

The person on the Tank must remain within view of the loader operator at all times.

- 2.2 One person, with a restraint tether, on the Tank to help guide the snow.

Repeatedly add a quantity of snow to Tank 1.

Circulate water between the RWS and Tank 1, warming the water. When the snow has melted, add more snow.

Continue until Tank 1 is full.

- 2.3 Maintain the water in Tank 1 above freezing, but below 24 °C.

REVISIONS				
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-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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TITLE							
<b>ICECUBE PHS PREP ENHANCED HOT WATER DRILL</b>							
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE		
SC <i>St. Paul</i>	10/27/05	JC/FF	10/27/05	HL <i>Tommy</i>	10/27/05		
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE		
AA/TH <i>Tommy</i>	10/27/05	MAZ <i>MAZ</i>	10/27/05	RJP <i>RJP</i>	10/27/05		
FILENAME	8510-0350.0510.doc			PROJECT NO.	8510		
DRAWING NO.	8510-0350		SCALE	SIZE	SHEET		
			NA	A	1 of 5		



8510-0350  
**PHS Prep**

References:

8510-0121 Anti-Freeze and Water Tanks Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0123 Fuel System Hazard Analysis  
8510-0120 Power Distribution System Hazard Analysis  
8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

Personnel: Full shift of 8 Drillers with radios  
Equipment: Copper flange gaskets, Manifold Pressure Transducers, Flow Meter Assemblies, Differential Pressure Switches, Portable Heater

Assumptions: Electrical Power is available to the SES

The fuel distribution system is active

1. Preparing the PHS Building

1.1 Set up the landing and entry steps for the building.

1.2 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

1.3 Install the Smoke/CO Detector, and change its battery.

1.4 **Verify:** PDM PHS Power 1 Breaker → Open  
**Verify:** PDM PHS Power 2 Breaker → Open

**Verify:** PHS Main 1 Breaker → Open  
**Verify:** PHS Main 2 Breaker → Open

Plug in the PHS main building power cables.

**Action:** PDM PHS Power 1 Breaker → Closed  
**Action:** PDM PHS Power 2 Breaker → Closed

**Action:** PHS Main 1 Breaker → Closed  
**Action:** PHS Main 2 Breaker → Closed

**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 1.5 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On
- 1.6 Connect the PHS building network cable.
- 1.7 Connect the PHS building E-Stop network cable.
- 1.8 Check that the furnace exhaust is not covered. If it is, remove the cover.  
Remove all heater chimney stack covers.  
Verify that the Makeup Air Vents are open and Fans are installed.
- 1.9 Hook up the fuel hose to the PHS building.  
Bleed the furnace fuel line.

**Note**

Warming the furnace with the portable heater should take approximately 3-4 hours.

- 1.10 If necessary, use Hermann Nelson heater to warm the furnace to above freezing.
- 1.11 When the furnace temperature reaches approximately 0 °C, activate the furnace.  
Set the furnace thermostat to 21 °C (70 °F).  
Place the electrical heater thermal setpoint at approximately 15.5 °C (60 °F).

**Warning**

The CO<sub>2</sub> bottle is extremely heavy. Two or more people are required for lifting, when weighing the bottle. Exercise care when lifting or moving the bottle.

- 1.12 Verify that the Fire Suppression System is in good order. Weigh the CO<sub>2</sub> bottle to verify that there is CO<sub>2</sub> remaining in the bottle.

8510-0350  
**PHS Prep**

- 1.13 Direct the output of a portable heater toward the Vane Pump for approximately 2 hours. This should raise its temperature to within the 10 – 21 °C range.

<b>Note</b>
-------------

If the Makeup Air Vent Fans are not installed, they should be located in the PHS building, where they were stored after winterization activities the previous year.
---

- 1.14 Verify that the Makeup Air Vents are open and Fans are installed.

2. Setting Up Plumbing

- 2.1 Apply lockouts to the circuit breakers that supply power to the Unico drives.

Install the PHS Unico drives for the Vane and Transfer Pumps.

For each drive installed:

Connect the communication cable between the pump motor and the Unico drive.

Connect the E-Stop cable to the Unico.

- 2.2 A person other than the one who performed Step 2.1 should check the installation.

- 2.3 Connect the Unico power feeds.

Remove the circuit breaker lockouts applied in Step 2.1.

<b>Note</b>
-------------

There are four heaters in the PHS.
------------------------------------

- 2.1 Install Flow Meter Assemblies for each heater.

Install a Differential Pressure Switch for each heater. Installation requires connection of two hoses and two wires per heater.

- 2.2 Install Manifold Pressure Transducers. There is one upper, and one lower manifolds. One transducer is installed for each manifold.

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**PHS Prep**

2.3 Perform an electrical motor test for each heater:

**Action:** Main Heater Control Switch → Manual (Position 1)

Verify that the fan motor comes on. The fan should be audible.

**Action:** Main Heater Control Switch → Off

2.4 If not already completed, connect the WT2 Submersible Pump to the PHS with a 4" hose.

If not already completed, connect the PHS Return Hose to WT2 with a 1½" hose.

2.5 Inspect the filter housing to ensure that filters are in good condition and when done, ensure that the covers are watertight.

2.6 Verify that all drain valves are closed.

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
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<b>Antarctic Astronomy &amp; Astrophysics Research Institute</b>					
MADISON, WISCONSIN					
TITLE					
<b>ICECUBE</b>					
<b>HPP PREP</b>					
<b>ENHANCED HOT WATER DRILL</b>					
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
SC	10/27/05	JC/FF	10/27/05	HL	10/27/05
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05
FILENAME	8510-0351.0510.doc			PROJECT NO.	8510
DRAWING NO.	8510-0351		SCALE	SIZE	SHEET
			NA	A	1 of 7

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**HPP Prep**

References:

- 8510-0121 Anti-Freeze and Water Tanks Hazard Analysis
- 8510-0122 Drill Control System Hazard Analysis
- 8510-0123 Fuel System Hazard Analysis
- 8510-0120 Power Distribution System Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

- Personnel: Full team of 8 Drillers with radios
- Equipment: 2½" to 1½" hose adapter, portable heater

Assumptions: Tank 2 prepared to support setup and test of the HPPs.

1. Preparing the HPP Building

- 1.1 Set up the landing and entry steps for the building.
- 1.2 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

- 1.3 Install the Smoke/CO Detector, and replace its battery.

- 1.4 **Verify:** PDM HPP Power Breaker → Open  
**Verify:** HPP Main Breaker → Open

Plug in the HPP main building power cable.

**Action:** PDM HPP Power Breaker → Closed

**Action:** HPP Main Breaker → Closed

**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 1.5 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On

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**HPP Prep**

- 1.6 Connect the HPP building network cable.
- 1.7 Connect the HPP building E-Stop network cable.
- 1.8 Check that the furnace exhaust is not covered. If it is, remove the cover.

Verify that the Makeup Air Vents are open and Fans are installed.

- 1.9 Hook up the fuel hose to the HPP building.

Bleed the furnace fuel line.

<b>Note</b>
-------------

Warming the furnace with the portable heater should take approximately 3-4 hours.
---

- 1.10 If necessary, use a portable heater to warm the furnace to above freezing.
- 1.11 When the furnace temperature reaches approximately 0 °C, activate the furnace.

Set the furnace thermostat to 21 °C (70 °F).

Place the electrical heater thermal setpoint at approximately 15.5 °C (60 °F).

<b>Warning</b>
----------------

The CO <sub>2</sub> bottle is extremely heavy. When weighing the bottle, exercise care when lifting or moving the bottle.
---

- 1.12 Verify that the Fire Suppression System is in good order. Weigh the CO<sub>2</sub> bottle to verify that there is CO<sub>2</sub> remaining in the bottle.

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**HPP Prep**

2. Unico Installation

**Caution**

If the HPP is activated without the Unico resolver cable in place, the motor can be destroyed.

2.1 For each of the four HPPs, perform the following steps:

Install the Unico drive.

Connect the communication cable between the pump motor and the Unico drive.

Connect the E-Stop cable to the Unico.

2.2 A person other than the one who performed Step 2.1 should check the installation.

2.3 Install the Intake Manifold Pressure Switch for each pump.

2.4 Plug in power to the Unico Drives. This requires hookup to the PDM. Remove the lockout from the PDM breakers that feed the HPPs.

2.5 If not already done, connect each HPP to its charge pump with a 4" heated hose. After attaching the hose, connect the heater to a 240V outlet.

**Caution**

Incorrect power connectivity between Charge Pumps and High Pressure Pumps can cause hardware damage when attempting to start a High Pressure Pump that does not have the expected Charge Pump active and supplying water.

2.6 Connect the Charge Pumps to their power ports on the HPP building.

3. Testing HPP components

3.1 Connect the MHP1 outlet to MHP3 return with a 1½" hose.  
Connect the MHP2 outlet to MHP4 return with a 1½" hose.

3.2 Place a 2½" to 1½" adapter on the Drill Supply Hose outlet.

Connect the Drill Supply Hose outlet to WT2, placing a manual valve on the WT2 end.



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**HPP Prep**

- 3.3 For each Charge Pump 1-4:  
Open the HPP Output Valve paired with the Charge Pump under test.  
Close all other HPP Output Valves.
- Turn the pump on, and visually verify water flow into WT2.
- Briefly (<1 minute) close the output valve, and observe that the output pressure exceeds 40 psi.
- In the DCC, verify that the HPP Input Pressure exceeds 40 psi.
- 3.4 For each High Pressure Pump 1-4:  
Open the HPP Output Valve for the High Pressure Pump under test. Close all other HPP Output Valves.
- Turn on the Charge Pump paired with the High Pressure Pump under test.
- Turn on the High Pressure Pump under test.
- Verify that flow rate vs. RPM is correct both on the manual flow meter and in the DCC. See Figure 3.1

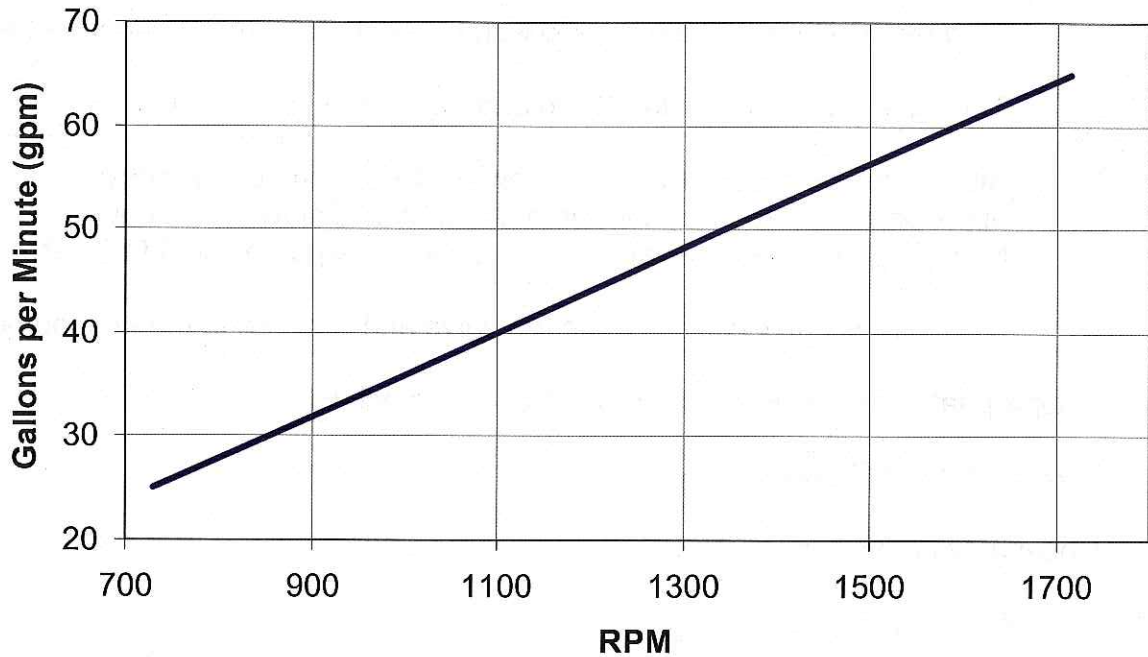


Figure 3.1 – HPP Flow Rate vs. Motor Speed

3.5 Turn off all High Pressure Pumps.

Turn on all Charge Pumps.

Bleed all air from the plumbing system.

Close the valve placed on the hose at the WT2 inlet.

Turn off all Charge Pumps.

Perform a proof test to 1200 psi.

Check all mechanical output pressure gauges against their equivalent DCC pressure readings.

Hold the pressure for 10 minutes, verifying that there is no more than a 50 psi drop during that period.

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**HPP Prep**

- 3.6 For each High Pressure Pump 1-4:  
Open the HPP Output Valve for the High Pressure Pump under test. Close all other HPP Output Valves.
- Turn on the Charge Pump paired with the High Pressure Pump under test.
- Turn on the High Pressure Pump under test. Set its flow rate to 50 gpm.
- Slowly close the output valve, observing the rise in output pressure. At approximately 1200 psi, the pump motor should slow as the controller limits torque. When the valve is fully closed, the pump should trip off.
- If not already fully closed, close the valve and proceed to the next pump.
- 3.7 If appropriate, test the Pressure Relief Valve for each HPP.
- 3.9 Turn on the Idle Pump.
- Observe water flow in WT2.
- Turn off the Idle Pump.
- 3.10 Disconnect the hose jumpers between MHP1 Outlet and MHP3 Return, and MHP2 Outlet and MHP4 Return.
- Disconnect the hose between Main Hose Reel Outlet and WT2, including the size adapter and manual valve.
- 3.11 Cap the hose outlets until they are needed during "MHP Prep."

**Note**

This procedure leaves the HPP building checked out, but in an incomplete configuration. The hoses between the HPPs and the MHPs are not heated. They will not be hooked up until the MHPs are checked out.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	5/30/07	TCB
	A	Annual revision	10/09/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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1	15	Antarctic Astronomy & Astrophysics Research Institute MADISON, WISCONSIN																																			
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5	19	Dennis Duling			09/21/07			Jeff Cherwinka			10/03/07			Alan El-Cheikh			10/03/07																				
6	20	CHECKER 2			DATE			QUALITY ASSURANCE			DATE			PROJECT APPROVAL			DATE																				
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**HPP Prep**

References:

- 8510-0121 Anti-Freeze and Water Tanks Hazard Analysis
- 8510-0122 Drill Control System Hazard Analysis
- 8510-0123 Fuel System Hazard Analysis
- 8510-0120 Power Distribution System Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

- Personnel: Full team of 8 Drillers with radios
- Equipment: 2½" to 1½" hose adapter, portable heater

Assumptions: Tank 2 prepared to support setup and test of the HPPs.

1. Preparing the HPP Building

- 1.1 Set up the landing and entry steps for the building.
- 1.2 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

- 1.3 Install the Smoke/CO Detector, and replace its battery.

- 1.4 **Verify:** PDM HPP Power Breaker → Open  
**Verify:** HPP Main Breaker → Open

Plug in the HPP main building power cable.

**Action:** PDM HPP Power Breaker → Closed

**Action:** HPP Main Breaker → Closed

**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 1.5 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On

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**HPP Prep**

- 1.6 Connect the HPP building network cable.
- 1.7 Connect the HPP building E-Stop network cable.
- 1.8 Check that the furnace exhaust is not covered. If it is, remove the cover.

Verify that the Makeup Air Vents are open and Fans are installed.

- 1.9 Hook up the fuel hose to the HPP building.

Bleed the furnace fuel line.

<b>Note</b>
Warming the furnace with the portable heater should take approximately 3-4 hours.

- 1.10 If necessary, use a portable heater to warm the furnace to above freezing.
- 1.11 When the furnace temperature reaches approximately 0 °C, activate the furnace.

Set the furnace thermostat to 21 °C (70 °F).

Place the electrical heater thermal setpoint at approximately 15.5 °C (60 °F).

<b>Warning</b>
The CO <sub>2</sub> bottle is extremely heavy. When weighing the bottle, exercise care when lifting or moving the bottle.

- 1.12 Verify that the Fire Suppression System is in good order. Weigh the CO<sub>2</sub> bottle to verify that there is CO<sub>2</sub> remaining in the bottle.

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**HPP Prep**

2. Unico Installation

**Caution**

If the HPP is activated without the Unico resolver cable in place, the motor can be destroyed.

2.1 For each of the four HPPs, perform the following steps:

Install the Unico drive.

Connect the communication cable between the pump motor and the Unico drive.

Connect the E-Stop cable to the Unico.

2.2 A person other than the one who performed Step 2.1 should check the installation.

2.3 Install the Intake Manifold Pressure Switch for each pump.

2.4 Plug in power to the Unico Drives. This requires hookup to the PDM. Remove the lockout from the PDM breakers that feed the HPPs.

2.5 If not already done, connect each HPP to its charge pump with a 4" heated hose. After attaching the hose, connect the heater to a 240V outlet.

**Caution**

Incorrect power connectivity between Charge Pumps and High Pressure Pumps can cause hardware damage when attempting to start a High Pressure Pump that does not have the expected Charge Pump active and supplying water.

2.6 Connect the Charge Pumps to their power ports on the HPP building.

3. Testing HPP components

3.1 Connect the MHP1 outlet to MHP3 return with a 1½" hose. Connect the MHP2 outlet to MHP4 return with a 1½" hose.

3.2 Place a 2½" to 1½" adapter on the Drill Supply Hose outlet.

Connect the Drill Supply Hose outlet to WT2, placing a manual valve on the WT2 end.

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**HPP Prep**

3.3 For each Charge Pump 1-4:

Open the HPP Output Valve paired with the Charge Pump under test.  
Close all other HPP Output Valves.

Turn the pump on, and visually verify water flow into WT2.

Briefly (<1 minute) close the output valve, and observe that the output pressure exceeds 40 psi.

In the DCC, verify that the HPP Input Pressure exceeds 40 psi.

3.4 For each High Pressure Pump 1-4:

Open the HPP Output Valve for the High Pressure Pump under test. Close all other HPP Output Valves.

Turn on the Charge Pump paired with the High Pressure Pump under test.

Turn on the High Pressure Pump under test.

Verify that flow rate vs. RPM is correct both on the manual flow meter and in the DCC. See Figure 3.1



8510-0351  
**HPP Prep**

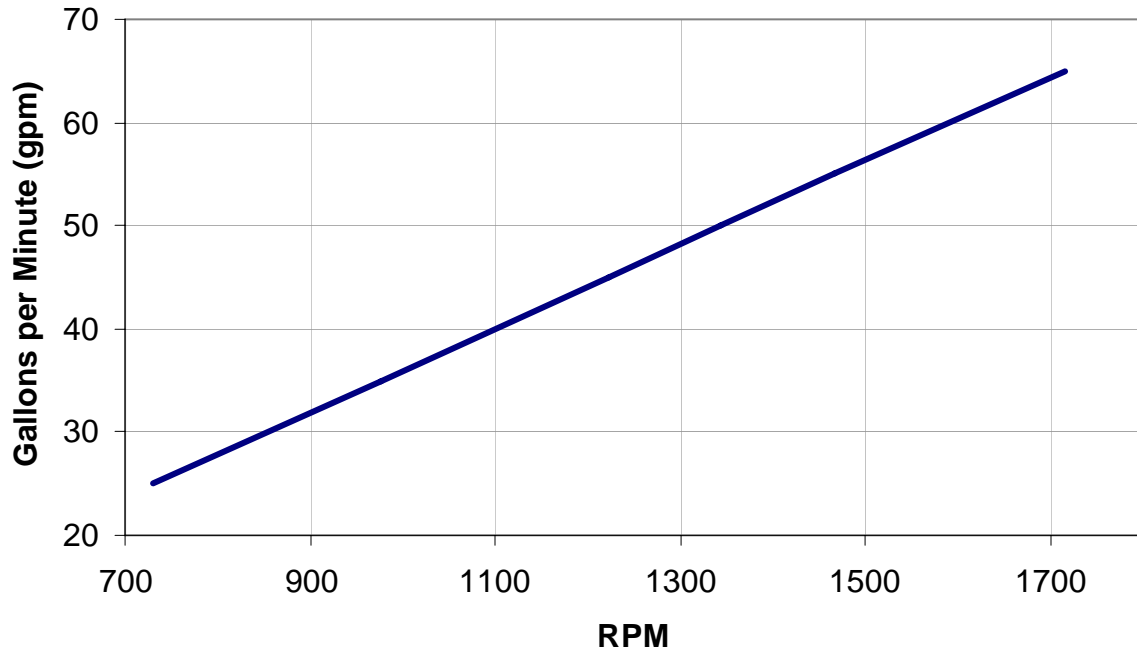


Figure 3.1 – HPP Flow Rate vs. Motor Speed

3.5 Turn off all High Pressure Pumps.

Turn on all Charge Pumps.

Bleed all air from the plumbing system.

Close the valve placed on the hose at the WT2 inlet.

Turn off all Charge Pumps.

Perform a proof test to 1200 psi.

Check all mechanical output pressure gauges against their equivalent DCC pressure readings.

Hold the pressure for 10 minutes, verifying that there is no more than a 50 psi drop during that period.

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**HPP Prep**

- 3.6 For each High Pressure Pump 1-4:  
Open the HPP Output Valve for the High Pressure Pump under test. Close all other HPP Output Valves.

Turn on the Charge Pump paired with the High Pressure Pump under test.

Turn on the High Pressure Pump under test. Set its flow rate to 50 gpm.

Slowly close the output valve, observing the rise in output pressure. At approximately 1200 psi, the pump motor should slow as the controller limits torque. When the valve is fully closed, the pump should trip off.

If not already fully closed, close the valve and proceed to the next pump.

- 3.7 If appropriate, test the Pressure Relief Valve for each HPP.

- 3.18 Disconnect the hose jumpers between MHP1 Outlet and MHP3 Return, and MHP2 Outlet and MHP4 Return.

Disconnect the hose between Main Hose Reel Outlet and WT2, including the size adapter and manual valve.

- 3.9 Cap the hose outlets until they are needed during "MHP Prep."

Note
This procedure leaves the HPP building checked out, but in an incomplete configuration. The hoses between the HPPs and the MHPs are not heated. They will not be hooked up until the MHPs are checked out.

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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<b>Antarctic Astronomy &amp; Astrophysics Research Institute</b> MADISON, WISCONSIN							
TITLE							
<b>ICECUBE MHP PREP ENHANCED HOT WATER DRILL</b>							
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE		
SC	<i>10/27/05</i>	JC/FF	<i>10/27/05</i>	HL	<i>10/27/05</i>		
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE		
AA/TH	<i>10/27/05</i>	MAZ	<i>10/27/05</i>	RJP	<i>10/27/05</i>		
FILENAME	8510-0352.0510.doc			PROJECT NO.	8510		
DRAWING NO.	8510-0352		SCALE	SIZE	SHEET		
			NA	A	1 of 9 <i>14</i>		

8510-0352  
**MHP Prep**

References:

- 8510-0122 Drill Control System Hazard Analysis
- 8510-0123 Fuel System Hazard Analysis
- 8510-0120 Power Distribution System Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

- Personnel: Full team of 8 Drillers with radios
- Equipment: Copper flange gaskets, Portable heater, Flow Meter Assemblies, Differential Pressure Switches, Manifold Pressure Transducers, Condensate system pump

Assumptions: Electrical Power is available to the SES

The fuel distribution system is active

1. Preparing the MHP Building

1.1 Set up the landing and entry steps for the building.

1.2 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

1.3 Install the Smoke/CO Detector, and replace its battery.

1.4 **Verify:** PDM MHP Power Breaker → Open  
**Verify:** MHP Main Breaker → Open

Plug in the MHP main building power cable.

**Action:** PDM MHP Power Breaker → Closed

**Action:** MHP Main Breaker → Closed

**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

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**MHP Prep**

- 1.5 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On
- 1.6 Connect the MHP building network cable.
- 1.7 Connect the MHP building E-Stop network cable.
- 1.8 Check that the furnace exhaust is not covered. If it is, remove the cover.  
Remove all heater chimney stack covers.  
Verify that the Makeup Air Vents are open and Fans are installed.
- 1.9 Hook up the fuel hose to the MHP building.  
Bleed the furnace fuel line.

<b>Note</b>
Warming the furnace with the portable heater should take approximately 3-4 hours.

- 1.10 If necessary, use a portable heater to warm the furnace to above freezing.
- 1.11 When the furnace temperature reaches approximately 0 °C, activate the furnace.  
Set the furnace thermostat to 21 °C (70 °F).  
Place the electrical heater thermal setpoint at approximately 15.5 °C (60 °F).

<b>Warning</b>
The CO <sub>2</sub> bottle is extremely heavy. Two or more people are required for lifting, when weighing the bottle. Exercise care when lifting or moving the bottle.

- 1.12 Verify that the Fire Suppression System is in good order. Weigh the CO<sub>2</sub> bottle to verify that there is CO<sub>2</sub> remaining in the bottle.

8510-0352  
**MHP Prep**

2. Setting Up Plumbing

<b>Note</b>
-------------

MHPs 1-3 require nine installations because there are nine heaters. MHP4 requires eight.
--

2.1 Install Flow Meter Assemblies for each heater.

Install a Differential Pressure Switch for each heater. Installation requires connection of two hoses and two wires per heater.

2.2 Install Manifold Pressure Transducers. There are two upper, and two lower manifolds. One transducer is installed for each manifold.

2.3 Do not proceed further until all four MHP buildings have reached this point, and you are ready to proceed with all the buildings.

2.4 Connect the MHP1 building to the HPP building – one insulated 1½" hose.

Connect the MHP1 building to the MHP4 building – two insulated 1½" hoses.

Connect the MHP2 building to the HPP building – one insulated 1½" hose.

Connect the MHP2 building to the MHP3 building – two insulated 1½" hoses.

Connect the MHP3 building to the HPP building – one insulated 1½" hose.

Connect the MHP4 building to the HPP building – one insulated 1½" hose.

2.5 Bleed the Heater fuel system.

2.6 Perform an electrical motor test for each heater:

**Action:** Main Heater Control Switch → Manual (Position 1)

Verify that the fan motor comes on. The fan should be audible.

**Action:** Main Heater Control Switch → Off

2.7 Connect the MHP Condensate Collection Tank to the PHS Condensate Tank using a heated hose.

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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2	16	TITLE					
3	17	ICECUBE					
4	18	SEW PREP					
5	19	ENHANCED HOT WATER DRILL					
6	20	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
7	21	SC	10/27/05	JC/FF	10/27/05	HI	11/22/05
8	22	DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
9	23	AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05
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11	25	DRAWING NO.	8510-0353		SCALE	SIZE	SHEET
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14	28						

8510-0353  
**SEW Prep**

References:

- 8510-0123 Fuel System Hazard Analysis
- 8510-0120 Power Distribution System Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

- Personnel: Full team of 8 Drillers with radios
- Equipment: Portable Heater

Assumptions: Electricity and fuel are available at the SES.

1. Preparing the SEW

- 1.1 Set up the landing and entry steps for the building.
- 1.2 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

- 1.3 Install the Smoke/CO Detector, and check its battery.
- 1.4 **Verify:** PDM SEW Power Breaker → Open  
**Verify:** SEW Main Breaker → Open

Plug in the SEW main building power cable.

**Action:** PDM SEW Power Breaker → Closed

**Action:** SEW Main Breaker → Closed

**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 1.5 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On
- 1.6 Connect the SEW network cable.



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**SEW Prep**

- 1.7 Check that the furnace exhaust is not covered. If it is, remove the cover.

Verify that the Makeup Air Vents are open and Fans are installed.

- 1.8 Hook up the fuel hose to the SEW.

Bleed the furnace fuel line.

<b>Note</b>
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Warming the furnace with the portable heater should take approximately 3-4 hours.
---

- 1.9 If necessary, use a portable heater to warm the furnace to above freezing.

- 1.10 When the furnace temperature reaches approximately 0 °C, activate the furnace.

Set the furnace thermostat to 21 °C.

Place the electrical heater thermal setpoint at approximately 15.5 °C.

- 1.11 Install the capacitor and control electronics for the Crimper.

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-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

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<b>MISC EQUIPMENT PREP</b>					
<b>ENHANCED HOT WATER DRILL</b>					
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**Miscellaneous Equipment Prep**

## References:

- 8510-0121 Anti-Freeze and Water Tanks Hazard Analysis
- 8510-0123 Fuel System Hazard Analysis
- 8510-0120 Power Distribution System Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis

## Requirements:

- Personnel: Full shift of 8 Drillers with radios
- Equipment: Portable heater

Assumptions: The DCC has been activated, possibly without the fuel system being hooked up.

1. Setting up the Gravity Tank

- 1.1 RPS places and levels the tank within the SES.
- 1.2 Run fuel lines to the other buildings within the SES. The lines should be available before the preparation activities at the other buildings call for fuel.
- 1.3 Verify that there are no leaks in the tank or any of the fuel lines.
- 1.4 Clean any accumulated snow out of the Gravity Tank's catch basin.
- 1.5 Connect network and fuel interface cables to the Gravity Tank.  
Connect the Fuel Transfer Pumps to power outlets on the DCC.
- 1.6 Fill the Gravity Tank, or ask RPS to fill it.

2. Setting up the Air Compressor

- 2.1 Plug the Air Compressor heater into a 120 V outlet.
- 2.2 Set up and activate a heater for the engine compartment. The heater should be directed toward the compressor unit itself at the rear of the engine compartment.
- 2.3 Activate the Air Compressor only after the compressor can be turned by hand, through manual rotation of the flywheel.
- 2.4 Refer to the Operator Manual for activation, checkout, and maintenance of the Air Compressor.

Hook up all air hoses.

## Miscellaneous Equipment Prep

### 3. Setting up the Anti-freeze Tank

- 3.1 When the Anti-freeze tank has been moved into place, place the immersion heater into the tank.

Verify that the heater is completely submerged.

Connect the heater to a 120V outlet.

- 3.2 Install the Submersible Pump, with a hose run to the location where the glycol is required, and a return hose back into the tank.

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<b>ROD WELL CREATION</b>			
<b>ENHANCED HOT WATER DRILL</b>			
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8510-0355  
**Rod Well Creation**

References:

8510-0121 Anti-Freeze and Water Tanks Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0123 Fuel System Hazard Analysis  
8510-0120 Power Distribution System Hazard Analysis  
8510-0112 Rodriguez Well Hazard Analysis  
8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

Personnel: 4 Drillers with radios  
Equipment: Silicone tape, Rod Well down hole spool

Assumptions:

RWS Prep has been completed.

The RWS flow path has been set up WT1 to WT1.

WT1 is full with >7000 gallons of water.

The DCC is operational.

The Rod Well pilot hole has been drilled.

Heaters in the RWS have been checked out and are operational.

1. Preparing the Rod Well

1.1 Locate the RWS Combo Cable Reel near the RWS building.

Anchor it to the RWS MDS.

Secure both Combo Cable connectors so that the reel can be rotated.

1.2 Apply a lockout to the RWS Combo Cable Reel motor controller.

Plug the RWS Combo Cable Reel motor controller into a 240V outlet on the RWS.

Connect cables between the Unico Drive Controller and the reel motor:

Motor brake  
Motor power

Remove the lockout on the RWS Combo Cable Reel motor controller.

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**Rod Well Creation**

**Warning**

If step 1.3 fails, the RWS Combo Cable Reel must not be used. Alert the shift lead. Operation of a faulty reel can cause personnel injury or hardware damage.

- 1.3 Test that the reel can rotate forward and backward.

Test that the reel brake stops reel rotation. Test both manual and electrical brake activation.

- 1.4 Set the Rod Well Down Hole Spool up over the pilot hole.

Measure the depth of the hole. One possible method is to use a string and a weight to make the measurement.

**Warning**

If step 1.5 fails, the RWS Hose Reel must not be used. Alert the shift lead. Operation of a faulty reel can cause personnel injury or hardware damage.

- 1.5 Test that the RWS Hose Reel can rotate forward and backward.

Test that the reel brake stops reel rotation. Test both manual and electrical brake activation.

- 1.6 Open the hose access hole in the side of the RWS by removing the faceplate.

- 1.7 Snake the hoses through the access hole and outside the RWS building.

- 1.8 Put slack in the hoses, and carry them across and past the Down Hole Spool to the other side of the hole.

Put slack in the Combo Cable, and carry it across and past the Down Hole Spool to the other side of the hole.

- 1.9 Move the RWS Submersible Pump to the ends of the hoses.

## Rod Well Creation

- 1.10 Connect the Submersible Pump to the Combo Cable, both mechanically and electrically.

Attach the RWS Return Water Hose to the Submersible Pump.

Attach the RWS Supply Hose to the Spray Nozzle.

Connect the temperature and pressure sensors to the Combo Cable.

- 1.11 Tape the hoses and cable together, three times, each 0.3m apart.

Measure the distance between the pressure sensor and the pump intake.

Measure the distance between the pressure sensor and the end of the hose.

Photo document the Submersible Pump Assembly.

### Warning

As much as possible, keep the weight of the pump assembly on the Hoses.

Do not let hoses or cables loop on the ground at any time. To do so creates a whipping hazard, should rotational control of the reels ever be lost.

- 1.12 Connect the Submersible Pump to the winch on the Down Hole Spool.

Using the winch, the Combo Cable Reel, and the Hose Reel, position the Submersible Pump assembly into the hole.

Make sure that as much as practical, the Hoses support the weight of the pump.

## 2. Configuring the System

- 2.1 **Action:** Submersible Pump Backflow Valve → Open  
**Action:** Return Water Bypass Output Selector → Rod Well

- 2.2 Configure one RWS flow path so that its output is to the Rod Well.

- 2.3 **Verify:** WT1 Bypass Flow is 1-10 gpm.

- 2.4 Request that the DCC Operator configure the heater for the flow path configured in Step 2.2 to On.



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**Rod Well Creation**

- 2.5 **Verify:** Water is flowing out the spray nozzle **and** the Submersible Pump

**Note**

While lowering the pump into the hole, the weight will be supported by the Hoses. This will prevent hose windings from "backing up" onto the reel while the Pump is being lowered.

- 2.6 Disengage the brake, and lower the Submersible Pump assembly into the hole, keeping the load on the Hoses.

Tape the hoses and cable together every 3m.

Continue lowering until the Submersible Pump reaches a depth approximately 1m less than that measured in Step 1.4.

- 2.7 Request that the DCC Operator configure the RWS with heaters and pumps appropriate to pump 30 gpm of hot water into the Rod Well.

When the pump is believed to be submerged in 3m of water, proceed.

**Caution**

The Combo Cable must be disconnected before the Combo Cable Reel can be rotated. Because the Combo Cable Reel lacks slip rings, the Cable will be damaged if the Reel is rotated with the Cable attached to the RWS.

- 2.8 To measure the water depth, perform the following steps:  
Engage the Combo Cable Reel Brake.

Demate, and then lockout, the plug that supplies the Motor Controller.

Plug the RWS end of the Combo Cable into its connector on the RWS.

## Rod Well Creation

### Note

If there is not at least 3m of water above the pressure sensor, and it is believed that the pump can be lowered further, then the Combo Cable must be disconnected from the RWS, re-secured to the Combo Cable Reel, and the lock-out removed from the Motor Controller.

The pump can be lowered further, and then Step 2.8 should be executed again.

2.9 **Verify:** At least 3m of water above the pressure sensor

3. Configure for Rod Well Creation and Enlargement

3.1 Request that the DCC Operator configure four RWS flow paths to: WT1 → Heater → Rod Well.

Request that the DCC Operator configure so that two flow paths have heaters on, two have heaters off.

3.2 **Action:** Submersible Pump Backflow Valve → Closed

3.3 Request that the DCC Operator configure four RWS flow paths to: Rod Well → WT1. Configure all four paths so that none have active heaters.

3.4 Request that the DCC Operator configure the remaining two flow paths to: WT1 → WT1. The DCC Operator can set the heaters to his own discretion, based upon temperatures in WT1.

3.5 **Action:** Rod Well Submersible Pump → On

**Verify:** WT1 Bypass Flow at 1-8 gpm

**Verify:** Rod Well Bypass Flow at 1-8 gpm

### Caution

The minimum flow rate for the Submersible Pump is 16 gpm. Flow rates lower than that can cause burn-out of the pump.

3.6 The DCC Operator should monitor temperature, water levels, and pump speeds and make adjustments required to grow the Rod Well.

8510-0355  
**Rod Well Creation**

**Caution**

The Combo Cable Reel Motor Controller is not designed to withstand the cold temperatures experienced at the South Pole without power applied for extended periods.

Hardware damage will occur.

The Motor Controller must be placed in warm storage when unpowered for extended periods.

- 3.7 Disconnect the Combo Cable Reel Motor Controller, and store it in the RWS MDS.

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SHEET REVISION STATUS

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## Rod Well Pump Repositioning

### References:

- 8510-0121 Anti-Freeze and Water Tanks Hazard Analysis
- 8510-0122 Drill Control System Hazard Analysis
- 8510-0123 Fuel System Hazard Analysis
- 8510-0120 Power Distribution System Hazard Analysis
- 8510-0112 Rodriguez Well Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis

### Requirements:

- Personnel: 3 Drillers with radios
- Equipment: Silicone tape, lockout for Combo Cable Reel

#### 1. Preparing to Lower the Pump

- 1.1 Adjust RWS flowpaths, so that 9 paths flow WT1 to WT1, and one path flows WT1 to the Rod Well.
- 1.2 Verify that all pump speeds and bypass flows are acceptable.
- 1.3 **Action:** Rod Well Submersible Pump → Off

**Action:** Submersible Pump Backflow Valve → Open

### Caution

The Combo Cable must be disconnected before the Combo Cable Reel can be rotated. Because the Combo Cable Reel lacks slip rings, the Cable will be damaged if the Reel is rotated with the Cable attached to the RWS.

- 1.4 Disconnect the Combo Cable from the RWS, and secure the connector to the reel, so that it does not snag when the Reel rotates.
- 1.5 Disconnect the Temperature and Pressure sensors.
- 1.6 Remove the Combo Cable Reel Motor Controller lockout.  
  
Attach a pendant to the Hose Reel.  
  
Apply power to the Combo Cable Reel Motor Controller.
- 1.7 Apply power to the RWS Hose Reel Motor Controller.

## Rod Well Pump Repositioning

### 2. Lowering the Submersible Pump

#### 2.1 Energize the Combo Cable Reel Motor Controller.

Energize the Hose Reel Motor Controller.

### Warning

Keep the weight of the pump assembly on the Hoses, and not on the Combo Cable.

Do not allow the Combo Cable or hoses to become wound or tangled on the ground. Doing so creates a personal injury hazard should positional control of the Pump Assembly be lost.

#### 2.2 **Action:** RWS Combo Cable Reel Brake → Disengaged

**Action:** RWS Hose Reel Brake → Disengaged

#### 2.3 Lower the Submersible Pump a distance consistent with available Rod Well models.

Create slack in the Combo Cable, and lower with the Hoses.

#### 2.4 **Action:** RWS Combo Cable Reel Brake → Engaged

**Action:** RWS Hose Reel Brake → Engaged

**Verify:** RWS Combo Cable Reel Brake Hydraulic Pressure – 0

**Verify:** RWS Hose Reel Brake Hydraulic Pressure – 0

#### 2.5 **Action:** RWS Combo Cable Reel Motor Controller → Off

**Action:** RWS Hose Reel Motor Controller → Off

Remove power from both Motor Controllers.

### Caution

The lockout of the Motor Controller prevents accidental rotation of the Combo Cable Reel. Rotation of the Reel with the Combo Cable attached to the RWS will damage the Cable.

#### 2.6 Apply a lockout on the power feed for the Combo Cable Reel Motor Controller.

#### 2.7 Remove the pendant from the Hose Reel.

## Rod Well Pump Repositioning

### 3. Restarting the Rod Well

3.1 Reconnect the RWS Combo Cable to the RWS.

Reconnect the Temperature and Pressure cables.

3.2 **Action:** RWS Submersible Pump Backflow Valve → Closed

3.3 **Action:** RWS Submersible Pump → On

3.4 Flowpaths and heater configurations are set at the discretion of the DCC Operator.

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SHEET REVISION STATUS

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8510-0357  
**TOS Setup**

References:

- 8510-0102 Power Distribution System Hazard Analysis Summary
- 8510-0002 Drill Camp Layout (latest revision)

Requirements:

- Personnel: 4 Drilling Team members with radios, Raytheon GA, Bulldozer operator, Fork Lift operator
- Equipment: Trencher, Bulldozer, Fork Lift

Assumptions: Power is available from the PDM.

The TOS Day Tank is full of fuel.

Surveying for the holes is completed, and the first hole for each Tower is staked out, with the exploratory hole drilled, and Deadman Anchors in place.

1. Moving the TOS and the Tower

- 1.1 Drag the Tower to the first drill site, and properly position the Tower over the hole as shown in drawing 8510-0002\_RevA, Page 3 - TOS.
- 1.2 Using the D7 bulldozer, connect to the TOS Double Wide Tow Bar, and drag the TOS to the drill site.

Remove the weather panels from the Tower and TOS faces that mate to each other.

Maneuver the TOS into position such that it lines up with the Tower and only a minimal gap remains where it joins the Tower. If necessary, nudge the Tower and TOS together with a 953 Fork Lift. Picture 1.1 shows the correct alignment between the TOS and Tower such that the TOS/Tower Anchor Straps can be attached to the TOS Anchor Points.

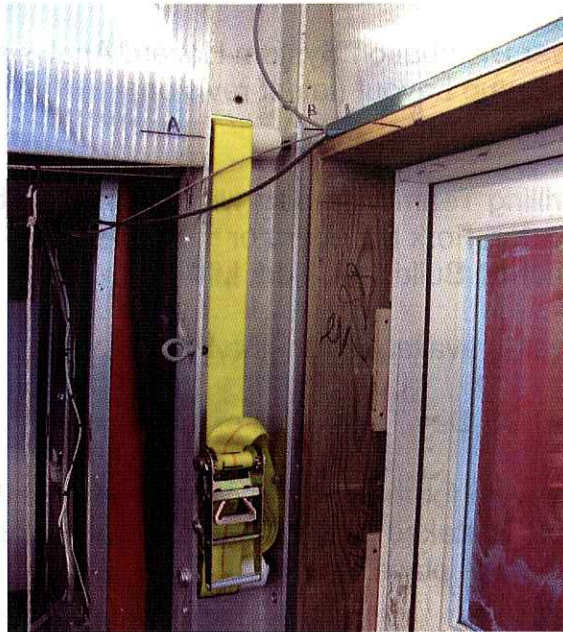
- 1.3 Enter the building.

Look for snow or ice. If any is observed, remove it.

Perform a visual inspection of all components.

- 1.4 Replace the battery in the Smoke/CO Detector.

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**TOS Setup**



Picture 1.1 – TOS/Tower Anchor Strap Alignment

1.5 Use a 953 forklift to drag the TOS Fuel Tank to the first drill site.

Request that a Raytheon Utility Technician attach the tank to the furnace inlet.

Bleed the fuel line.

**Caution**

The feeder cables can be damaged if driven over by tracked vehicles.

1.6 **Verify:** PDM TOS Power Circuit Breaker 1 – Open  
**Verify:** PDM TOS Power Circuit Breaker 2 – Open  
**Verify:** PDM TOS Submersible Pump Power Circuit Breaker – Open

Connect the feeder cables at the PDM.

Drag the three feeder cables to the TOS.

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**TOS Setup**

1.7 Connect the three feeder cables to the TOS power inputs.

**Action:** PDM TOS Power Circuit Breaker 1 → Closed  
**Action:** PDM TOS Power Circuit Breaker 2 → Closed  
**Action:** PDM TOS Submersible Pump Power Circuit Breaker → Closed

**Action:** TOS Main Circuit Breaker 1 → Closed  
**Action:** TOS Main Circuit Breaker 2 → Closed  
**Action:** TOS Submersible Pump Power Circuit Breaker → Closed

**Warning**

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

1.8 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On

**Note**

Warming the furnace with the portable heater should take approximately 3-4 hours.

1.9 If necessary, use a portable heater to warm the furnace to above freezing.

1.10 When the furnace temperature reaches approximately 0 °C, activate the furnace.

Set the furnace thermostat to 21 °C (70 °F).

Place the electrical heater thermal setpoint at approximately 15.5 °C (60 °F).

1.11 Attach the TOS/Tower Anchor Straps as shown in Picture 1.1.

1.12 Seal the interface between the Tower and the TOS with insulating foam.

1.13 Connect the TOS RH to the top of the Tower using two cargo straps as shown in Picture 1.2.

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**TOS Setup**

1.14 Use a Trencher to cut anchor trenches according to Figure 1.3.

Install anchors for the Drill Cable Reel  
Install anchors for the Return Water Hose Reel  
Install anchors for the Deployment Reel

2. Installing DNF Equipment into the TOS

2.1 Run the network and E-Stop cables from the SES to the TOS.

Connect the network cable.

Do not connect the E-Stop cable.

2.2 Configure the E-Stop system as a local island, disconnected from the SES.

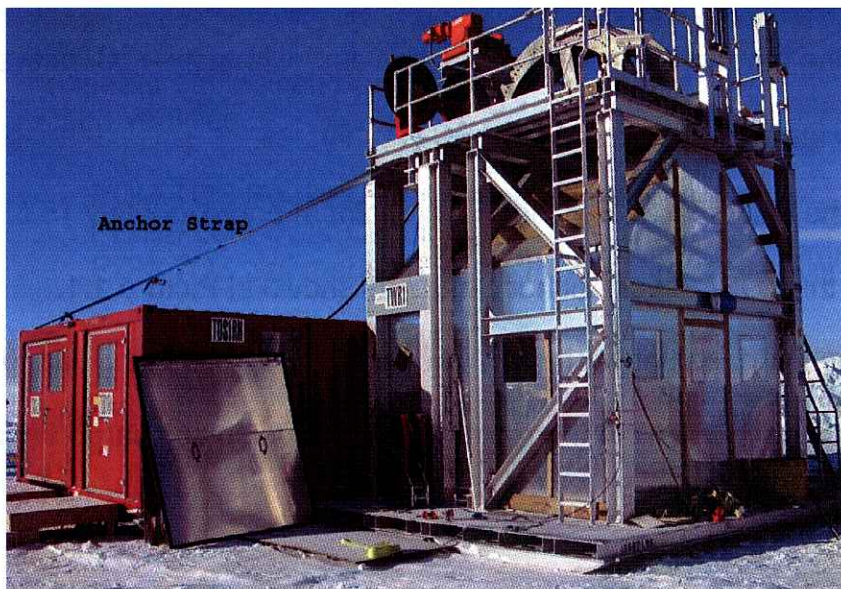
2.3 Retrieve the TOS UPS from DNF storage and install the UPS.

Retrieve the TOS Computers from DNF storage, and install the computers.

Perform any required hardware upgrades.

Perform any required software upgrades.

Activate the computers.



Picture 1.2 – TOS/Tower Anchor Strap Configuration

8510-0357  
**TOS Setup**

2.4 Remove TOS Unico Drives from DNF Storage.

Install and check out the Unico Drives.

Someone other than the installer must check the Unico installation.

2.5 Install and connect the external webcams.

Attach their power and signal cables.

2.6 Connect the Load Cell cables between the Load Cell Junction Box and the TOS.

2.7 Request that RPS connect the telephone.

2.8 Set up the radio base station.

2.9 Set up the radio battery chargers.

2.10 When the TOS/Tower are warmed to above freezing, place the Drill Head, Firm Drill, and Weight Stacks into the Tower.

2.11 Remove any other items needed from DNF storage, and install it into the TOS/Tower.

8510-0357  
**TOS Setup**

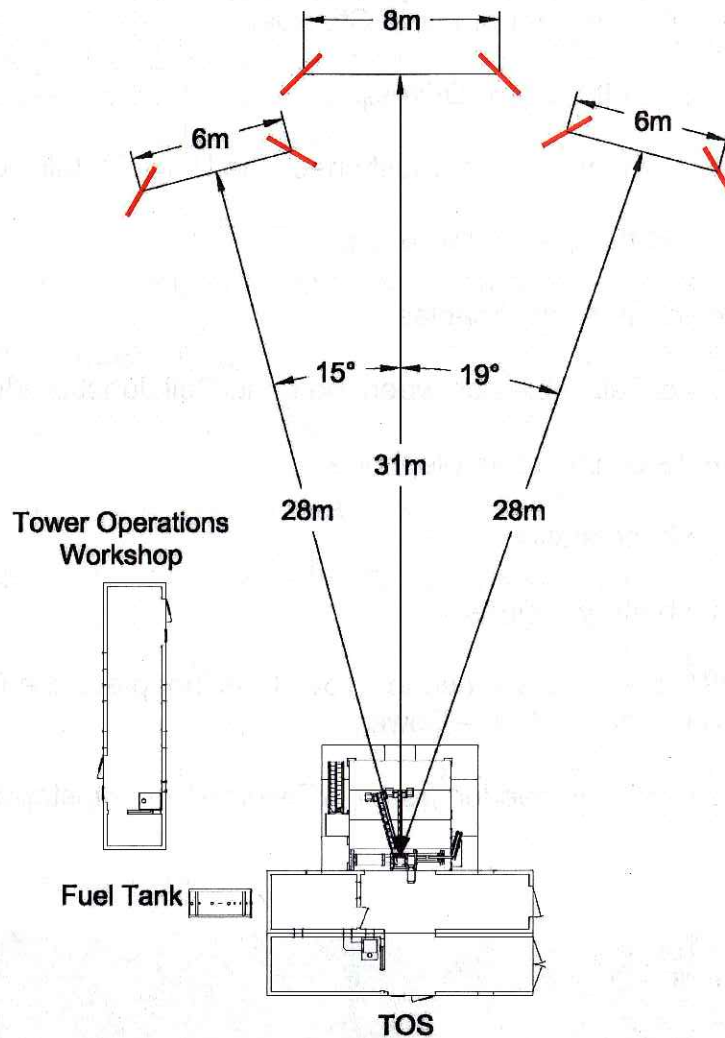


Figure 1.3 – Tower Operations Site Anchor Locations

3. Relocating Reels and Hoses
- 3.1 Cap the ends of the Main Hose and Return Water Hose.

**Caution**

The end of the Main Hose and Return Water Hose must be secured to their reels before attempting to move the reels. Failure to do so can cause damage to the hoses as they drag across the ice.

8510-0357  
**TOS Setup**

3.2 Secure the end of the Main Supply Hose to the Main Supply Hose Reel.

Secure the end of the Return Water Hose to the Return Water Hose Reel.

3.3 Use a D7 bulldozer to move the Main Supply Hose Reel to the TOS. Figure 2.1 shows the Drill Supply Hose Reel's position relative to the new hole, and to the Tower.

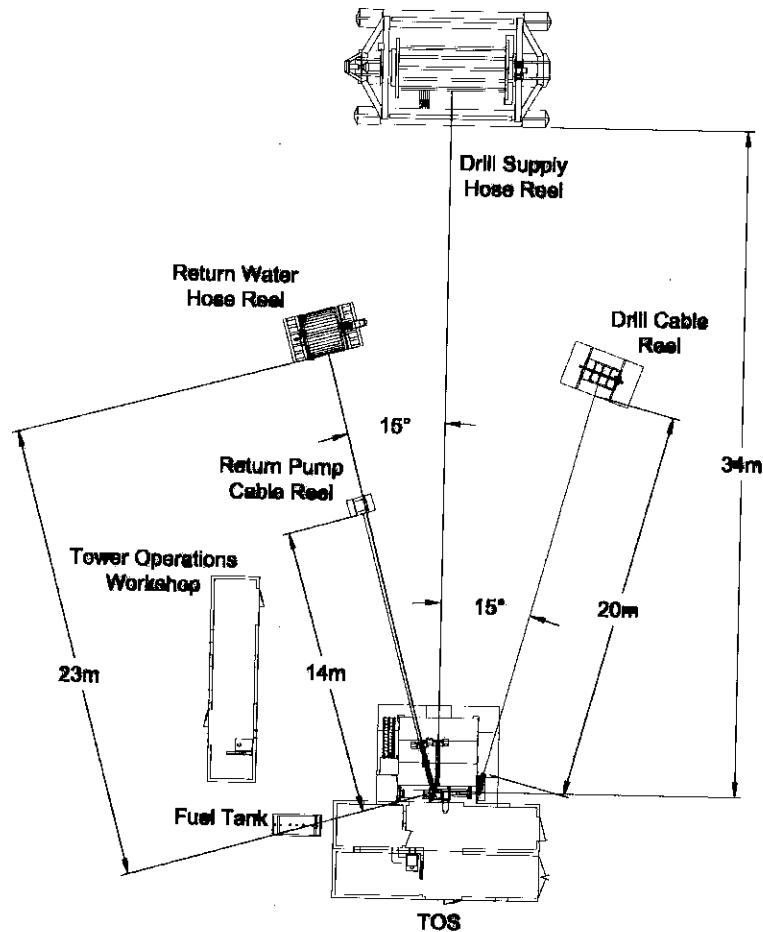


Figure 3.1 – Tower Operations Site Equipment Layout

3.4 Use a 953 forklift to move the Return Water Hose Reel into position at TOS. Figure 3.1 shows the distance and angle of the reel relative to the hole.

8510-0357  
**TOS Setup**

**Caution**

Avoid driving over hoses with tracked vehicles while the hoses are being moved.

- 3.5 Move the Surface Supply Hose and Surface Return Hose to the TOS, and place them such that they will easily reach the Main Hose Reel and Return Water Hose Reels.

**Caution**

Avoid driving over cable with tracked vehicles while the hoses are being moved.

- 3.6 Use a 953 forklift to move the Return Water Pump Combo Cable Reel into position at the new drill site. Figure 3.1 shows the distance and angle of the reel relative to the hole.
- 3.7 Use a 953 forklift to move the Drill Cable Reel into position at the new drill site. Figure 3.1 shows the distance and angle of the reel relative to the hole.
- 3.8 Attach the Drill Cable Reel to its anchors.

Attach the Return Water Hose Reel to its anchors.

Attach the Return Water Combo Cable Reel to its anchors.



REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document		10/27/05
	A	Annual review	10/24/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	A	A	A	A														

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		<b>TITLE</b> <b>ICECUBE Hose Prep</b>																	
		<b>ORIGINATOR</b>			<b>DATE</b>			<b>ENGINEER</b>			<b>DATE</b>			<b>CHECKER 1</b>			<b>DATE</b>		
		Jeff Cherwinka			10/19/07						10/24/07								
		<b>CHECKER 2</b>			<b>DATE</b>			<b>QUALITY ASSURANCE</b>			<b>DATE</b>			<b>PROJECT APPROVAL</b>			<b>DATE</b>		
								Tim Brenner			10/24/07								
		<b>FILENAME</b> 8510-0358									<b>PROJECT NO.</b> 8510								
		<b>DRAWING NO.</b> 8510-0358						<b>SCALE</b>			<b>SIZE</b>			<b>SHEET</b> 1 of 4					
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8510-0358  
**Hose Prep**

References:

8510-0107 Drill Hose Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis  
8510-0112 Rodriguez Well Hazard Analysis  
8510-0108 Tower Hazard Analysis  
8510-0109 Mobile Drilling Structure Hazard Analysis

Requirements:

Personnel: 4 Drillers with radios  
Equipment: Two portable heater units, SES air compressor, Chromalox Heater, one large tarp.

Assumptions: SES Setup is complete, and all components are ready to support drilling and deployment operations.

Main Supply Hose Reel and Return Water Hose Reel are ready to support.

1. Preparing the Reels

1.1 Move the two portable heaters and the air compressor to the TOS, next to where the two reels are located.

1.2 Drape the tarp over the Drill Supply Hose Reel.

Run the output of one portable heater under the tarp.

Run the output of the second portable heater through the center of the Drill Supply Hose Reel.

1.3 Connect a hose between the air compressor output and the Chromolox heater.

Connect a hose between the Chromolox heater and the Surface Hose end of the Drill Supply Hose. The heater output should now be able to travel through the Drill Supply Hose.

1.4 Connect the Drill end of the Drill Supply Hose to the Submersible Pump end of the Return Water Hose. The heater output, after passing through the Drill Supply Hose should now be able to travel through the Return Water Hose.

8510-0358  
**Hose Prep**

<b>Note</b>
-------------

There is a heat exchanger on the Air Compressor that reduces the temperature of the air as it exits the compressor. This heat exchanger should be at least partially bypassed during Hose Prep, if possible.
--

- 1.5 Activate the portable heaters.

Activate the air compressor.

Activate the Chromolox heater.

- 1.6 When the temperature at the output of the Return Water Hose reaches -3 – -5 °C, proceed to Step 3.

2. Warming the Surface Hoses

- 2.1 Drag the ends of both Surface Hoses to the Main Supply Hose Reel.

- 2.2 Connect the Supply Water Surface Hose to the Return Water Surface Hose in a loopback configuration.

- 2.3 Request that the DCC Operator configure for 88 °C water at 200 gpm through the Surface Hoses.

When warm water is observed flowing back into Tank 2 from the Return Water Surface Hose, a lower temp and lower flow setpoints can be used at the discretion of the DCC Operator (to save fuel).

In addition, the DCC Operator should monitor the temperature in WT1, and if it exceeds 25 °C, then a bypass that directs the water from the Surface Return Hose to the Rod Well should be set up.

- 2.4 When Step 1 has been completed, proceed to Step 3.

3. Configuring for Loopback on All Hoses

- 3.1 Deactivate the Chromolox heater and air compressor.

Remove the hose connecting the heater and the Surface Hose end of the Drill Supply Hose Reel.

8510-0358  
**Hose Prep**

**Caution**

Water flow through the Surface Hoses is about to terminate. Lack of water flow through the hoses presents a freezing hazard. Allowing water in the hoses to freeze can damage the hoses and hardware attached to the hoses.

Water circulation, which is reestablished in Step 3.5, must be restored within 60 minutes.

3.2 Request that the DCC Operator terminate flow through the Surface Hoses.

3.3 Break the siphon in the Surface Return Hose at WT1.

Close the valves at the TOS ends of the Surface Hoses.

Disconnect the Supply Water Surface Hose from the Return Water Surface Hose.

3.4 Connect the Surface Supply Hose to the Drill Supply Hose.

Connect the Surface Return Hose to the Return Water Hose.

3.5 Request that the DCC Operator configure for 88 °C water at 200 gpm through the hoses, maintaining, or initiating the Rod Well bypass discussed in Step 2.3, as appropriate.

Over time, the DCC Operator should prudently reduce temperature and water flow so that fuel usage can be reduced, but there will be no danger of freezing water in the hoses.

The minimum temperature and flow rate setpoints are expected to be approximately 50 gpm at 18 °C.

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
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2	16	TITLE						
3	17	<b>ICECUBE</b>						
4	18	<b>PRE-DRILLING CHECKLIST</b>						
5	19	<b>ENHANCED HOT WATER DRILL</b>						
6	20	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE	
7	21	SC	10/27/05	JC/FF	10/27/05	HL	10/27/05	
8	22	DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE	
9	23	AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05	
10	24	FILENAME	8510-0359.0510.doc			PROJECT NO.	8510	
11	25	DRAWING NO.	8510-0359		SCALE	SIZE	SHEET	
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13	27							
14	28							

## Pre-Drilling Checklist

### References:

8510-0106	Drill Head Supply Hose Hazard Analysis
8510-0114	Cable Reel Hazard Analysis
8510-0122	Drill Control System Hazard Analysis
8510-0107	Drill Hose Reel Hazard Analysis
8510-0124	Drilling Operations Hazard Analysis
8510-0219	Return Water Cable Reel Hazard Analysis
8510-0115	Return Water Hose Reel Hazard Analysis
8510-1018	Tower Hazard Analysis

### Requirements:

Personnel:	2 drillers with radios
Equipment:	Weight Stacks, 6mm drill bits, 6mm Allen wrenches, anti-seize, large crescent wrenches, large box end wrenches.

Assumptions: The Tower is in place, with a checked out E-Stop network.

The Drill Cable and Drill Supply Hose have both been run into the Tower.

The Return Water Hose has been run into the Tower, and has a 50m 1½" hose extension installed.

### 1. Checking the TOS

- 1.1 Verify that the level winds on the reels are properly lined up.
- 1.2 Make sure that the webcams are all set up as desired.
- 1.3 Check all anchors, anchor straps, and tie points for all drill equipment.
- 1.4 Verify that weight stacks, connectors, all required tools, 6mm drill bits and Allen wrenches, and a tube of anti-seize are all available.

### 2. Checking the SES

- 2.1 Check with the DCC Operator to verify that at least 3000 gallons of fuel are available in one tank, with another full tank connected to the system.

## **Pre-Drilling Checklist**

- 2.2 Check with the DCC Operator to verify that WT1 has >7000 gallons of water available.

In addition, verify that WT2 has ~7000 gallons of water available, and that the water temp is at least 10 °C.

- 2.3 Check with the DCC Operator to verify that the Rod Well has at least 2m of water above the pump.
- 2.4 Verify that the Deployment Team is ready for the Drilling Team to start drilling.

REVISIONS				
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-	NA	Original Document		10/27/05
	A	Annual review	10/23/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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		<b>ORIGINATOR</b>			<b>DATE</b>			<b>ENGINEER</b>			<b>DATE</b>			<b>CHECKER 1</b>			<b>DATE</b>		
		Alan El-Cheikh			9/24//07			Dan Wahl			10/23/07			Terry Matt			10/23/07		
		<b>ENGINEER</b>			<b>DATE</b>			<b>QUALITY ASSURANCE</b>			<b>DATE</b>			<b>PROJECT APPROVAL</b>			<b>DATE</b>		
		Jeff Cherwinka			10/23/07			Tim Brenner			10/23/07								
		<b>FILENAME</b> 8510-0360									<b>PROJECT NO.</b> 8510								
		<b>DRAWING NO.</b>						<b>SCALE</b>			<b>SIZE</b>			<b>SHEET</b>					
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8510-0360  
**Firn Drilling**

References:

- 8510-1022 Drill Control System Hazard Analysis
- 8510-0107 Drill Hose Reel Hazard Analysis
- 8510-0124 Drilling Operations Hazard Analysis
- 8510-0115 Return Water Hose Reel Hazard Analysis
- 8510-0108 Tower Hazard Analysis

Firn Drill Operator Manual – Lee Greenler

Requirements:

- Personnel: 4 Drillers
- Equipment: Portable Air Compressor

Assumptions: Main Supply and Return Water Hoses have been run into the Tower and are looped together, with water flowing. The hoses have >80 °C water circulating.

The 1.5 inch blue hose has already been attached to the end of the return hose.

Pre-Drilling Checklist is complete, with no issues.

**Caution**

Do not allow objects, especially those heavier than water, to fall into the hole. An object dropped into the hole will lodge at the bottom of the hole and interfere with subsequent drilling activities.

When possible, keep a cover over the hole.

**Warning**

When working in the Tower during periods when cables or hoses are been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the area where an emergency takes place and your attention should be focused on it as much as possible

8510-0360  
**Firn Drilling**

**Warning**

The Firn Drill head weighs 505 lb. (220 kg). Exercise caution when moving it.

1. Preparing Firn Drill

- 1.1 Connect the Tower Hoist to the Firn Drill.  
Attach a secondary restraint tether to the Firn Drill, and attach the tether to an anchor point.
- 1.2 Lift the Firn Drill with the Tower Hoist and place it over the hole.

**Caution**

Water flow through the Surface Hoses, and Drill Water Supply and Return Water Hoses is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 1.11. If Step 1.11 cannot be completed within 60 minutes, back out and restore water flow within the hose for at least 60 minutes before starting Step 1.3 again.

- 1.3 Request that the DCC Operator terminate water flow through the Surface Hoses and wait for flow to stop.

**Action:** Drill Supply Hose Valve → Closed

**Action:** Return Water Hose Valve → Closed

Remove the jumper between the two hoses.

- 1.4 Connect the Main Supply and Return Water Hoses to the Firn Drill

**Action:** Drill Supply Hose Valve → Open

**Action:** Return Water Hose Valve → Open

- 1.5 Request that the DCC Operator configure the SES so that the return water goes to the Rod Well instead of WT1.

8510-0360  
**Firn Drilling**

**Caution**

The 6 ball valves must be fully open before water flow to the Firn Drill commences. Failure to open the ball valves can cause an overpressure that can damage Firn Drill components.

In addition, leaving a ball valve closed prevents hot water from reaching one of the melt circuits, which will impact the speed and efficiency with which the Drill operates.

- 1.6 Open all 6 Ball Valves on the Firn Drill, but do not open the leaker circuits or remove the tip cover at this stage.
- 1.7 Raise the Drill Supply Hose Reel to take load off of the Return Water Hose Reel, the Tower Hoist, and the secondary tether.

**Note**

As much as possible, keep the weight of the Firn Drill head on the Drill Supply Hose. It is much stronger than the Return Water Hose.

- 1.8 Disconnect the Tower Hoist from the Firn Drill, and move the Tower Hoist hook out of the way.

Remove the secondary restraint tether from the Firn Drill.

**Warning**

Water in the Firn Drill will be pressurized, and if there is a leak, the stream of hot water can travel several feet. Locating the Firn Drill below the Tower floor before water flow is initiated significantly reduces the likelihood of striking a Drill Team member with hot water if there is a leak.

- 1.9 As much as possible, lower the Firn Drill to just below the floor.

If one is available, place a clear shield around the Firn Drill to protect Tower occupants from spraying hot water.

8510-0360  
**Firn Drilling**

<b>Note</b>
In Step 1.11, the freezing hazard caused in Step 1.3 is eliminated.

<b>Note</b>
Water flow through the firn Drill is best specified in increments of 7.5 gpm. This is because each heater in the MHP supplies 7.5 gpm at 88 °C. When calculating how much flow to call for in step 1.11, use the following: 2-3 gpm for flow from the tip 0-15 gpm for flow from the leaker circuits 35 gpm for the melter circuits  Then round up to the next 7.5 gallon increment and use that value.

- 1.10 Ask DCC Operator to start water flow and ramp up to approximately 52 gpm, making sure the water pressure at the DCC does not exceed 350 psi.

The Drilling Team should inspect the Firn Drill for leaks as the water flow is being ramped up.

Ask the DCC operator to bring up heaters as additional water flow allows until the water leaving the HPP is at around 88°C.

<b>Note</b>
Despite the firn drill having been blown dry from the previous run, it is still possible that water has frozen inside the thin copper tubing, preventing water flowing through all the circuits of the drill.  The operator must make sure water is flowing through all the drill melter and leaker circuits, as well as out the bottom nozzle before drilling commences (See Firn Drill Operator Manual)

- 1.11 With the leaker circuits closed, Check to make sure water is flowing through all melter circuits of the drill by placing a hand on each circuit and checking if it's cold or warm. It should be easy to tell which circuits are frozen.

8510-0360  
**Firn Drilling**

- 1.12 Apply heat to each circuit, either by using a large heater directed at the drill head or by directing multiple heat guns to the frozen circuits, until flow is established in all circuits.

<b>Note</b>
Water needs to be at near operating temperature of 88°C before moving onto the next step.
If the water in the hoses wasn't pre warmed prior to attaching the drill, then a wait of up to an hour may be necessary to bring the water up to temperature.

- 1.13 Lower the drill head so that the nozzle is sitting just below the tower floor and carefully remove it while making sure it doesn't fall down the hole. A catching blanket may need to be placed directly under the drill and covering the hole, to make sure the nozzle cover does not fall down the hole.
- 1.14 Make sure water is flowing out the drill nozzle. If not, use a heat gun directed at the nozzle until it thaws out.
- 1.15 Lower the drill until it is almost all the way in the hole, but with the leaker circuits valve still reachable. (This is to prevent the leaker circuits from spraying water inside the tower once their valve is opened.)
- 1.16 Open the leaker valve and commence drilling as detailed below.

8510-0360  
**Firn Drilling**

2. Firn Drilling

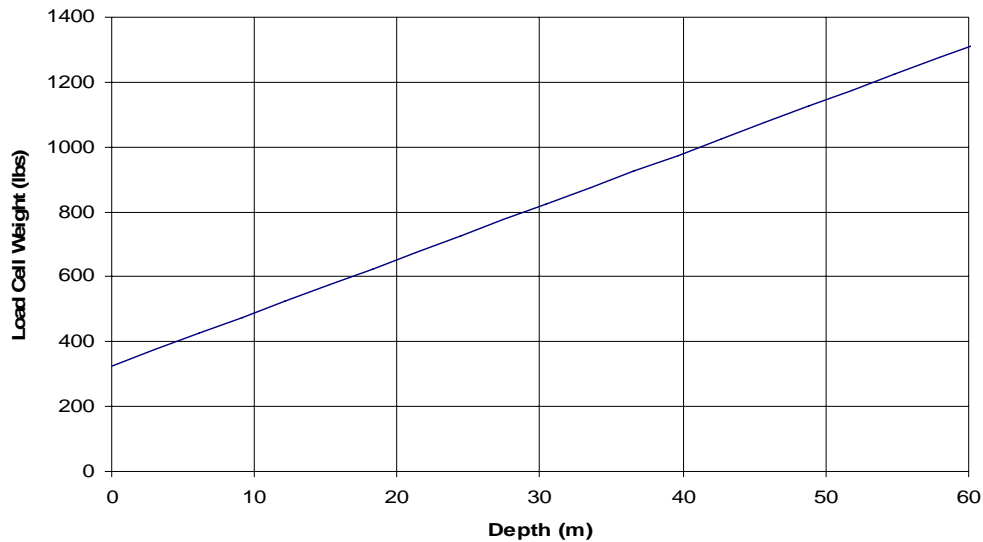


Figure 2.1 – Load Cell Weight vs. Drill Depth

<b>Note</b>
For purposes of calculating the proper load cell indicated weight, 0m places the connections between the hoses and the Firn Drill at floor level.

- 2.1 Slowly lower the drill through the firn ice, maintaining the load on the Drill Supply Hose Crescent load cell as shown in Figure 2.1.

<b>Note</b>
IVG markings on the Return Water Hose are approximately 0.3m apart.

- 2.2 As the Firn Drill is lowered, tape the Drill Supply Hose and Return Water Hose together approximately every 3m (~10 IVG marks).
- 2.3 Lower the Firn Drill until water is observed to pool around the Drill. This should occur at a depth of approximately 45m.
- 2.4 During the rest of the drilling operation, maintain constant monitoring of the drilled hole to make sure it is being drilled straight. Drill speed should be somewhere between 0.1-0.2m/min, however drill slower if necessary to maintain a straight hole. Also, if necessary, bring the drill back up to re-drill a crooked section.

8510-0360  
**Firn Drilling**

3. Deconfiguring the Firn Drill

- 3.1 Once water is observed to pool in the hole, using the Drill Supply Hose Reel, raise the Firn Drill to about floor level while removing the tape as necessary and taking up the slack on the return water hose reel.

If the hole looks an acceptable shape, then bring the drill back up as fast as is safe to do so (but less than 5 m/min), while maintaining a close watch on the drill hose load cell to make sure it doesn't spike up, as this would indicate the drill is caught down the hole. During this retrieval operation, reduce flow rate to conserve water, while maintaining flow in the hoses to prevent freezing.

If the hole does NOT look an acceptable shape, bring the drill back up slowly with 52 gpm flow in order to try and straighten the hole.

**Caution**

Water flow through the Surface Hoses, and Main Water Supply and Return Water Hoses is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 3.8. If Step 3.8 cannot be completed within 60 minutes, back out and restore water flow within the hose for at least 60 minutes before starting Step 3.2 again.

- 3.2 Request that the DCC Operator discontinue water flow.

**Action:** Drill Supply Hose Valve → Closed

**Action:** Return Water Hose Valve → Closed

Record the time at which water flow was terminated.

- 3.3 Connect the Tower Hoist to the Firn Drill.
- 3.4 Lift the Firn Drill with the Tower Hoist to relieve load from the Drill Supply Hose Reel and Return Water Hose Reel.
- 3.5 Attach a secondary tether to the Firn Drill, and tie the tether off to the Tower structure.

8510-0360  
**Firn Drilling**

- 3.6 Disconnect the Return Water Hose from the Firn Drill.
- 3.7 Remove the Main Water Hose from the Firn Drill.

Note
In Step 3.8, the freezing hazard caused in Step 3.2 is eliminated.

- 3.8 Loop the Main Water Hose and Return Water Hose together.

**Action:** Drill Supply Hose Valve → Open  
**Action:** Return Water Hose Valve → Open

Request that the DCC Operator restore water flow through the hoses.

- 3.9 Place the tip protector on the Firn Drill.
- 3.10 Close all the ball valves.
- 3.11 Connect the air compressor fitting to the Firn Drill at the Drill Supply Hose fitting. Connect the air compressor hose to the fitting on the Firn Drill.
- 3.12 Open the Firn Drill Return Manifold Drain Valve.

Blow the water out of the Firn Drill with compressed air by opening each ball valve for 2 minutes and then closing it.

Close all the melt circuit ball valves.

Open the leak circuit ball valve, and blow water out for 2 minutes.

Open all the melt circuit ball valves.

When the Drill appears clear of water, remove the tip protector to ensure that any water remaining in the tip is cleared.

With the tip protector removed and all the ball valves for melt and leak circuits open, blow out the Firn Drill for an additional 5 minutes. If practical, shake the Firn Drill lightly during the blowout to dislodge any water droplets that might remain.

Replace the tip protector on the Firn Drill.



8510-0360  
**Firn Drilling**

3.13 Remove the air compressor hose and fitting from the Firn Drill.

Close the Return Manifold Drain Valve.

3.14 Lift the Firn Drill with the Tower Hoist, and move it to its stowage location. Secure it there.

Remove the Tower Hoist and secondary restraint tether from the Firn Drill.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document		10/27/05
	A	Annual review	10/23/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	A	A	A	A	A	A	A	A										

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		<b>TITLE</b> <b>ICECUBE Main Hole Drilling Prep</b>																	
		<b>ORIGINATOR</b>			<b>DATE</b>			<b>ENGINEER</b>			<b>DATE</b>			<b>ENGINEER</b>			<b>DATE</b>		
		Alan El-Cheikh			10/10//07			Jeff Cherwinka			10/23/07			Terry Matt			10/23/07		
		<b>CHECKER 2</b>			<b>DATE</b>			<b>QUALITY ASSURANCE</b>			<b>DATE</b>			<b>PROJECT APPROVAL</b>			<b>DATE</b>		
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## Main Hole Drilling Prep

### References:

8510-0106 Drill Head Supply Hose Hazard Analysis  
8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0107 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis  
8510-0108 Tower Hazard Analysis

Drill Startup Procedure – South Pole – 20050929 by Jack Ambuel

### Requirements:

Personnel: Full team of 8 Drillers with radios  
Equipment: Pipe clamps, elevators, lifting clamps, safety straps, ladder

### Assumptions:

The Combo Cable Reel drive is installed and warmed up.

Pre-Drilling Checklist is complete, with all constraints met.

Firn Drilling is complete.

The Drill Cable has been run into the Tower.

The Drill Supply and Return Water Hoses have been run into the Tower and looped together.

Water is circulating in the hoses at about 40gpm and at about 25°C.

### **Caution**

Do not allow objects, especially those heavier than water, to fall into the hole. An object dropped into the hole will lodge at the bottom of the hole and interfere with subsequent drilling activities.

When possible, keep a cover over the hole.

## Main Hole Drilling Prep

### Warning

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the area where an emergency occurs, and is where your attention should be focused as much as practical.

#### 1. Assembling the Weight Stack

##### Note

About 20 minutes from the anticipated start of drilling, the circulating water flow in the hoses should be increased to 200gpm and 88°C to allow time for the water at the drill head to reach operating temperature as drilling is ready to commence.

- 1.1 Position the weight stack assembly plate over the hole
- 1.2 Place the 4" pipe elevator below the welded collar on the weight stack tip, and lock it into place.
- 1.3 Connect the Tower Winch to the pipe elevator.
- 1.4 Attach a safety strap to the pipe elevator, and tie the strap to an anchor point at the top of the tower.
- 1.5 Using the Tower Winch, lift the Drill Tip and lower it into the hole. The top of the Drill Tip should be left at a convenient working height above the Tower floor.
- 1.6 Attach a quick clamp. Lock the quick clamp handle down, and apply a safety lock.

Lower the Tower Winch until the weight of the Drill Tip is on the quick clamp.

Remove the Tower Winch cable from the weight stack while keeping the safety strap attached to the weight stack.

## Main Hole Drilling Prep

Note
Steps 1.7-1.13 are performed 6 times, so that a total of 7 Weight Stack segments are attached to one another.

- 1.7 Attach a 5" elevator to the next segment of the Weight Stack below the welded collar and lock in place.

Connect the Tower Winch to the elevator.

Attach a safety strap to the pipe elevator, and tie the strap to an anchor point at the top of the tower.

- 1.8 Using the Tower Winch, lift the next Weight Stack segment, and insert it in the previous segment.
- 1.9 Clamp the 2 sections together using a weight stack collar clamp, after inspecting the collar to make sure it is not cracked or otherwise damaged.
- 1.10 Remove the safety strap from the lower segment.
- 1.11 Using the Tower Winch, lift the Weight Stack, until the quick clamp can be removed.
- 1.12 Remove the quick clamp.
- 1.13 Lower the Weight Stack to a convenient working height.

Install a quick clamp on the upper segment of the Weight Stack. Lock the quick clamp handle down and apply a safety lock.

Lower the Weight Stack until the load is on the quick clamp.

Repeat until all seven Weight Stack segments are assembled.

## 2. Preparing the Drill Head

## Main Hole Drilling Prep

Note
Step 4 assumes that the Drill Head has been stored vertically against the wall of the Tower.

- 2.1 Attach the Drill Cable to the mounting hole at the top of the Drill Head.

Do not plug the electrical connection in yet, but make sure that the connector is protected.

- 2.2 Attach a safety strap to the Drill Head body, and connect the safety strap to the Tower Winch.

Caution
Do not apply side loads to the Drill Head Load Cell. Application of a side load can bend and damage the load cell.

Caution
Exercise caution when lifting the Drill Head, as there will be very little clearance between the Drill Head and the top of the Tower. If the Drill Head is pulled too high, damage to the Drill Head, the Drill Cable, or Tower components can occur.

- 2.3 Being careful not to bend the Drill Head's neck, lift the Drill Head and place it over the Weight Stack. Lower the Drill Head onto the Weight Stack so that the weight stack adaptor on the drill head mates with the weight stack.
- 2.4 Clamp the 2 sections together using a weight stack collar clamp, after inspecting the collar to make sure it is not cracked or otherwise damaged.
- 2.5 Inspect the weight stack adaptor attached to the drill head to make sure there are no missing or loose screws.
- 2.6 Attach the drill cable weight strength member to the weight bearing pin on the drill head. Lock the pin in place and place tape around the pin to make sure the cotter pin doesn't come loose.

## **Main Hole Drilling Prep**

- 2.7 Slowly winch up with the drill cable reel until all the weight of the drill head and weight stack is taken up by the drill cable.
- 2.8 Disconnect the Weight Stack safety strap, but leave the drill head safety strap in place.  
  
Disconnect the Weight Stack elevator.
- 2.9 Using a ladder, attach the Drill Cable electrical connector to the Drill Head.
- 2.10 Check that the Drill Head is operational by applying power and checking for meaningful data output. See Drill Startup Procedure – South Pole – 20050929 by Jack Ambuel.
- 2.11 Using the main drill cable reel, slowly lower the drill head and weight stack down the hole until the top of the drill head is at a convenient height for attaching the main drill hose to the drill head.

## Main Hole Drilling Prep

### 3. Reconfiguring the Return Water Hose and Preparing to Drill

#### Caution

Water flow through the Drill Supply and Return Water Hoses is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 2.5. If Step 2.5 cannot be completed within 60 minutes, back out and restore water flow within the hose at 50 gpm for at least 60 minutes before starting Step 2.1 again.

- 3.1 Request that the DCC Operator turn off heaters and pumps supplying water to the Surface Hoses.

Record the time at which water flow stops.

- 3.2 Close the valves at the ends of the Drill Supply and Return Water hoses.

**Action:** Drill Supply Hose Valve → Closed

**Action:** Return Water Hose Valve → Closed

- 3.3 Inside the Tower, disconnect the Main Supply Hose from the Return Water Hose.

- 3.4 Connect the main drill hose to the drill head using hose clam shell connectors and open the drill supply hose valve

**Action:** Drill Supply Hose Valve → open

#### Note

The next step (3.4) needs to be performed only if it looks like there will be a significant delay between commencing main hole drilling and lowering the submersible pump. If the return water hose can be attached to the submersible pump and back flushing down the return water line and pump can be done in less than 60 minutes, then the return water hose does not need to be looped back to the bypass valve and can be left hanging in the tower until ready to be connected to the return water pump



## Main Hole Drilling Prep

- 3.4 if required (see note above), connect the Return Water Hose to the Main Hose Reel Bypass valve on the Drill Supply Hose Reel using the 2.5" blue hose as an adaptor hose.

**Action:** Return Water Hose Valve → Open

**Action:** Drill Supply Hose Reel Valve → Open

**Action:** Return Water Hose Reel Valve → Open

**Action:** Drill Supply Hose Reel Bypass Valve → Open

**Action:** Drill Supply Hose Reel Valve → Open

The Drill Supply Hose Reel Bypass Valve should be opened only enough to allow some flow through the Return Water Hose.

- 3.5 Request that the DCC Operator restore water flow through the hoses at 50 gpm and at 88°C.
- 3.6 Remove all remaining safety straps from the Drill.
- 3.7 Commence drilling at 50gpm flow rate and at about 0.5m/min drill speed while preparing the return water pump for installation down hole.
- 3.8 Set the zero point for the payout meter when the widest part of the caliper is at the Tower floor level.
- 3.9 When the drill head is past the tower and down the hole install the kick plate assembly over the hole.


REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
REVISION	-	-	-	-	-	-	-	-	-										

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1	15	<b>Antarctic Astronomy &amp; Astrophysics Research Institute</b> MADISON, WISCONSIN					
2	16	TITLE					
3	17	<b>ICECUBE</b>					
4	18	<b>SUBMERSIBLE PUMP LOWERING</b>					
5	19	<b>ENHANCED HOT WATER DRILL</b>					
6	20						
7	21	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
8	22	SC	10/27/05	JC/FF	10/27/05	HL	10/27/05
9	23	DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
10	24	AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05
11	25	FILENAME	8510-0362.0510.doc		PROJECT NO.	8510	
12	26			SCALE	SIZE	SHEET	
13	27	DRAWING NO.	8510-0362		NA	A	1 of 8
14	28						

## **Submersible Pump Lowering**

References:

8510-0124 Drilling Operations Hazard Analysis  
8510-0108 Tower Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis

Requirements:

Personnel: 5 Drillers, all carrying radios  
Equipment: Safety gloves, 60m ropes, power drill with 6mm hex bit, 2 three-pulley blocks, tape, choker bands, cargo straps

Assumptions:

The Main Drill is in the hole.

The Return Water Hose and Combo Cable have been run into the Tower. The Return Water Hose, with a 50m 1 ½" extension, is connected to the Drill Supply Hose Reel Bypass through a port in the Tower Wall.

The Return Water Combo Cable Reel is on the TOS Reel Stop network.

## Submersible Pump Lowering

### Caution

Do not allow objects, especially those heavier than water, to fall into the hole. An object dropped into the hose will lodge at the bottom of the hole and interfere with subsequent drilling activities.

When possible, keep a cover over the hole.

### Warning

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the focus of any emergency, and is where your attention should be focused as much as practical.

### Warning

For the duration of this procedure, during any operation in which the Submersible Pump is being raised or lowered using the Return Water Hose or the Electrical Combo Cable, there must be one operator standing by at each reel brake, and the brakes must be applied upon indication that any sort of an emergency condition has occurred.

#### 1. Reconfiguring the Return Water Hose

- 1.1 Rotate the Return Water Hose Reel to clear the 1½" hose from the reel. Drag the hose off the reel, and run it in lines between the reel and the Tower, avoiding walking beneath the Drill Supply Hose.

When the Return Water Hose begins to leave the Return Water Hose Reel, drag the end of the hose to the base of the Tower, and tie it off there.

- 1.2 With one person in the Tower, one person outside the Tower where the 1½" hose exits the Tower, and one person out on the surface of the snow arranging the 1½" hose into serpentine loops on the snow, haul the 1½" hose down through the Tower and out onto the snow.

## Submersible Pump Lowering

- 1.3 When there is no slack left in the 1½" hose, tie a rope to the end of the Return Water Hose, and sling the rope over the Return Water Hose Crescent, and down into the Tower.

Tie one 3-pulley block to the Tower floor.

Connect one 3-pulley block to the Tower Winch.

Run the rope through the 3-pulley blocks, and tie the rope off to the Tower floor.

- 1.4 When the rope is secured to the Tower floor, release the Return Water Hose tie-off outside the Tower.

- 1.5 Raise the Tower Winch, dragging the Return Water Hose into the Tower.

When the end of the Return Water Hose has reached a comfortable working height, tie the hose off to a Tower anchor.

Remove the blocks from the Tower Winch and Tower floor.

### Caution

Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 2.8.

- 1.6 **Action:** Return Water Hose Valve → Closed

Close the valve on the end of the 1½" hose.

**Action:** Drill Supply Hose Reel Bypass Valve → Closed

- 1.7 Disconnect the 1½" hose extension from the Return Water Hose.

Drag the remaining 1½" hose from the Tower.

- 1.8 Walk the 1½" hose clear of water, and store the hose.

- 1.9 Connect a 1½" heated hose between the Drill Supply Hose Reel Bypass Valve and the Return Water Hose Reel Bypass Valve.

## Submersible Pump Lowering

### 2. Lowering the Submersible Pump

- 2.1 Attach a choker band to the top of the Submersible Pump and securely tape the band to the Pump to prevent slippage.

Attach the other end of the choker band to the Tower hoist.

Note
For greater ease of handling, the Submersible Pump should be placed in the Tower instead of the TOS.

- 2.2 With one person operating the hoist, and three people guiding the Pump, lift the Pump upright near the hole.
- 2.3 Use a portable drill with 6 mm hex head to attach the Return Water Hose to the Submersible Pump.
- 2.4 One person operating the Return Water Reel Pendant

Using the Return Water Hose Reel, take up any slack in the Return Water Hose. Then proceed further until the Return Water Hose has taken over support of the Submersible Pump from the Tower hoist.

Note
IVG markings on the Return Water Hose are approximately 0.3m apart.

- 2.5 Tape the pressure sensor to the Submersible Pump 0.3m above the Pump intake.

Tape the temperature sensor 0.6m above the pump.

- 2.6 **Verify:** Return Water Pump Motor Controller (V3) – Off

Attach the Electrical Combo Cable to the pump connector.

Attach the Electrical Combo Cable to the pressure and temperature sensors attached to the pump.

Attach the Electrical Combo Cable Load Bearing Shackle to the choker band.

Tape any loose wiring and connectors to the pump.

## Submersible Pump Lowering

### Caution

The Combo Cable must be disconnected before the Combo Cable Reel can be rotated. Because the Combo Cable Reel lacks slip rings, the Cable will be damaged if the Reel is rotated with the Cable attached to the TOS.

- 2.7 Confirm that the jumper cable between the Electrical Combo Cable Reel and the TOS is disconnected at the Reel end.

### Note

Make sure that the siphon required in this step is established at the SES.

- 2.8 **Action:** Return Water Hose Valve → Open

Open the Bypass Valves on the Drill Supply and Return Water Hose Reels to establish flow in the Return Water Hose. This prevents the pump from freezing while being lowered.

### Warning

In an emergency, failure to engage the Return Water Hose and Electrical Combo Cable Reel brakes can result in injury or hardware damage.

- 2.9 One person operating Return Water Pump Cable Reel **and** its brake  
 One person operating Return Water Hose Reel pendant (*observe reels and cable slack through the window*)  
 One person taping the electrical Combo Cable to the Return Water Hose

**Action:** Return Water Hose Reel Hydraulic Brake → Released  
**Verify:** Return Water Hose Reel Hydraulic Brake – Released

**Action:** Electrical Combo Cable Reel Hydraulic Brake → Released  
**Verify:** Electrical Combo Cable Reel Hydraulic Brake – Released

## Submersible Pump Lowering

### Note

The Electrical Combo Cable should have a little slack when lowering or raising the Submersible Pump.

This is not because the Electrical Combo Cable cannot support the weight of the Submersible Pump. Instead, it is to prevent the two Reel drive motors from fighting for control during the pump lowering process.

The Combo Cable must always be lowered in synch with the Return Water Hose such that it is not taking load, but not slack enough that it touches the ground.

### Warning

Under no circumstances should the Electrical Combo Cable be allowed to run slack and coil itself on the ground.

Allowing a slack Electrical Combo Cable to rest on the ground presents a whipping hazard should rotational control of both reels be lost.

- 2.10 Detach the choker band from the Tower hoist.
- 2.11 Position the Submersible Pump into the hole such that the water intake is level with the Tower Floor.

Mark this position as zero depth.

### Note

IVG markings on the Return Water Hose are approximately 0.3m apart.

- 2.12 Reel the Submersible Pump into the hole. Make sure that at all times, the Return Water Hose is bearing the weight of the pump, and that there is some slack in the Electrical Combo Cable, so that it does not bear any of the pump's weight.

At 3m intervals, tape the Electrical Combo Cable to the Return Water Hose. Mark the bands with a depth value, using the 0m depth position as a reference.

Use the beam light to determine when the Submersible Pump enters the water.



## Submersible Pump Lowering

- 2.13 Continue to lower the Submersible Pump until it reached a depth of 8m (as measured by the hose markings).

**Action:** Return Water Hose Reel Hydraulic Brake → Engaged

**Verify:** Return Water Hose Reel Hydraulic Brake – Engaged

- 2.14 Take up any slack in the Electrical Combo Cable.

**Action:** Electrical Combo Cable Reel Hydraulic Brake → Engaged

**Verify:** Electrical Combo Cable Reel Hydraulic Brake – Engaged

- 2.15 **Verify:** Return Water Pump Motor Controller – Off

Remove the lockout from the Return Water Pump Motor Controller.

Connect the Pump Extension Cable between the TOS and the Electrical Combo Cable connector on the Reel.

Connect the Temperature and Pressure cables.

- 2.16 Terminate the water backflow established in Step 2.8, and position valves for normal operation.

**Action:** Return Water Hose Reel Bypass Valve → Closed

**Action:** Drill Supply Hose Reel Bypass Valve → Closed

- 2.17 **Action:** Return Water Pump Motor Controller → On

**Verify:** Return Water Pump Motor Controller – On

**Action:** Return Water Pump Motor Speed → 2700 RPM

**Verify:** Return Water Pump Motor Speed – 2700 RPM

**Verify:** Downhole Pressure Sensor – 8m or greater.

If Downhole Pressure does not exceed 8m, reposition the pump by executing "Submersible Pump Repositioning."

Adjust pump RPMs as necessary to maintain the water level at 8m.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document		10/27/05
	A	Annual review	10/24/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	A	A	A	A	A	A	A											

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1	15	Antarctic Astronomy & Astrophysics Research Institute MADISON, WISCONSIN																							
2	16																								
3	17	TITLE																							
4	18	ICECUBE																							
5	19	Main Hole Drilling																							
6	20																								
7	21	ORIGINATOR			DATE			ENGINEER			DATE			CHECKER 1			DATE								
8	22	Alan El-Cheikh			10/10//07																				
9	23	CHECKER 2			DATE			QUALITY ASSURANCE			DATE			PROJECT APPROVAL			DATE								
10	24							Tim Brenner			10/24/07														
11	25	FILENAME									8510-0363									PROJECT NO.			8510		
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13	27	DRAWING NO.									SCALE			SIZE			SHEET								
14	28	8510-0363															1 of 7								

8510-0363  
**Main Hole Drilling**

References:

- 8510-0106 Drill Head Supply Hose Hazard Analysis
- 8510-0114 Cable Reel Hazard Analysis
- 8510-0122 Drill Control System Hazard Analysis
- 8510-0107 Drill Hose Reel Hazard Analysis
- 8510-0124 Drilling Operations Hazard Analysis
- 8510-0219 Return Water Cable Reel Hazard Analysis
- 8510-0115 Return Water Hose Reel Hazard Analysis
- 8510-0108 Tower Hazard Analysis
  
- 8510-0365 Drilling Shift Handover
- 8510-0362 Submersible Pump Lowering

Requirements:

- Personnel: Full team of 8 drillers with radios
- Equipment: Tape

Assumptions: The Drill has been assembled, and is just below the Tower floor, with water flowing and at a drilling temperature of 88°C.

The Return Water Hose is in the Tower. It may or may not be attached to the Drill Supply Hose Reel Bypass through a Tower wall port.

**Note**

In general, during drilling, the Drilling Team members are distributed this way:

- 1 in the DCC walking the SES systems
- 1 in the DCC with an assistant operating the systems
- 2 at the SES performing maintenance and repair
- 1 at the TOS operating Drill systems
- 1 in Tower banding
- 1 walking the TOS

**Caution**

At all times, while lowering the Drill, monitor the Level Winds on the Reels. The Level Winds should be adjusted as needed to prevent damage to the Hoses and Reels.

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**Main Hole Drilling**

**Caution**

At all times, while lowering the Drill, monitor the inclinometer and both Load Cells. If any measurement exceeds tolerances, perform corrective actions.

**Caution**

Do not drop any objects into the hole while drilling. Objects in the hole, especially metallic ones, can result in an angled or non-circular hole.

**Warning**

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the area where an emergency occurs, and is where your attention should be focused as much as practical.

1. Lowering the Drill and Preparing the submersible pump

**Note**

Water through the Drill Supply Hose at high temperatures is best specified in increments of 7.5 gpm. This is because each heater in an MHP supplies 7.5 gpm at 88 °C.

- 1.1 Request that the DCC Operator ramp the flow rate to 100 gpm, and ramp the water temperature to 88 °C.

**Note**

IVG markings on the Drill Supply Hose are approximately 0.3m apart.

- 1.2 Lower the Drill at ~1m/min.

At approximately every 3m, tape the Drill Supply Hose to the Drill Cable, with 3 bands of tape overlapping ~25%.

- 1.3 While the drill is being lowered, commence positioning of the submersible pump down hole by following the "Submersible Pump Lowering" Procedure.

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**Main Hole Drilling**

Note
The Weight Stack is 18.4m in length.

Caution
To prevent Drill damage, the water flowing through the Drill must be at 88 °C before the Drill leaves the firm and enters the ice.  The ramp to 88 °C was started in Step 1.1, and should be completed ~18m before the Drill starts to leave the firm.

- 1.4 Note the depth at which the Drill Head Pressure Sensor enters the water.

When the entire Drill is below the bottom of the firm ice, stop the downward progress of the Drill for 10 minutes, so that a “bulb” can be created. The “bulb” is a wider section of the hole in which the Submersible Pump can be placed.

The added width is intended to allow the Submersible Pump, Drill Cable, and Drill Supply Hose to pass by one another without interference.

Note the depth at which the “bulb” is created.

- 1.5 While the “bulb” is started, continue execution of “Submersible Pump Lowering” Procedure. Before lowering the pump down to its operating depth, make sure the Drill has cleared well past the depth to which the Submersible Pump will be lowered.
- 1.6 When lowering of the Drill begins again, determine where the widest point in the “bulb” is located using the Drill Calipers, and use that as the target depth for the Submersible Pump.

2. Drilling the Hole

- 2.1 Once the Submersible Pump has been lowered and activated, request that the DCC Operator ramp flow to 200 gpm and 88 °C.

8510-0363  
**Main Hole Drilling**

<b>Note</b>
IVG markings on the Drill Supply Hose are approximately 0.3m apart.

- 2.2 Lower the Drill through the ice at the recommended target speed calculated by the hole model and displayed on the Drill Computer.

At approximately every 3m, tape the Drill Supply Hose to the Drill Cable, with 3 bands of tape overlapping ~25%.

<b>Caution</b>
<p>The Drill Head can be damaged by oscillations in its downward motion that can cause it to impact the ice.</p> <p>The Drill Head is oscillating if:</p> <ul style="list-style-type: none"><li>• The Drill Supply Hose load cell varies over short durations by more than 200 lbs.</li><li>• The Drill Weight Stack load cell disagrees with the payout model by more than 200 lbs.</li><li>• The Drill Accelerometer shows a value more than 1g from the “at rest” value.</li></ul> <p>If any of these conditions are observed, take corrective action immediately. Corrective action will typically include a reduction of drill speed or stopping payout until the oscillations stop.</p>

<b>Caution</b>
<p>Do not allow hoses or cables to become twisted as the Drill is lowered through the ice.</p> <p>If the Drill Supply Hose develops twists, use the Hose Wrench to remove the twist.</p>

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**Main Hole Drilling**

2.3 Monitor the following parameters, and adjust Drill speed as appropriate:  
Verify that Drill inclination  $< 0.1^\circ$ .

Verify that there are no oscillations in the load cells, the Drill, the Drill Cable/Hose, or the Drill Accelerometer.

Use the Drill Caliper measurements to verify that the hole diameter exceeds 0.34m.

Verify that there is substantial agreement between the payout model, and load cell values for the Weight Stack, Drill Supply Hose, and Drill Cable.

At all times, monitor temperature and flow at the Drill, and adjust the Drill speed accordingly.

Every ten minutes, log depth, velocity, caliper, water flow and temperature, tilt, rotation, tension, power delivery, heading, and the accelerometer.

Every hour, log the fuel tank depth.

Every half hour do a walk around the winches to verify that all is well, brakes are deactivated and the level winds are tracking properly. Adjust level winds if necessary.

**Caution**

It is very important that the level winds are continuously monitored, especially as they reach the end of their travel in one direction and are about to change direction.

If the level winds are mistracking, they could damage the hose or drill cable.

If the level winds do not change direction when they reach the end of their travel, they roller screw driving the level winds will cause severe damage to the winch system.

At shift change, use the "Drilling Shift Handover" procedure.

If, at any point, hot water delivery to the Drill Head is completely lost, stop the drill, record the payout meter value for later use, pull the drill up 10 m and wait until the problem is rectified.

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**Main Hole Drilling**

2.4 Drill to 2500m.

When the Drill reaches 2500m, stop downward motion, and dwell for 15 minutes at full water flow.

As the Drill depth approaches 2500m, transition to “Main Hole Reaming and Handover.”



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
REVISION	-	-	-	-	-	-	-	-	-										

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4	18	<b>ICECUBE</b>																	
5	19	<b>MAIN HOLE REAMING AND HANDOVER</b>																	
6	20	<b>ENHANCED HOT WATER DRILL</b>																	
7	21	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE												
8	22	SC	10/27/05	JC/FF	10/27/05	HL	10/27/05												
9	23	DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE												
10	24	AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05												
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12	26																		
13	27	DRAWING NO.	8510-0364				SCALE	SIZE	SHEET										
14	28						NA	A		1 of 14									

## Main Hole Reaming and Handover

### References:

8510-0106 Drill Head Supply Hose Hazard Analysis  
8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0107 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis  
8510-0108 Tower Hazard Analysis

### Requirements:

Personnel: Full team of 8 Drillers with radios  
Equipment: none

Assumptions: Drill is approaching the target depth of 2500m.

## Main Hole Reaming and Handover

### Caution

At all times, while raising the Drill, monitor the Level Winds on the Reels. The Level Winds should be adjusted as needed to prevent damage to the Hoses and Reels.

### Caution

Do not allow objects, especially those heavier than water, to fall into the hole. An object dropped into the hose will lodge at the bottom of the hole and interfere with subsequent drilling activities.

When possible, keep a cover over the hole.

### Warning

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the focus of any emergency, and is where your attention should be focused as much as practical.

1. Reaming the Hole
  - 1.1 Determine the depth of the Submersible Pump, and add 10m to that depth. This is the target depth at which reaming should stop. This value is required for Step 1.7.
  - 1.2 Ramp the downward Drill velocity to 0m/min as the target depth of 2500m is reached.  
  
Dwell for 30 minutes at 0m/min when 2500m is reached.
  - 1.3 Ramp the upward Drill velocity to ~3m/min. This is the nominal target velocity, but the instantaneous velocity will vary.
  - 1.4 As the Drill moves upward, one Driller should remove tape from the Drill Supply Hose and Drill Cable.

## Main Hole Reaming and Handover

- 1.5 Use Drill Caliper measurements and analytical models to determine the speed with which the Drill should be raised. The TOS Computer screen supplies the target speed.

<b>Note</b>
If the Drill, Calipers, and models are all operating correctly, then the hole diameter should exceed the 0.45m target after 30 hours.

- 1.6 At 500m depth, contact the Deployment Lead to begin the process of handing the hole over to the Deployment Team.
- 1.7 As the target depth calculated in Step 1.1 is reached, ramp the Drill speed to 0 m/min.
- 1.8 Request that the DCC Operator configure with the Idle Pump set at 25 gpm with a water temperature of 38 °C.
- 1.9 Execute "Submersible Pump Retrieval."

REVISIONS				
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-	NA	Original Document		
	A	Annual review	10/24//07	TCB

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**Antarctic Astronomy & Astrophysics Research Institute  
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**TITLE**

**ICECUBE  
Drilling Shift Handover**

ORIGINATOR	DATE	ENGINEER	DATE	CHECKER	DATE
Alan El-Cheikh	10/19//07				

CHECKER	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
Tim Brenner			10/24/07		

<b>FILENAME</b>	8510-0365	<b>PROJECT NO.</b>	8510
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<b>DRAWING NO.</b>	8510-0365	<b>SCALE</b>		<b>SIZE</b>		<b>SHEET</b>	1 of 2
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## Drilling Shift Handover

### 1. DCC-based Hand Over Between Teams

- 1.1 The members of the oncoming shift are required at the DCC at shift start.

Members of the team should receive a verbal handover of status and configuration from counterparts on the departing team.

The oncoming Shift Lead should review the Drilling Log, and then receive a verbal briefing from the departing Shift Lead.

- 1.2 The oncoming Shift Lead should inspect the SES, including the following:
- Fuel levels in the Main Tanks, Rod Well hoses and cables, Heaters
  - Verify no leaks in the Water Tanks
  - Monitoring system (including webcams) operation
- 1.3 The oncoming team should hold a short team briefing, with meeting notes recorded, which includes the following:
- Team members present
  - Each team member reports on the handover received from counterparts
  - Potential safety concerns for upcoming work
  - Procedure changes or deviations made or anticipated

### 2. TOS-based Hand Over Between Teams

- 2.1 The TOS team should move to the TOS, where the oncoming Shift Lead or Deputy Shift Lead should survey:
- Tower, Crescents, and Tower Winch from the Tower upper deck.
  - Tower Winch is operating correctly
  - Location and stability of anchors
  - Any hardware that must be used (e.g. temperature or pressure sensors) is available at the TOS, and is
- 2.2 Members of the oncoming shift should check that the Drill Head, Firm Drill, Weight Stack, and Submersible Pump are secured, as appropriate.

### 3. Shift Handover

- 3.1 Upon notification by the oncoming Shift Lead that the handover is complete, the off-going Shift Lead should identify a natural transition point, and at that point, the oncoming team should take over drilling activities at the DCC and TOS.
- 3.2 The departing team should perform housecleaning tasks if necessary, including removal of trash from the Tower floor.

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-	NA	Original Document	10/01/05	

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TITLE					
<b>ICECUBE SUBMERIBLE PUMP REPOSITIONING ENHANCED HOT WATER DRILL</b>					
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
SC <i>[Signature]</i>	10/27/05	JC/FF <i>[Signature]</i>	10/27/05	HL <i>[Signature]</i>	10/27/05
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
AA/TH <i>[Signature]</i>	10/27/05	MAZ <i>[Signature]</i>	10/27/05	RJP <i>[Signature]</i>	10/27/05
FILENAME	8510-0366.0510.doc			PROJECT NO.	8510
DRAWING NO.	8510-0366		SCALE	SIZE	SHEET
			NA	A	1 of 6

## **Submersible Pump Repositioning**

**References:**

- 8510-0124 Drilling Operations Hazard Analysis
- 8510-0108 Tower Hazard Analysis
- 8510-0219 Return Water Cable Reel Hazard Analysis
- 8510-0115 Return Water Hose Reel Hazard Analysis
  
- 8510-0362 Submersible Pump Lowering

**Requirements:**

- Personnel:** 4 Drillers, all carrying radios
- Equipment:** safety gloves, tape

**Assumptions:** The Combo Cable Reel drive is installed and warmed up.



## Submersible Pump Repositioning

### Caution

Do not allow objects, especially those heavier than water, to fall into the hole. An object dropped into the hose will lodge at the bottom of the hole and interfere with subsequent drilling activities.

When possible, keep a cover over the hole.

### Warning

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the focus of any emergency, and is where your attention should be focused as much as practical.

### Warning

For the duration of this procedure, during any operation in which the Submersible Pump is being raised or lowered using the Return Water Hose or the Electrical Combo Cable, there must be one operator standing by at each reel brake, and the brakes must be applied upon indication that any sort of an emergency condition has occurred.

1. Repositioning the Submersible Pump
  - 1.1 Assemble the full team of four people and review the procedure with anyone new to the procedure, or with a role they have not previously performed.

## Submersible Pump Repositioning

### Caution

Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved at the end of Step 1.8. If Step 1.8 cannot be completed within 60 minutes, and the Submersible Pump remains underwater, perform "Submersible Pump Lowering" – Step 4.23 for at least 20 minutes before proceeding.

- 1.2 **Action:** Return Water Pump → Off  
**Verify:** Return Water Pump – Off

### Warning

Failure to allow the motor controller capacitors to discharge fully presents an electrical shock hazard.

- 1.3 **Action:** Return Water Pump Motor Controller → Off  
**Verify:** Return Water Pump Motor Controller – Off

Apply a lockout to the Return Water Pump Motor Controller.

Wait five minutes to allow the motor controller capacitors to discharge.

### Caution

The Combo Cable must be disconnected before the Combo Cable Reel can be rotated. Because the Combo Cable Reel lacks slip rings, the Cable will be damaged if the Reel is rotated with the Cable attached to the TOS.

- 1.4 Disconnect the Return Water Pump Cable extension from the Electrical Combo Cable at the reel end.

Disconnect the Temperature and Pressure Sensor cables from the Cable Reel.

- 1.5 **Verify:** Return Water Hose Reel Pendant – Active  
**Verify:** Electrical Combo Cable Reel Pendant – Active  
**Verify:** Return Water Hose Reel Motor – Humming  
**Verify:** Electrical Combo Cable Reel Motor – Humming

## Submersible Pump Repositioning

### Note

Hydraulic brake instructions are clearly placarded on the reel.

- 1.6 **Action:** Return Water Hose Reel Brake → Released  
**Verify:** Return Water Hose Reel Brake – Released

- Action:** Electrical Combo Cable Reel Brake → Released  
**Verify:** Electrical Combo Cable Reel Brake – Released

### Note

The Electrical Combo Cable should have a little slack when lowering or raising the Submersible Pump.

This is not because the Electrical Combo Cable cannot support the weight of the Submersible Pump. Instead, it is to prevent the two Reel drive motors from fighting for control during the pump lowering process.

The Combo Cable must always be lowered in synch with the Return Water Hose such that it is not taking load, but not slack enough that it touches the ground.

### Warning

Under no circumstances should the Electrical Combo Cable be allowed to run slack and coil itself on the ground.

Allowing a slack Electrical Combo Cable to rest on the ground presents a whipping hazard should rotational control of both reels be lost.

- 1.7 Add a small amount of slack to the Electrical Combo Cable.
- 1.8 Reposition the pump to a depth of 8m by following Steps 2.9, 2.12 – 2.15, and 2.17 in “Submersible Pump Lowering.” Be aware that there are Note and Warning blocks that apply to several procedure steps.

## Submersible Pump Repositioning

### 2. Restoring Pump Function

Note
Hydraulic brake instructions are clearly placarded on the reel.

- 2.1 **Action:** Return Water Hose Reel Brake → Engaged  
**Verify:** Return Water Hose Reel Brake – Engaged

- Action:** Electrical Combo Cable Reel Brake → Engaged  
**Verify:** Electrical Combo Cable Reel Brake – Engaged

- 2.2 Connect the Return Water Pump Cable extension to the Electrical Combo Cable at the reel end.

Connect the Temperature and Pressure Sensor cables to the Cable Reel.

- 2.3 If the Pressure Sensor does not indicate a depth of at least 8m, then start again at Step 1.4 to position the Submersible Pump at 8m depth.

- 2.4 Remove the lockout from the Return Water Pump Motor Controller.

- 2.5 **Action:** Return Water Pump Motor Controller → On  
**Verify:** Return Water Pump Motor Controller – On

Note
Execution of Step 2.6 ends the freezing hazard identified in Step 1.2.

- 2.6 **Action:** Return Water Pump → On  
**Verify:** Return Water Pump – On

8510-0367

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-	NA	Original Document	10/01/05	

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3	17	<b>ICECUBE</b>					
4	18	<b>SUBMERIBLE PUMP RETRIEVAL</b>					
5	19	<b>ENHANCED HOT WATER DRILL</b>					
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## **Submersible Pump Retrieval**

### References:

8510-0124 Drilling Operations Hazard Analysis  
8510-0108 Tower Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis

### Requirements:

Personnel: 5 Drillers, all carrying radios  
Equipment: Safety gloves, 60m ropes, power drill with 6mm hex bit, 2 three-pulley blocks, tape, choker bands, cargo straps

### Assumptions:

The hole has been reamed, and based upon discussions between the Drill and Deployment Teams, the Drill Team is comfortable removing the Submersible Pump.

The Combo Cable Reel drive is installed and warmed up.

There is a yale grip attached to the Return Water Hose 6-7m from the end of the hose.

## Submersible Pump Retrieval

### Warning

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the focus of any emergency, and is where your attention should be focused as much as practical.

### Warning

For the duration of this procedure, during any operation in which the Submersible Pump is being raised or lowered using the Return Water Hose or the Electrical Combo Cable, there must be one operator standing by at each reel brake, and the brakes must be applied upon indication that any sort of an emergency condition has occurred.

1. Preparing to Raise Pump
  - 1.1 Assemble the full team of five people and review this procedure with anyone new to the procedure, or with a role they have never performed.

### Caution

Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 1.5.

- 1.2 **Action:** Return Water Pump → Off  
**Verify:** Return Water Pump – Off

## Submersible Pump Retrieval

### Warning

Failure to allow the motor controller capacitors to discharge fully presents an electrical shock hazard.

- 1.3 **Action:** Return Water Pump Motor Controller → Off  
**Verify:** Return Water Pump Motor Controller – Off

Wait five minutes to allow the motor controller capacitors to discharge.

### Caution

The Combo Cable must be disconnected before the Combo Cable Reel can be rotated. Because the Combo Cable Reel lacks slip rings, the Cable will be damaged if the Reel is rotated with the Cable attached to the TOS.

- 1.4 Disconnect the Return Water Pump Cable extension from the Electrical Combo Cable at the reel end.

Disconnect the Temperature and Pressure Sensor cables from the Cable Reel.

- 1.5 Open the Bypass Valves on the Drill Supply and Return Water Hose Reels to establish flow in the Return Water Hose. This prevents the pump from freezing while being lowered.

- 1.6 **Verify:** Return Water Hose Reel Pendant – Active  
**Verify:** Electrical Combo Cable Reel Pendant – Active  
  
**Verify:** Return Water Hose Reel Motor – Humming  
**Verify:** Electrical Combo Cable Reel Motor – Humming



## Submersible Pump Retrieval

### 2. Raising the Submersible Pump

#### Note

Hydraulic brake instructions are clearly placarded on the reel.

#### Warning

In an emergency, failure to engage the Return Water Hose and Electrical Combo Cable Reel brakes can result in injury or hardware damage.

2.1 **Action:** Return Water Hose Reel Brake → Released  
**Verify:** Return Water Hose Reel Brake – Released

**Action:** Electrical Combo Cable Reel Brake → Released  
**Verify:** Electrical Combo Cable Reel Brake – Released

#### Note

The Electrical Combo Cable should have a little slack when the lowering or raising the Submersible Pump.

This is not because the Electrical Combo Cable cannot support the weight of the Submersible Pump. Instead, it is to prevent the two Reel drive motors from fighting for control during the pump lowering process.

The Combo Cable must always be lowered in synch with the Return Water Hose such that it is not taking load, but not slack enough that it touches the ground.

#### Warning

Under no circumstances should the Electrical Combo Cable be allowed to run slack and coil itself on the ground.

Allowing a slack Electrical Combo Cable to rest on the ground presents a whipping hazard should rotational control of both reels be lost.

2.2 Add a small amount of slack to the Electrical Combo Cable.

## Submersible Pump Retrieval

- 2.3 One person operating the pendant  
One person ready to go to the top of the Tower should the need arise  
One person operating the Tower hoist  
One person by the hole

Raise the Submersible Pump with the Return Water Hose Reel, allowing the Electrical Combo Cable to remain slightly slack.

Remove banding tape from the Return Water Hose and Electrical Combo Cable as it clears the hole.

### Warning

The Tower Winch must support the weight of the Submersible Pump before Return Water Hose is removed.

Failure to do so will cause the Return Water Hose and Electrical Combo Cables to whip, which can cause severe injury to members of the drill team.

- 2.4 When the Submersible Pump has cleared the hole sufficiently to do so, attach the Tower winch to the choker band.

Lift the Tower winch to relieve the load from the Return Water Hose.

- 2.5 Attach a Yale grip to the Return Water Hose between the Crescent and the Return Water Hose Reel.

Secure the Yale Grip to the Crescent with a cargo strap.

## Submersible Pump Retrieval

### Caution

Water flow through the Return Water Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 1.8 of Drill Retrieval.

- 2.6 **Action:** Return Water Hose Reel Valve → Closed

### Caution

Ice formation will damage the Submersible Pump if it is not blown dry and subsequently is allowed to freeze.

- 2.7 Using the Tower air compressor, blow out the Submersible Pump.
- 2.8 Use a portable drill with a 6mm hex head to detach the Return Water Hose from the Submersible Pump.
- Allow any remaining water to drain down the hole.
- Cap the Return Water Hose and tie it off to the side of the Tower.
- 2.9 One person operating the Tower Winch  
Three people guiding the pump
- Use the Tower winch to lift the Submersible Pump fully out of the hole.
- Lower the Submersible Pump to the Tower floor.
- 2.10 Disconnect the Electrical Combo Cable from the Submersible Pump
- Disconnect the Temperature and Pressure Sensors from the Submersible Pump.
- Disconnect the Electrical Combo Cable load bearing shackle from the Submersible Pump.
- Disconnect the Tower Winch from the Submersible Pump.

## Submersible Pump Retrieval

2.11 Store the Submersible Pump out of the way in the Tower.

**Action:** Return Water Hose Reel Hydraulic Brake → Engaged  
**Verify:** Return Water Hose Reel Hydraulic Brake Pressure – 0

**Action:** Electrical Combo Cable Reel Hydraulic Brake → Engaged  
**Verify:** Electrical Combo Cable Reel Hydraulic Brake Pressure – 0

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		Alan El-Cheikh				10/19//07																			
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8510-0368  
**Drill Retrieval**

References:

8510-0106 Drill Head Supply Hose Hazard Analysis  
8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0107 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis  
8510-0108 Tower Hazard Analysis

Requirements:

Personnel: Full team of 8 Drillers with radios

Assumptions:

The Submersible Pump has been removed from the hole.

The Return Water Hose is inside the Tower and capped.

There is agreement between the Deployment Manager and Drill Manager that removing the Drill hardware from the hole is acceptable.

8510-0368  
**Drill Retrieval**

**Warning**

When working in the Tower during periods when cables or hoses have been run into the hole, take care not to turn your back on the hole. If you must turn away from the hole momentarily, step back, and turn partway, so that the hole region is still within your peripheral vision.

The hole is likely to be the focus of any emergency, and is where your attention should be focused as much as practical.

1. Preparing to Remove the Drill

**Caution**

Do not allow hoses or cables to become twisted as the Drill is lowered through the ice.

If the Drill Supply Hose develops twists, use the Hose Wrench to remove the twist.

1.1 Using the Drill Cable, lift the Drill until it hangs just below the Tower floor.

Hand over control of the Drill Supply Hose and Drill Cable from the computer to the pendants.

**Caution**

Water flow through the Main Supply Hose is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 1.8.

1.2 Request that the DCC Operator terminate water flow through the hoses.

**Action:** Drill Supply Hose Reel Valve → Closed

Record the time at which the water flow was stopped.

1.3 Remove the Kickplate from the hole.

8510-0368  
**Drill Retrieval**

**Caution**

Take care when lifting the Drill out of the hole, as there will be very little clearance above the Drill. Raising the Drill too high can damage the Drill, the Drill Cable, and the Tower Crescents.

- 1.4 Using the Drill Cable, lift the Drill to a comfortable working height.
- 1.5 Attach a safety strap to the Drill body, below the Calipers.  
Attach the safety strap to the Tower Winch.
- 1.6 Tie off the Drill Supply Hose at the Crescent using the Yale Grip.  
Disconnect the Drill Supply Hose from the Drill, allowing water in the hose to drain down the hole.
- 1.7 Jumper the Return Water and Drill Supply Hoses together. Secure them out of the way of work still in progress near the hole.

**Action:** Drill Supply Hose Reel Valve → Open

**Action:** Return Water Hose Reel Valve → Open

**Note**

Step 1.8 restores water flow through the Drill Supply Hose and starts flow through the Return Water Hose, which was terminated in Step 2.7 of Submersible Pump Retrieval.

- 1.8 Request that the DCC Operator restart water flow through the hoses at 50 gpm.
- 1.9 Using Tower Winch, lift the Drill to an appropriate working height.  
Attach a clamp to the Weight Stack.  
Attach an elevator to the Weight Stack.  
Attach a quick clamp to the Weight Stack.  
Attach a safety strap to the Weight Stack, and tie the safety strap off to an anchor.
- 1.10 Using the Tower Winch and Drill Cable, lower the Drill until the quick clamp is supporting the load.



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**Drill Retrieval**

- 1.11 Using a ladder, disconnect the electrical connector from the Drill. Protect the connector.

**Caution**

Do not apply side loads to the Drill Head Load Cell. Application of a side load can bend and damage the load cell.

- 1.12 If this is not the last hole of the season for this Drill Head:

Disconnect the Drill Head from the Weight Stack.

Secure the Drill Head to the wall of the Tower in an upright position.

Disconnect the Drill Cable from the Drill Head, and secure it out of the way.

If this is the last hole of the season for this Drill Head:

The operators of the Tower Winch and Drill Cable Reel pendants must act in coordination to lower the Drill Head to horizontal in its crate.

The weight should initially be supported by the Drill Cable, with the Drill Head vertical. As the Drill is lowered, an increasing portion of the weight should be supported by the Tower Winch. The third person, at the neck, should work to prevent the neck from bending.

At the end, all the weight should be on the Tower Winch, with the Drill Cable slack.

Disconnect the Drill Cable from the Drill Head, and secure it out of the way.

2. Disassembling the Weight Stack

2.1 Attach the Tower Winch to the elevator.

2.2 Using the Tower Winch, raise the Weight Stack to a comfortable working height.

2.3 Release the quick clamp.

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**Drill Retrieval**

- 2.4 Attach a clamp to the next section of the Weight Stack.  
Attach an elevator to the next section of the Weight Stack.  
Attach a quick clamp to the next section of the Weight Stack.  
Attach a safety strap to the next section of the Weight Stack, and tie the safety strap off to an anchor.
- 2.5 Using the Tower Winch, lower the Weight Stack until the load is on the quick clamp.
- 2.6 Remove the couplers connecting the two segments of the Weight Stack.
- 2.7 Using the Tower Winch, lower the top segment of the Weight Stack to the rack.
- 2.8 Remove the elevator from the Weight Stack segment.  
Remove the clamp from the Weight Stack segment.  
Remove the safety strap from the Weight Stack segment.
- 2.9 Perform Step 2 again if there is another segment of the Weight Stack in the hole.
3. Reinstalling the Kickplate
  - 3.1 Reinstall the Kickplate at the hole.  
Replace the hole cover.

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<b>RELOCATION PREP</b>							
<b>ENHANCED HOT WATER DRILL</b>							
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE		
SC	10/27/05	JC/FF	10/27/05	HL	10/27/05		
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE		
AA/TH	10/27/05	MAZ	10/27/05	RJP	10/27/05		
FILENAME	8510-0369.0510.doc			PROJECT NO.	8510		
DRAWING NO.	8510-0369		SCALE	SIZE	SHEET		
			NA	A	1 of 9		

8510-0369  
**Relocation Prep**

References:

- 8510-0107: EHWD Hose Reel Hazard Analysis Summary.
- 8510-0106: EHWD Drill Head Supply Hose Hazard Analysis Summary.
- 8510-0102: EHWD Power Distribution System Hazard Analysis Summary.
- 8510-0114: EHWD Cable Reel Hazard Analysis Summary.
- 8510-0109: EHWD Mobile Drilling Structures & Contained Equipment Hazard Analysis Summary.

8510-0371 Tower Relocation

Requirements:

- Personnel: Raytheon heavy equipment operator, Raytheon General Assistant, DCC operator, 3 drillers with radios
- Equipment: D7, 953 fork lift, 60m Static Rope, safety gloves, 2 three-pulley blocks, power drill with 6mm Hex bit, 4 3m rope lengths.

Assumptions:

The drill head has been disconnected from the cable and properly stored.

The return water pump has been removed from the hole, disconnected from the hose and power combo cable and properly stored.

The Return Water Pump Combo Cable, Drill Cable, and both the Drill Supply and Return Water Hoses are still hanging in the tower and plumbed so that water is circulating through both hoses.

All reel brakes are engaged.

The second TOS/Tower and associated cabling is already in position at the next drill site.

8510-0369  
**Relocation Prep**

1. Removing the Drill Supply Hose and Return Water Hose From the Tower

**Caution**

Water flow through the Surface Hoses, and Main Supply and Return Water Hoses is about to terminate. This presents a freezing hazard, which can result in hardware damage.

To prevent hose and pump damage, water flow must be restored within 60 minutes. This is achieved in Step 2.10. If Step 2.10 cannot be completed within 60 minutes, back out and restore water flow within the hose for at least 60 minutes before starting Step 2.1 again.

**Warning**

For any operation involving guiding the hose on or off the tower, a walk around the tower site must be made prior to the operation to make sure no one is in danger of being hit and injured if control of the hose is lost.

1.1 Request that the DCC Operator turn off the Idle Pump, Charge Pumps, and High Pressure Pumps.

**Action:** Drill Supply Hose Valve → Closed  
**Action:** Return Water Hose Valve → Closed

**Note**

If the two Hose Valves are properly closed, it should take no longer than one minute for any water remaining in the hoses to drain.

1.2 Remove the coupler that connects the Main Supply Hose to the Return Water Hose, and allow the water in each hose to drain down the hole.

8510-0369  
**Relocation Prep**

- 1.3 Cap the end of the main hose using a hose end cap.

Attach a pulley block or carabineer to the Drill Supply Hose end cap.

Attach a pulley block assembly to an anchor point on the tower floor near the hole.

Tie one end of a 60m static rope to the floor and run the rope through the pulleys and a "figure 8" as shown in Fig 1.1 below.

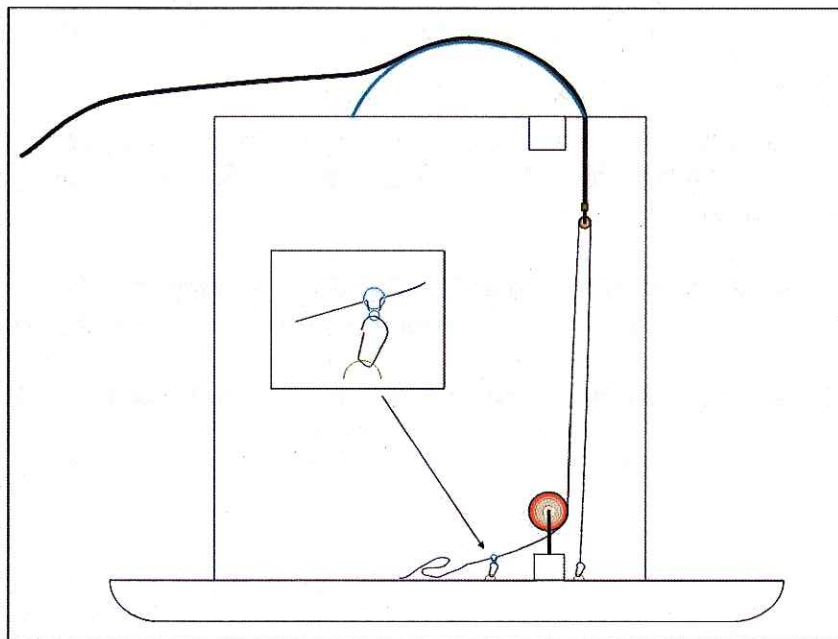


Figure 1.1 – Removing the Drill Supply Hose From the Tower

Slowly wind the Drill Supply Hose back onto the Drill Supply Hose Reel while the person on the rope keeps it taut by applying friction via the "figure 8" belay device.

- 1.4 When the Main Hose has reached the ground, remove the rope and continue to wind the Main Hose onto the Main Hose Reel until about 5m remain on the snow.
- 1.5 **Action:** Main Supply Hose Reel Brake → Engaged  
**Verify:** Main Supply Hose Reel Hydraulic Brake Pressure – 0

**Relocation Prep**

- 1.6 Cap the end of the return water hose using a hose end cap.

Attach a pulley block or carabineer to the return water hose end cap

Attach a pulley block assembly to an anchor point on the tower floor near the hole.

Tie one end of a 60m static rope to the floor and run the rope through the pulleys and a "figure 8" as shown in Fig 2.1 above.

Slowly wind the Return Water Hose back onto the Return Water Hose Reel while the person on the rope keeps it taut by applying friction via the "figure 8" belay device.

- 1.7 When the Return Water Hose has reached the ground, remove the rope, and continue to wind the Return Water Hose onto the Return Water Hose Reel until about 3m remain on the floor.

- 1.8 **Action:** Return Water Hose Reel Brake → Engaged  
**Verify:** Return Water Hose Reel Hydraulic Brake Pressure – 0

- 1.9 Reattach the coupler that connects the Main Supply Hose to the Return Water Hose.

8510-0369  
**Relocation Prep**

**Note**

At 25 gpm, approximately 100 minutes should be required for hot water to make a full circuit through the hoses and hose reels.

**Note**

When step 2.10 is completed, water flow through the hoses will be reestablished, and the freezing hazard will be removed.

- 1.10 **Action:** Drill Supply Hose Valve → Open  
**Action:** Return Water Hose Valve → Open

Request that the DCC Operator turn on the Idle Pump and set the rate to 25 gpm at 50 °C.

Let the hot water make a full circuit through the hoses to prepare for moving the hoses and reels.

Observe that water is dumping into WT1 to verify flow.

Let the hot water circulate for at least 100 minutes to ensure that the hoses and reels are hot soaked.

2. Removing the Drill Cable Reel From the Tower

**Warning**

For the rest of this operation, triggering an E-Stop/Reel Stop at the TOS/Tower site will only shut down the Reels. It will not stop water flow to the hoses or shut down the heaters.

While there should only be minimal flow and temperature (50 gpm and 30-40 °C) from this point on, care must be taken and checks performed with the DCC operator to make sure it is safe to undertake any re-plumbing work. Failure to do so could cause severe burns if the system is inadvertently left running in high flow and high temperature mode.

- 2.1 Perform "E-Stop Reconfiguration" Step 1.



8510-0369  
**Relocation Prep**

**Caution**

Until the drill cable is safely clear of all cable sheaves, the drill cable reel should not be operated. The operation to remove the cable from the tower and clear of the cable sheaves should be performed by hand. Failure to do so could result in damage to the drill cable connector.

- 2.2 One person on the Tower  
One person handling the rope
- Tie a rope onto the cable end.
- 2.3 While the person on the Tower guides the Drill Cable connector over the two sheaves on top of the tower, slowly let the cable play up and out of the Tower.
- Lower the Drill Cable to the surface outside the Tower.
- Guide the cable through the lower sheave on the tower base.
- If necessary, disassemble this Lower and Upper Sheaves to allow the connector to pass through the sheave assembly.
- 2.4 Attach a pendant to the Drill Cable Reel I/O.
- 2.5 **Verify:** Drill Cable Reel Motor Controller V1 – On  
**Verify:** Drill Cable Reel Level Wind Motor Controller V2 – On.
- 2.6 **Action:** Pendant “Computer/ Pendant” Switch → Computer Mode  
**Action:** Pendant “Computer/ Pendant” Switch → Pendant Mode  
**Verify:** Green light on and steady (not flashing)
- 2.7 **Action:** Pendant “Velocity Mode” Switch → Depressed  
**Verify:** Blue Velocity Light – On
- 2.8 **Verify:** Reel Motor – Humming
- 2.9 **Action:** Cable Reel Brake → Disengaged

8510-0369  
**Relocation Prep**

**Caution**

Do not allow the Drill Cable connector to reach the Level Wind. To do so will cause a jam, damaging the Drill Cable and the Cable Reel.

- 2.10 One person with radio watching the Drill Cable Reel  
One person with radio operating the Drill Cable Reel pendant

Slowly wind the cable onto the Drill Cable Reel, leaving approximately 2m free.

Tie the cable tail off so that the connector and cable does not get damaged during relocation.

- 2.11 **Action:** Drill Cable Reel Brake → Engaged  
**Verify:** Drill Cable Reel Hydraulic Brake Pressure = 0
- 2.12 **Action:** Drill Cable Reel Motor Controller → Off  
**Verify:** Drill Cable Reel Motor Controller – Off
- 2.13 **Action:** Drill Cable Reel Level Wind Motor Controller → Off.  
**Verify:** Drill Cable Reel Level Wind Motor Controller – Off.

**Warning**

Completion of Step 2.14 when Step 2.13 has not been verified complete presents an electrical shock hazard.

- 2.14 Disconnect the power cable from the Drill Cable Reel Motor.  
Disconnect the Brake cable from the Drill Cable Reel.  
Disconnect the Resolver cable from the Drill Cable Reel Motor.  
Disconnect the Power cable from the Drill Cable Reel Level Wind Motor.  
Disconnect the resolver cable from the Drill Cable Reel level wind motor.  
Disconnect the E-Stop/ Reel Stop cable from the Drill Cable Reel.

Keep these cables connected to the TOS and temporarily move them out of the way so that the Deployment reel can be moved into position. Some of these cables will be used to power the Deployment Cable Reel.

- 2.15 Disconnect the Drill Cable Reel from its anchors. Attach the anchors to a 953 Fork Lift and remove them from the snow. Store these anchors.

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**Relocation Prep**

2.16 If necessary, hook the 953 Fork to the Drill Cable Reel and drag the reel just far enough away from the operations site such that the Deployment Reel can be moved into position between the tower and the Drill Supply Hose Reel.

3. Removing the Return Water Pump Combo Cable From the Tower

- 3.1 One person on the Tower  
One person operating the Return Water Cable Reel  
One person in the Tower managing the rope

**Verify:** Submersible Pump Motor Controller – Off

3.2 Attach a 60m static rope to the end of the Electrical Combo Cable.

**Caution**

The person in the Tower must guide the Electrical Combo Cable and its connector past any obstacles.

The person managing the rope must keep the tension on the rope and Electrical Combo Cable.

Failure to do this can result in damage to the Electrical Combo Cable or its connector.

- 3.3 **Action:** Electrical Combo Cable Reel Brake → Disengaged  
**Verify:** Electrical Combo Cable Reel Brake – Disengaged

Slowly wind the Electrical Combo Cable over the Tower and onto the Electrical Combo Cable Reel.

Wind the Electrical Combo Cable completely onto the Electrical Combo Cable Reel.

- 3.4 **Action:** Electrical Combo Cable Reel Brake → Engaged  
**Verify:** Electrical Combo Cable Reel Brake Hydraulic Pressure – 0

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**Relocation Prep**

**Note**

The Drill is now in a safe configuration, with all hoses and cables out of the Tower, and water flowing through the hoses outside the Tower.

4. Setting Up the Deployment Reel

**Caution**

The space in front of the Drill Supply Hose Reel must remain clear during equipment moves, so that no hoses or cables become snagged.

- 4.1 One 953 Forklift and operator  
One person with a radio guiding the 953 driver  
One person inside the TOS operating the Deployment Reel pendant

Direct the 953 driver to tow the Deployment Reel into position in front of the Main Hose Reel. See Figure 4.1 for positioning information.

Attach the deployment reel to the anchors which should already be in place. See "Tower Relocation" for anchor locations.

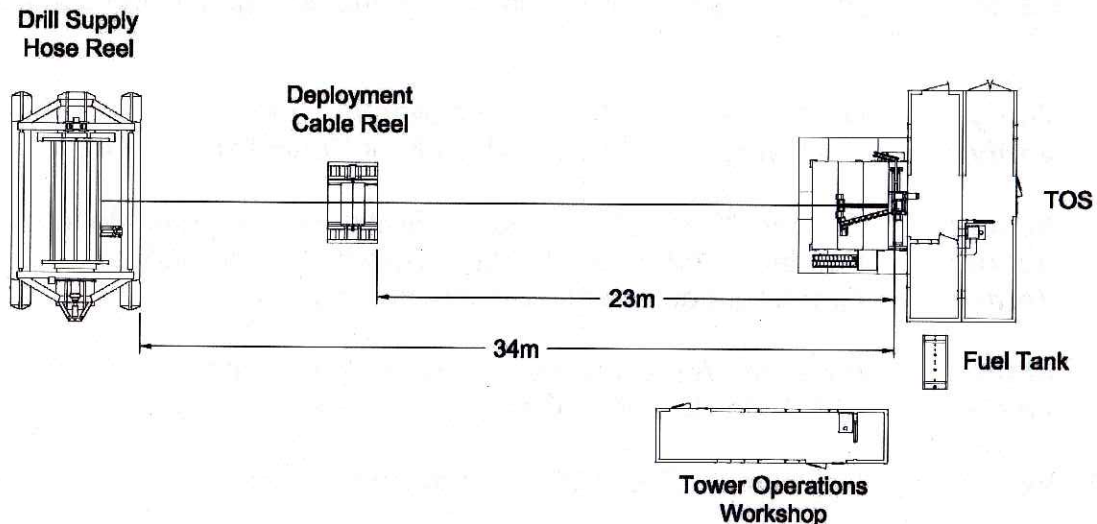


Figure 4.1 – Deployment Reel Layout

8510-0369  
**Relocation Prep**

4.2 **Verify:** DCR Motor Controller V1 – Off

**Warning**

Completion of Step 4.3 when Step 4.2 has not been verified complete presents an electrical shock hazard.

- 4.3 Connect the Drill Cable Reel Power Cable to the Deployment Reel Motor.  
Connect the Drill Cable Reel Encoder Cable to the Deployment Reel Encoder.  
Connect the Drill Cable Reel Brake Cable to the Deployment Reel Brake.
- 4.4 Perform “E-Stop Reconfiguration” Step 2.
- 4.5 Attach a pendant to the Deployment Reel I/O Connector.

**Warning**

Locking pins in the Deployment Reel arms must be removed for the reel dump to work properly. Dumping the Reel is the last resort method for stopping a runaway reel.

- 4.6 Plug in the hydraulic heat for the Deployment Reel.  
Jack the Reel up, and release it.  
Remove the locking pins from the arms, so that the emergency reel dump will work.
- 4.76 **Verify:** Deployment Reel Motor Controller V1 – On  
**Verify:** Deployment Reel Level Wind Motor Controller V2 – On.
- 4.8 **Action:** Pendant “Computer/ Pendant” Switch → Computer Mode  
**Action:** Pendant “Computer/ Pendant” Switch → Pendant Mode  
**Verify:** Green light on and steady (not flashing)
- 4.9 **Action:** Pendant “Velocity Mode” Switch → Depressed  
**Verify:** Blue Velocity Light – On
- 4.10 **Verify:** Deployment Reel Motor – Humming
- 4.11 **Action:** Deployment Reel Brake → Disengaged

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**Relocation Prep**

- 4.12 **Action:** Deployment Cable Reel Motor → Down  
**Verify:** Deployment Cable Reel Motor – On  
**Verify:** Smooth and free reel rotation in forward direction
- Action:** Deployment Cable Reel Motor → Up  
**Verify:** Deployment Cable Reel Motor – On  
**Verify:** Smooth and free reel rotation in reverse direction
- 4.13 Hand the Deployment Reel over to the Deployment team.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document		10/27/05
	A	Annual review	10/24/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

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1	15	<b>Antarctic Astronomy &amp; Astrophysics Research Institute MADISON, WISCONSIN</b>																																			
2	16	<b>TITLE</b>																																			
3	17	<b>ICECUBE Drill Relocation</b>																																			
4	18	<b>ORIGINATOR</b>				<b>DATE</b>				<b>ENGINEER</b>				<b>DATE</b>				<b>ENGINEER</b>				<b>DATE</b>															
5	19	Alan El-Cheikh				10/10/07																															
6	20	<b>CHECKER 2</b>				<b>DATE</b>				<b>QUALITY ASSURANCE</b>				<b>DATE</b>				<b>PROJECT APPROVAL</b>				<b>DATE</b>															
7	21	Tim Brenner								10/24/07																											
8	22	<b>FILENAME</b>									8510-0370									<b>PROJECT NO.</b>									8510								
9	23	<b>DRAWING NO.</b>									8510-0370									<b>SCALE</b>				<b>SIZE</b>				<b>SHEET</b>									
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8510-0370  
**Drill Relocation**

References:

- 8510-0106 Drill Head Supply Hose Hazard Analysis
- 8510-0115 Return Water Hose Reel Hazard Analysis
- 8510-0219 Return Water Cable Reel Hazard Analysis
- 8510-0114 Cable Reel Hazard Analysis
- 8510-0107 Drill Hose Reel Hazard Analysis
- 8510-0108 Tower Hazard Analysis
- 8510-0109 Mobile Drilling Structure Hazard Analysis
- 8510-0002 Drill Camp Layout Seasonal Equipment Site – latest revision
  
- 8510-0372 E-Stop Reconfiguration

Requirements:

- Personnel: Raytheon heavy equipment operator, Raytheon General Assistant, DCC operator, 3 drillers with radios
- Equipment: D7, 953 fork lift, 60m Static Rope, safety gloves, 2 three-pulley blocks, power drill with 6mm Hex bit, 4 3m rope lengths

Assumptions:

The “Relocation Prep” procedure has been completed and deployment is under way.

A Yale Grip is installed on the Main Supply Hose ~7m from the hose end.

Hoses and reels have been pre-heated in preparation for the move.

1. Hose and Cable Preparation

**Warning**

For the rest of this operation, until the E-Stop system is re-established at the new TOS site, there is no E-stop system operational near where the surface and return water hoses are being plumbed and re-plumbed.

While there should only be minimal flow and temperature (25 gpm and 30-40 °C) from this point on, care must be taken and checks performed with the DCC operator to make sure it is safe to undertake any re-plumbing work.

Failure to do so could cause severe burns if the system is inadvertently left running in high flow and high temperature mode.



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**Drill Relocation**

**Warning**

Verify that power is removed before disconnecting power cables. Attempting to remove an energized connector presents an electrical shock hazard.

- 1.1 **Verify:** Return Water Pump Motor Controller V3 – Off

Disconnect the Return Water Pump Cable Extension from TOS connector CD13.

Coil the Cable Extension, and secure it to the Return Water Electrical Combo Cable Reel.

- 1.2 **Verify:** Return Water Hose Reel Motor Controller V4 – Off

Disconnect the return water hose reel motor power cable from TOS connector CD12.

Disconnect the Return Water Hose Reel Motor Resolver cable from Motor Controller V4 inside the TOS.

Disconnect the Return Water Hose Reel-Stop cable from Motor Controller V4 inside the TOS.

Coil the cables and secure them to the Return Water Hose Reel cables for the move.

- 1.3 Disconnect the Return Water Hose Reel from its anchors.

Pull the anchors from the snow with a 953 forklift.

Store the anchors and chains in their storage box.

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**Drill Relocation**

**Warning**

Verify that power is removed before disconnecting power cables. Attempting to remove an energized connector presents an electrical shock hazard.

- 1.4 **Verify:** Return Water Pump Combo Cable Reel Motor Controller – Off

Disconnect the Return Water Pump Combo Cable Reel Motor Power cable at the TOS.

Disconnect the Return Water Pump Combo Cable Reel Motor Reel Stop cable from the Allen-Bradley box.

Coil both cables and secure them to the Combo Cable Reel.

- 1.5 Disconnect the Combo Cable Reel from the Return Water Hose Reel.

Pull the anchors from the snow with a 953 forklift and store anchors and chain on the tower deck. These will be used at the new drill site to which this tower will be relocated.

8510-0370  
**Drill Relocation**

**Warning**

Verify that power is removed before disconnecting power cables. Attempting to remove an energized connector presents an electrical shock hazard.

- 1.6 **Verify:** Drill Supply Hose Reel Motor Controller V6 – Off  
**Verify:** Drill Supply Hose Reel Level Wind Motor Controller V5 – Off

Disconnect the DSHR Drum Motor Power cable from TOS Connector CD5.

Disconnect the DSHR Level Wind Motor Power cable from TOS connector CD6.

Disconnect the DSHR brake power cable from TOS connector CD4.

Disconnect the DSHR Reel-Stop cable from Motor Controller V6 inside the TOS.

Disconnect the DSHR drum motor encoder cable from Motor Controller V6 inside the TOS.

Disconnect the DSHR level wind motor resolver cable from Motor Controller V5 inside the TOS.

Coil all cables and secure them to the Drill Supply Hose Reel

## Drill Relocation

### 2. Relocating Reels and Hoses

#### Caution

Water flow through the Surface Hoses, the Drill Supply Hose, and Return Water Hose is about to terminate, so that the hoses can be moved to the next drill location.

This presents a freezing hazard. Allowing water in the hoses to freeze can damage the hoses and hardware attached to the hoses.

Water circulation must be restored within 3 hours for the hoses and reels. This is longer than normally allowed because all hoses have been pre-heated.

Water circulation through the Surface Hoses is restored in Step 2.6. Water circulation through the Main Supply Hose and Return Water Hose is restored in Step 2.17. If flow cannot be restored within the allotted three hours, back out, and circulate water through the hoses for at least 60 minutes before proceeding.

- 2.1 Request that the DCC Operator turn off the Idle, Charge, and High Pressure Pumps.

Record the time at which water circulation through the hoses was terminated.

- 2.2 **Action:** Drill Supply Hose Valve → Closed  
**Action:** Return Water Hose Valve → Closed

- 2.3 Remove the coupler that connects the Main Supply Hose to the Return Water Hose.

#### Caution

The end of the Main Hose and Return Water Hose must be secured to their reels before attempting to move the reels. Failure to do so can cause damage to the hoses as they drag across the ice.

- 2.4 Secure the end of the Drill Supply Hose to the Drill Supply Hose Reel.

Secure the end of the Return Water Hose to the Return Water Hose Reel.

## Drill Relocation

- 2.5 Disconnect the Surface Supply Hose from the Drill Supply Hose Reel.

Disconnect the Surface Return Hose from the Return Water Hose Reel.

Connect the Surface Supply Hose to the Surface Return Hose using the coupler removed in Step 2.3

Note
Step 2.6 restores water flow through the Surface Hoses, ending the hazard of freezing water. Note that the hazard still exists for the Main Hose and the Return Water Hose, which have had no water flowing through them since Step 2.1.

- 2.6 **Action:** Drill Supply Hose Valve → Open  
**Action:** Return Water Hose Valve → Open

Request that the DCC Operator turn on the Idle Pump and set the rate to 25 gpm.

Caution
While being transported to the new drilling site, the Main Supply Hose Reel must remain upon the compacted road at all times. Travel off the prepared surface can result in the reel becoming bogged in the snow.

- 2.7 Remove the heat trace power leads from the reels.
- 2.8 Use a D7 bulldozer to move the Main Supply Hose Reel to the new drill site. Figure 2.1 shows the Drill Supply Hose Reel's position relative to the new hole, and to the Tower, which should already be set up at the new site.

8510-0370  
**Drill Relocation**

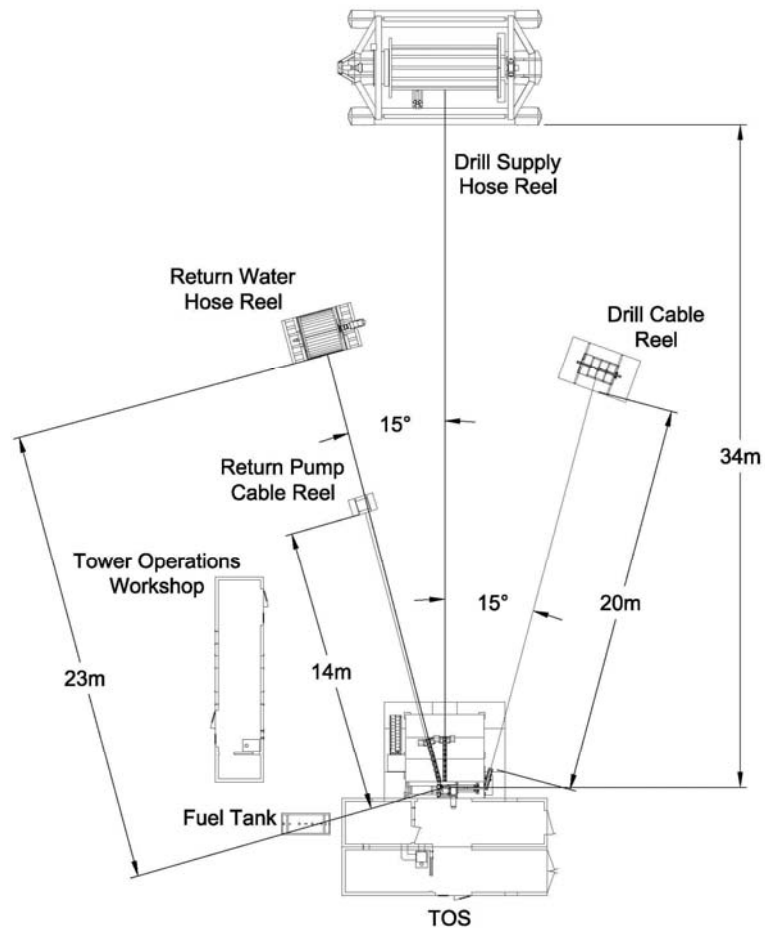


Figure 2.1 – Equipment Layout For Drilling Operations

- 2.9 Use a 953 forklift to move the Return Water Hose Reel into position at the new drill site. Figure 2.1 shows the distance and angle of the reel relative to the hole.

**Caution**

To prevent damage, do not drive over hoses with tracked vehicles while the hoses are being moved.

- 2.10 Move the looped-together Surface Supply Hose and Surface Return Hose to the new drill site, and place them such that they will easily reach the Drill Hose Reel and Return Water Hose Reel.
- 2.11 Reconnect the heat trace power leads to the reels.

**Drill Relocation****Caution**

Water flow through the Surface Hoses is about to terminate, so that the hoses can be connected to the Main Hose Reel and Return Water Hose Reel, and water flow through the hoses on the reel can be reestablished.

Lack of water flow through the hoses presents a freezing hazard. Allowing water in the hoses to freeze can damage the hoses and hardware attached the hoses.

Water circulation must be restored as soon as possible.

Water flow through the hoses is restored in Step 2.16.

- 2.12 Request that the DCC operator turn off the Idle Pump that is providing circulation through the Surface Hoses.

**Action:** Drill Supply Hose Valve → Closed

**Action:** Return Water Hose Valve → Closed

- 2.13 Remove the coupler that connects the Surface Supply Hose to the Surface Return Hose.

- 2.14 Connect the Surface Supply Hose to the Drill Supply Hose Reel.

Connect the Surface Return Hose to the Return Water Hose Reel.

Connect the Drill Supply Hose to the Return Water Hose using the coupler removed in Step 2.13.

- 2.15 **Action:** Drill Supply Hose Valve → Open

**Action:** Return Water Hose Valve → Open

**Note**

Step 2.16 restores water flow through the Surface Hoses, the Main Hose, and the Return Water Hose, ending the hazard of freezing water.

This ends the hazardous conditions caused in Step 2.1 and Step 2.12.

- 2.16 Request that the DCC Operator turn on the Idle Pump and set the flow rate to 25 gpm.

## Drill Relocation

- 2.17 Use a 953 forklift to move the Return Water Combo Cable Reel into position at the new drill site. Figure 2.1 shows the distance and angle of the reel relative to the hole.
- 2.18 Use a 953 forklift to move the Drill Cable Reel into position at the new drill site. Figure 2.1 shows the distance and angle of the reel relative to the hole.
- 2.19 Attach the Main Cable Reel to its anchors.

Attach the Return Water Hose Reel to its anchors.

Attach the Return Water Combo Cable Reel to the Return Water Hose Reel.

### 3. Reconnecting Power and Signal Cables

Note
The TOS/Tower at the next hole should already be in place and the power feeder cables CD1 and CD3 connected to the TOS. The only power active to the TOS should be to the lighting and heating circuit, Panel TOS C, CB2/4/6. All other breakers should be Open.

Warning
Make sure all circuit breakers are Off to the equipment about to be connected. Attempting to connect an energized connector presents an electrical shock hazard.

- 3.1 **Verify:** Panel TOS C, CB 7/9/11 (Drill Supply Hose Reel Drum Motor) Breaker – Off
- Verify:** Panel TOS C, CB 13/15/17, (Drill Supply Hose Reel Level Wind Motor) – Off
- Verify:** Panel TOS A, CB 7/9/11, Drill Cable Reel Drum Motor – Off
- Verify:** Panel TOS A, CB 8/10/12, Drill Cable Reel Level Wind Motor – Off
- Verify:** Panel TOS B, CB7/9/11, Return Water Reel Motor – Off
- Verify:** Return Water Combo Cable Reel is off and unpowered



8510-0370  
**Drill Relocation**

3.2 Reconnect Reel Motor Power, Level Wind Power, Brake, Reel Stop, and Encoder Cables according to Table 3.1.

<u>Cable Type</u>	<u>Reel End Connector ID</u>	<u>Reel end cable ID</u>	<u>TOS end cable ID</u>	<u>TOS connector ID</u>
<b><u>Drill Supply Hose Reel (DSHR)</u></b>				
Drill Supply Hose Reel Drum Motor	HR1-CD1	HR1-CD1/C	TOS1(2)-CD5/C	TOS1(2)-CD5
Drill Supply Hose Reel Level Wind Motor	HR1-CD2	HR1-CD2/C	TOS1(2)-CD6/C	TOS1(2)-CD6
Drill Supply Hose Reel Brake	HR1-CD3	HR1-CD3/C	TOS1(2)-CD4/C	TOS1(2)-CD4
Hose Reel Drum Motor Encoder	Connects to Hose Reel Drum Motor Encoder Connector			Connects to "Hose Reel Drum Motor Encoder" Connector on TOS Reel I/O Box
Hose Reel Level-Wind Motor Encoder	Connects to Hose Reel Level Wind Motor Encoder Connector			Connects to "Hose Reel Level Wind Motor Encoder" Connector on TOS Hose Reel I/O Box
Hose Reel E-Stop and Reel-stop	Connects to "E-Stop/Reel-Stop" Connector on Hose Reel Safety Enclosure			Connects to "Hose Reel E-Stop & Reel-Stops" Connector on TOS E-Stop Panel
Hose Reel Limit-Stop	Connects to "Limit Stop" Connector on Hose Reel Safety Enclosure			Connects to "Hose Reel Limit Stops" Connector on TOS E-Stop Panel
<b><u>Drill Cable Reel (DCR)</u></b>				
Drill Cable Reel Drum Motor	DH1-CD1	DH1-CD1/C	TOS1(2)-CD9/C	TOS1(2)-CD9
Drill Cable Reel Level Wind Motor	DH1-CD2	DH1-CD2/C	TOS1(2)-CD10/C	TOS1(2)-CD10
Drill Cable Reel Brake	DH1-CD3	DH1-CD3/C	TOS1(2)-CD11/C	TOS1(2)-CD11
Cable Reel Drum Motor Encoder	Connects to Cable Reel Drum Motor Encoder Connector			Connects to "Cable Reel Drum Motor Encoder" Connector on TOS Cable Reel I/O Box
Cable Reel Level-Wind Motor Encoder	Connects to Cable Reel Level Wind Motor Encoder Connector			Connects to "Cable Reel Level Wind Motor Encoder" Connector on TOS Cable Reel I/O Box
Cable Reel E-Stop and Reel-Stop	Connects to "E-Stop/Reel-Stop" Connector on Cable Reel Safety Enclosure			Connects to "Cable Reel E-Stop & Reel-Stops" Connector on TOS E-Stop Panel
Cable Reel Limit-Stop	Connects to "Limit Stop" Connector on Cable Reel Safety Enclosure			Connects to "Cable Reel Limit Stops" Connector on TOS E-Stop Panel
<b><u>Return Water Hose Reel</u></b>				
Return Water Reel Motor	RW1-CD1	RW1-CD1/C	TOS1(2)-CD12/C	TOS1(2)-CD12

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**Drill Relocation**

Return Water Reel-Stop Reel Motor Resolver	Connects to Return Water Reel Motor			Connects to TOS Return Water Reel Vector Drive V4
Return Water Reel Reel-Stop	Connects to Return Water Reel Safety Enclosure			Connects to "Return Water Reel Stop" Connector on TOS E-Stop Panel
<b><u>Return Water Combo Cable Reel</u></b>				
Main motor power				
Main motor resolver				
E-stop/ Reel Stop				

Table 3.1 – Reel Cables Connection Matrix

3.3 Relocate the TOS end of the Fiber Optic Network Cable to the new drill location.

Relocate the SES to TOS E-Stop Cable to the new drill location.

Execute Step 3 of “E-Stop Reconfiguration.”

4. Tower Operations Workshop Relocation

4.1 Turn off all equipment inside the TOW.

**Action:** TOW Main Breaker, Panel TOW A, CB1 → Open

4.2 **Action:** PDM TOW Power Breaker → Open

**Warning**

Verify that power is removed before disconnecting power cables. Attempting to remove an energized connector presents an electrical shock hazard.

4.3 Disconnect the TOW Main Feeder Cable at the TOW end, TOW-CD1.

Disconnect any other cables that may be anchored to the TOW.

4.4 If a fuel tank is connected to the TOW:

**Action:** TOW Fuel Supply Valve → Closed

Disconnect the Fuel Tank from the TOW.

4.5 Use a 953 forklift or a D7 bulldozer to move the TOW into position at the new drill site. Use Figure 2.7 to guide in positioning of the TOW.

**Drill Relocation**

- 4.6 With the main TOW feeder cable still connected to at the PDM end, drag the TOW end (marked TOW-CD1/C) over to the new TOW site and reconnect to the TOW Connector, TOW- CD1.
- 4.7 **Action:** PDM TOW Power Breaker → Closed
- Action:** TOW Main Breaker, Panel TOW-A, CB1 → On
- Verify:** Panel TOW B Breakers – All Closed
- Turn on Electric Space heaters.
- 4.8 If the TOW is using the furnace then:  
Connect the fuel tank to the TOW.  
**Action:** TOW Fuel Supply Valve → Open  
**Action:** TOW Furnace → On

5. Verifying Reel Function**Warning**

If any of steps 5.1 – 5.7 fails, the Main Supply Hose Reel must not be used. Alert the shift lead. Operation of a faulty reel can cause personnel injury or hardware damage.

- 5.1 One person with radio next to each Reel  
One person with radio in the Tower operating the pendants
- Attach a pendant to the Drill Supply Hose Reel I/O Connector.
- Action:** TOS C (DSHR Drum Motor), CB7/9/11 → Closed
- Action:** TOS CB13/15/17 (DSHR Level Wind) → Closed  
**Verify:** DSHR Drum Motor Drive V6 – On
- Verify:** DSHR Level Wind Motor Drive V5 – On
- Verify:** TOS E CB 18 (DSHR & DCR Brake) – Closed

**Drill Relocation**

5.2 Attach a pendant to the Drill Cable Reel I/O Connector.

- Action:** TOS A CB1/3/5 (Main) → On  
**Action:** TOS A CB 7/9/11 (DCR Drum) → On  
**Action:** TOS A CB 8/10/12 (DCR Level Wind) → On  
**Verify:** DCR Drum motor Drive V1 – On  
**Verify:** DCR Level Wind Motor Drive V2 – On

5.3 Testing the DSHR.

- Action:** DSHR Computer/Pendant Switch → Computer Mode  
**Action:** DSHR Computer/Pendant Switch → Pendant Mode  
**Verify:** Green light on and steady (not flashing)

5.4 **Action:** Pendant “Velocity Mode” Switch → Depressed  
**Verify:** Blue Velocity light – On

5.5 **Verify:** DSHR Reel Motor – Humming

If the reel Motor is humming, then power is available, and the motor is available for use.

<b>Note</b>
Hydraulic brake instructions are clearly placarded on the reel.

5.6 **Action:** DSHR Hydraulic Brake → Released

5.7 **Action:** DSHR Motor → Down  
**Verify:** DSHR Motor – On  
**Verify:** Smooth and free reel rotation in forward direction

**Action:** DSHR Motor → Up  
**Verify:** DSHR Motor – On  
**Verify:** Smooth and free reel rotation in reverse direction

Verify correct level wind operation.

**Drill Relocation****Warning**

If any of steps 5.7 – 5.11 fails, the Drill Cable Reel must not be used. Alert the shift lead. Operation of a faulty Reel can cause personnel injury or hardware damage.

## 5.8 Testing the DCR.

Verify that the Drill Cable Reel Pendant is in Velocity Mode

**Action:** DCR Computer/Pendant Switch → Computer Mode

**Action:** DCR Computer/Pendant Switch → Pendant Mode

**Verify:** Green light on and steady (not flashing)

5.9 **Action:** Pendant “Velocity Mode” Switch → Depressed

**Verify:** Blue Velocity light – On

5.10 **Verify:** Drill Cable Reel Motor – Humming

If the Reel Motor is humming, then power is available, and the motor is available for use.

**Note**

Hydraulic brake instructions are clearly placarded on the reel.

5.11 **Action:** Drill Cable Reel Hydraulic Brakes → Released

**Action:** Drill Cable Reel Motor → Down

**Verify:** Motor – On

**Verify:** Smooth and free reel rotation in forward direction

**Action:** Drill Cable Reel Motor → Up

**Verify:** Motor – On

**Verify:** Smooth and free reel rotation in reverse direction

Verify correct level wind operation.

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**Drill Relocation**

**Warning**

If any of steps 5.12 – 5.17 fails, the Drill Cable Reel must not be used. Alert the shift lead. Operation of a faulty Reel can cause personnel injury or hardware damage.

**Note**

It may not be possible to test Return Water Hose Reel until deployment is completed and the main power feeder cable is connected to the TOS input power connector CD2.

5.12 Attach a pendant to the Return Water Hose Reel I/O Connector.

**Action:** TOS B CB 7/9/11 (Return Water Reel) → Closed  
**Verify:** Return Water Reel Motor Drive V4 – On

5.13 **Action:** Computer/Pendant Switch → Computer Mode  
**Action:** Computer/Pendant Switch → Pendant Mode  
**Verify:** Green light on and steady (not flashing)

5.14 **Action:** Pendant “Velocity Mode” Switch → Depressed  
**Verify:** Blue Velocity light – On

5.15 **Verify:** Reel Motor – Humming

If the reel Motor is humming, then power is available, and the motor is available for use.

**Note**

Hydraulic brake instructions are clearly placarded on the reel.

5.16 **Action:** Return Water Hose Reel Hydraulic Brake → Released (both)

5.17 **Action:** Return Water Hose Reel Motor → Down  
**Verify:** Return Water Hose Reel Motor – On  
**Verify:** Smooth and free reel rotation in forward direction

**Action:** Return Water Hose Reel Motor → Up  
**Verify:** Return Water Hose Reel Motor – On  
**Verify:** Smooth and free reel rotation in reverse direction

**Drill Relocation****Warning**

If any of steps 5.18 – 5.22 fails, the Electrical Combo Cable Reel must not be used. Alert the shift lead. Operation of a faulty Reel can cause personnel injury or hardware damage.

5.18 Attach a pendant to the Return Water Combo Cable Reel I/O Connector.

**Verify:** Return Water Combo Cable Drive – On

5.19 **Action:** Computer/Pendant Switch → Computer Mode

**Action:** Computer/Pendant Switch → Pendant Mode

**Verify:** Green light on and steady (not flashing)

5.20 **Action:** Pendant “Velocity Mode” Switch → Depressed

**Verify:** Blue Velocity light – On

5.21 **Action:** Return Water Combo Cable Reel Motor Controller → On

**Verify:** Return Water Combo Cable Reel Motor – Humming

If the Reel Motor is humming, then power is available, and the motor is available for use.

5.22 **Action:** Return Water Combo Cable Reel Hydraulic Brakes → Released  
(both)

**Action:** Return Water Combo Cable Reel Motor → Down

**Verify:** Motor – On

**Verify:** Smooth and free reel rotation in forward direction

**Action:** Return Water Combo Cable Reel Motor → Up

**Verify:** Motor – On

**Verify:** Smooth and free reel rotation in reverse direction

5.23 Perform “Reel Stop Test”

## 6. Preparing Hoses and Cables

6.1 Assemble the full team of five people and review Step 6 with anyone new to the procedure, or with a role they have never performed.

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**Drill Relocation**

**Caution**

Water flow through the Surface Hoses, Main Supply Hose and Return Water Hose is about to terminate, so that the hoses can be moved into the Tower.

This presents a freezing hazard, as there will be no process to keep the water in the hoses warm. Allowing water in the hoses to freeze can damage the hoses and hardware attached the hoses.

Water circulation must be restored within 60 minutes.

Water circulation through the hoses is restored in Step 6.12. If Step 6.12 cannot be completed within the allotted hour, then the procedure must be backed out, and water must circulate through the hoses for at least 60 minutes before attempting to complete the procedure.

- 6.2 Request that the DCC Operator turn off the Idle Pump providing circulation through the Hoses.
- 6.3 **Action:** Drill Supply Hose Valve → Closed  
**Action:** Return Water Hose Valve → Closed
- 6.4 Remove the coupler connecting the Main Supply Hose to the Return Water Hose.
- 6.5 Attach a 60m static rope to the Drill Supply Hose and sling the rope over the Drill Supply Hose Crescent and down into the Drill Tower.
- Attach a three pulley block assembly to the Tower hoist.
- Attach a three pulley block assembly to the floor anchor.
- Run the rope through the pulleys and tie off the end to a floor anchor.



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**Drill Relocation**

**Warning**

The Crescent is constructed of spoked pulleys, instead of solid ones. This provides additional opportunity for clothing or extremities to snag on rotating hardware, and cause injury. Exercise caution.

- 6.6 One person operating the pendant  
One person atop the Tower  
One person operating the Tower hoist

**Action:** Drill Supply Hose Reel Hydraulic Brake → Released

**Verify:** Drill Supply Hose Reel Hydraulic Brake – Released

Use the Tower hoist to lift the Drill Supply Hose through the Fairlead Assembly, over the Crescent, and down into the Tower.

When the Drill Supply Hose has reached eye level within the Tower, secure the Drill Supply Hose by placing a cargo strap between the hose Yale grip and the Crescent.

Disconnect the Tower Winch, and the blocks.

- 6.7 Attach a 50m 1½” hose to the Return Water Hose.

- 6.8 Tie a rope to the Return Water Hose, and sling the rope over the Return Water Hose Crescent.

Haul the Return Water Hose into the Tower.

Tie the Return Water Hose off to an anchor.

Wind any slack onto the Return Water Hose Reel.

- 6.9 **Action:** Drill Supply Hose Reel Hydraulic Brake → Engaged  
**Verify:** Drill Supply Hose Reel Hydraulic Brake Pressure – 0

**Action:** Return Water Hose Reel Hydraulic Brake → Engaged

**Verify:** Return Water Hose Reel Hydraulic Brake Pressure – 0

- 6.10 Reattach the coupler between the Drill Supply Hose and the Return Water Hose that was removed in Step 6.4

**Drill Relocation**

- 6.11 **Action:** Drill Supply Hose Valve → Open  
**Action:** Return Water Hose Valve → Open

**Note**

When Step 6.12 is completed, water flow through the hoses will be reestablished, and the freezing hazard created in Step 6.2 will be eliminated.
--

- 6.12 Request that the DCC Operator turn on the Idle Pump and set the flow rate to 25 gpm.
- 6.13 Attach a 60m static rope to the Drill Cable and sling the rope over the Drill Cable Guide on the Tower and down into the Tower.
- 6.14 One person operating the Drill Cable Reel pendant **and** the Drill Cable Reel Brake  
 One person atop Tower  
 One person inside Tower

**Action:** Drill Cable Reel Hydraulic Brake → Released  
**Verify:** Drill Cable Reel Hydraulic Brake – Released

Haul the cable up through the Fairlead Assembly, over the cable guide, and down into the Tower.

Tie the cable off to a shackle on the side of the Tower.

- 6.15 Attach a 60m static rope to the Electrical Combo Cable and sling the rope over the Cable Guide on the Tower and down into the Tower.
- 6.16 One person operating the Electrical Combo Cable Reel pendant **and** the Reel Brake  
 One person atop Tower  
 One person inside Tower

**Action:** Electrical Combo Cable Reel Hydraulic Brake → Released  
**Verify:** Electrical Combo Cable Reel Hydraulic Brake – Released

Haul the cable up through the Fairlead Assembly, over the cable guide, and down into the Tower.

Tie the cable off to a shackle on the side of the Tower.

## Drill Relocation

- 6.17 **Action:** Drill Cable Reel Hydraulic Brake → Engaged  
**Verify:** Drill Cable Reel Hydraulic Brake Pressure – 0
- Action:** Combo Cable Reel Hydraulic Brake → Engaged  
**Verify:** Combo Cable Reel Hydraulic Brake Pressure – 0

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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THE UNIVERSITY OF WISCONSIN					
<b>Antarctic Astronomy &amp; Astrophysics Research Institute</b> MADISON, WISCONSIN					
TITLE					
<b>ICECUBE TOWER RELOCATION ENHANCED HOT WATER DRILL</b>					
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
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DRAWING NO.	8510-0371		SCALE	SIZE	SHEET
			NA	A	1 of 08

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**Tower Relocation**

References:

8510-0107 Hose Reel Hazard Analysis Summary  
8510-0106 Drill Head Supply Hose Hazard Analysis Summary  
8510-0102 Power Distribution System Hazard Analysis Summary  
8510-0114 Cable Reel Hazard Analysis Summary  
8510-0002 Drill Camp Layout

Requirements:

Personnel: D7 driver, Raytheon General Assistant, 2 Drillers with radios  
Equipment: D7, 953 fork lift, 60m Static Rope, safety gloves, 2 three-pulley blocks, power drill with 6mm Hex bit, 4 3m rope lengths

Assumptions: Deployment is completed, and the Deployment Team no longer needs the Tower for operational purposes.

Power feeders are still connected at the TOS.

The TOS is still heated.

1. Preparing the TOS and the Tower

**Caution**

The Deployment Cable can be damaged if it becomes snagged when being removed from the Tower.

1.1 Unscrew the rail near the Tower Hoist that holds the two sections of the Crystal Palace together.

Gently guide the Deployment Cable out through the gap between the two sections of the Crystal Palace.

Replace the rail segment.

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**Tower Relocation**

**Warning**

Verify that power is removed before disconnecting power cables. Attempting to remove an energized connector presents an electrical shock hazard.

- 1.2 **Verify:** Drill Cable Reel Motor Controller (V1) – Off

After powering down the Motor Controller, wait for 5 minutes, or until the power LED on the controller is Off.

Disconnect all cables from the Deployment Cable Reel.

Loop and tie the cables off on the outside of the TOS.

- 1.3 Disconnect the Load Cell cable between the Load Cell Junction Box and the TOS.

Disconnect the Payout Encoder Cables.

Disconnect the E-Stop Cable between the Tower and the TOS.

Disconnect the network cable between the Tower and the TOS.

Disconnect the webcam cables between the Tower and the TOS.

Verify that all cables between the Tower and the TOS have been disconnected.

Verify that no external cables remain connected to the Tower or TOS.

- 1.4 Disconnect the external webcams.

Coil the cables and place them in the Tower or the TOS, as appropriate.

- 1.5 Turn the Furnace Off.

Disconnect the fuel line.

## Tower Relocation

- 1.6 Disconnect the two cargo straps that hold the Tower to the TOS RH. See Figure 2.1.

Disconnect the two cargo straps that hold the top of the Tower to the read of the TOS. See Figure 2.2.

Place the straps in the TOS.

- 1.7 Power down all equipment in the TOS.  
Switch all TOS Circuit Breakers to Open.
- 1.8 Open all PDM Circuit Breakers that feeds the TOS.

**Action:** TOS Power Breaker 1 → Open

**Action:** TOS Power Breaker 2 → Open

**Action:** PDM TOS Submersible Pump Power Breaker → Open

### Warning

Verify that power is removed before disconnecting power cables. Attempting to remove an energized connector presents an electrical shock hazard.

- 1.9 Disconnect Main Power Feeders from TOS.

Disconnect the Submersible Pump feeder cable from the TOS.

2. Moving the TOS and the Tower

### Caution

While the Tower and TOS are being separated, any cables that remain in place between them can be damaged. Verify that all cables are disconnected.

Cables and hoses can be damaged if objects are dragged over them, or if they are driven over by tracked vehicles.

## Tower Relocation

- 2.1 Verify that the Deployment Cable has been moved out of the way and is not in the path of the Tower move.

Using a D7 bulldozer or 953 forklift connected to the Tower, slowly drag the Tower away from the TOS, verifying visually that no cables or equipment remain connected between the TOS and the Tower.

When observers have verified that the TOS and Tower are safely separated, drag the Tower to the next drill site, and properly position the Tower over the hole as shown in drawing 8510-0002\_RevA, Page 3 - TOS.

- 2.2 Move the Deployment Cable so that it is out of the path for the TOS relocation.
- 2.3 Using the D7 bulldozer, connect to the TOS Double Wide Tow Bar, and drag the TOS to the next drill site.

Maneuver the TOS into position such that it lines up with the Tower and only a minimal gap remains where it joins the Tower. If necessary, nudge the Tower and TOS together with a 953 Fork Lift. Figure 2.1 shows the correct alignment between the TOS and Tower such that the TOS/Tower Anchor Straps can be attached to the TOS Anchor Points.

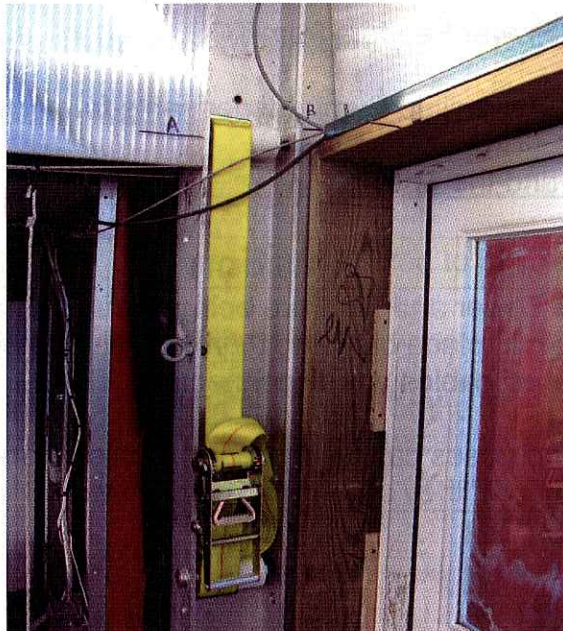


Figure 2.1 – TOS/Tower Anchor Strap Alignment



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**Tower Relocation**

- 2.4 Use a 953 forklift to drag the TOS Fuel Tank to the new drill site.

Request that a Raytheon Utility Technician attach the tank to the furnace inlet.

**Caution**

The feeder cables can be damaged if driven over by tracked vehicles.

- 2.5 **Action:** PDM TOS Power Circuit Breaker 1 → Open  
**Action:** PDM TOS Power Circuit Breaker 2 → Open

Drag the two feeder cables from the old Tower site to the new site. Position the cables such that they will not interfere with other cables and hoses at the current site or the next hole.

Move the Submersible Pump feeder cable from the old Tower site to the new site. Position the cables such that they will not interfere with other cables and hoses at the current site or the next hole.

- 2.6 Connect the two feeder cables to the TOS power inputs.

Connect the Submersible Pump feeder cable to the TOS.

- Action:** PDM TOS Power Circuit Breaker 1 → Closed  
**Action:** PDM TOS Power Circuit Breaker 2 → Closed  
**Action:** PDM TOS Submersible Pump Circuit Breaker → Closed

- 2.7 Turn on the TOS furnace.

Turn on all the TOS heaters.

- 2.8 Attach the TOS/Tower Anchor Straps as shown in Figure 2.2.

- 2.9 Seal the interface between the Tower and the TOS with insulating foam.

- 2.10 Connect the TOS RH to the top of the Tower using two cargo straps as shown in Picture 2.2.

8510-0371  
**Tower Relocation**

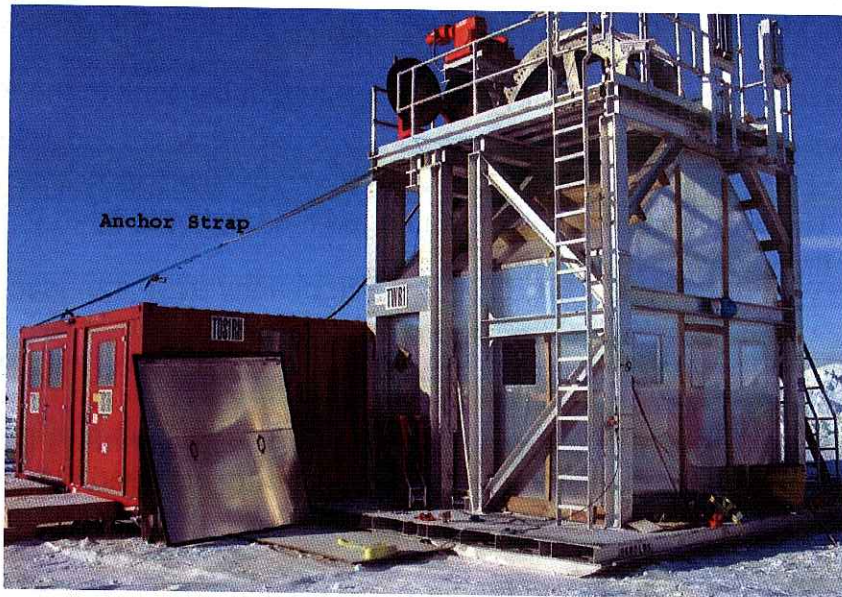


Figure 2.2 – TOS/Tower Anchor Strap Configuration

- 2.11 Reconnect the external webcams.  
Attach their power and signal cables.
- 2.12 Reconnect the Load Cell cable between the Load Cell Junction Box and the TOS.  
Reconnect the Payout Encoder Cables.  
Reconnect the E-Stop Cable between the Tower and the TOS.  
Reconnect the network cable between the Tower and the TOS.
- 2.13 Use a Trencher to cut anchor trenches according to Figure 2.3.  
Install anchors for the Drill Cable Reel  
Install anchors for the Return Water Hose Reel  
Install anchors for the Deployment Reel

8510-0371  
**Tower Relocation**

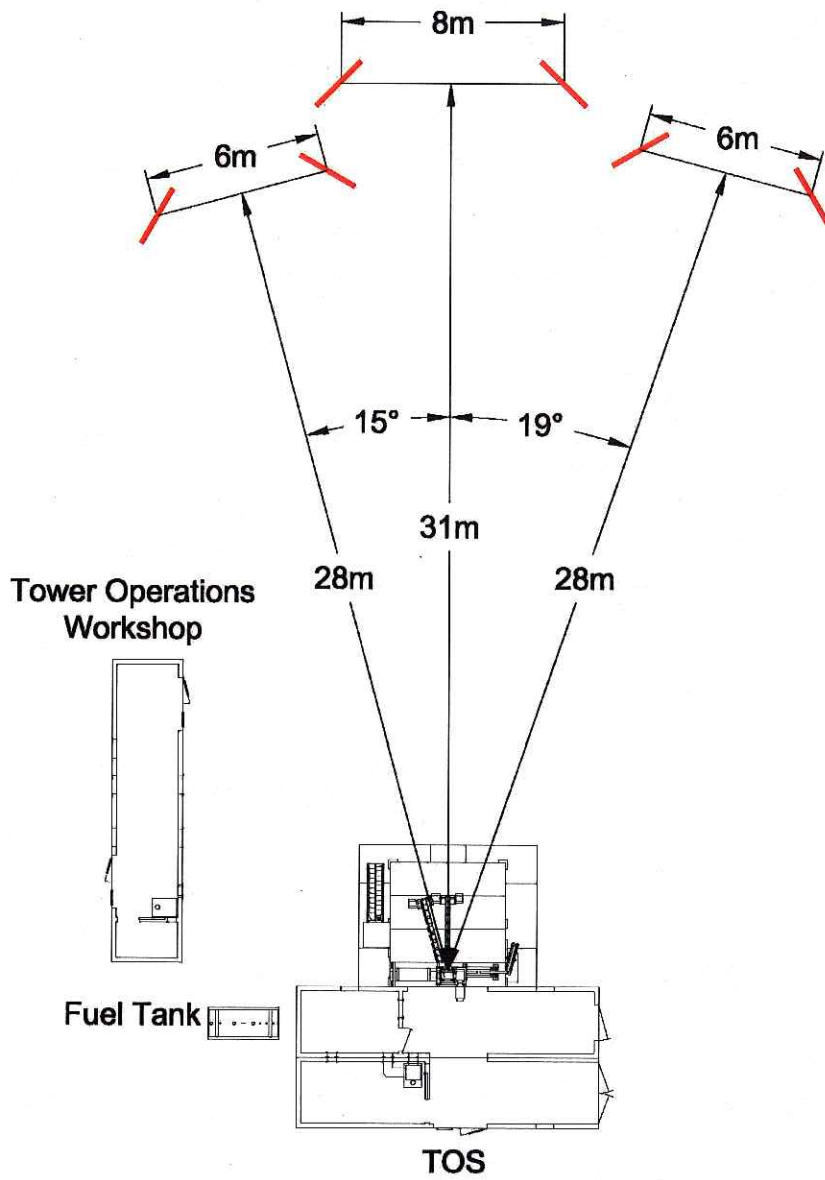


Figure 2.3 – Anchor Locations

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	8/30/07	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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## **E-Stop Reconfiguration**

### References:

8510-0114	Cable Reel Hazard Analysis
8510-0122	Drill Control System Hazard Analysis
8510-1017	Drill Hose Reel Hazard Analysis
8510-0124	Drilling Operations Hazard Analysis
8510-0123	Fuel System Hazard Analysis
8510-0219	Return Water Cable Reel Hazard Analysis
8510-0112	Rodriguez Well Hazard Analysis
8510-0108	Tower Hazard Analysis
8510-0109	Mobile Drilling Structure & Contained Equipment Hazard Analysis
9400-0061	DOM Deployment Hazard Analysis
8510-0343	TOS Reel Stop Test
8510-0345	TOS E-Stop Test

### Requirements:

Personnel:	3 Drillers with radios
Equipment:	E-Stop system termination caps

### Assumptions:

The SES, and the Tower that has been used for drilling, are in a single E-Stop network.

E-Stop Controllers exist in both TOSs.

The PHS building is the connection point for the TOS/Tower E-Stop cable.

The E-Stop reconfiguration is being performed at a time when no harm will come to hardware if equipment remains inactive for some short duration while a mistake or failure is investigated.

The Deployment Cable Reel has been moved to the TOS.

## E-Stop Reconfiguration

### Warning

Operating without a properly operating E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

#### 1. Disconnecting the Tower from the SES E-Stop System

##### Note

The DCC Operator alert is precautionary only. There is no expectation that an E-Stop will be triggered by the following actions.

- 1.1 Alert the DCC Operator that an E-Stop network reconfiguration is about to occur. Wait for a “Go” from the DCC Operator.

In the PHS building, perform the following steps to remove the TOS from the SES E-Stop network:

**Action:** E-Stop Control Box E-Stop Bypass → Press and Hold

Disconnect the Tower E-Stop cable

Place a terminating cap on the E-Stop cable connector

**Action:** E-Stop Control Box E-Stop Bypass → Released

#### 2. Setting up the Tower E-Stop System for Deployment

- 2.1 Connect the input of Tower Outside Lower E-Stop slap switch to the Tower E-Stop Controller.

- 2.2 Attach a terminating cap on the connector for the RWHR E-Stop Cable on the Tower E-Stop box.

Attach a terminating cap on the connector for the RWCCR E-Stop Cable on the Tower E-Stop box.

Attach a terminating cap on the connector for the DSHR E-Stop Cable on the Tower E-Stop box.

- 2.3 Connect an E-Stop cable between the Tower and the Deployment Reel.  
Connect a Reel Stop cable between the Tower and the Deployment Reel.

- 2.4 Activate the Tower E-Stop system

**Action:** E-Stop Controller Key → Start

## E-Stop Reconfiguration

**Action:** E-Stop Controller Key → Run

Note
For the E-Stop test in Step 2.5, only the Deployment Cable Reel will be connected to the TOS E-Stop system.

Warning
Operating without a properly operating E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

2.5 Perform Step 2 of “E-Stop Test.” Perform any required debugging.

Note
The Tower E-Stop system has been checked out, and is safe for use.

Warning
Operating without a properly operating Reel Stop system poses a severe safety hazard. If the Reel Stop system is called upon to stop a rotating Reel, and does not do so, injury to members of the Drill or Deployment teams is possible.

2.6 Execute “TOS Reel Stop Test.” Perform any required debugging.

3. Connecting the E-Stop System at the Next Drilling Site

3.1 Plug in all the reels

3.2 Activate the Tower E-Stop System

**Action:** E-Stop Controller Key → Start

**Action:** E-Stop Controller Key → Run

3.3 Test the E-Stop System by executing Step 2 of “E-Stop Test.” Perform any required debugging.

Note
The Tower E-Stop network has been tested and found operating correctly.

3.4 Deactivate the Tower E-Stop System

**Action:** E-Stop Controller Key → Off

## E-Stop Reconfiguration

- 3.5 Disconnect the Tower E-Stop Controller Box from the input of Tower Outside Lower E-Stop slap switch.

Connect the SES E-Stop Cable to the input of Tower Outside Lower E-Stop slap switch.

Note
The DCC Operator alert is precautionary only. There is no expectation that an E-Stop will be triggered by the following actions.

- 3.6 Alert the DCC Operator that an E-Stop network reconfiguration is about to occur. Wait for a "Go" from the DCC Operator.

In the PHS building, perform the following steps to include the TOS into the SES E-Stop network.

**Action:** E-Stop Control Box E-Stop Bypass → Press and Hold  
Remove the terminating cap from the E-Stop cable connector  
Connect the Tower E-Stop cable

**Action:** E-Stop Control Box E-Stop Bypass → Released

Warning
Operating without a properly operating E-Stop system poses a severe safety hazard. If the E-Stop system is called upon to safe a hazardous condition during an emergency, and does not do so, injury to members of the Drill or Deployment teams is possible.

- 3.7 Execute Step 3 of "E-Stop Test."

Note
The global E-Stop network has been integrated and is operational.



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
REVISION	-	-	-	-	-	-	-	-	-										

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<b>Antarctic Astronomy &amp; Astrophysics Research Institute</b>					
MADISON, WISCONSIN					
TITLE					
<b>ICECUBE</b>					
<b>SES DEACTIVATION AND GLYCOL FLUSHING</b>					
<b>ENHANCED HOT WATER DRILL</b>					
ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
SC <i>[Signature]</i>	10/27/05	JC/FF <i>[Signature]</i>	10/27/05	HL <i>[Signature]</i>	10/27/05
DRILL MGR	DATE	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
AA/TH <i>[Signature]</i>	10/27/05	MAZ <i>[Signature]</i>	10/27/05	RJP <i>[Signature]</i>	10/27/05
FILENAME	8510-0373.0510.doc			PROJECT NO.	8510
DRAWING NO.	8510-0373		SCALE	SIZE	SHEET
			NA	A	1 of 48

**SES Deactivation and Glycol Flushing****References:**

8510-0121 Anti-Freeze and Water Tanks Hazard Analysis  
8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0107 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0123 Fuel System Hazard Analysis  
8510-0120 Power Distribution System Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis  
8510-0112 Rodriguez Well Hazard Analysis  
8510-0108 Tower Hazard Analysis  
8510-0109 Mobile Drilling Structure Hazard Analysis  
9000-0002 IceCube Safety Manual – Confined Space Entry Procedure  
  
8510-0374 SES Deactivation Checklist

**Requirements:**

**Personnel:** Full shift of 8 Drillers, RPS fuel technician  
**Equipment:** Buckets, catch pans, hose adapters, compressed air/glycol valve assembly, portable air compressor, 55 gallon drums, heater flow meter jumper hoses, shop vac, squeegee, sump pump, furnace vent covers, heater chimney covers, vent covers, circuit breaker lockouts

**Assumptions:** Hoses are looped at the TOS, through the Reels. Warm water is being circulated through the hoses with the Idle Pump.

Drill MDS hardware is all active.

The Rod Well is active.

# SES Deactivation and Glycol Flushing

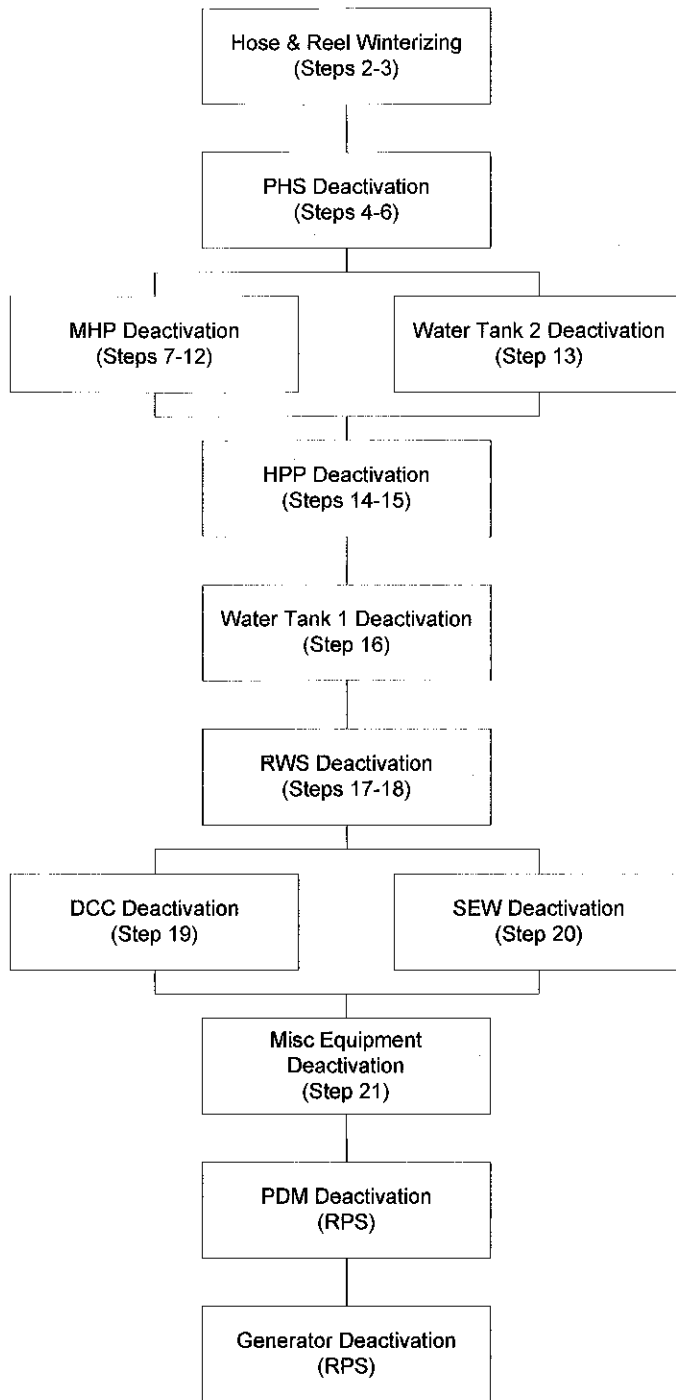


Figure 1.1 – SES Deactivation Flow

## SES Deactivation and Glycol Flushing

### 1. Pre-Heating the Glycol Tank

- 1.1 Approximately two days before beginning to deactivate the SES, the glycol tank heater should be turned on.

### 2. Hose and Reel Winterizing

- 2.1 Move the Air Compressor to the TOS.

#### Caution

Water flow through the Surface and Drill hoses is about to terminate. This presents a freezing hazard. If water freezes in the hoses, Drill hardware, including the hoses themselves, can suffer damage.

Water flow must be restored within one hour, or the water must be removed from the hoses.

- 2.2 Request that the DCC Operator terminate water flow through the Surface Hoses.

**Action:** Drill Supply Hose Valve → Closed

**Action:** Return Water Hose Valve → Closed

Break the circulation loop by removing the coupler between the Drill Supply Hose Reel and the Return Water Hose Reel.

- 2.3 Detach the Surface Supply Hose from the HPP MDS, and drag the end of the hose to the Rod Well. Place the end of the hose in the Rod Well hole.
- 2.4 Wind the end of the Drill Supply Hose onto the Reel, and then tie it securely in place on the Reel.

#### Note

While performing Step 2.5, Step 3 should be performed in parallel. Doing so will help ensure that water is removed from the Return Water and Surface Return Hoses before it can freeze.

Step 3 requires use of the Air Compressor, which will be needed once Step 2.5 is completed and Step 2.6 commences.

## SES Deactivation and Glycol Flushing

- 2.5 **Action:** Drill Supply Hose Valve → Open

Rotate the Drill Supply Hose Reel downhole to force water from the hose and into the Rod Well.

Proceed until water stops flowing from the end of the hose (~3 hours).

- 2.6 When water no longer flows from the end of the hose, terminate rotation of the Drill Supply Hose Reel, and connect the Air Compressor to the Drill Supply Hose at the Drill end of the Hose.

If possible, defeat the Air Compressor intercooler. The intercooler should remain in this configuration until the end of the procedure.

**Action:** Air Compressor → On

**Action:** Service Air → On

Blow compressed air through the Hose until there is no longer any misting visible at the end of the hose in the Rod Well hole.

- 2.7 **Action:** Service Air → Off

- 2.8 Disconnect the Drill Supply Hose Reel from the Surface Supply Hose.

Connect the Air Compressor to the Surface Supply Hose.

**Action:** Service Air → On

Blow air through the Surface Supply Hose for at least 15 minutes.

- 2.9 **Action:** Service Air → Off

- 2.10 Disconnect the Air Compressor from the Surface Supply Hose.

Connect the Air Compressor to the Drill Supply Hose at the Drill end of the Hose.

**Action:** Service Air → On

Blow air through the Drill Supply Hose for at least 15 minutes.

- 2.11 **Action:** Service Air → Off

**Action:** Air Compressor → Off

## SES Deactivation and Glycol Flushing

2.12 If Step 3 has already been completed, proceed to Step 4. Otherwise, proceed to Step 3.

### 3. Drying the Return Water and Surface Return Hoses

3.1 Connect the Air Compressor to the end of the Return Water Hose at the Submersible Pump end of the hose.

**Action:** Return Water Hose Valve → open

3.2 **Action:** Air Compressor → On

**Action:** Service Air → On

Blow the Return Water and Surface Return Water Hoses dry. Water in the Hoses will flow back directly into WT1.

Break open the fitting at the top of WT1 to directly observe the hose output. When there is no longer mist or spray leaving the hose, it is assumed dry.

Blow air for an additional 15 minutes.

3.3 **Action:** Service Air → Off

**Action:** Air Compressor → Off

3.4 If Step 3 was performed in parallel with Step 2, complete Step 2. Otherwise, continue with Step 4.

### 4. Deactivating the PHS Heaters

4.1 Return the Air Compressor to the SES.

4.2 Confirm with the DCC Operator that HPP output is to WT1, and that the MHP heaters are Off.

4.3 Drain Water Tank Filter housings into the catch pans.

Dump the catch pans into WT2.

## SES Deactivation and Glycol Flushing

### Note

Only the Water Tank filter system is being deactivated. Deactivation of the Condensate System will occur in Step 5.

- 4.4 Remove and discard the Water Tank system filters.
- 4.5 Reseal the Water Tank Filter housings.
- 4.6 Connect the Air Compressor output to a 4" hose adapter on the PHS WT2 Inlet.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

- 4.7 For four filters:

**Action:** Heater Inlet Valve → Closed  
**Action:** Heater Output Valve → Closed  
**Action:** Filter Inlet Valve → Open  
**Action:** Filter Output Valve → Open

- 4.8 **Action:** Air Compressor → On  
**Action:** Service Air → On

Blow air for the longer of 15 minutes, or until there is no mist or spray at the Drain Valves on the Water Tank Filter Housings.

- 4.9 **Action:** Service Air → Off

- 4.10 For the four heaters:

**Action:** Heater Inlet Valve → Open  
**Action:** Heater Output Valve → Open  
**Action:** Filter Inlet Valve → Closed  
**Action:** Filter Output Valve → Closed

## SES Deactivation and Glycol Flushing

4.11 **Action:** Service Air → On

Blow air for the longer of 15 minutes, or until there is no mist or spray at the Outlet Manifold Drain Valve.

4.12 **Action:** Service Air → Off

4.13 Configure from Compressed Air to Glycol.

Configure so that PHS Output is moved from WT2 to the Glycol Tank.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

4.14 For four heaters:

**Action:** Heater Inlet Valve → Closed

**Action:** Heater Output Valve → Closed

**Action:** Filter Inlet Valve → Open

**Action:** Filter Output Valve → Open

4.15 **Action:** Glycol Pump → On

Wait until there is good glycol flow back into the glycol tank, free of water slugs.

4.16 **Action:** Glycol Pump → Off

4.17 For the four heaters:

**Action:** Heater Inlet Valve → Open

**Action:** Heater Output Valve → Open

**Action:** Filter Inlet Valve → Closed

**Action:** Filter Output Valve → Closed



**SES Deactivation and Glycol Flushing**

4.18 **Action:** Glycol Pump → On

Wait until there is good glycol flow back into the glycol tank, free of water slugs.

4.19 **Action:** Glycol Pump → Off

4.20 Configure from Glycol to Compressed Air.

Caution
All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

4.21 For four heaters:

**Action:** Heater Inlet Valve → Closed

**Action:** Heater Output Valve → Closed

**Action:** Filter Inlet Valve → Open

**Action:** Filter Output Valve → Open

4.22 **Action:** Air Compressor → On

**Action:** Service Air → On

Blow air for the longer of 15 minutes, or until there is no mist or spray at the hose outlet into the Glycol Tank.

4.23 **Action:** Service Air → Off

4.24 For the four heaters:

**Action:** Heater Inlet Valve → Open

**Action:** Heater Output Valve → Open

**Action:** Filter Inlet Valve → Closed

**Action:** Filter Output Valve → Closed

4.25 **Action:** Service Air → On

Blow air for the longer of 15 minutes, or until there is no mist or spray at the hose outlet into the Glycol Tank.

## SES Deactivation and Glycol Flushing

- 4.26 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

### 5. Deactivating the Condensate Filter System

<b>Note</b>
Deactivation of the PHS Condensate system requires work in all four MHPs.

- 5.1 Sequentially, for each MHP MDS, perform the following steps:  
 Manually empty the triangular condensate collection tanks.
- Remove the condensate outlet line from the collection tank.
- Use a portable air compressor to blow the line into the PHS Condensate Collection Tank. Make sure that the line is clear (~10 minutes).
- Remove and store the hoses.
- 5.2 For MHPs 1-3, perform the following steps. Do not perform these steps for MHP4.
- Remove the MHP Condensate Pump.
- Place it in a container of glycol, with a short return line directly back into the glycol.
- Run the pump for 5-10 seconds.
- Drain glycol from the tank back into the container.
- Tag the pump and place it into DNF storage.
- 5.3 Remove the PHS Condensate Sump Pump, and place it in a container of glycol, with a short return line directly back into the glycol.
- Run the pump for 5-10 seconds.
- Drain glycol from the tank back into the container.
- Tag the pump and place it into DNF storage.
- 5.4 Drain the Centrifuge Filter into the Condensate Tank.

**SES Deactivation and Glycol Flushing****Note**

Water drained through the bottom outlets of the filter housings is safe for return to Water Tank 2. Special disposal is not required.

5.5 Drain the filter system into catch pans.

Dump the catch pans into WT2.

When the filters no longer gravity drain into the catch pans, proceed to Step 5.6.

5.6 Install the sump pump from MHP4 (which was not treated with glycol in Step 5.2) into the Condensate Collection Tank.

Pump the contents of the Condensate Tank into 55 gallon drums for disposal.

Empty the buckets into WT1.

5.7 Remove and dispose of the used Condensate Filter System bags.

There will be water remaining in the filter housings and the filters which should be added to the 55 gallon drums for disposal.

5.8 For the MHP4 pump used in Step 5.6, place the pump in a container of glycol, with a short return line directly back into the glycol.

Run the pump for 5-10 seconds.

Drain glycol from the tank back into the container.

Tag the pump and place it into DNF storage.

6. Shutting Down the PHS MDS

6.1 Remove the four Pressure Transducers.

Tag the Pressure Transducers, and place them in DNF storage.

**SES Deactivation and Glycol Flushing**

- 6.2 Confirm that Unico archives have been saved.  
Lockout power sources for the Unico drives.  
Remove the 3 Unico Drives.  
Tag the drives and place them in DNF storage.
- 6.3 **Action:** Furnace → Off  
Remove the PHS fuel line.
- 6.4 Disconnect the Fire Suppression CO<sub>2</sub> Bottle from the Fire Suppression System.
- 6.5 Disconnect the PHS network and E-Stop cables.
- 6.6 Place covers over all vents, chimneys, and holes in the building.  
Cap all hose ports.
- 6.7 Remove the Smoke/CO alarm, and place it in DNF storage.  
Remove the Emergency Light, and place it in DNF storage.
- 6.8 Open all Circuit Breakers in the PHS power panel.
- 6.9 In the PDM, open the Circuit Breakers that feed power to the PHS.
- 6.10 Remove the PHS power feeders from the PHS.  
Coil them and place them on top of the PHS.
- 6.11 Place the steps and landing back inside the PHS.

**Note**

The PHS is fully winterized, and ready to be moved to the winter storage area.

**7. Preparing for MHP Deactivation**

- 7.1 Request that the DCC Operator reduce Idle Pump flow rate to ~16.

## SES Deactivation and Glycol Flushing

- 7.2 For each MHP MDS, remove the Heater Flow Meters. Perform the following steps for each Heater in each MHP:

**Action:** Overhead Valve → Closed

**Action:** Output Manifold Valve → Closed

Remove the Heater's Flow Meter Assembly.

Drain the water into a container.

Install a jumper hose in place of the Flow Meter. Daisy chain the Heaters.

**Action:** Overhead Valve → Open

**Action:** Output Manifold Valve → Open

- 7.3 Verify that all Heater valves are fully open before proceeding.

8. Winterizing MHPs 2 and 3

<b>Note</b>
WT2 Deactivation can occur in parallel with deactivation of the MHPs. However, WT2 cannot be fully drained until MHPs 1 and 4 are blown free of water in Step 11.10

- 8.1 Terminate flow through MHPs 2 and 3

**Action:** HPP Inlet Manifold 2 & 3 Valve → Closed

**Action:** HPP Output Manifold 2 & 3 Valve → Closed

- 8.2 Connect the MHP2 Cold Input Hose to the Air Compressor

Run the MHP3 Hot Output Hose to WT2.

## SES Deactivation and Glycol Flushing

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

- 8.3 **Verify:** MHP2 Cold Inlet Manifold Valve – Open  
**Verify:** MHP2 Hot Output Manifold Valve – Open  
**Verify:** MHP2 Cold Output Manifold Valve – Open
- Verify:** MHP3 Cold Inlet Manifold Valve – Open  
**Verify:** MHP3 Hot Output Manifold Valve – Open  
**Verify:** MHP3 Cold Output Manifold Valve – Open

- 8.4 **Action:** Air Compressor → On  
**Action:** Service Air → On

Maintain airflow until the flow into WT2 is predominantly air.

- 8.5 **Action:** MHP2 Cold Output Manifold Valve → Closed

- 8.6 Leaving the valve for MHP2 Heater 1 open, Close the Heater Outlet Valves for all other MHP2 Heaters (Heaters 2-9).

Wait 5 minutes, while continuing to blow air.

- 8.7 In sequence, cycle through the remaining MHP2 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of water.

For each Heater, flow air for 5 minutes before proceeding to the next Heater.

After all Heaters have been blown clear of water, only the Outlet Valve for Heater 9 should be Open.

- 8.8 **Action:** MHP2 Cold Output Manifold Valve → Open  
**Action:** MHP3 Hot Inlet Manifold Valve → Closed

## SES Deactivation and Glycol Flushing

- 8.9 Leaving the valve for MHP3 Heater 1 open, Close the Heater Outlet Valves for all other MHP3 Heaters (Heaters 2-9).

Wait 5 minutes while continuing to blow air through the system.

- 8.10 In sequence, cycle through the remaining MHP3 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of water.

For each Heater, flow air for 5 minutes before proceeding to the next Heater.

After all Heaters have been blown clear of water, only the Outlet Valve for Heater 9 should be Open.

- 8.11 For each of the two Manifold Drain Valves in each MHPs 2 and 3, Open the Valve briefly to allow water collected there to drain out.

- 8.12 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

- 8.13 Configure from Air Compressor to Glycol Tank.

Move the MHP3 Hot Output Hose from WT2 to the Glycol Tank.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

- 8.14 **Action:** Glycol Pump → On

Continue until there has been flow back into the Glycol Tank for at least 5 minutes.

- 8.15 In sequence, cycle back through the remaining MHP3 Heaters toward Heater 1, Opening the previous Heater's Outlet Valve and then closing the Outlet Valve for the Heater just filled with glycol.

Run glycol through each Heater for 5 minutes.

- 8.16 **Action:** Glycol Pump → Off

## SES Deactivation and Glycol Flushing

8.17 Configure from Glycol Tank to Air Compressor.

8.18 **Action:** Air Compressor → On  
**Action:** Service Air → On

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

8.19 Recover most of the glycol, one heater at a time.

In sequence, cycle through the remaining MHP3 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of glycol.

Blow air through each heater for 5 minutes.

8.20 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

### Note

For MHP2, the Heater 9 Outlet Valve should Open, with the Outlet Valves for Heaters 1-8 Closed.

8.21 **Action:** MHP2 Cold Output Manifold Valve → Closed  
**Action:** MHP3 Hot Inlet Manifold Valve → Open

8.22 Configure from Air Compressor to Glycol Tank.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.



## SES Deactivation and Glycol Flushing

8.23 **Action:** Glycol Pump → On

Continue until there has been flow back into the Glycol Tank for at least 5 minutes.

8.24 In sequence, cycle back through the remaining MHP2 Heaters toward Heater 1, Opening the previous Heater's Outlet Valve and then closing the Outlet Valve for the Heater just filled with glycol.

Run glycol through each Heater for 5 minutes.

8.25 **Action:** Glycol Pump → Off

8.26 Configure from Glycol Tank to Air Compressor.

8.27 **Action:** Air Compressor → On  
**Action:** Service Air → On

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

8.28 Recover most of the glycol, one heater at a time.

In sequence, cycle through the remaining MHP2 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of glycol.

Blow air through each heater for 5 minutes.

8.29 Open all Heater Outlet Valves for MHPs 2 and 3.

Open all Manifold Valves for MHPs 2 and 3.

8.30 Blow compressed air through the system for at least 15 minutes to recover the remaining glycol.

8.31 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

## SES Deactivation and Glycol Flushing

### 9. Shutting Down MHP 2 and 3 MDSs

- 9.1 Remove the 4 Pressure Transducers, two for each manifold, from each of MHPs 2 and 3.

Tag the transducers, and place them in DNF storage.

Remove all other DNF items from, including the Smoke/CO Detector and Emergency Light. Tag and place them into DNF storage.

- 9.2 Seal the Make Up Air Fan intakes.

- 9.3 For each of MHPs 2 and 3:

**Action:** Furnace → Off

Remove the MHP fuel line.

- 9.4 Disconnect the Fire Suppression CO<sub>2</sub> Bottle from the Fire Suppression System for each of MHPs 2 and 3.

- 9.5 Disconnect the network and E-Stop cables for each of MHPs 2 and 3.

- 9.6 Place covers over all vents, chimneys, and holes in MHPs 2 and 3.

Cap all hose ports for MHPs 2 and 3.

- 9.7 Open all Circuit Breakers in the MHP 2 and 3 power panels.

- 9.8 In the PDM, open the Circuit Breakers that feed power to MHPs 2 and 3.

- 9.9 Remove the MHP power feeders from MHPs 2 and 3.

Coil the feeders and place each on the roof of its MHP.

- 9.10 Place the steps and landings back inside MHPs 2 and 3.

Note
MHPs 2 and 3 are fully winterized, and ready to be moved to the winter storage area.

### 10. Deactivating the Charge Pumps

- 10.1 Request that the DCC Operator turn off all four Charge Pumps.

**SES Deactivation and Glycol Flushing**

10.2 Shut down the four High Pressure Pump Motor Controllers.

Open the Circuit Breakers to the High Pressure Pump Motor Controllers.

Apply lockouts to the Circuit Breakers that feed the High Pressure Pumps.

10.3 For each High Pressure Pump:

**Action:** HPP Inlet Port Valve → Closed

10.4 Remove the 4" hoses from the WT2 Manifolds.

Drain the 4" hoses to the snow.

Remove the 4" hoses from the HPP MDS.

Run the hoses dry.

10.5 Cap the 4" hoses just removed.

Cap the HPP outlets.

Cap the WT2 Manifolds.

**Warning**

Footing on the Tank can be unstable. Exercise caution when bracing feet to raise the pumps from the Tank.

10.6 Remove the Charge Pumps from WT2.

## SES Deactivation and Glycol Flushing

### Note

The Charge Pump motor starters are not DNF.

### Caution

Failure to treat a Charge Pump with glycol can lead to water freezing in and on the pump, which can damage the pump.

Each pump should be treated as it is removed from the tank, before proceeding to the next pump. Each pump should be treated within 5 minutes of removal.

- 10.7 For each Charge Pump:  
Immediately place the pump in a container of glycol, with a short return line directly back into the glycol. Run the pump for 5-10 seconds.

Treat the Charge Pump Motor with glycol.

Drain the glycol out of the motor.

### 11. Winterizing MHPs 1 and 4

- 11.1 Connect the MHP1 Cold Input Hose to the Air Compressor

- 11.2 Run the MHP4 Hot Output Hose to WT2.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

- 11.3 **Verify:** MHP1 Cold Inlet Manifold Valve – Open  
**Verify:** MHP1 Hot Output Manifold Valve – Open  
**Verify:** MHP1 Cold Output Manifold Valve – Open
- Verify:** MHP4 Cold Inlet Manifold Valve – Open  
**Verify:** MHP4 Hot Output Manifold Valve – Open  
**Verify:** MHP4 Cold Output Manifold Valve – Open

**SES Deactivation and Glycol Flushing**

- 11.4 **Action:** Air Compressor → On  
**Action:** Service Air → On

Maintain air flow until the flow into WT2 is predominantly air.

- 11.5 **Action:** MHP1 Cold Output Manifold Valve → Closed

- 11.6 Leaving the valve for MHP1 Heater 1 open, Close the Heater Outlet Valves for all other MHP1 Heaters (Heaters 2-9).

Wait 5 minutes while maintaining air flow.

- 11.7 In sequence, cycle through the remaining MHP1 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of water.

For each Heater, flow air for 5 minutes before proceeding to the next Heater.

After all Heaters have been blown clear of water, only the Outlet Valve for Heater 9 should be Open.

- 11.8 **Action:** MHP1 Cold Output Manifold Valve → Open  
**Action:** MHP4 Hot Inlet Manifold Valve → Closed

- 11.9 Leaving the valve for MHP4 Heater 1 open, Close the Heater Outlet Valves for all other MHP4 Heaters (Heaters 2-8).

Wait 5 minutes while maintaining air flow.

<b>Note</b>
Once the water blowout for MHPs 1 and 4 has completed, WT2 Deactivation can be completed.

- 11.10 In sequence, cycle through the remaining MHP4 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of water.

For each Heater, flow air for 5 minutes before proceeding to the next Heater.

After all Heaters have been blown clear of water, only the Outlet Valve for Heater 8 should be Open.

## SES Deactivation and Glycol Flushing

11.11 For each of the two Manifold Drain Valves in each MHPs 1 and 4, Open the Valve briefly to allow water collected there to drain out.

11.12 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

11.13 Configure from Air Compressor to Glycol Tank.

Move the MHP4 Hot Output Hose from WT2 to the Glycol Tank.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

11.14 **Action:** Glycol Pump → On

Continue until there has been flow back into the Glycol Tank for at least 5 minutes.

11.15 In sequence, cycle back through the remaining MHP4 Heaters toward Heater 1, Opening the previous Heater's Outlet Valve and then closing the Outlet Valve for the Heater just filled with glycol.

Run glycol through each Heater for 5 minutes.

11.16 **Action:** Glycol Pump → Off

11.17 Configure from Glycol Tank to Air Compressor.

11.18 **Action:** Air Compressor → On  
**Action:** Service Air → On

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

## SES Deactivation and Glycol Flushing

11.19 Recover most of the glycol, one heater at a time.

In sequence, cycle through the remaining MHP4 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of glycol.

Blow air through each heater for 5 minutes.

11.20 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

### Note

For MHP1, the Heater 9 Outlet Valve should Open, with the Outlet Valves for Heaters 1-8 Closed.

11.21 **Action:** MHP1 Cold Output Manifold Valve → Closed  
**Action:** MHP4 Hot Inlet Manifold Valve → Open

11.22 Configure from Air Compressor to Glycol Tank.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

11.23 **Action:** Glycol Pump → On

Continue until there has been flow back into the Glycol Tank for at least 5 minutes.

11.24 In sequence, cycle back through the remaining MHP1 Heaters toward Heater 1, Opening the previous Heater's Outlet Valve and then closing the Outlet Valve for the Heater just filled with glycol.

Run glycol through each Heater for 5 minutes.

11.25 **Action:** Glycol Pump → Off

11.26 Configure from Glycol Tank to Air Compressor.

## SES Deactivation and Glycol Flushing

- 11.27 **Action:** Air Compressor → On  
**Action:** Service Air → On

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

- 11.28 Recover most of the glycol, one heater at a time.

In sequence, cycle through the remaining MHP1 Heaters, Opening the next Heater's Outlet Valve and then closing the Outlet Valve for the Heater just blown clear of glycol.

Blow air through each heater for 5 minutes.

- 11.29 Open all Heater Outlet Valves for MHPs 1 and 4.

Open all Manifold Valves for MHPs 1 and 4.

- 11.30 Blow compressed air through the system for at least 15 minutes to recover the remaining glycol.

- 11.31 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

## 12. Shutting Down MHPs 1 and 4

- 12.1 Remove the 4 Pressure Transducers, two for each manifold, from each of MHPs 1 and 4.

Tag the transducers, and place them in DNF storage.

Remove all other DNF items, including the Smoke/CO Detector and Emergency Light, and place them in DNF storage.

- 12.2 Seal the Make Up Air Fan intakes.



**SES Deactivation and Glycol Flushing**

12.3 For each of MHPs 1 and 4:

**Action:** Furnace → Off

Remove the MHP fuel line.

12.4 Disconnect the Fire Suppression CO<sub>2</sub> Bottle from the Fire Suppression System for each of MHPs 1 and 4.

12.5 Disconnect the network and E-Stop cables for each of MHPs 1 and 4.

12.6 Place covers over all vents and holes in MHPs 1 and 4.

Cap all hose ports for MHPs 1 and 4.

12.7 Open all Circuit Breakers in the MHP 1 and 4 power panels.

12.8 In the PDM, open the Circuit Breakers that feed power to MHPs 1 and 4.

12.9 Remove the MHP power feeders from MHPs 1 and 4.

Coil the feeders and place each on the roof of its MHP.

12.10 Place the steps and landings back inside MHPs 1 and 4.

<b>Note</b>
MHPs 1 and 4 are fully winterized, and ready to be moved to the winter storage area.

## SES Deactivation and Glycol Flushing

### 13. Water Tank 2 Deactivation

#### Note

Step 13.1 can be started at any time. However, since water from the MHPs is blown into WT2, the process of draining the tank cannot be completed until after Step 11.10 is finished.

#### Caution

Do not run the Transfer Pumps dry. To avoid damage to the pump, they must be stopped before they run dry.

- 13.1 Request that the DCC Operator drain all water from WT2. The water should be directed to WT1, and from there down the Rod Well.

#### Note

Step 13.2 cannot be started until after Step 11.10 is complete.

There will probably be 0.2m of water left in WT2 when complete.

#### Caution

Failure to treat a Transfer Pump with glycol can lead to water freezing in and on the pump, which can damage the pump.

Each pump should be treated as it is removed from the tank, before proceeding to the next pump. Each pump should be treated within 5 minutes of removal.

- 13.2 Remove the Transfer Pumps from WT1 and WT2. For each of the two pumps, immediately place the pump in a container of glycol, with a short return line directly back into the glycol. Run the pump for 5-10 seconds.
- 13.3 Lower a sump pump into WT2 with a discharge hose to WT1.  
Remove as much of the remaining water from WT2 as practical.
- 13.4 Remove the Sump Pump from WT2. Place the pump into WT1.

## SES Deactivation and Glycol Flushing

### Warning

Failure to follow the Permit Required Confined Space Entry procedure can cause suffocation.

13.5 Use a shop vac and squeegee to remove the remaining water from WT2.

If necessary, heat the air volume during water removal to keep the remaining water from freezing.

Use the Permit Required Confined Space Entry Procedure.

13.6 Remove the temperature and pressure sensors, and remove them to DNF storage.

13.7 Close the lids.

Disconnect the stairs.

### Note

WT2 is fully winterized, and ready to be moved to the winter storage area.

14. HPP Deactivation

14.1 Drain the Cold Outlet Bypass Fitting.

Drain the Hot Return Bypass Fitting.

14.2 Attach the Glycol Tank hose to the HPP 1 Inlet.

14.3 Jumper the HPP Outlet Manifold to the Glycol Tank.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

14.4 **Action:** HPP 1 Inlet Valve → Open

14.5 **Action:** HPP Outlet Manifold Valve → Open

**SES Deactivation and Glycol Flushing**

14.6 **Action:** Glycol Pump → On

Run HPP1 at 50 RPM for 5 seconds to clear it of water.

Run glycol through the pump until the returning glycol stream is clear of water.

14.7 **Action:** Glycol Pump → Off

14.8 **Action:** HPP 1 Inlet Valve → Closed

14.8 Disconnect the Glycol Tank Hose from the HPP 1 Inlet and move it to the HPP 2 Inlet.

14.9 **Action:** HPP 2 Inlet Valve → Open

**Action:** Glycol Pump → On

Run HPP2 at 50 RPM for 5 seconds to clear it of water.

Run glycol through the pump until the returning glycol stream is clear of water.

14.10 **Action:** Glycol Pump → Off

**Action:** HPP 2 Inlet Valve → Closed

14.11 Disconnect the Glycol Tank Hose from the HPP 2 Inlet and move it to the HPP 3 Inlet.

14.12 **Action:** HPP 3 Inlet Valve → Open

14.13 **Action:** Glycol Pump → On

Run HPP3 at 50 RPM for 5 seconds to clear it of water.

Run glycol through the pump until the returning glycol stream is clear of water.

14.14 **Action:** Glycol Pump → Off

**Action:** HPP 3 Inlet Valve → Closed

14.15 Disconnect the Glycol Tank Hose from the HPP 3 Inlet and move it to the HPP 4 Inlet.

**SES Deactivation and Glycol Flushing**

14.16 **Action:** HPP 4 Inlet Valve → Open

**Action:** Glycol Pump → On

Run HPP4 at 50 RPM for 5 seconds to clear it of water.

Run glycol through the pump until the returning glycol stream is clear of water.

14.17 **Action:** Glycol Pump → Off

14.18 Configure from Glycol Tank to Air Compressor.

**Caution**

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

14.19 Limit Air Compressor output pressure to 30 psi.

14.20 **Action:** Air Compressor → On

**Action:** Service Air → On

14.21 Blow out HPP 4 for 5 minutes.

Run HPP4 at 50 RPM for 5 seconds to clear it of glycol.

**Action:** Service Air → Off

**Action:** HPP 4 Inlet Valve → Closed

14.22 Disconnect the air hose from the HPP 4 Inlet and move it to the HPP 3 Inlet.

14.23 **Action:** HPP 3 Inlet Valve → Open

**SES Deactivation and Glycol Flushing**

14.24 **Action:** Service Air → On

Run HPP3 at 50 RPM for 5 seconds to clear it of glycol.

Blow out HPP 3 for 5 minutes.

**Action:** Service Air → Off

14.25 **Action:** HPP 3 Inlet Valve → Closed

14.26 Disconnect the air hose from the HPP 3 Inlet and move it to the HPP 2 Inlet.

14.27 **Action:** HPP 2 Inlet Valve → Open

Run HPP2 at 50 RPM for 5 seconds to clear it of glycol.

14.28 **Action:** Service Air → On

Blow out HPP 2 for 5 minutes.

**Action:** Service Air → Off

14.29 **Action:** HPP 2 Inlet Valve → Closed

14.30 Disconnect the air hose from the HPP 2 Inlet and move it to the HPP 1 Inlet.

14.31 **Action:** HPP 1 Inlet Valve → Open

**Action:** Service Air → On

Run HPP1 at 50 RPM for 5 seconds to clear it of glycol.

Blow out HPP 1 for 5 minutes.

Make sure that all other lines are blown dry.

**Action:** Service Air → Off

**Action:** Air Compressor → Off

14.32 **Action:** HPP 1 Inlet Valve → Closed

14.33 Verify that all valves are closed.

14.34 Remove the 30 psi air compressor limit established in Step 14.19.

**SES Deactivation and Glycol Flushing**15. Winterizing the HPP

15.1 For each of the two Pressure Relief Valves in each HPP MDS, remove the brass cap from the Valve to release any water collected behind it, and then immediately replace the cap.

15.2 Remove the 4 Pressure Transducers.

Tag the transducers, and place them in DNF storage.

15.3 Remove the 5 Flow Meters.

Tag the Flow Meters, and place them in DNF storage.

15.4 Apply lockouts to the Circuit Breakers that supply power to the Unico drives.

Remove the 8 Unico Drives.

Tag the Unico Drives, and place them in DNF storage.

15.5 **Action:** Furnace → Off

Remove the MHP fuel line.

15.6 Disconnect the Fire Suppression CO<sub>2</sub> Bottle from the Fire Suppression System.

Remove the Smoke/CO Detector, the Emergency Light, and any other DNF equipment, and place them into DNF storage.

15.7 Disconnect the HPP network and E-Stop cables.

15.8 Place covers over all vents and holes.

Cap all hose ports.

15.9 Open all Circuit Breakers in the HPP power panel.

15.10 In the PDM, open the Circuit Breaker that feeds power to the HPP.

15.11 Remove the HPP power feeder. Coil the feeder, and place it on the roof of the HPP.

15.12 Place the steps and landing back inside the HPP.

**SES Deactivation and Glycol Flushing****Note**

The HPP is fully winterized, and ready to be moved to the winter storage area.

16. Water Tank 1 Deactivation

16.1 **Action:** RWS Flow to Gen Set Valve → Closed

**Action:** RWS Flow to Gen Set Solenoid Valve → Closed

16.2 Disconnect the Generator Waste Heat Water Loop Hose.

16.3 Blow the hose out with the Air Compressor.

16.4 Request that the DCC Operator drain all water from WT1. The water should be directed down the Rod Well.

16.5 Place a sump pump into WT1 with its output hose running down the Rod Well hole.

Remove as much of the remaining water from WT2 as practical.

**Caution**

Failure to treat the Sump Pump with glycol can lead to water freezing in and on the pump, which can damage the pump.

The pump should be treated within 5 minutes of removal.

16.6 Remove the Sump Pump from WT1. Immediately place the pump in a container of glycol, with a short return line directly back into the glycol. Run the pump for 5-10 seconds.

Drain excess glycol from the pump.



**SES Deactivation and Glycol Flushing****Warning**

Failure to follow the Permit Required Confined Space Entry procedure can cause suffocation.

- 16.7 Use a shop vac and squeegee to remove the remaining water from WT1.

If necessary, heat the air volume during water removal to keep the remaining water from freezing.

Use the Permit Required Confined Space Entry Procedure.

- 16.8 Remove the temperature and pressure sensors, and remove them to DNF storage.

- 16.9 Close the lids.

Disconnect the stairs.

**Note**

WT1 is fully winterized, and ready to be moved to the winter storage area.

17. Deactivating the Rod Well

- 17.1 Remove the 2 Flow Meters. Tag and place them in DNF storage.

- 17.2 **Action:** Submersible Pump → Off

**Action:** Submersible Pump Backflow Valve → Open

- 17.3 Break the siphons in the Supply and Return Hoses.

**Caution**

The Combo Cable must be disconnected before the Combo Cable Reel can be rotated. Because the Combo Cable Reel lacks slip rings, the Cable will be damaged if the Reel is rotated with the Cable attached to the RWS.

- 17.4 Disconnect the Combo Cable from the RWS, and secure the connector to the reel, so that it does not snag when the Reel rotates.

## SES Deactivation and Glycol Flushing

- 17.5 Disconnect the Temperature and Pressure sensors.
- 17.6 Remove the Combo Cable Reel Motor Controller lockout.
- Apply power to the Combo Cable Reel Motor Controller.
- 17.7 Apply power to the RWS Hose Reel Motor Controller.
- 17.8 Attach a pendant to the Hose Reel.
- 17.9 Energize the Combo Cable Reel Motor Controller.
- Energize the Hose Reel Motor Controller.

### Warning

Keep the weight of the pump assembly on the Hoses, and not on the cable.

Do not allow the Combo Cable or hoses to become wound or tangled on the ground. Doing so creates a personal injury hazard should positional control of the Pump Assembly be lost.

- 17.10 **Action:** RWS Combo Cable Reel Brake → Disengaged  
**Action:** RWS Hose Reel Brake → Disengaged

- 17.11 Raise the Submersible Pump to the surface.

Remove the tape bands holding the hoses and sensor lines together as the Pump is raised.

Leave the depth marking tape bands in place.

- 17.12 **Action:** RWS Combo Cable Reel Brake → Engaged  
**Action:** RWS Hose Reel Brake → Engaged
- Verify:** RWS Combo Cable Reel Brake Hydraulic Pressure – 0  
**Verify:** RWS Hose Reel Brake Hydraulic Pressure – 0
- 17.13 **Action:** RWS Combo Cable Reel Motor Controller → Off  
**Action:** RWS Hose Reel Motor Controller → Off

## SES Deactivation and Glycol Flushing

### Caution

The Submersible Pump can be damaged if it freezes. To prevent freeze damage, it must be treated with glycol within 5 minutes of removal from the hole.

17.14 Move the Submersible Pump Assembly away from the hole and place it on a sled.

Disconnect the Temperature and Pressure sensors, the Supply and Return Hoses, and the Combo Cable.

17.15 Move the sled to the Glycol Tank, and run glycol through the Submersible Pump for 5-10 seconds.

Remove excess glycol from the pump.

### Caution

All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

17.16 Place the Supply and Return Hoses with their ends down the Rod Well hole.

17.17 Connect the Air Compressor to the RWS Tank 1 Inlet.

17.18 Run a hose from the WT1 Outlet to snow.

17.19 **Action:** Air Compressor → On

**Action:** Service Air → On

17.20 **Action:** Tank1 Cold Supply Manifold Valve → Open

**Action:** Gen Set Flow Valve → Closed

**Action:** RWS Backflow Valve → Closed

17.21 **Action:** Well Hot Return Manifold Valve → Open

17.22 Configure all heaters with Tank1 as inlet, Rod Well as outlet, and Open.

**SES Deactivation and Glycol Flushing**

17.23 **Action:** Air Compressor → On  
**Action:** Service Air → On

Wait 5 minutes while continuing air flow.

17.24 **Action:** Vane Pump 1 Inlet Valve → Closed

Wait 2 minutes while continuing air flow.

17.25 **Action:** Vane Pump 1 Inlet Valve → Open  
**Action:** Vane Pump 2 Inlet Valve → Closed

Wait 2 minutes while continuing air flow.

17.26 **Action:** Vane Pump 2 Inlet Valve → Open

**Action:** Rod Well Supply Manifold Valve → Open

Configure all main Heater valves to Closed.

Wait 2 minutes.

17.27 Configure all main Heater valves to Open.

**Action:** Rod Well Supply Manifold Valve → Closed

**Action:** Rod Well Utility Cold Valve → Open

Wait 2 minutes.

17.28 Configure main Heater valves 2-10 to Closed.

Wait 2 minutes.

**Action:** Heater 1 Input Valve → Rod Well

Wait 2 minutes.

17.29 **Action:** Heater 2 Valve → Open

**Action:** Heater 1 Valve → Closed

Wait 2 minutes.

**Action:** Heater 2 Input Valve → Rod Well

**SES Deactivation and Glycol Flushing**

Wait 2 minutes.

Repeat these actions for each heater.

17.30 Configure all heater input selector valves to Tank1.

**Action:** Tank1 Return Valve → Open

**Action:** Heater 1 → Open

Configure main Heater valves 2-10 to Closed.

**Action:** Heater 1 Output Selector Valve → Tank1

Wait 2 minutes.

17.31 **Action:** Heater 2 Valve → Open

**Action:** Heater 1 Valve → Closed

Wait 2 minutes.

**Action:** Heater 2 Output Selector Valve → Tank1

Wait 2 minutes.

Repeat these actions for each heater.

17.32 Configure all main heater valves to Open.

Configure all Heater Input Selector Valves to Tank1.

Configure all Heater Output Selector Valves to Tank1.

Wait 2 minutes.

17.33 **Action:** Gen Set Valve → Open

**Action:** Gen Set Solenoid Valve → Open

17.34 **Action:** Tank1 Supply Manifold Valve → Closed

Wait 2 minutes.

**SES Deactivation and Glycol Flushing**

17.35 **Action:** Gen Set Valve → Closed  
**Action:** Gen Set Solenoid Valve → Closed

17.36 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

17.37 Open all 12 Vent Drain Valves.

Wait until all valves have drained any water they contain.

Close all 12 Vent Drain Valves.

17.38 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

17.39 **Action:** RWS Hose Reel Motor Controller → On

17.40 Wind the Supply and Return Hoses back into the RWS MDS.

Connect the two hoses together in a loopback configuration.

Caution
All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

17.41 Configure from Air Compressor to Glycol Tank.

17.42 Glycol Pump → On

17.43 Request that the DCC Operator turn on the Vane Pumps at minimum speed.

17.44 **Action:** Tank1 Cold Supply Manifold Valve → Open

**Action:** Gen Set Flow Valve → Closed

**Action:** RWS Backflow Valve → Closed

17.45 **Action:** Well Hot Return Manifold Valve → Open

17.46 Configure all heaters with Tank1 as inlet, Rod Well as outlet, and On.

**SES Deactivation and Glycol Flushing**

17.47 **Action:** Air Compressor → On  
**Action:** Service Air → On

Wait 5 minutes.

17.48 **Action:** Vane Pump 1 Inlet Valve → Closed

Wait 2 minutes.

17.49 **Action:** Vane Pump 1 Inlet Valve → Open  
**Action:** Vane Pump 2 Inlet Valve → Closed

Wait 2 minutes.

17.50 **Action:** Vane Pump 2 Inlet Valve → Open

**Action:** Rod Well Supply Manifold Valve → Open

Configure all main Heater valves to Closed.

Wait 2 minutes.

17.51 Configure all main Heater valves to Open.

**Action:** Rod Well Supply Manifold Valve → Closed

**Action:** Rod Well Utility Cold Valve → Open

Wait 2 minutes.

17.52 Configure main Heater valves 2-10 to Closed.

Wait 2 minutes.

**Action:** Heater 1 Input Valve → Rod Well

Wait 2 minutes.

**SES Deactivation and Glycol Flushing**

17.53 **Action:** Heater 2 Valve → Open

**Action:** Heater 1 Valve → Closed

Wait 2 minutes.

**Action:** Heater 2 Input Valve → Rod Well

Wait 2 minutes.

Repeat these actions for each heater.

17.54 Configure all heater input selector valves to Tank1.

**Action:** Tank1 Return Valve → Open

**Action:** Heater 1 → Open

Configure main Heater valves 2-10 to Closed.

**Action:** Heater 1 Output Selector Valve → Tank1

Wait 2 minutes.

17.55 **Action:** Heater 2 Valve → Open

**Action:** Heater 1 Valve → Closed

Wait 2 minutes.

**Action:** Heater 2 Output Selector Valve → Tank1

Wait 2 minutes.

Repeat these actions for each heater.

17.56 Configure all main heater valves to Open.

Configure all Heater Input Selector Valves to Tank1.

Configure all Heater Output Selector Valves to Tank1.

Wait 2 minutes.



**SES Deactivation and Glycol Flushing**

17.57 **Action:** Gen Set Valve → Open  
**Action:** Gen Set Solenoid Valve → Open

17.58 **Action:** Tank1 Supply Manifold Valve → Closed

Wait 2 minutes.

17.59 **Action:** Gen Set Valve → Closed  
**Action:** Gen Set Solenoid Valve → Closed

17.60 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

17.61 Open all 12 Vent Drain Valves.

Wait until all valves have drained any water they contain.

Close all 12 Vent Drain Valves.

17.62 Request that the DCC Operator turn the Vane Pumps Off.

17.63 Glycol Pump → Off

17.64 Configure from Glycol Tank to Air Compressor.

Caution
All water removal steps must be performed as written. Failure to perform one or more of the water removal steps during air blowing or glycol treating can lead to water in the system that can damage system components when it freezes.

17.65 **Action:** Air Compressor → On  
**Action:** Service Air → On

17.66 **Action:** Tank1 Cold Supply Manifold Valve → Open

**Action:** Gen Set Flow Valve → Closed

**Action:** RWS Backflow Valve → Closed

17.67 **Action:** Well Hot Return Manifold Valve → Open

**SES Deactivation and Glycol Flushing**

17.68 Configure all heaters with Tank1 as inlet, Rod Well as outlet, and On.

17.69 **Action:** Air Compressor → On  
**Action:** Service Air → On

Wait 5 minutes.

17.70 **Action:** Vane Pump 1 Inlet Valve → Closed

Wait 2 minutes.

17.71 **Action:** Vane Pump 1 Inlet Valve → Open  
**Action:** Vane Pump 2 Inlet Valve → Closed

Wait 2 minutes.

17.72 **Action:** Vane Pump 2 Inlet Valve → Open

**Action:** Rod Well Supply Manifold Valve → Open

Configure all main Heater valves to Closed.

Wait 2 minutes.

17.73 Configure all main Heater valves to Open.

**Action:** Rod Well Supply Manifold Valve → Closed  
**Action:** Rod Well Utility Cold Valve → Open

Wait 2 minutes.

17.74 Configure main Heater valves 2-10 to Closed.

Wait 2 minutes.

**Action:** Heater 1 Input Valve → Rod Well

Wait 2 minutes.

**SES Deactivation and Glycol Flushing**

17.75 **Action:** Heater 2 Valve → Open

**Action:** Heater 1 Valve → Closed

Wait 2 minutes.

**Action:** Heater 2 Input Valve → Rod Well

Wait 2 minutes.

Repeat these actions for each heater.

17.76 Configure all heater input selector valves to Tank1.

**Action:** Tank1 Return Valve → Open

**Action:** Heater 1 → Open

Configure main Heater valves 2-10 to Closed.

**Action:** Heater 1 Output Selector Valve → Tank1

Wait 2 minutes.

17.77 **Action:** Heater 2 Valve → Open

**Action:** Heater 1 Valve → Closed

Wait 2 minutes.

**Action:** Heater 2 Output Selector Valve → Tank1

Wait 2 minutes.

Repeat these actions for each heater.

17.78 Configure all main heater valves to Open.

Configure all Heater Input Selector Valves to Tank1.

Configure all Heater Output Selector Valves to Tank1.

Wait 2 minutes.

**SES Deactivation and Glycol Flushing**

- 17.79 **Action:** Gen Set Valve → Open  
**Action:** Gen Set Solenoid Valve → Open
- 17.80 **Action:** Tank1 Supply Manifold Valve → Closed

Wait 2 minutes.

- 17.81 **Action:** Gen Set Valve → Closed  
**Action:** Gen Set Solenoid Valve → Closed
- 17.82 **Action:** Service Air → Off  
**Action:** Air Compressor → Off

- 17.83 Open all 12 Vent and Drain Valves.

Wait until all valves have drained any water they contain.

Close all 12 Vent and Drain Valves.

- 17.84 For each of three Pressure Relief Valves in the RWS, remove each Valve's cap to remove any water trapped behind it, then reinstall the cap.

18. Winterizing the RWS MDS

- 18.1 RWS Combo Cable Reel Motor Controller → On

Wind the Combo Cable completely onto the Combo Cable Reel.

- 18.2 RWS Combo Cable Reel Motor Controller → Off

Remove power from the Combo Cable Reel Motor Controller

Lock out the Circuit Breaker that supplies the Combo Cable Reel Motor Controller.

- 18.3 Disconnect the Combo Cable Reel from the RWS MDS.
- 18.4 Tag the Submersible Pump and place it in DNF storage.
- 18.5 Remove the Crescent, cover the hole, and mark the hole.
- 18.6 Remove the Pressure Transducers.

Tag and place them in DNF storage.

**SES Deactivation and Glycol Flushing**

18.7 Remove the Differential Pressure Switches.

Tag and place them in DNF storage.

18.8 Remove the 5 Unico Drives.

Tag and place them in DNF storage.

18.9 **Action:** Furnace → Off

Remove the RWS fuel line.

18.10 Disconnect the Fire Suppression CO<sub>2</sub> Bottle from the Fire Suppression System.

Remove the Smoke/CO Detector and Emergency Light and remove them to DNF storage.

Remove any other DNF items to DNF storage.

18.11 Disconnect the RWS network and E-Stop cables.

18.12 Place covers over all vents and holes.

Cap all hose ports.

18.13 Open all Circuit Breakers in the RWS power panel.

18.14 In the PDM, open the Circuit Breaker that feeds power to the RWS.

18.15 Remove the RWS power feeder.

Coil the feeder, and place it on the roof of the RWS.

18.16 Place the steps and landing back inside the RWS.

**SES Deactivation and Glycol Flushing****Note**

The RWS is fully winterized, and ready to be moved to the winter storage area.

19. Deactivating the DCC19.1 **Action:** Furnace → Off

Remove the DCC fuel line.

19.2 Disconnect the Gravity Tank Fuel Transfer Pump cables from DCC power outlets.

19.3 Disconnect the E-Stop cable.

Remove and store all external communications hardware.

19.4 Place covers over all vents and holes.

19.5 Open all Circuit Breakers in the DCC power panel.

19.6 In the PDM, open the Circuit Breaker that feeds power to the DCC.

19.7 Remove the DCC Power feeder, coil it, and place it on the roof of the DCC.

19.8 Place the steps and landing into the DCC.

19.9 Request that RPS move the DCC to the winter site.

Once the DCC is at the winter site, request that RPS connect the building to a generator.

19.10 Set up the ladder and entry steps for the building.

19.11 Check the battery in the Smoke Detector.

19.12 **Action:** DCC Main Breaker → On

## SES Deactivation and Glycol Flushing

### Caution

Be careful not to place objects close to the electrical heaters. Heat from the electrical heaters can char, warp, or ignite items placed too closely.

- 19.13 **Action:** Electrical Heater 1 → On  
**Action:** Electrical Heater 2 → On  
**Action:** Electrical Heater 3 → On

19.14 Set up and test the Power/Temperature warning light.

### 20. Deactivating the SEW

20.1 **Action:** Furnace → Off

Remove the SEW fuel line.

20.2 Disconnect the SEW network cable.

20.3 Place covers over all vents and holes.

20.4 Open all Circuit Breakers in the SEW power panel.

20.5 In the PDM, open the Circuit Breaker that feeds power to the SEW.

20.6 Remove the SEW power feeder, coil it, and place it on the SEW roof.

20.7 Place the steps and landing back inside the SEW.

### Note

The SEW is fully winterized, and ready to be moved to the winter storage area.

### 21. Deactivating Other Equipment

21.1 Request that RPS remove the Gravity Tank to winter storage.

21.2 Restore the Air Compressor intercool function to its normal configuration.

Request that RPS remove the Air Compressor to winter storage.

21.3 Remove the immersion heater from the Glycol Tank.

**SES Deactivation and Glycol Flushing**

21.4 Request that RPS remove the Glycol Tank to winter storage.



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original Document	10/01/05	

SHEET REVISION STATUS

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4	18	WINTERIZING CHECKLIST					
5	19	ENHANCED HOT WATER DRILL					
6	20	ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
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**SES Winterizing Checklist****Hoses and Reels Winterized**

- MSHR blown dry
- RWHR blown dry
- Surface Supply Hose blown dry
- Surface Return Hose blown dry

**Pre-Heat System Winterized**

- Water Drained and system winterized
- PHS Unico drives transferred to DNF
- MHP1 Condensate system winterized
- MHP2 Condensate system winterized
- MHP3 Condensate system winterized
- MHP4 Condensate system winterized
- PHS Condensate system winterized
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Building ready to move

**SES Winterizing Checklist****Main Heating Plant 1 Winterized**

- Water Drained and system winterized
- Pressure Transducers transferred to DNF
- Pressure Relief Valve caps removed to release trapped water
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Building ready to move

**Main Heating Plant 2 Winterized**

- Water Drained and system winterized
- Pressure Transducers transferred to DNF
- Pressure Relief Valve caps removed to release trapped water
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Building ready to move

**SES Winterizing Checklist****Main Heating Plant 3 Winterized**

- Water Drained and system winterized
- Pressure Transducers transferred to DNF
- Pressure Relief Valve caps removed to release trapped water
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Building ready to move

**Main Heating Plant 4 Winterized**

- Water Drained and system winterized
- Pressure Transducers transferred to DNF
- Pressure Relief Valve caps removed to release trapped water
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Building ready to move

**SES Winterizing Checklist****Tank2 Winterized**

- Charge Pump 1 winterized
- Charge Pump 2 winterized
- Charge Pump 3 winterized
- Charge Pump 4 winterized
- Tank1 Transfer Pump winterized
- Tank2 Transfer Pump winterized
- Tank2 Fully drained and dried
- Temperature and Pressure sensors removed
- Tank2 Sealed
- Tank2 ready to move

**High Pressure Pump Building Winterized**

- HPP 1 winterized
- HPP 2 winterized
- HPP 3 winterized
- HPP 4 winterized
- Pressure Transducers transferred to DNF
- Flow Meters transferred to DNF
- Unico Drives transferred to DNF
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Building ready to move

**SES Winterizing Checklist****Tank1 Winterized**

- Tank1 Fully drained and dried
- Temperature and Pressure sensors removed
- Tank1 Sealed
- Tank1 ready to move

**RWS Winterized**

- Submersible Pump winterized
- Water drained and system winterized
- Combo Cable Reel power lockout applied
- Submersible Pump transferred to DNF
- Crescent removed and hole closed out
- Furnace Deactivated
- CO2 Bottle Disconnected
- All DNF items removed
- Building sealed
- Electrical lockout applied in PDM
- Building ready to move

**DCC Winterized**

- Furnace Deactivated
- Building Sealed
- Gravity Tank Pump Power Disconnected
- DCC moved to winter storage
- Generator connected
- Warning light tested

## SES Winterizing Checklist

### SEW Winterized

- Furnace Deactivated
- All DNF items removed
- Building Sealed
- Building ready to move

### Misc Equipment Winterized

- Gravity Tank moved
- Air Compressor moved
- Glycol Tank moved

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**Antarctic Astronomy & Astrophysics Research Institute**  
MADISON, WISCONSIN

**TITLE**  
**ICECUBE**  
**REEL START**  
**ENHANCED HOT WATER DRILL**

ORIGINATOR	DATE	ENGINEER	DATE	SAFETY MGR	DATE
SC <i>[Signature]</i>	10/27/05	JC/FF <i>[Signature]</i>	10/27/05	HL <i>[Signature]</i>	10/27/05
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8510-0376  
**Reel Start**

References:

8510-0114 Cable Reel Hazard Analysis  
8510-0122 Drill Control System Hazard Analysis  
8510-0107 Drill Hose Reel Hazard Analysis  
8510-0124 Drilling Operations Hazard Analysis  
8510-0219 Return Water Cable Reel Hazard Analysis  
8510-0115 Return Water Hose Reel Hazard Analysis  
8510-0108 Tower Hazard Analysis  
9400-0061 DOM Deployment Hazard Analysis

Requirements:

Personnel: 2 Drillers or Deployers, with radios

Assumptions:

Brakes, motors, and E-Stop were all tested and verified to be working correctly.

Motors are off as a result of the Reel Stop or E-Stop that caused entry into this procedure.

**Note**

This procedure, as written, is most appropriate for use during drilling operations. If execution of this procedure is required during deployment, then any action for a Hose Reel can be disregarded.

**Caution**

Do not rotate a reel, or command one to a mode where rotation is possible if the reel's brake is on.

Doing so can damage the reel.

1. Entering a Known Safe State

1.1 Turn off Hose and Cable Reel motors from the computer.

**Note**

Pendant buttons can have a slow response. Hold times of up to ½ second may be required before a depressed button is recognized.

1.2 **Action:** Hose Reel Pendant Selection Switch → Comp  
**Action:** Cable Reel Pendant Selection Switch → Comp

8510-0376  
**Reel Start**

**Warning**

When the Reel Stop or E-Stop was activated, the Reel brakes should have automatically engaged. If this did not happen, then the system may not be able to engage the brakes again in some subsequent emergency.

Alert the shift lead to this fact. This deficiency must be addressed before reel operation can be considered safe again.

- 1.3 **Verify:** Hose Reel Level Wind Motor – Off  
**Verify:** Hose Reel Motor – Off
- Verify:** Cable Reel Level Wind Motor – Off  
**Verify:** Cable Reel Motor – Off
- Verify:** Hose Reel Brake – Engaged  
**Verify:** Cable Reel Brake – Engaged

**Warning**

Resolve the root cause of the Reel Stop or E-Stop before proceeding any further to recover function of the Reels. To do otherwise will possibly leave the Reels in an unsafe configuration where movement might not be fully controlled.

- 1.4 Correct the root cause of the Reel Stop or E-Stop.

Reset the E-Stop system if needed.

If the cause of the Reel Stop is activation of a level wind limit switch, proceed to Step 3 of this procedure.

Otherwise, proceed to Step 2.

8510-0376  
**Reel Start**

2. Restarting From a Non-Limit Switch Stop

2.1 Reset the Reel Stop Relay

**Note**

A relay transfer sound may be heard from within the E-Stop box after the Reel Start button is pressed.

**Action:** Reel Stop Reset → Press and Release

2.2 Release the Reel Brakes

**Action:** Hose Reel Pendant Selector Switch → Pend

**Action:** Hose Reel Pendant Velocity Button → Depressed

**Action:** Cable Reel Pendant Selector Switch → Pend

**Action:** Cable Reel Pendant Velocity Button → Depressed

**Action:** Hose Reel Brake → Released

**Action:** Cable Reel Brake → Released

**Verify:** Cable Reel Brake – Released

**Verify:** Hose Reel Brake – Released

**Note**

The level winds move slowly. The “left hand rule” can be used to determine the direction of the level winds when the movement is too slow to observe.

2.3 Use the Up and Down buttons, and the Velocity knob on the affected pendant to move the Level Wind to the correct position on the Reel.

2.4 If the reels need to be operated in computer mode, perform:

**Action:** Cable Reel Pendant Selector Switch → Comp

**Action:** Hose Reel Pendant Selector Switch → Comp

**Verify:** Cable Reel Brake – Released

**Verify:** Hose Reel Brake – Released

2.5 Verify that the Level Wind moves in the correct direction when movement of the reel resumes.

STOP EXECUTION OF THIS PROCEDURE

8510-0376  
**Reel Start**

**Caution**

Recovery will cause the Level Winds to move as the Reels rotate. If the Level Winds move in the wrong direction, severe damage to the Level Wind mechanism, the Reels, and the Hose might occur.

Make sure that an observer maintains visual contact with the Level Wind mechanism and reports proper operation when function is recovered.

3. Restarting From a Limit Switch Stop

**Note**

The level winds move slowly. The “left hand rule” can be used to determine the direction of the level winds when the movement is too slow to observe.

**Note**

A relay transfer sound may be heard from within the E-Stop box after the Bypass button is pressed.

3.1 For affected reel:

**Action:** Bypass Button → Press (and Hold until Step 3.6)

**Note**

A relay transfer sound may be heard from within the E-Stop box after the E-Stop Reset button is pressed.

3.2 **Action:** Reel Stop Reset → Press and Release

3.3 **Action:** Hose Reel Pendant Selector Switch → Pend  
**Action:** Cable Reel Pendant Selector Switch → Pend

**Action:** Hose Reel Brake → Released  
**Action:** Cable Reel Brake → Released

**Verify:** Cable Reel Brake – Released  
**Verify:** Hose Reel Brake – Released

3.4 **Action:** Affected Reel Pendant Selector Switch → L (Level Wind)  
**Verify:** Light – On

8510-0376  
**Reel Start**

**Action:** Affected Reel Pendant Selector Switch → Velocity  
**Verify:** Green Light – On

3.5 **Action:** Affected Reel Pendant Velocity Knob → 0

Use the Up and Down buttons, and the Velocity knob on the affected pendant to move the Level Wind off the hard stop.

**Verify:** Level Wind is not longer in contact with hard or soft stop switches.  
**Verify:** Level Wind movement is in the correct direction when Reel turns.

Note
There should be no relay transfer sound heard from within the E-Stop box after the Bypass button is released.

3.6 **Action:** Bypass Button → Release

3.7 Use the Up and Down buttons, and the Velocity knob on the affected pendant to move the Level Wind to the correct position on the Reel.

3.8 If the reels need to be operated in computer mode, perform:

**Action:** Cable Reel Pendant Selector Switch → Comp

**Action:** Hose Reel Pendant Selector Switch → Comp

**Verify:** Cable Reel Brake – Released

**Verify:** Hose Reel Brake – Released

3.9 Verify that the Level Wind moves in the correct direction when movement of the reel resumes.

**REVISIONS**

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**Antarctic Astronomy & Astrophysics Research Institute**  
**MADISON, WISCONSIN**

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**TITLE**

**ICECUBE  
ENHANCED HOT WATER DRILL  
Integration, Verification, & Test Plan: Heater Control System Upgrades**

<b>ORIGINATOR</b> MAZ	<b>DATE</b> 12/02/05	<b>SYS. ENGINEER</b> JC OK/Jeff Chruszka	<b>DATE</b> 11/27/05	<b>TEST ENGR. 1</b> RB OK/pa/Robinson	<b>DATE</b> 12/2/05
<b>TEST ENGR 2</b> JPH OK/pa/Jeff Heide	<b>DATE</b> 12/01/05	<b>QUALITY ASSURANCE</b> MAZ	<b>DATE</b> 12/02/05	<b>FINAL APPROVAL</b> FF OK/pa/Farhad Faraj	<b>DATE</b> 12/2/05

**FILENAME** 8510-0378.051130      **PROJECT NO.** 8510

<b>DRAWING NO.</b> <b>8510-0378</b>	<b>SCALE</b>	<b>SIZE</b>	<b>SHEET</b> 1 of 10
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## 1 PURPOSE

The Enhanced Hot Water Drill (EHWD) system was designed, fabricated, and tested at the University of Wisconsin for use at the South Pole. The system is capable of drilling an 8,038 ft deep hole in the South Pole ice that remains open to 17.7 inches 36 hours after drilling is complete. After an initial start-up supply of water, the system must be capable of producing all of its water needs. The system has a budget of 7,200 +/- 800 gallons of fuel on average per hole for an entire season.

After the initial operation of the EHWD at the South Pole, the heater control units did not show an acceptable reliability level. A program for design and testing of upgrades were undertaken in 2005. This document provides the IV&T plan for the Enhanced Hot Water Drill (EHWD) Heater Control System Upgrade (HCSU).

## 2 SCOPE

Each HCSU includes three subsystems:

- Differential Pressure Switch Assembly (DPS)
- Electronic Thermostat Unit (ETU)
- DGH and Indicator modules (DGH/I)

These units are assembled and tested separately at the University of Wisconsin. They are then assembled into HCSU units and shipped to the South Pole. At the South Pole each of the large heaters in all four MHPs are retrofitted with a HCSU.

## 3 REFERENCES

8510-0379: I, V, & T Report: Heater Control System Upgrades

## 4 DEFINITIONS

DCC.....	Drill Control Center
EHWD .....	Enhanced Hot Water Drill
F .....	Fahrenheit
ft .....	foot or feet
GPM .....	gallons per minute
hp .....	horsepower
HPP .....	High Pressure Pump
IV&T .....	Integration, Verification, & Test
lbs .....	pounds
MHP .....	Main Heating Plant
MW .....	Megawatt(s)
PHS .....	PreHeat System
psia.....	pounds per square inch absolute
psig.....	pounds per square inch gauge
PSL.....	Physical Sciences Lab
RWS.....	Rodriguez Well System
TOS.....	Tower Operations Site
UW .....	University of Wisconsin
WT1.....	Water Tank 1
WT2.....	Water Tank 2



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## 5 TEST PLAN

### *Differential Pressure Switch Assembly (DPS)*

#### 5.1 Subsystem Testing

##### 5.1.1 Pre-Qualification Testing of DPS

*Component:* DPS

*Supplier:* Orange Research, Inc.

*Testing by:* UW

*Purpose:* Differential pressure gages were chosen for testing for possible replacement of the current paddle switches. For this to happen, they needed to meet the following criteria:

- **Minimize false readings that cause unnecessary shutdown.**
- **Be reliable enough to last through the upcoming season without replacement.**
- **Prevent any catastrophic event.**

*Description:* Three differential pressure gages were attached to the model 75 Production Heater. These were used to monitor the pressure drop caused by the flow of water through the heater coils. Two of these were diaphragm based 0-30 psi gages with one set to monitor the top coil, and the other the bottom coil of the heater. The third gage was a piston based 0-60 psi gage that measured the pressure drop across the entire heater.

Each differential pressure gage contains two reed switches that can be set to close at a desired psi. These are wired in series with the thermostat and connected to the Honeywell control unit, so that if any of the switches open due to insufficient flow, it would turn off the heater. An electrical bypass system was also set up so that any of the differential pressure gages could be bypassed. This way the system could be set up so that only one of the gages could turn the heater off.

*Measurement:* The heater will be set up to run with the water flow cycling from 7.5 gal/min to 4.0 gal/min. This is done by attaching a temperature activated valve to the incoming water supply. When the water coming out of the heater reaches a temperature that was set on the valve, the valve would open and divert some of the flow away from the heater, creating a bypass. As water was diverted, the flow through the heater will drop which lowers the pressure drop in the coil and should lead to the DPS opening. This action shuts off the heater and causes the water temperature to drop. After the temperature had dropped, the bypass would close again increasing the flow of water through the heater.

The thermostat is set all the way up, so that the only thing cycling the heater was the differential pressure gages. Individual gages could be tested through the use of the electrical bypass system. There is also a system that indicates if the gage failed to shut off the heater at low flow, which should never happen.

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	Each of the six reed switches in the differential pressure gages will be each subjected to a total of 1600 on and off cycles, hopefully, without a single observed failure or unneeded shutdown.
<i>Test Conditions:</i>	The heater was then set up to run with the water flow cycling from 7.5 gal/min to 4.0 gal/min.
<i>Extent:</i>	Each of three DPS samples: 1 piston type, and 2 diaphragm types.
<i>Acceptance Criteria:</i>	There must be no visual evidence of damage to the DPS. No migration of water should be observable through the unit that could carry debris, affecting the gage. No leaks. The gages cannot fail to shut -off at low flow. The set points cannot migrate during test.
<i>Safety Issues:</i>	The testing is performed at low (60 psi) throughout the test. The test set-up includes an over-pressure check valve designed to blow at 100 psi. In case of an accident, high pressure steam is released from a hose approximately 20' from the tester with no direct steam path to tester.
<i>Reporting:</i>	The selected supplier will provide a certificate of conformance for each DPS in the form of a "Hydrostatic Body Test Report ". The responsible engineer must approve results before delivery can be accepted. An IV & T test report must be generated and signed by the responsible engineer, the system engineer, the project manager and the quality/safety officer. Copies of the signed test report will be sent to the NSF.

### 5.1.2 Batch Qualification Testing

<i>Component:</i>	DPS
<i>Supplier:</i>	Orange Research, Inc.
<i>Testing by:</i>	UW
<i>Purpose:</i>	Differential pressure gages are selected for testing for possible replacement of the current paddle switches. For this to happen, they need to meet the following criteria: <ul style="list-style-type: none"> <li>○ <b>Minimize false readings that cause unnecessary shutdown.</b></li> <li>○ <b>Be reliable enough to last through the upcoming season without replacement.</b></li> <li>○ <b>Prevent any catastrophic event.</b></li> </ul>

The Batch Qualification Testing will provide 100% verification as to the performance of the new DPS gages.

<i>Description:</i>	The tests are described as follows: <ol style="list-style-type: none"> <li>1. <b>Full Pressure Test:</b> Switches and Test environment must be dry. Attach five samples to the PSL Test Pump. The Pump is part of a system comprised of a Honeywell Controller and Water pump. The unit provides very low volume at high pressure and is driven by air pressure. Pressurize unit through both ports. Once system pressure is above 1,000 psi, the yellow handled valve at the pump as well as the discharge valve off of the lower manifold should be in the "off" position. The Differential Control Valve between manifolds should be open. Allow all the DPSs to be under a pressure &gt; 1,000 psi for at least ten minutes. Check visually and with</li> </ol>
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fingers for leaks along the diaphragm seal and end fittings, especially. Note date and time on sheet for Start and Finish.

**2. Full Operating Pressure across Diaphragm Test:** This test checks the integrity of the Diaphragm. Close differential valve between manifolds. Open discharge Valve long enough to vent all pressure (**remove all air from line**), but not to drain all water. Close Discharge Valve. Open yellow valve at pump to re-pressurize high pressure side of switches to 1,000 psi or greater. Wait for a minimum of two minutes. Look at gage for pressure drop, indicating loss of water. Check Discharge Valve for pressure build-up. Note start and Stop times.

**3. Second Non-Differential Pressure Check:** Open Differential Valve and re-pressurize full system. Allow two minutes to confirm system integrity. Note start and Stop times.

**4. Reed Switch Rough Calibration and Operational Test:** Close Differential valve. Using Discharge Valve, drain off pressure to set gages to 20 psi. Note any gages two or more psi off from others. Check all reed switches. All should be off. If not, set as necessary. Go to 25 psi by draining off some more from discharge. All reed switches should be on. If not, adjust as necessary. Go back to 20 psi. All reed switches should be off; however, they all may not be due to the switch dead band range. If not off, adjust slightly. Once all adjustments are done, cycle once between 20 and 25 psi without adjustment necessary and document. It will be necessary to occasionally bleed in pressure from pump to Main Differential. Note time of completion.

**5. Log serial numbers after test by batch.**

- Measurement:*
1. **Full Pressure Test:** Leak check with system @ 1,000 psi or greater for at least 10 minutes.
  2. **Full Operating Pressure across Diaphragm Test:** Diaphragm integrity check with high pressure side switches pressurized to 1000 psi or greater for at least 2 minutes. Look for gage pressure drop and for pressure build-up in Discharge Valve.
  3. **Second Non-Differential Pressure Check:** Leak check with system under 1,000 psi or greater for at least 2 minutes to confirm system integrity.
  4. **Reed Switch Rough Calibration and Operational Test:** When cycling between 20 and 25 psi, the differential between the actual pressure and the respective gage reading cannot exceed 2 psi, initially. At final cycling, the readings must match with no adjustments necessary.
- Test Conditions:* The heater is set up to run with the water flow cycling from 7.5 gal/min to 4.0 gal/min. The system pressure will run from zero to 20-25 psi, and up to 1000psi or greater during the testing.
- Extent:* 100% of Lot received from supplier
- Acceptance Criteria:* There must be no visual evidence of damage to the DPS. The diaphragm must maintain its integrity throughout the testing. The set points cannot migrate during calibration.
- Safety Issues:* While there is water under high pressure (1000 psi), the water is at ambient temperature, posing no real safety threat---**as long as all air is purged from lines.**

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*Reporting:* The selected supplier will provide a certificate of conformance for each DPS in the form of a "Hydrostatic Body Test Report ". The responsible engineer must approve results before delivery can be accepted. An IV & T test report must be generated and signed by the responsible engineer, the system engineer, the project manager and the quality/safety officer. Copies of the signed test report will be sent to the NSF.

### 5.1.3 Electronic Thermostat Unit (ETU)

*Component:* ETU

*Supplier:* Paktronics

*Testing by:* UW

*Purpose:* Digital Thermostats were chosen for testing for possible replacement of the current thermostats. For this to happen, they need to meet the following criteria:

- **Minimize false readings that cause unnecessary shutdown.**
- **Be reliable enough to last through the upcoming season without replacement.**
- **Prevent any catastrophic event.**

*Description:* The test is described as follows:

Digital thermostats will be installed in both the Production and Prototype model 75 heaters, but all of the major testing will be done with the Prototype Heater. To maximize the effectiveness of the testing, a rig was constructed so that an additional four digital thermostats could be tested along with thermostat installed in the Prototype Heater, allowing for the simultaneous testing of five thermostats.

The digital thermostat in the Prototype Heater has a switch that connects to a Honeywell unit, and a type J thermocouple. Normally the switch is open, preventing the Honeywell from turning on the flame to the heater. When the digital thermostat calls for heat, it closes the switch completing a circuit with the Honeywell and allowing it to turn on the flame.

The testing rig consists of a power supply that acts as the Honeywell control unit. The four digital thermostats connect to this supply in parallel; each with a LED in series with its switch. When a digital thermostat calls for heat in the rig, it will complete a circuit between the LED and the power supply, causing the light to come on. This allows an observer to determine if the thermostat is working, and also provides current across the switch, simulating the control of an actual heater.

The digital thermostats in the testing rig, along with the digital thermostat controlling the Prototype Heater, will all be set to the same temperature with each of their thermocouples plumbed into the output of the heater. A digital display is also connected to one of the thermostats in the rig, and another display is connected to the controlling thermostat so that the temperature they are reading can be seen. A separate thermal couple with reader was also plumbed into the heater to independently verify temperature readings. When the heater was turned on, the controlling thermostat would call for heat until the temperature reached the set point, at which time the heater and all the LED's would turn off within a few seconds of each other. The heating/cooling cycle of the heater when set to 150 °F was slightly under two minutes.

*Measurement:* Visually check to determine that light comes on when thermostat is supposed to be calling for heat. Temperatures were taken when the thermostat should call for heat at the set point (<160 F) and at the max-point of the water @ 200 F.

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Temperature readings are also taken on the Production heater with an independent thermocouple and reader to check consistency of operation. Readings are taken every 10 to 15 minutes, showing that the turn off and turn on temperature readings were within 2 °F each time. The digital thermostat from the production heater will also be removed after a month of use and put into a freezer. It will be chilled to -110 °F, and after being allowed to thaw, will hopefully work just as before with no noticeable differences.

- Test Conditions:* To maximize the effectiveness of the testing, a rig was constructed so that an additional four digital thermostats could be tested along with thermostat installed in the Prototype Heater, allowing for simultaneous testing of five thermostats. The thermostats were all set to 150 F. The digital thermostat from the production heater was chilled down to -110 F prior to testing.
- Extent:* 5 Samples from Supplier
- Acceptance Criteria:* There must be no visual evidence of damage to the Digital Thermostats. The indicator light must turn on when the thermostat calls for heat. The set points cannot migrate during testing. Thermostat readings must be within 2 F deg of the thermocouple readings. On/Off temperature readings must be within 2 F deg of the set point and max point.
- Safety Issues:* The test set-up has a Differential Pressure Switch that shuts off with a loss of water flow. Further, a shut-off valve exists that effectively shuts down the test should the water temperature exceed 220 F.
- Reporting:* UW will provide a "Digital Thermostat Test Report ". The responsible engineer must approve results before delivery can be accepted. The IV & T test report must be generated and signed by the responsible engineer, the system engineer, the project manager and the quality/safety officer. Copies of the signed test report will be sent to the NSF.

#### 5.1.4 DGH and Indicator modules (DGH/I)

##### 5.1.4.1 Model 75 heaters

- Component:* DGH/I
- Supplier:* UW
- Testing by:* UW
- Purpose:* New DGH boxes and Plumbing Assemblies were chosen for testing for possible replacement of the current system. The DGH Box and Plumbing Assemblies are designed to monitor the status of the model 75 heaters with a computer. For this to happen, they need to meet the following criteria:
- **Minimize false readings that cause unnecessary shutdown.**
  - **Be reliable enough to last through the upcoming season without replacement.**
  - **Prevent any catastrophic event.**

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*Description:* The test is described as follows:

The Plumbing Assemblies consist of a water-proof box attached to a pipe with an RTD to measure temperature and a flow meter. The box contains two DGH units that connect the RTD and the flow meter to the network, a lighted display to report the current water temperature, and a terminal strip to rout all the wires.

Each DGH Box has a female military connector port mounted on the bottom, and a length of network cable with a male military connector at the end. This allows all of the boxes to be connected together to deliver power to the DGH's and display. It also connects all the DGH's to a computer to display and record temperature and water flow.

Testing will be accomplished by networking all the DGH Boxes together, and connecting their pipe assemblies in a long line. The boxes are then connected to the drill computer and the pipes put into a loop with the test model 75 heater. Water could then be pumped through the pipes and heated to simulate actual operation.

Testing is broken down into two stages, a low flow, low temperature stage and a high flow, high temperature stage. In order to pass each stage, the assemblies would need to report to the drill computer, and display on its box, a temperature within 2 1/2 degrees Celsius of the average for the individual test. This would insure that all temperatures reported would be within a 5 degree window. Each assembly would also need to report a flow to the drill computer within 0.3 gal/min of the average for the test.

*Measurement:* Water temperature in C deg is measured. Water flow is recorded in gal/min.

*Test Conditions:* All DGH boxes will be networked together. Water is pumped through the pipes to simulate actual operation. The sensors and the readout electronics are the same as used last year. They are just being repackaged and rewired. We are not testing the reliability of the sensors, but rather, the verification of the wiring and addressing of the electronics.

*Extent:* 100% of DGH and Plumbing Assemblies

*Acceptance Criteria:* There must be no visual evidence of damage to any component. The recorded temperature must be with 2 1/2 C deg of the average of the individual DGHs tested. Each assembly would also need to report a flow to the drill computer within 0.3 gal/min of the average for the test.

*Safety Issues:* The test set-up has a Differential Pressure Switch that shuts off with a loss of water flow. Further, a shut-off valve exists that effectively shuts down the test should the water temperature exceed 220 F.

*Reporting:* UW will provide a "DGH Box and Plumbing Assembly Test Report ". The responsible engineer must approve results before delivery can be accepted. The IV & T test report must be generated and signed by the responsible engineer, the system engineer, the project manager and the quality/safety officer. Copies of the signed test report will be sent to the NSF.

#### 5.1.4.2 Stinger Heaters

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*Component:* DGH/I

*Supplier:* UW

*Testing by:* UW

*Purpose:* New DGH boxes and Plumbing Assemblies were chosen for testing for possible replacement of the current system. The DGH Box and Plumbing Assemblies are designed to monitor the status of the Stinger heaters with a computer. For this to happen, they need to meet the following criteria:

- **Minimize false readings that cause unnecessary shutdown.**
- **Be reliable enough to last through the upcoming season without replacement.**
- **Prevent any catastrophic event.**

*Description:* The test is described as follows:

The test mirrors the testing methodology for the Model 75 Heaters with the following exceptions:

DGH boxes designed for the Stinger heaters were also tested. These boxes do not have pipe assemblies because they will each require custom plumbing at the pole to be installed. They also only have only one DGH to report just the temperature to the drill computer.

These Stinger boxes are tested by temporarily connecting a RTD to the DGH and display to verify that the display worked and that the DGH could report the temperature to the computer.

*Measurement:* Pass/Fail data is recorded to ensure that the water temperature could be reported to the computer.

*Test Conditions:* Each DGH box will be tested separately.

*Extent:* 100% of DGHs for stinger heaters

*Acceptance Criteria:* There must be no visual evidence of damage to any component. The DGHs must be able to provide the water temperature information to the computer.

*Safety Issues:* None. This test is purely a low voltage/ low current software evaluation.

*Reporting:* UW will provide a "DGH Box and Plumbing Assembly Test Report ". The responsible engineer must approve results before delivery can be accepted. The IV & T test report must be generated and signed by the responsible engineer, the system engineer, the project manager and the quality/safety officer. Copies of the signed test report will be sent to the NSF.

**6. Records:** Records for all tests are depicted in the IV &T test report, Doc # 8510-0379.

REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original Document		

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
REVISION	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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THE UNIVERSITY OF WISCONSIN			
Antarctic Astronomy & Astrophysics Research Institute			
MADISON, WISCONSIN			
<u>TITLE</u>			
ICECUBE ENHANCED HOT WATER DRILL Integration, Verification, & Test Report: Heater Control System Upgrades			
ORIGINATOR	DATE	SYS. ENGINEER	DATE
MAZ	12/02/05	JC	11/27/05
TEST ENGR. 1	DATE	TEST ENGR. 2	DATE
RB	12/21/05	JPH	12/01/05
FINAL APPROVAL	DATE	QUALITY ASSURANCE	DATE
FF	12/21/05	MAZ	12/02/05
FILENAME	8510-0379.051130	PROJECT NO.	8510
DRAWING NO.	SCALE	SIZE	SHEET
8510-0379			1 of 12



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**1. PURPOSE**

This document provides the forms for IV&T for the Enhanced Hot Water Drill (EHWD) Heater Control System Upgrade (HCSU). HCSU includes three subsystems:

1. Differential Pressure Switch Assembly (DPS)
2. Electronic Thermostat Unit (ETU)
3. DGH and Indicator module (DGH/I)

These units are assembled and tested separately. They are then assembled into HCSU units.

**2. SCOPE**

These forms follow the scope and order of the tests presented in the EHWD IV&T plan.

**3. REFERENCES**

- 3.1 Heater Control System Upgrade Test Plan: 8510-0378

**4. DEFINITIONS**

- 4.1 DCC - Drill Control Center
- 4.2 EHWD - Enhanced Hot Water Drill
- 4.3 HPP - High Pressure Pumps
- 4.4 IV&T - Inspection, verification and testing activity for the EHWD
- 4.5 MDS - Mobile Drilling Structures
- 4.6 MHP - Main Heat Plant
- 4.7 PDM - Power Distribution Module
- 4.8 PHS - Preheat System
- 4.9 RWS - Rodriguez Well System
- 4.10 SEW - Seasonal Equipment Workshop
- 4.11 TOS - Tower Operations Structure
- 4.12 UW-SSEC - University of Wisconsin-Space Science & Engineering Center

**5. RESPONSIBILITY**

- 5.1 IceCube Configuration Management is responsible for the maintenance and revision of this document.
- 5.2 IceCube Quality Assurance is responsible for ensuring that appropriate processes for document control and change are followed.

## 6. TEST REPORTS (RECORDS)

Records of the test and verification activities will be maintained on the following forms in accordance with the IV&T Test Plan.

### 6.1 Subsystem Testing

#### 6.1.1 Differential Pressure Switch Assembly (DPS)

#### Test Results-Differential Pressure Sensor (DPS)

Test Date	Gage 3 (psi)		Gage 4 (psi)		Gage 5 (psi)	
<b>6/7</b>	25 +/- 4 (Pstart - Pstop) <or = 4	P / F	12 +/- 4 (Pstart - Pstop) <or = 4	P / F	35 +/- 4 (Pstart - Pstop) <or = 4	P / F
Start	25	P	12	P	35	P
Stop	22	P	11	P	30	F
<b>6/8 (morning)</b>						
Start	24	P	12	P	33	P
Stop	22	P	10	P	28	F
<b>6/8 (afternoon)</b>						
Start	23	P	12	P	33	P
Stop	21	P	11	P	29	P
<b>6/9</b>						
Start	24	P	12	P	32	P
Stop	22	P	9	P	28	P
<b>6/10 (morning)</b>						
Start	25	P	12	P	32	P
Stop	22	P	10	P	27	F
<b>6/10 (afternoon)</b>						
Start	24	P	12	P	32	P
Stop	22	P	10	P	27	F
<b>6/13</b>						
Start	24	P	12	P	32	P
Stop	22	P	11	P	28	P
<b>6/14</b>						
Start	24	P	12	P	33	P
Stop	22	P	11	P	29	P
<b>6/15</b>						
Start	24	P	12	P	32	P
Stop	22	P	10	P	27	F

Gage 3: Diaphragm 0-30 differential pressure over bottom coil: Orange Research

Gage 4: Diaphragm 0-30 differential pressure over top coil: Orange Research

Gage 5: Piston 0-60 differential pressure over top and bottom coils: Orange Research

The diaphragm based gages worked the best since they did not allow for migration of water that could carry debris that would affect the gage. They also gave a more accurate reading than the piston based model due to the lack of friction.

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The differential pressure gages were monitored to determine if the set point migrated. Over a week of checking there was no significant change in the pressure that caused the reed switches to open and close. When checked again after an additional month, the set point had not changed.

Each of the six reed switches in the differential pressure gages were each subjected to a total of 1600 on and off cycles without a single observed failure or unnecessary shutdown. With ten holes planned for this year, and 50 low flow events during a hole considered catastrophic, it is safe to say the gages should easily last the season. With less than 80 holes to go, we would need to average 20 low flow events per hole to reach the number currently achieved in testing. This also seems very unlikely to happen, so the differential pressure gage should last the life of the project.

The differential pressure gage has met and surpassed the three criteria set, and has proven to be very reliable, easy to work with, and most importantly, **safe**.

### 6.1.2 Batch Qualification Testing

DATE	S/N	Full Press. Test Start / Stop (10 min. min.)	Result	Diff. Press. Test Start/Stop (2 min min)	Result	Re-Press. Test Start/Stop (2 min. min.)	Result	Reed Test Stop Time (as tested)	Result
09/29/05 Batch 1	116161	*	Pass	*	Pass	*	Pass	*	Pass
	116153	*	Pass	*	Pass	*	Pass	*	Pass
	115535	*	Pass	*	Pass	*	Pass	*	Pass
	116158	*	Pass	*	Pass	*	Pass	*	Pass
	115537	*	Pass	*	Pass	*	Pass	*	Pass
09/29/05 Batch 2	116160	*	Pass	*	Pass	*	Pass	*	Pass
	115525	*	Pass	*	Pass	*	Pass	*	Pass
	115528	*	Pass	*	Pass	*	Pass	*	Pass
	116115	*	Pass	*	Pass	*	Pass	*	Pass
	115529	*	Pass	*	Pass	*	Pass	*	Pass
09/30/05 Batch 3	116154	9:50 -10:15 No Leaks	Pass	10:15-10:20 No H2O Loss	Pass	10:20-10:25 No Leaks	Pass	No Adjustment	Pass
	115530	9:50 -10:15 No Leaks	Pass	10:15-10:20 No H2O Loss	Pass	10:20-10:25 No Leaks	Pass	No Adjustment	Pass
	116163	9:50 -10:15 No Leaks	Pass	10:15-10:20 No H2O Loss	Pass	10:20-10:25 No Leaks	Pass	No Adjustment	Pass
	115533	9:50 -10:15 No Leaks	Pass	10:15-10:20 No H2O Loss	Pass	10:20-10:25 No Leaks	Pass	No Adjustment	Pass
	113801	9:50 -10:15 No Leaks	Pass	10:15-10:20 No H2O Loss	Pass	10:20-10:25 No Leaks	Pass	No Adjustment	Pass
09/30/05 Batch 4	115523	10:56-11:06 No Leaks	Pass	11:07-11:10 No H2O Loss	Pass	11:11-11:13 No leaks	Pass	11:30 Minor Adj.	Pass
	116165	10:56-11:06 No Leaks	Pass	11:07-11:10 No H2O Loss	Pass	11:11-11:13 No leaks	Pass	11:30 Minor Adj.	Pass
	114211	10:56-11:06 No Leaks	Pass	11:07-11:10 No H2O Loss	Pass	11:11-11:13 No leaks	Pass	11:30 Minor Adj.	Pass
	115532	10:56-11:06 No Leaks	Pass	11:07-11:10 No H2O Loss	Pass	11:11-11:13 No leaks	Pass	11:30 Minor Adj.	Pass
	116152	10:56-11:06 No Leaks	Pass	11:07-11:10 No H2O Loss	Pass	11:11-11:13 No leaks	Pass	11:30 Minor Adj.	Pass
09/30/05 Batch 5	116162	11:55-12:05 No Leaks	Pass	1:20-1:24 No H2O Loss	Pass	1:25-1:27 No Leaks	Pass	---	Pass
	116150	11:55-12:05 No Leaks	Pass	1:20-1:24 No H2O Loss	Pass	1:25-1:27 No Leaks	Pass	---	Pass

DATE	S/N	Full Press. Test Start / Stop (10 min. min.)	Result	Diff. Press. Test Start/Stop (2 min min)	Result	Re-Press. Test Start/Stop (2 min. min.)	Result	Reed Test Stop Time (as tested)	Result
	115534	11:55-12:05 No Leaks	Pass	1:20-1:24 No H2O Loss	Pass	1:25-1:27 No Leaks	Pass	---	
	115526	11:55-12:05 No Leaks	Pass	1:20-1:24 No H2O Loss	Pass	1:25-1:27 No Leaks	Pass	---	Pass
	113800	11:55-12:05 No Leaks	Pass	1:20-1:24 No H2O Loss	Pass	1:25-1:27 No Leaks	Pass	---	Pass
10/03/05 Batch 6	116164	11:45-11:55 No leaks	Pass	11:57-12:02 No H2O Loss	Pass	12:05-12:07 No Leaks	Pass	---	Pass
	116999	11:45-11:55 No leaks	Pass	11:57-12:02 No H2O Loss	Pass	12:05-12:07 No Leaks	Pass	---	Pass
	115527	11:45-11:55 No leaks	Pass	11:57-12:02 No H2O Loss	Pass	12:05-12:07 No Leaks	Pass	---	Pass
	1170_5	11:45-11:55 No leaks	Pass	11:57-12:02 No H2O Loss	Pass	12:05-12:07 No Leaks	Pass	---	Pass
	116994	11:45-11:55 No leaks	Pass	11:57-12:02 No H2O Loss	Pass	12:05-12:07 No Leaks	Pass	---	Pass
10/03/05 Batch 7	116996	1:20 -1:32 No leaks	Pass	1:32-1:34 No H2O Loss	Pass	1:34-1:36 No Leaks	Pass	---	Pass
	115536	1:20 -1:32 No leaks	Pass	1:32-1:34 No H2O Loss	Pass	1:34-1:36 No Leaks	Pass	---	Pass
	117002	1:20 -1:32 No leaks	Pass	1:32-1:34 No H2O Loss	Pass	1:34-1:36 No Leaks	Pass	---	Pass
	116151	1:20 -1:32 No leaks	Pass	1:32-1:34 No H2O Loss	Pass	1:34-1:36 No Leaks	Pass	---	Pass
	113804	1:20 -1:32 No leaks	Pass	1:32-1:34 No H2O Loss	Pass	1:34-1:36 No Leaks	Pass	---	Pass
10/03/05 Batch 8	114212	1:57-2:08 No Leaks	Pass	2:09-2:12 No H2O Loss	Pass	2:12-2:14 No Leaks	Pass	2:30	Pass
	116998	1:57-2:08 No Leaks	Pass	2:09-2:12 No H2O Loss	Pass	2:12-2:14 No Leaks	Pass	2:30	Pass
	116159	1:57-2:08 No Leaks	Pass	2:09-2:12 No H2O Loss	Pass	2:12-2:14 No Leaks	Pass	2:30	Pass
	113804	1:57-2:08 No Leaks	Pass	2:09-2:12 No H2O Loss	Pass	2:12-2:14 No Leaks	Pass	2:30	Pass
	117009	1:57-2:08 No Leaks	Pass	2:09-2:12 No H2O Loss	Pass	2:12-2:14 No Leaks	Pass	2:30	Pass
10/03/05 Batch 9	117003	2:45-2:59 No Leaks	Pass	2:56-2:59 No H2O Loss	Pass	3:01-3:07 No Leaks	Pass	3:11 No Leaks	Pass
	117006	2:45-2:59 No Leaks	Pass	2:56-2:59 No H2O Loss	Pass	3:01-3:07 No Leaks	Pass	3:11 No Leaks	Pass
	117001	2:45-2:59 No Leaks	Pass	2:56-2:59 No H2O Loss	Pass	3:01-3:07 No Leaks	Pass	3:11 No Leaks	Pass
	116156	2:45-2:59 No Leaks	Pass	2:56-2:59 No H2O Loss	Pass	3:01-3:07 No Leaks	Pass	3:11 No Leaks	Pass
	116993	2:45-2:59 No Leaks	Pass	2:56-2:59 No H2O Loss	Pass	3:01-3:07 No Leaks	Pass	3:11 No Leaks	Pass
10/03/05 Batch 10	117004	3:27-3:37 No Leaks	Pass	3:38-3:49 No H2O Loss	Pass	3:50-3:54 No Leaks	Pass	No Leaks	Pass
	117000	3:27-3:37 No Leaks	Pass	3:38-3:49 No H2O Loss	Pass	3:50-3:54 No Leaks	Pass	No Leaks	Pass
	113802	3:27-3:37 No Leaks	Pass	3:38-3:49 No H2O Loss	Pass	3:50-3:54 No Leaks	Pass	No Leaks	Pass
	117007	3:27-3:37 No Leaks	Pass	3:38-3:49 No H2O Loss	Pass	3:50-3:54 No Leaks	Pass	No Leaks	Pass
	117008	3:27-3:37 No Leaks	Pass	3:38-3:49 No H2O Loss	Pass	3:50-3:54 No Leaks	Pass	No Leaks	Pass
10/03/05 Batch 11	115531	4:17-4:30 No Leaks	Pass	4:33-4:44 No H2O Loss	Pass	4:44-4:51 No Leaks	Pass	No Leaks	Pass

	116157	4:17-4:30 No Leaks	Pass	4:33-4:44 No H2O Loss	Pass	4:44-4:51 No Leaks	Pass	No Leaks	Pass
<b>DATE</b>	<b>S/N</b>	<b>Full Press. Test Start / Stop (10 min. min.)</b>	<b>Result</b>	<b>Diff. Press. Test Start/Stop (2 min min)</b>	<b>Result</b>	<b>Re-Press. Test Start/Stop (2 min. min.)</b>	<b>Result</b>	<b>Reed Test Stop Time (as tested)</b>	<b>Result</b>
	113803	4:17-4:30 No Leaks	Pass	4:33-4:44 No H2O Loss	Pass	4:44-4:51 No Leaks	Pass	No Leaks	Pass
	116997	4:17-4:30 No Leaks	Pass	4:33-4:44 No H2O Loss	Pass	4:44-4:51 No Leaks	Pass	No Leaks	Pass
	109573	4:17-4:30 No Leaks	Pass	4:33-4:44 No H2O Loss	Pass	4:44-4:51 No Leaks	Pass	No Leaks	Pass
10/03/05 Batch 12	115524	5:13-5:23 No Leaks	Pass	5:24-5:26 No H2O Loss	Pass	5:26-5:28 No Leaks	Pass	---	Pass

\* The data for Batches 1 and 2 was not available for this report. The final report will be updated once the data is retrieved. All units did pass as indicated.

**6.1.3 Electronic Thermostat Unit (ETU)**

Digital thermostats were installed in both the Production and Prototype model 75 heaters, but all of the major testing was done with the Prototype Heater. To maximize the effectiveness of the testing, a rig was constructed so that an additional four digital thermostats could be tested along with thermostat installed in the Prototype Heater, allowing for simultaneous testing of five thermostats.

**Test Results-Electronic Thermostat Unit (ETU)**

<b>DATE:</b>	<b>SAMPLE #</b>	<b>Number of Hours</b>	<b>Set Point (Temp On) DEG F</b>	<b>ACCEPTANCE CRITERIA 160 deg F +/- 2: Set-Point</b>	<b>PASS/FAIL</b>	<b>Max-Point (Temp Off) DEG F</b>	<b>ACCEPTANCE CRITERIA: 200 deg F +/- 2: Max-Point</b>	<b>PASS/FAIL</b>
06/06/05	1 (Prod. Heater)	---	160	160 deg F +/-2	PASS	201	200 deg F +/-2	PASS
06/06/05	2	---	160	160 deg F +/-2	PASS	199	200 deg F +/-2	PASS
06/06/05	3	---	159	160 deg F +/-2	PASS	201	200 deg F +/-2	PASS
06/06/05	4	---	159	160 deg F +/-2	PASS	199	200 deg F +/-2	PASS
06/06/05	5	---	159	160 deg F +/-2	PASS	199	200 deg F +/-2	PASS
07/11/05	1(Prod. Heater)	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/11/05	2	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/11/05	3	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/11/05	4	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/11/05	5	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/12/05	1(Prod. Heater)	3	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/12/05	2	3	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/12/05	3	3	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS

DATE:	SAMPLE #	Number of Hours	Set Point (Temp On) DEG F	ACCEPTANCE CRITERIA 160 deg F +/- 2: Set-Point	PASS/FAIL	Max-Point (Temp Off) DEG F	ACCEPTANCE CRITERIA: 200 deg F +/- 2: Max-Point	PASS/FAIL
07/12/05	4	3	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/12/05	5	3	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/13/05	1(Prod. Heater)	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/13/05	2	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/13/05	3	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/13/05	4	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/13/05	5	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/15/05	1(Prod. Heater)	6	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/15/05	2	6	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/15/05	3	6	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/15/05	4	6	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/15/05	5	6	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/28/05	1(Prod. Heater)	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/28/05	2	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/28/05	3	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/28/05	4	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS
07/28/05	5	2	---	160 deg F +/-2	PASS	---	200 deg F +/-2	PASS

The heating/cooling cycle of the heater when set to 160 °F was slightly under two minutes. The rig has been run for approximately 15 hours so far, resulting in about 450 cycles on each of the five thermostats without failure.

Temperature readings were also taken on the Production heater with an independent thermocouple and reader to check consistency of operation. Readings were taken every 10 to 15 minutes, showing that the turn off and turn on temperature readings were within 2 °F each time. The actual readings were recorded for the first day of testing. The digital thermostat from the production heater was also removed after a month of use and put into a freezer. It was chilled to -110 °F, and after being allowed to thaw, worked just as before with no noticeable differences.

Testing is continuing on the digital thermostats, but with ten holes planed for this season and an average of much less than 45 cycles a hole, the digital thermostats have shown they will at least make it through the upcoming season. Though more freezer testing is also planned, the thermostats have proven an ability to handle the extreme cold of wintering over. Testing is continuing on the digital thermostats, but with a total of 1800 cycles already between the five being tested, it is very likely that they will be able to safely operate for the life of the project.

**6.1.4 DGH and Indicator Modules (DGH/I)**

**6.1.4.1 Model 75 Heaters**

**Test Results-DGH and Indicator Modules (DGH/I)**

w/o 08/22/05						
<b>MHP 1</b>						
<b>Test 1</b>			<b>Test 2</b>			
Heater	Temp(°C) +/- 2.5 C deg avg	Flow(gal/min) +/- 0.3 g/m (avg)	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)		<b>Result</b>
1	25.5	2.24	69.7	7.68		pass
2	24.3	2.36	67.1	7.98		pass
3	24.6	*1.89	68.4	7.78		pass
4	24.1	2.29	68.9	7.92		pass
5	24.4	2.27	68.1	7.69		pass
6	24.3	2.36	68.5	8.1		pass
7	24	2.43	68.3	8.06		pass
8	26	2.39	69.2	8.01		pass
9	24.8	2.39	69.7	7.89		pass
AVG	24.7	2.29	68.7	7.90		

<b>MHP 2</b>						
<b>Test 1</b>			<b>Test 2</b>			
Heater	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)		<b>Result</b>
1	24	2.35	68	7.92		pass
2	23.5	2.35	66.6	7.93		pass
3	26.1	2.35	69.6	7.83		pass
4	23.7	2.36	67.4	7.81		pass
5	23.4	2.34	66.8	7.89		pass
6	23.4	2.3	66.5	8.01		pass
7	23.4	2.27	67.4	8.01		pass
8	26.3	2.33	68.9	7.61		pass
9	23.6	2.39	66.9	7.81		pass
AVG	24.2	2.34	67.6	7.87		

<b>MHP 3</b>						
<b>Test 1</b>			<b>Test 2</b>			
Heater	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)		<b>Result</b>
1	25.1	2.33	66.2	8.15		pass
2	28.9	2.25	70.4	7.95		pass
3	26.8	2.39	68.2	8.26		pass
4	26.7	2.29	68.6	8.05		pass
5	26.2	2.33	68.4	8.21		pass
6	26.9	2.35	68.7	8.25		pass
7	26.3	0	68.6	0		failed flow meter



8	26.3	2.31	67.7	8.02	pass
9	N/A	N/A	N/A	N/A	electrical short
AVG	26.7	2.32	68.4	8.13	
<b>MHP 4</b>					
	<b>Test 1</b>		<b>Test 2</b>		
Heater	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m (avg)	<b>Result</b>
1	27.5	1.99	72.1	7.84	pass
2	28.2	2.01	70.8	7.99	pass
3	29	1.98	73.3	7.72	pass
4	27.7	1.96	72.1	7.61	pass
5	28	0	71.3	0	failed flow meter
6	28.5	0	72.4	0	failed flow meter
7	28.7	2	71.9	7.83	pass
8	28	1.97	72.4	7.61	pass
AVG	28.2	1.99	72.0	7.77	
<b>Retesting</b>					
	<b>Test 1</b>		<b>Test 2</b>		
	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m of (avg)	Temp (°C) +/- 2.5 C deg avg	Flow (gal/min) +/- 0.3 g/m of (avg)	<b>Result</b>
MHP3-7	28.1	1.95	69.6	7.62	pass
MHP3-9	28.7	1.98	70.2	7.66	pass
MHP4-5	27.8	2.02	70.6	7.71	pass
MHP4-6	28.8	2	70.1	7.68	pass
AVG	28.4	1.99	70.1	7.67	

\* Initially, the flow rate was off on MPL 1, heater 3. Further monitoring at the low flow rate has shown that the unit is operating per specification. The erroneous data point was left in for verification purposes and further monitoring.

Testing was broken into two stages, a low flow low temperature stage and a high flow, high temperature stage. In order to pass each stage, the assemblies would need to report to the drill computer, and display on its box, a temperature within 2 1/2 degrees Celsius of the average for the individual test. This would insure that all temperatures reported would be within a 5 degree window. Each assembly would also need to report a flow to the drill computer within 0.3 gal/min of the average for the test.

Three broken flow meters and an electrical short were found during the testing, along with a few minor wiring problems that were fixed. The three assemblies with broken flow meters and the assembly with the short were rebuilt and rewired. They were then tested again to ensure that they worked properly.

**6.1.4.2 Stinger Heaters****Test Results-DGH and Indicator Modules (DGH/I)**

W/O:

08/22/05

**Stinger Box Testing**

Heater	Result
1	Pass-DGH could report temp to computer
2	Pass- DGH could report temp to computer
3	Pass- DGH could report temp to computer
4	Pass- DGH could report temp to computer
5	Pass- DGH could report temp to computer
6	Pass- DGH could report temp to computer
7	Pass- DGH could report temp to computer
8	failed programming error
9	Pass -DGH could report temp to computer
10	Pass- DGH could report temp to computer
11	Pass- DGH could report temp to computer
10	Pass- DGH could report temp to computer

**Retesting**

Heater	Result
8	Pass- DGH could report temp to computer

PASS

DGH boxes designed for the Stinger heaters were also tested. These boxes did not have pipe assemblies because they will each require custom plumbing at the pole to be installed. They also only have only one DGH to report just the temperature to the drill computer.

These Stinger boxes were tested by temporarily connecting a RTD to the DGH and display to verify that the display worked and that the DGH could report the temperature to the computer.

All of the boxes passed this test with one exception due to a programming error. The DGH was programmed again and the box passed the retest.

Doc. #: 8510-0379, rev. -

**7.0 SUMMARY:**

With the satisfactory results attained during the selection and screening of the following subsystems:

- 6.1.1 Differential Pressure Switch Assembly (DPS)
- 6.1.2 Batch Qualification Testing
- 6.1.3 Electronic Thermostat Unit (ETU)
- 6.1.4 DGH and Indicator Modules (DGH/I)
  - 6.1.4.1 Model 75 Heaters
  - 6.1.4.2 Stinger Heaters

We feel comfortable with using the new components at the South Pole this coming year as a part of the Heater upgrade package.

Test Engineer: OK per Robin Bolsey (e-mail appv.) Date: 12/02/05

Project Engineer: OK per Jeff Chervinton (e-mail appv) Date: 11/27/05

Final Approval: OK per Firohid Fezzji (e-mail appv) Date: 12/2/05

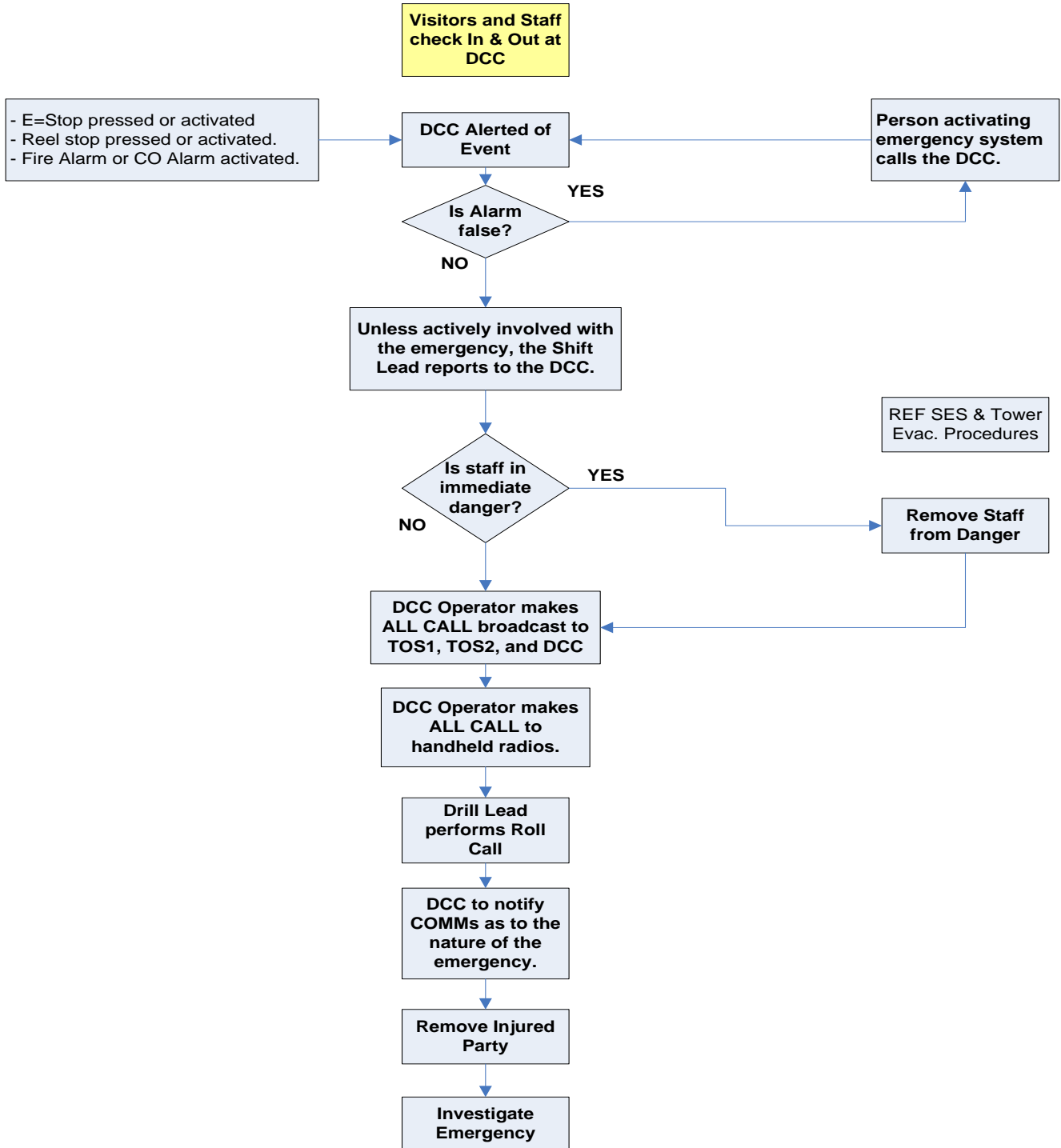
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A	NA	Annual review	10/27/08	MAZ
B	NA	Annual Review	10/21/09	MAZ
C	NA	Annual Review	10/21/10	MAZ

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4		18	ICECUBE																															
5		19	EHWD																															
6		20	HIGH LEVEL EMERGENCY PLAN																															
7		21	ORIGINATOR				DATE				ENGINEER				DATE				DRILLING MANAGER				DATE											
8		22	Mike Zernick				11/21/10				D. Wray				11/21/10				Al. Elcheikh				11/21/10											
9		23	On-Ice Lead				DATE				SAFETY				DATE				PROJECT APPROVAL				DATE											
10		24	T. Gaisser				11/21/10				Mike Zernick				11/21/10				Tom Hutchings				11/21/10											
11		25	FILENAME								8510-0396.RevC								PROJECT NO.								8510							
12		26	DRAWING NO.								8510-0396								SCALE				SIZE				SHEET							
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# High Level Emergency Plan



MAZ, AE, Than, THu

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A	NA	Annual review	10/27/08	MAZ
B	NA	<b>Annual Review</b>	11/21/09	MAZ
C	NA	Annual Review	11/21/10	MAZ

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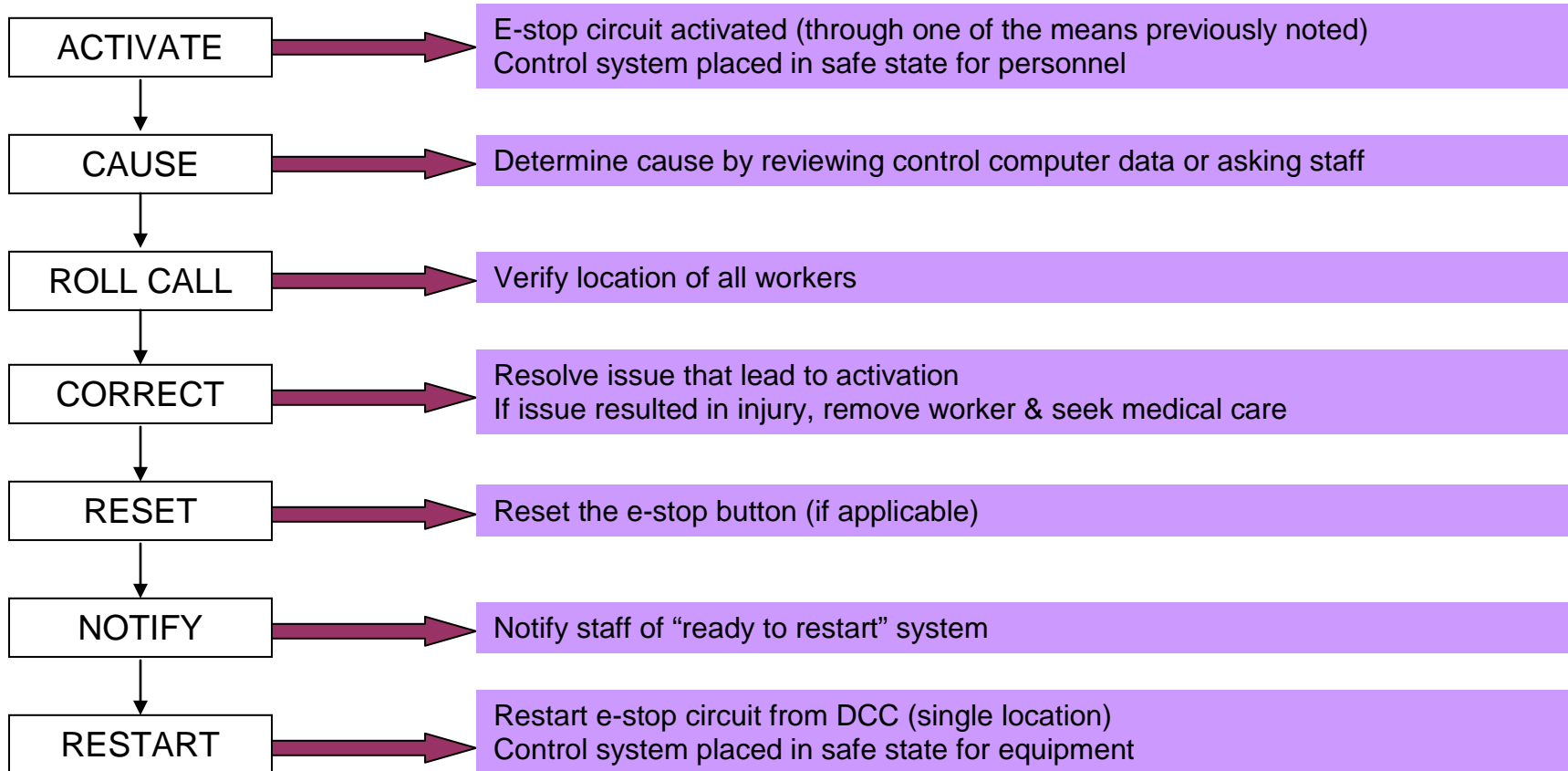
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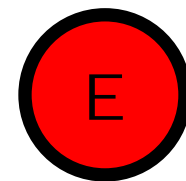
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14		28

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<b>Antarctic Astronomy &amp; Astrophysics Research Institute MADISON, WISCONSIN</b>					
<b>TITLE</b>					
<b>ICECUBE ENHANCED HOT WATER DRILL EMERGENCY (E-STOP) PROCEDURE</b>					
<b>ORIGINATOR</b>		<b>DATE</b>		<b>ENGINEER</b>	
Mike Zernick		11/21/10		D. Wray	
				11/21/10	
<b>DRILL MANAGER</b>		<b>DATE</b>			
AI El-Cheikh		11/21/10			
<b>ON ICE LEAD</b>		<b>DATE</b>		<b>QUALITY ASSURANCE</b>	
Tom Gaisser		11/21/10		Mike Zernick	
				11/21/10	
<b>PROJECT APPROVAL</b>		<b>DATE</b>			
Tom Hutchings		11/21/10			
<b>FILENAME</b>			<b>PROJECT NO.</b>		
8510-0399.RevC			8510		
<b>DRAWING NO.</b>			<b>SCALE</b>		<b>SIZE</b>
8510-0399			NA		A
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					1 of 2

# Emergency Stop Procedure



**EMERGENCY STOP SYSTEM**



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-	NA	Original Document	08/30/07	TCB

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<b>Antarctic Astronomy &amp; Astrophysics Research Institute MADISON, WISCONSIN</b>					
<b>TITLE</b>					
<b>ICECUBE Drill Startup Procedure</b>					
<b>ORIGINATOR</b>	<b>DATE</b>	<b>ENGINEER</b>	<b>DATE</b>	<b>CHECKER 1</b>	<b>DATE</b>
Jack Ambuel	6/01/07	Jeff Cherwinka	08/30/07	Al El-Cheikh	08/30/07
<b>CHECKER 2</b>	<b>DATE</b>	<b>QUALITY ASSURANCE</b>	<b>DATE</b>	<b>PROJECT APPROVAL</b>	<b>DATE</b>
		Mike Zernick	08/30/07		
<b>FILENAME</b>	8510-0456			<b>PROJECT NO.</b>	8510
<b>DRAWING NO.</b>	8510-0456		<b>SCALE</b>	<b>SIZE</b>	<b>SHEET</b>
					1 of 6



## **EHWD Refurbished Amanda Drill Head and EHWD New Drill Head X Startup Procedure at South Pole**

1. Move drill to desired position.
2. Connect Hose
3. Connect **Slip Ring to TOS Cable** to slip ring if not already connected.
4. Connect other end of **Slip Ring to TOS Cable** to mating connector on Rack Mount Power Supply and Communications Interface Box (Labeled RPSn, where n = 1 or 2). RPSn should be located in TOS Computer Rack. Note: RPS1 and RPS2 should have a fixed voltage output of nominally 75 volts. These supplies should be used for normal drilling operations (see below). There is a third supply at the Pole with variable voltage output. For this supply the voltage is adjustable from 0 to 100 Volts out from the front panel. This should only be used for troubleshooting or pre – operational testing (see last section on use of 50 foot drill head to power supply adapter cable below). **Care must be taken when using the variable supply not to exceed 75 volts. If 75 volts is exceeded – particularly when using the 50 foot cable – the drill head power supply can be damaged.**
5. If possible, do continuity check from RS485 monitoring port banana jack connectors on front panel to Impulse CCP connector on Drill Head end of Cortland Cable (see attached CCP connector pinout and wiring diagrams):
  - RS485 + Signal from Yellow connector on RPSn front panel to Pin 13 of CCP connector
  - RS485- Signal from Green connector on RPSn front panel to Pin 15 of CCP connector
  - RS485 Ground from Black connector on RPSn front panel to Pin 12 of CCP connector

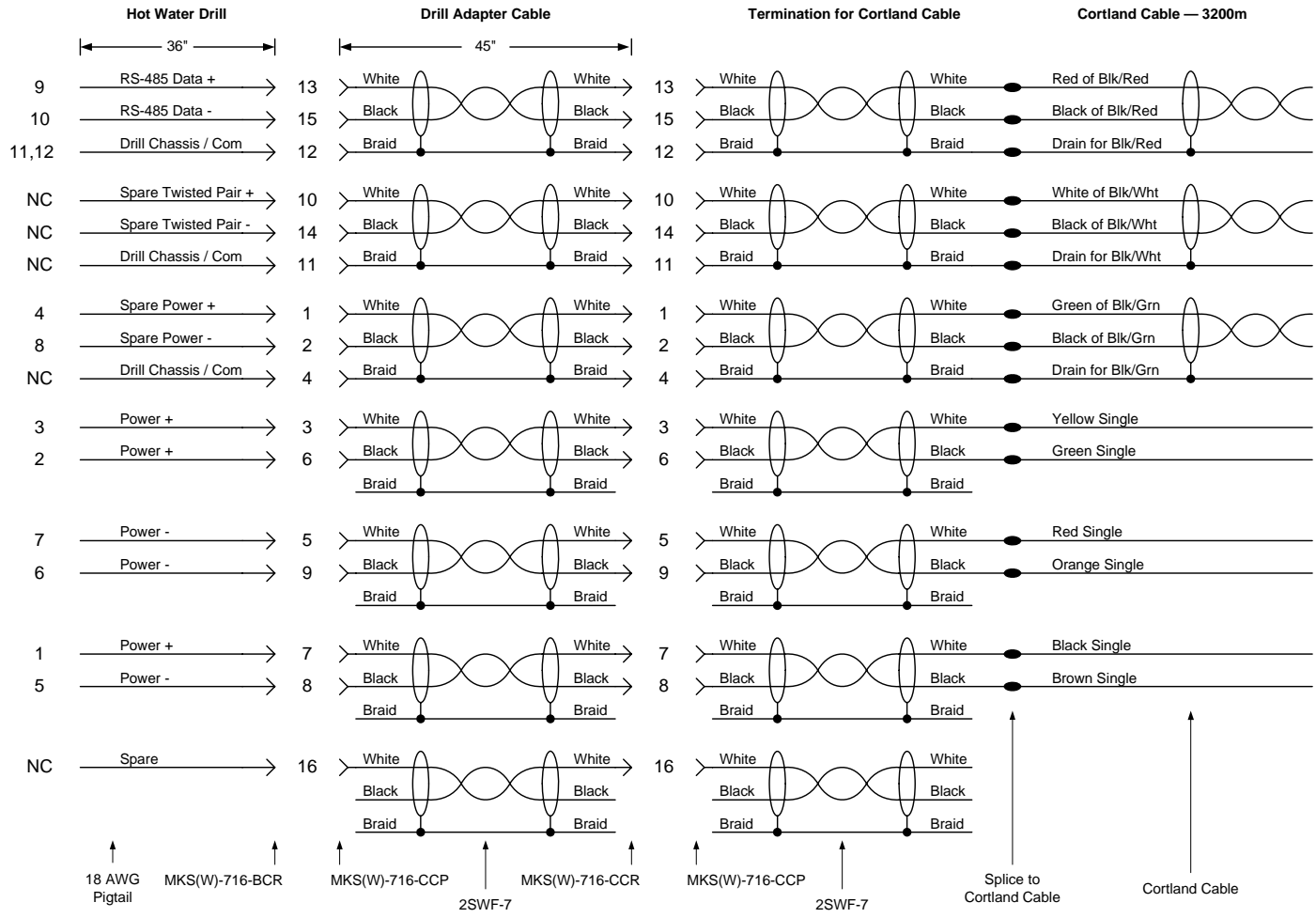
End to End resistance for each conductor should be approximately 100 ohms.  
Note: Continuity test should be done with power cord to RPSn power supply disconnected
6. Connect RPSn power cord to outlet strip in TOS Computer Rack if not already connected.
7. Turn on RPSn (Switch is on Kepco Supply on Front Panel). Voltage should read ~75 Volts and Current should read 0 Amps. Notes:
  - The Voltage is fixed at 75 volts (nominally). Turning the knob will not affect the output
  - The Current limit is variable. Make sure knob is turned all the way clockwise
8. Check Voltage at Impulse CCP connector at drill head end of Cortland Cable (see attached CCP connector pinout). Verify that voltage between from each +PWR pin to each –PWR pin on CCP connector is ~75 Volts. Verify that voltages between Pin 13 (RS-485+) and Pin 12 (Drain) and between Pin 15 (RS-485-) and Pin 12 are in –5 Volt to + 5 Volt range
9. Turn off RPSn Kepco Supply.

10. Connect drill end of Cortland Cable to Drill Head Adapter Cable (attached to Drill Head).
11. Turn on Laptop computer with EHWD Visual Basic Test Software Program installed.
12. Connect RS232 cable from RPSn RS232 Drill Head Data Connector to laptop serial port (COM1).
13. Start Test Software
14. For New Drill Head X: Start *EWHD\_FT01\_COM1Only\_Project.exe* (Visual Basic Test Program)
15. Setup New Drill Head X program as follows:
  - Click on HEX button and change to RPROD
  - Click on Drill ID Toggle Button and Change Adjacent Box to ICECUBEX
16. For Refurbished Drill Head: Start *EHWD2005\_RDH\_Project.exe* (Visual Basic Test Program)
17. Setup Refurbished Drill Head Test program as follows:
  - Click on HEX button and change to RPROD
  - Click on Drill ID Toggle Button and Change Adjacent Box to Refurbished
18. Turn on RPSn Kepco Power Supply. Kepco Supply typical currents for the Refurbished and New Drill Heads are:
  - Refurbished Supply Current ~ 195 ma
  - New Drill Head X or Y Supply Current ~ 220 maThese values are read on the front panel of the drill head power supply
19. After slight delay – drill head data should be displayed on test program screen – both streaming raw data messages in large central data display window and scaled values in separate labeled boxes above display window. Look at the following scaled variables (typical values for the Pole are shown next to each):
  - Heat sink temperature = ambient temperature in degrees F and then rising
  - Hose and Hole Water temperature with drill head on surface = ambient temperature in degrees F
  - Vin = 65 to 66 volts with supply set to 75 volts and drill head connected through main cable
  - Vout = 24 Volts
  - Cavity Air Pressure = 14 PSI
  - Tseal1 and TSeal2 Pressures = 5 to 25 PSI
  - Drill Hole Pressure = Ambient pressure (around 10 to 11 PSI) when drill head on surface
  - Nav Pack Bank and Tilt with Drill Head vertical < +/- 0.10 degrees with drill head vertical
20. To Log Drill Data:
  - Click on Open Log File button
  - Select Folder
  - Enter Filename
  - Click Log Off button to change to Log On => this starts logging
  - To stop logging click Log ON button to change to Log Off
21. Note1: Data Message comes out approx 5 times per second for New Drill Head X and 3 times a second for the Refurbished Drill Head so logging files grow fast

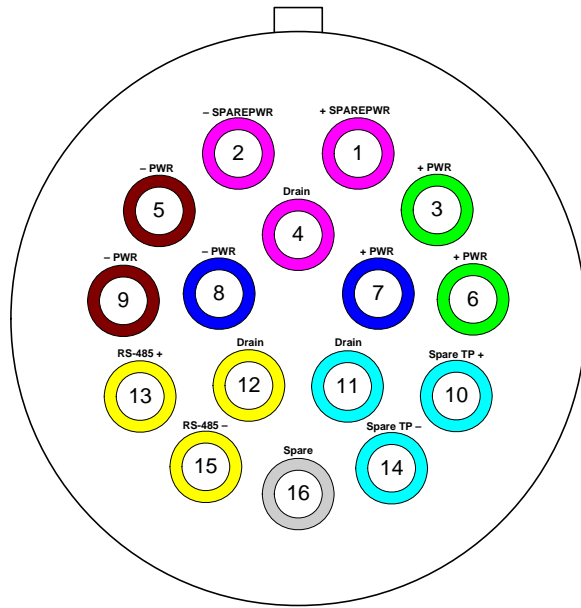
22. Note2: If drill head is already powered on, keep the RS232 cable disconnected from the drill head and first startup and initialize the VB Test software. After initialized, start log file if logging is planned. Then hot plug the RS232 cable into the RS232 Drill Head Data Port on the front panel of the drill head power supply. Data should appear on the screen and logging should start

**EHWD Refurbished Amanda Drill Head and EHWD New Drill Head X Startup Procedure Using the 50 Foot Drillhead to Power Supply adapter cable:**

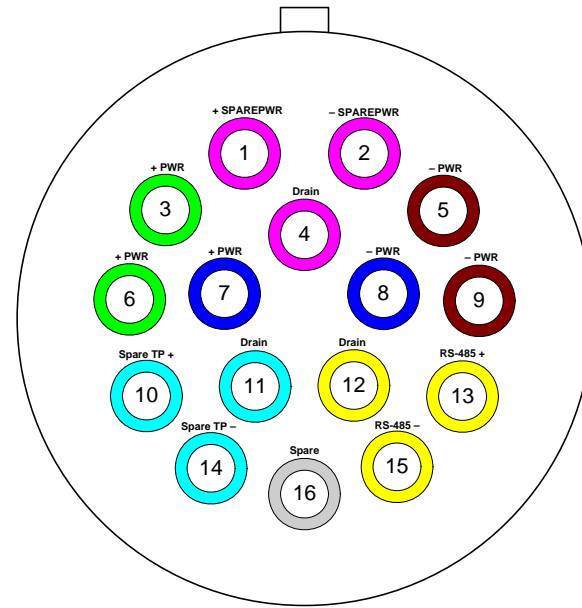
Here the procedure is the same as above with exception that a 50 foot adapter cable is used in place of the Cortland Cable and the Slip Ring to TOS cable. Because the cable is shorter and the voltage drop is less, the power supply voltage should be less than 75 volts. Set the supply voltage to the input voltage normally seen by the drill heads (65 volts DC). There will be insignificant drop over the adapter cable and the applied voltage seen by the drill head will equal the power supply voltage of 65 volts. The voltage reported by the drill head will be 1 to 2 volts less due to the diode drops in the drill head power supply. When using the 50 foot adapter cable, therefore, the variable voltage output power supply should be used. Set the output of this supply to 65 volts and measure the voltage before connecting to the drill head. After verifying that the voltage is 65 volts, turn off the supply, connect the drill head to the power supply through the 50 foot cable, connect COM1 of a laptop with test software installed to the power supply RS232 drill head data output connector on the front panel of supply, startup the test software program, setup the program, turn on the power supply. After turning on the supply – data should be displayed on the test program screen.



**Power/Telemetry Cable Interconnections for Enhanced Hot Water Drill Drill Head**




**MKS(W)-716-CCR Contact Configuration**  
**Receptacle Face View**  
**MKS(W)-716-CCP Contact Configuration Plug: Solder Side**



**MKS(W)-716-CCR Contact Configuration**  
**Receptacle: Solder Side**  
**MKS(W)-716-CCP Contact Configuration Plug: Face Side**

**(CCR is Female Barrel (Receptacle) with Male Pins)**

DRILL HEAD ELECTRONICS – Drill Head Connectors		
Impulse MKS(W)-716-CCP and CCR Connectors		
 <b>PHYSICAL SCIENCES LABORATORY</b> <small>UNIVERSITY OF WISCONSIN (608-877-2200)</small>		
DATE	DRAWN BY	DWG NO
01/03/2005	JRA	

**REVISIONS**

LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original version	11/15/05	MAZ

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Antarctic Astronomy & Astrophysics Research Institute  
**MADISON, WISCONSIN**

TITLE:  
***IceCube Project***  
**Enhanced Hot Water Drill (EHWD)/Deployment**  
**On-Ice Process Changes**

ORIGINATOR <i>Michael C. Zinnel</i> MAZ	DATE 11/15/05	DEPLOYMENT MGT <i>Tommy Ahn</i> TH	DATE 11/15/05	DRILL MGR OK per AE	10/01/08	DATE
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CHECKER <i>Michael C. Zinnel</i> MC	DATE 11/15/05	PRODUCT ASSURANCE / SAFETY <i>Michael C. Zinnel</i> MAZ/ML	DATE 11/15/05	PROJECT APPROVAL <i>Ed Paulos</i> BP	DATE 11-15-05
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**References:**

9000-0005 IceCube Document Control Procedure  
 9000-0004 IceCube Configuration Management Plan  
 9000-0019 IceCube (CR) Change Request Form

**Requirements:**

**Personnel:** Everyone on Ice can participate  
**Equipment:** 9000-0019 IceCube (CR) Change Request Form  
**Location:** In addition to its location in Docushare, hard copies of this and all approved and appropriate procedures will be placed at the South Pole in binders in the following sites: TOS1, TOS2, DCC, and Break Room.

**Definitions:**

“One-Off” Change: a one time only process deviation, necessary for a short period of time, typically implemented to accommodate an equipment loss or manpower shortage.

**Documentation:**

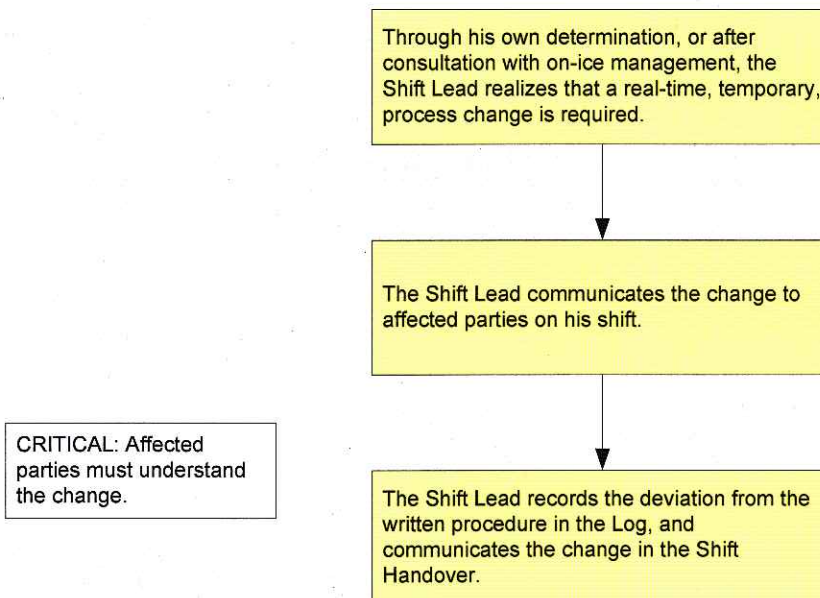
SOPs, Forms, Drawings et al.

**Scope:**

This document will depict the way in which process changes will be made and communicated on Ice at the South Pole. This document will describe the process for handling “one-off” changes as well as permanent changes.

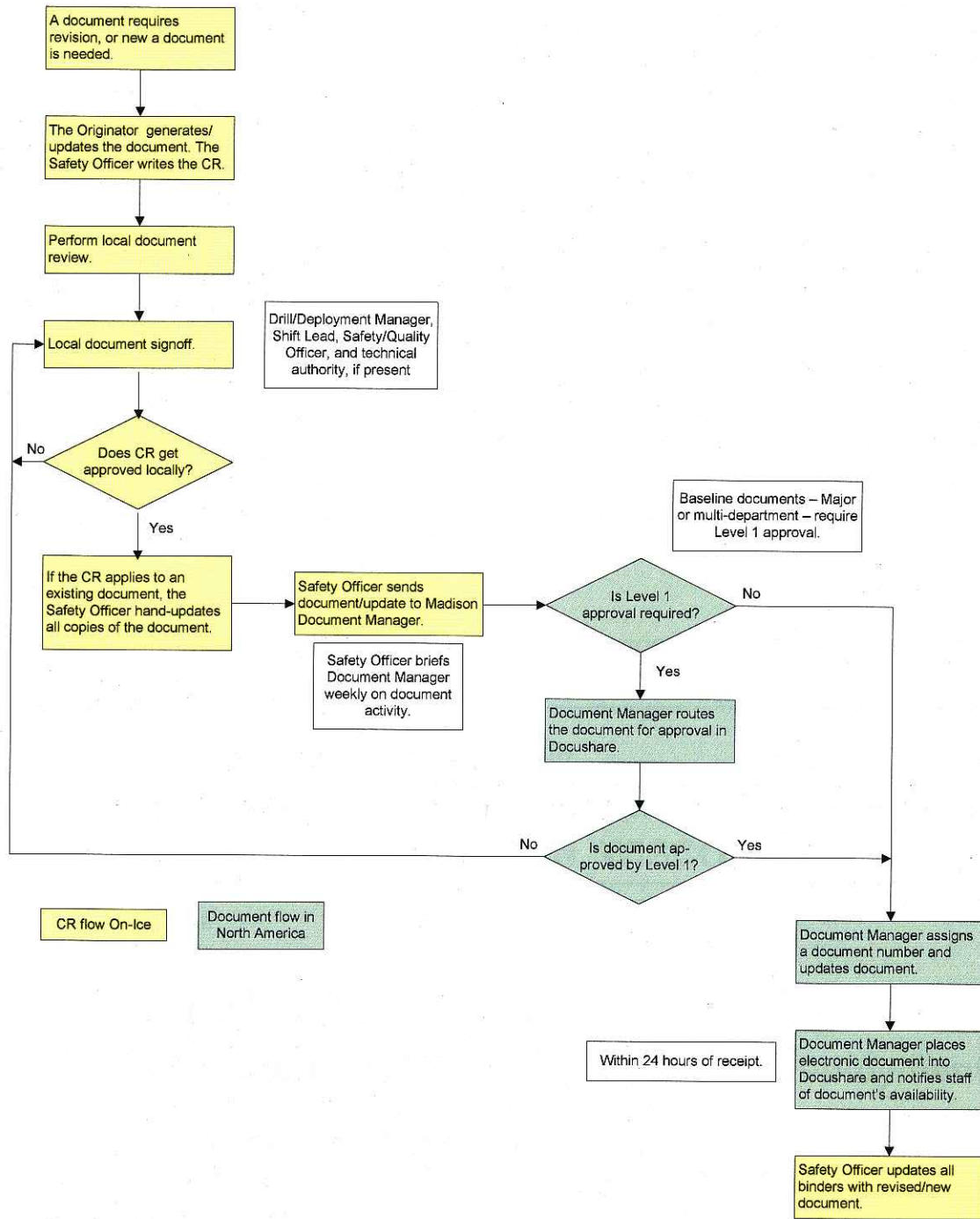
**Authority:**

The Shift Leads in conjunction with the Safety/Quality Officer On-Ice will enforce the implementation of this process.

**1. One-Off Changes:****2. Permanent Change- Real Time**

The Shift Lead follows the aforementioned process with the exception that the mark-ed up documentation is submitted to the cognizant Safety/Quality Officer on Ice for further processing.

### 3. IceCube Change Process





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-	NA	Original Document	08/30/07	TCB

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		<b>ICECUBE Shipping Standard Operating Procedure (SOP)</b>																							
		<b>ORIGINATOR</b>			<b>DATE</b>			<b>ENGINEER</b>			<b>DATE</b>			<b>CHECKER 1</b>			<b>DATE</b>								
		Terry Hannaford			08/30/07			Jeff Cherwinka			08/30/07			Al El-Cheikh			08/30/07								
		<b>CHECKER 2</b>			<b>DATE</b>			<b>QUALITY ASSURANCE</b>			<b>DATE</b>			<b>PROJECT APPROVAL</b>			<b>DATE</b>								
		Jim Baccus			08/30/07			Mike Zernick			08/30/07			Tom Hutchings			08/30/07								
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**References:**

"Purchasing Policy and Procedure Importing and Exporting Goods and Services, Number PPP20, Effective 6/15/05".

Raytheon Polar Services Company "Instructions on Packaging and Shipping, 2002-2003", LO-A-100, Revision #2, 8/14/02

Raytheon Polar Services Company "Continental Area Acquisition Schedule for 2005-06"

KRC Purchasing Policy & Procedures- Title "Shipping", KPP Np.1, 07/03/02, Replaces 11/16/98

Raytheon Polar Services Company web address;  
<http://www.polar.org/>

**Requirements:**

Personnel: PSL and/or IceCube Logistics and Drill Team

Equipment: Computer for generating Bill of Lading and other shipping documents

**Assumptions:**

Shipment of IceCube cargo or equipment remains under the guidelines of the "Purchasing Policy and Procedure Importing and Exporting Goods and Services, Number PPP20, Effective 6/15/05", with some unique approvals in place to accommodate transit to the South Pole Station. Questions or specific concerns regarding Purchasing, Freight Forwarding/Customs Brokerage House services, related to IceCube support should be directed to; Hartley Murray- [hmurray@bussvc.wisc.edu](mailto:hmurray@bussvc.wisc.edu) of UW Central Purchasing

or

Gail Movrich- [gmovrich@bussvc.wisc.edu](mailto:gmovrich@bussvc.wisc.edu) of UW Central Purchasing

Shipment of IceCube equipment to the South Pole Station (NPX) is essential for operation of Enhanced Hot Water Drill EHWD or the IceCube Observatory

Shipments should be packaged for transport via truck, surface vessel, and air freight (including LC130 ski plane to South Pole Station)

1. Equipment to be shipped to NPX

1.1 Contact appropriate project lead to determine what equipment is to be shipped and assign the proper "Required On Site" (ROS) date

**Action:** Provide IceCube Logistics or PSL Shipping Department;

- Type of equipment (e.g. Drill, Data Acquisition, IceTop, etc.)
- ROS date
- Dimensions of crate, package, container
  - Whether equipment is "Do Not Freeze" (DNF)
  - Hazardous equipment should be identified and a Material Safety Data Sheet (MSDS) shall be provided-Contact RPSC (Ray Gabriel
  - Equipment should be packaged by the person shipping
  - Provide IceCube Lead contact name and information along with packing list and value for items being shipped (electronic and printed versions preferred)
  - Whether equipment is able to be drift unloaded at NPX (South Pole Station)
  - Instructions for labeling shipment (e.g. "Keep Dry", "This Side Up", "Fragile", Do Not Freeze, etc.)
  - Crate should be constructed of new material in accordance with the guide lines described in Raytheon Polar Services Company "Instructions on Packaging and Shipping, 2002-2003", LO-A-100, Revision #2, 8/14/02 (page 22)

- Identify the correct destination by station abbreviation and stations code on the shipping label  
McMurdo Station- ZCM      Code-DR1  
South Pole Station- NPX    Code-DR3  
Christchurch NZ-CHC      Code-DR9

**Action:** Provide equipment to IceCube or PSL personnel, at PSL, or supplier location for disposition

**Action:** If item is shipping direct from supplier location provide Logistics or PSL personnel with above information and contact information for supplier

2. Shipment of items via courier service to Christchurch, New Zealand

2.1 This method of shipment is typically used to ship smaller pieces of equipment with a more urgent delivery or ROS to NPX

Guide Lines for shipment using courier

- Preferred courier service is DHL
- Package destination is Christchurch, New Zealand
- Typical package to be shipped
  - Less than \$2000 in value
  - Nominal combined Length plus width plus height is not greater than 84inches
  - Weight should not exceed 120 lbs for a single package and no more than 150 lbs may shipped to a single destination per delivery
  - Provide IceCube Logistics or PSL shipping department all information as required in 1.1 Action Items

3. Shipment of items to foreign countries (other than Christchurch, NZ)

3.1 Contact IceCube Logistics or PSL Shipping Department and provide all information is required in 1.1 Action Items including contact information for destination location

3.2 Non Courier shipments from the USA to Europe or from the USA to New Zealand should utilize the services of ScanAM as preferred Freight Forwarder and Customs House Broker.

3.3 Contact information for ScanAM is:

Rasmus Nielsen, Branch Manager, Chicago

[rni@scanam.com](mailto:rni@scanam.com)

ScanAm Transport (USA) Inc  
1473 Hamilton Parkway, Ste B  
Itasca, (Chicago) IL 60143  
Ph: +1 (630) 773 4300  
Fx: +1 (630) 773 4333  
Cell +1 (630) 701 0912  
<http://www.scanam.com>

4. Notification to UW Risk Management of Shipment of IceCube Equipment

4.1 IceCube Logistics, PSL Shipping Department, or IceCube Lead, shall notify Risk Management via email with a complete list of items to be shipped (regardless of destination and include value for each piece of equipment) 48 hours in advance of shipment. Contact in Risk Management office is; Margaret Hoffman - [mhoffman@bussvc.wisc.edu](mailto:mhoffman@bussvc.wisc.edu))

5. Communicate with IceCube Logistics and PSL Shipping Department regarding shipment of IceCube equipment-

5.1 For communication via email, copy all below, including IceCube Leads

IceCube Logistics - Terry Hannaford

[terryh@icecube.wisc.edu](mailto:terryh@icecube.wisc.edu)

IceCube office: 608-261-1428

PSL office: 608-877-2423

Personal Cell: 608-751-3925

To Leave Phone Message in Christchurch while in transit to NPX: 643 358 1470

NPX office: TBD

IceCube Logistics Alternate Contact (during IceCube Deployment to NPX)

TBD  
Email Address  
PSL office: 608-877-2422  
Personal Cell: 920-420-2578

PSL Shipping Dept- TBD  
Email address  
PSL office: 608-877-2269

6. All shipments require the shipper to complete a "Request To Ship" form and provide it to IceCube Logistics or PSL Shipping Department 48 hours prior to the ship date of the equipment. Document available via Docushare link- <http://docushare.icecube.wisc.edu/docushare/dsweb/Get/Document-17150/Request+to+Ship+IceCube+Equipment.xls>
- 6.1 Be sure the 'ship to' address is correct for the destination in any of the correspondence with IceCube Logistics or PSL Shipping Department.

The shipping address for Port Hueneme is;

National Science Foundation  
C/O Raytheon Polar Services Company Port Hueneme Operations  
Bldg 471- North End  
Naval Base Ventura County-Port Hueneme  
Port Hueneme, CA 93043  
Attn: Brian Brooks  
(805) 985-6851

The shipping address for Christchurch, New Zealand is;

National Science Foundation  
C/O Raytheon Polar Services (NZ) Limited  
International Antarctic Centre  
38 Orchard Road North  
Christchurch International Airport  
Christchurch, New Zealand

Phil Ambler: Manager Terminal Operations  
Raytheon Polar Services (NZ) Ltd  
Direct Ph: +643 358 1470  
Mobile Ph: +643 025 422 874  
mailto: phil.ambler@iac.org.nz

RPSC Freight Forwarders Address in Christchurch:

Anglo Pacific International  
PO Box 14 107  
Christchurch International Airport  
Christchurch, New Zealand  
Tel: +64-3-358 8191  
Fax: +64-3-358 8896

Note: API Contact Alan Johansson, e-mail "[alan@angloPacific.co.nz](mailto:alan@angloPacific.co.nz)"

7. All shipments require the shipper to complete a NSF "Bill of Lading" form and provide it to IceCube Logistics or PSL Shipping Department 48 hours prior to the ship date of the equipment. Document available via Docushare link-  
<http://docushare.icecube.wisc.edu/docushare/dsweb/Get/Document-17151/3603-NSFBillofLading+100705.rtf>

- 7.1 All shipments must have a shipping label affixed to the package or crate. A sample shipping label is available via Docushare link-  
<http://docushare.icecube.wisc.edu/docushare/dsweb/Get/Document-17152/DCP+2.dot>

- 7.1 Notice of all shipments including electronic documentation shall be forwarded via email to the following RPSC and IceCube personnel;

Terry Hannaford IceCube- [terryh@icecube.wiec.edu](mailto:terryh@icecube.wiec.edu)  
PSL- TBD

Patricia Douglas RPSC- [Patricia.Douglas@usap.gov](mailto:Patricia.Douglas@usap.gov)

Ray Gabriel RPSC- [Ray.Gabriel@usap.gov](mailto:Ray.Gabriel@usap.gov)

Jackie Samuel RPSC- [Jackie.Samuel@usap.gov](mailto:Jackie.Samuel@usap.gov)

- 7.2 Notice of expedited shipments destined for Christchurch including electronic documentation shall be treated as shipments in 7.1 above to include the following:

Phil Ambler RPSC in Christchurch- [phil.ambler@iac.org.nz](mailto:phil.ambler@iac.org.nz)

David Jobson RPSC in Christchurch- [dave.jobson@iac.org.nz](mailto:dave.jobson@iac.org.nz)

API Contact Alan Johansson in NZ- ["alan@angloPacific.co.nz"](mailto:alan@angloPacific.co.nz)

# IceCube Generator Operations and Maintenance, South Pole Station

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**OP-S-349**

**Revision 0**

**Approved by BK Grant**

**Posting Date 1/4/06**

**Active Divisions/Departments:**

**South Pole Area Directorate**

**FEMC**

**IceCube**

*Raytheon Polar Services Company*

*South Pole Area Directorate*

*Contract No. OPP 0000373*

**Hard Copy Not Controlled—Controlled Copy Available On-line**



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## Purpose

This procedure describes the operations, maintenance and storage requirements for the power generation system used to support the IceCube Seasonal Equipment Site.

## Scope/Applicability

This procedure applies to all RPSC and IceCube personnel involved in maintaining, operating, monitoring, and storing the electrical power generation system for the IceCube seasonal equipment site.

## Terms and Definitions

**CO<sub>2</sub>**

Carbon Dioxide

**COMMS/SOC**

South Pole Communications Center/Station Operations Center

**DCC**

Drill Control Center

**EMCP II**

Electronic Modular Control Panel mounted on the Caterpillar Generator set

**Hz**

Hertz

**kW**

Kilowatt

**Mapcon**

Software used to track inventory, labor, and maintenance/repairs

**NGH**

New Generation Heater

**On Line**

Generators actively providing power to the main buss for distribution to the IceCube drill and camp

**Parallel**

Running two engines on the same power grid in isochronous mode

**PDM**

Power Distribution Module

**PPE**

Personal Protective Equipment

**SES**

Seasonal Equipment Site—location of IceCube drilling operations in the Dark Sector

**V**

Volts

**VMF**

Vehicle Maintenance Facility (equipment garage)

## Responsibilities

### ***RPSC Power Plant Personnel***

Responsible for annual start up, maintenance, and repairs to the generators and associated power generation equipment in the Power Distribution Module (PDM) according to the manufacturer's recommended schedules. Provide materials and parts for the PDM generator sets. Maintain maintenance records for the engines and generators.

### ***RPSC VMF Mechanic, Facilities Engineer***

Provide technical support and advice as requested by Power Plant personnel.

### ***RPSC Fleet Operations Personnel***

Responsible for towing the modules into place and for winter storage of the units at the end of each austral summer.

### **RPSC Facilities Maintenance Personnel**

Provide assistance as required for building maintenance, including fire suppression equipment and electrical maintenance in the generator modules and PDM.

### **IceCube Drill Personnel (Summer)**

Provide monitoring (watches) and switching of power at the PDM. Maintain fuel supply to the generators and heat recovery water (when necessary).

## **Discussion**

### **Description of system**

The IceCube power and distribution system consists of three (3) Caterpillar SR4B generator sets with 3306 Caterpillar engines in individual portable modules, and a switchgear module. The units are arranged in a group at the downwind end of the Seasonal Equipment Site (SES). See attachment OP-S-349a, *IceCube Drill Camp Layout, South Pole Station* for details. The generator modules and PDM are designed and built by National Electric Systems Inc. The generators are rated at 221 kW (sea level rating) and de-rated to 165 kW at the South Pole (elevation: 9,306 feet).

The system is designed to operate with all three generator modules connected to the PDM. The PDM then controls load sharing and generator switching operations. Monitoring of each generator set output is also done from the PDM. Power distribution to the SES is done from the PDM main breakers.

The generator sets can be operated one at a time or in any combination up to and including all three engines for a short period of time.

The “Caterpillar” controls on each generator set are not operable, so the units cannot be operated independently from the generator module or disconnected from the PDM for service, maintenance, or testing. Control signal cables for voltage and frequency have been rerouted through the PDM. To operate the units individually, these cables would have to be rerouted to the governor control behind the EMCP II. Individual engines could be run disconnected from the PDM for service, but voltage and frequency controls on individual units are not operable.

## Safety

Follow general safety procedures for working with electrical systems, mechanical equipment, and fuel at all times.

Specific personal protective equipment (PPE) for working in the generator modules should include eye protection and hearing protection when the engines are operating.

The fire system is a carbon dioxide (CO<sub>2</sub>) system, manually controlled from the outside of the building.

**WARNING!** Ensure no people are inside the building before discharging the CO<sub>2</sub> fire suppression system.

Floor surfaces can be slippery from melting snow or fluid residue. Use caution when entering the buildings.

Follow all manufacturers' warning labels posted inside the module.

Whenever the status of the generators is going to be changed (switching generators or paralleling generators, for example), notify the Drill Control Center (DCC) because unexpected loss of power could cause safety or equipment issues in other parts of the drill system.

## Set Up

At the beginning of each season, the RPSC Fleet Operations staff will tow the modules into place at the SES. Once in position, the following steps should be followed for all three generator modules:

1. Heat up each generator module and the PDM using New Generation Heaters (NGH). This should take 4 to 8 hours depending on conditions.
2. Make all electrical connections between PDM and generator modules for power and control cables. Be sure control cables are fully inserted on both ends.
3. Make sure fuel supply lines have been connected and primed.
4. Install governors and load sharing controllers in the generator modules and the PDM module per diagram inside each cabinet.

5. Prime the fuel system using the engine primer pump on the Caterpillar engine.
6. Check oil level. The oil should have been changed at the end of the previous season.
7. Fill engine coolant, as it should have been drained at the end of the previous season.
8. Install charged batteries.
9. Open the upper vent panel on all three of the ventilation ducts.
10. Open exhaust stack.
11. Remove the insulation from the air intake in the center of the generator module.
12. Hook up the CO<sub>2</sub> cylinders to the fire suppression system.
13. Open the generator breaker on the panel below the EMCP II panel.
14. Set throttle control to the IDLE position.
15. Turn the start selector switch on the EMCP II to MANUAL START.
16. After the engine has started and warmed up to operating temperatures, move the throttle to full rated speed. Do not run the generator for too long in “stand alone” mode because there is no power to the auxiliary equipment.
17. Check engine for leaks.
18. Cool down and shut off engine.
19. Close the generator breaker on the panel below the EMCP II panel and set the start selector switch on the EMCP II to AUTO START.
20. Move to the PDM and start engine to test cables from PDM to generator switch.
21. Close the breaker in the PDM connecting a generator to the power distribution buss. This will energize the transformer in the PDM that feeds 208 V power back to all three generator modules to power the battery charger, ventilation motors, heating systems, lights, and other auxiliary equipment.

22. After the units have been individually tested and checked for operation, the entire system should be checked, testing for the following:
- Start and shut down each generator set from the PDM.
  - During running of individual generators, check calibration of both frequency and voltage meters using a reliable, separate meter.
  - Parallel all three generators from the PDM.

## **Training**

The RPSC Facilities Engineer will ensure that RPSC personnel provide annual training in the operation and monitoring of the system.

Persons who should attend the training include key IceCube personnel (identified by IceCube on-site management), RPSC Power Plant Engineer, Power Plant Mechanic, and any VMF personnel identified to assist with maintenance of the system.

## **Operation**

During the season, the system will be operated by IceCube personnel who will run the generators in combination as required for drilling and camp support power and complete the daily log sheets (See Attachment OP-S-349b, *IceCube Power Plant Watch Log, South Pole Station*)

The following instructions demonstrate the steps required to start up, shut down and parallel engines:

### ***Starting an Engine***

1. Make sure generator module is free of unauthorized personnel.
2. Check for proper oil level and antifreeze level.
3. Make sure no leaks are present under or around the engine.
4. Check that fuel valve is in ON position for both supply and return.

5. Check that air inlet and air exhaust doors are open from the outside of the building.
6. Check that main generator breaker is closed.
7. Check that the control switch on the EMCP II is in the AUTO position.
8. From the PDM main panel, turn the SYNC SCOPE switch on the main panel to the number engine that will be started. (This step can be skipped if a single engine is to be brought on line).
9. Turn the control switch to the MANUAL position for the generator to be brought on line. The generator will start automatically and the ENGINE RUNNING light will be illuminated on the panel.
10. Check that line voltage and frequency are correct for the engine being brought on line. (480 Volts and 60 Hz.)

**Parallel Engines:**

1. With one generator running on line, determine which engine is to be brought on line in parallel with it.
2. Check the engine to be brought up, making sure it is clear of personnel and ready to start.
3. Start the engine as described in “Starting an engine” section above.
4. Place the generator synchronizing switch into the position of the engine that is about to be closed.
5. Check the generator being brought on line for proper voltage and frequency. If problems exist, contact the RPSC Power Plant or the Facilities Engineer.
6. The synchronizing scope meter should be rotating in a clockwise rotation. If corrections are necessary, contact the RPSC Power Plant or the Facilities Engineer.
7. When the lights on the sync scope are dark, the two generators are in phase. When the hand on the dial reaches the twelve o’clock position, close the breaker for the engine being brought on line. The engine is now connected to



the buss in parallel with other engines that are connected to the buss. (The breaker will not close if the engine being brought on line is not synchronized with the buss.) If the breaker does not close, reset breaker and try again.

8. After closing the breaker, the amperage and wattage of the two generators should be about equal. If this is not the case, take one generator off line and contact RPSC maintenance personnel.
9. If an engine is to be taken off line, it can be done so now by opening the breaker tying the generator to the buss. The engine will remain running, but it will not produce power for distribution. The engine can then be turned off by placing the control switch in the PDM in the OFF/RESET position. The engine coming off line will be automatically cooled down and shut off. (Depending on the temperature of the engine, it may take 10 minutes or more for this cycle to be completed.)

### **Trouble Condition Alarm**

A failure in the generator system or the engine will result in the termination of the faulted generator. The cause of the trouble will be displayed at the faulted generators main panel or EMCP II display. The control switch on the EMCP II panel must be switched to the OFF/RESET position before the engine can be restarted. Call COMM/SOC to report the failure before attempting to restart the engine.

### **Emergency Shutdown**

An EMERGENCY SHUTDOWN button can be found on the PDM panel (red and silver button) for each generator and inside each generator on the EMCP II Panel (red button). These buttons can be used to stop each generator if emergency shutdown is required.

**WARNING!** The red buttons on the outside of the generator and PDM buildings are NOT generator shutdown buttons, but rather drill system E-stop buttons. These buttons will stop all high pressure pumps, heaters, and reels in the drill system, but will not stop the generators.

## **Fire Suppression System**

The fire suppression system is a manual CO<sub>2</sub> system. A PULL HANDLE on the outside of the building will activate the discharge of the CO<sub>2</sub>. Make sure the building is clear of all personnel before activating the system.

## **Maintenance**

Engine and generator maintenance are conducted in accordance with the manufacturers' recommendations. Work order records and schedules are maintained in the station's Mapcon database.

## **Storage for Winter**

After the drill season is complete, the generator sets are prepared for winter storage. The generator modules and PDM are stored downwind of the Summer Camp berm, parked in line with other IceCube modules.

The following steps are taken to prepare the generators for storage:

1. Change oil and oil filter.
2. Change engine fuel filter.
3. Remove, mark, and store generator batteries.
4. Check hours for other major services due during the next summer season and perform as needed.
5. Drain antifreeze for winter storage.
6. Remove and mark batteries in the PDM.
7. Seal exhaust stack.
8. Close and seal all air inlet openings into the module.
9. Disconnect CO<sub>2</sub> cylinders and cap them.

10. Tag EMCP II start selector with a note saying that the antifreeze is empty, batteries are removed, exhaust stack is sealed, ventilation ducts are sealed, governors are removed, and CO<sub>2</sub> is disconnected.
11. Remove any records from the generator and PDM (such as daily watch logs) and store them in the station power plant.

## References

Southworth Milton Caterpillar *IceCube Project Operations and Maintenance Manual*  
Caterpillar maintenance management schedule “SEBU6042-04”

## Records

<b>Record Identification, Format, &amp; Owner</b>	<b>Active Location Storage, Protection, &amp; Retrieval</b>	<b>Facility Storage, Protection &amp; Retrieval</b>	<b>Retention Time</b>	<b>Ultimate Disposition</b>
Daily watch sheets (hardcopy) owned by Facilities Engineer	PDM module for hardcopy original , transfer to electronic file by Power Plant personnel	Transfer to electronic file maintained by Facilities Engineer	Active: 1 year Facility Storage: 2 years	Records may be deleted after 2 yrs.
Maintenance records	Mapcon	Mapcon database	Life of the units	N/A

## Attachments

OP-S-349a *IceCube Drill Camp Layout, South Pole Station*

OP-S-349b *IceCube Power Plant Watch Log, South Pole Station*

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	7/26/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 6; 9-11;14-15; 17; 26</li> <li>Eliminated hazards due to ethanol; ethanol is not planned to be used as an anti-freeze</li> <li>All items closed</li> <li>Removed Revision History on page 2 (redundant)</li> <li>Updated section 4</li> <li>Added paragraph that we no longer planned to use ethanol as anti-freeze</li> </ul>	2/4/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment  Added Item 28	07/31/2005	MAZ
C		Eliminated all chemical hazards from the analysis.  Added USE-tripping hazard, added, 3 mechanical hazards, added strain relief hazard.	10/27/06	TCB
D		Eliminated non-bootstrapped hose failure. Added hazard #9	7/23/07	TCB
E		Annual Review and Revision	7/24/08	TCB
F		Annual Review and Revision	6/22/09	TR
G		Annual Review and Revision	4/14/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G														

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																								
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																								
		<b>MADISON, WISCONSIN</b>																								
		TITLE																								
		<b>ENHANCED HOT WATER DRILL DRILL HEAD SUPPLY HOSE HAZARD ANALYSIS SUMMARY</b>																								
1	15	ORIGINATOR				DATE				ENGINEER				DATE				DRAFTSPERSON				DATE				
2	16	Tim Rubino				4/14/10				T. Benson				4/14/10												
3	17	CHECKER				DATE				PRODUCT ASSURANCE				DATE				PROJECT APPROVAL				DATE				
4	18									M. Zernick				4/14/10												
5	19	FILENAME								8510-0106.revG.doc								PROJECT NO.								8510
6	20									8510-0106.revG.xls																
7	21	DRAWING NO.								8510-0106								SCALE				SIZE				SHEET
8	22																	NA				A				Page 1 of 4
9	23																									
10	24																									
11	25																									
12	26																									
13	27																									
14	28																									

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Drill Head Supply Hose
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Drill Head Supply Hose
<b>DOCUMENT #:</b>	8510-0106
<b>REVISION:</b>	G
<b># OF PAGES:</b>	4
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Closed (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Main Drill Hose for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Main Drill Hose.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0105 – Drill Head Supply Hose Specifications

Hazard Analysis Table (FMEA) table (for 8510-0106)

Hazard Analysis, Meeting Notes for (8510-0106)

### 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical – N/A
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Thermal – Burns
- Use - Tripping

### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	30
Major Risk Reduced to Moderate:	0
Major to Minor:	0
Moderate to Moderate:	0
Moderate to Minor:	15
Minor to Minor:	15
# Mitigated to Minor:	15
# Justified:	0
# Unmitigated (or minor to minor):	15
# Eliminated:	0

### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.

- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
	None	

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

**CLOSED – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.**

*IMPLEMENT –* The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW –* The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN –* This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.1 The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
5	Instructions to attach fittings	Systems are pressure tested; staff experience assembling fittings
6	Seasonal inspection plan (to check the fittings)	SP system test prior to drilling
1	Temperature analysis of hose & fittings (thermal conductivity)	Temperature unlikely to be hot enough to ignite a material; should not be in contact w/ combustible material
3	Review design of hose fittings to verify that: (1) there are no sharp edges, (2) end cap design is appropriate, (3) design of fittings	PMI 3.1 No end caps needed for current flushing procedure
7	2000 psi factory test procedure	IV&T 6.1.1 – See HA item 14
9	Verify use of pressure relief & torque limits on pumps	PMI 4.2
8	Tensile load test results	IV&T 6.1.3 – See HA item 14
11	Verify use of pressure monitors in control system	Subsystem & system testing
12	Instructions for hose deployment	Safety Training, Chapter 13 discusses how to address holes formed in snow
14	Pressure test results	IV&T 6.1.1 – See HA item 14
15	Cyclical fatigue test under tarp/bending	Write-Up from Jeff

## HAZARD ANALYSIS

### Subsystem: Drill Head Supply Hose

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	FIRE - Fire	Hose or fitting comes in contact with flammable item	4	1	1	4	Outside temperature of hose & fittings is not hot enough to ignite a nearby item	4	1	1	4	(5) Temperature analysis of hose & fittings - NA; outside temperature of hose coupling should be <180F; contact w/ a flammable material unlikely	Closed	
2		Hose sustains fire	4	2	1	8	Hose is tested to withstand 350°F; would require an outside ignition source to start hose on fire	4	2	1	8	None	Closed	Per J. Green, hose can sustain flame.
3	MECHANICAL - Cuts	Sharp edges on fittings	3	2	3	18	Edges are rounded; handler is gloved	3	2	1	6	(7) Verify edges are rounded - PMI 3.1	Closed	
4	MECHANICAL - Pinch point	Fingers pinched between hose fittings or in fitting clamp when coupling the hose pieces together	2	3	1	6	Instructions on coupling the fittings	2	2	1	4	Staff is gloved while completing task (2) Instructions to attach fittings - Systems are pressure tested; staff has experience assembling these fittings	Closed	
5	MECHANICAL - Trauma from release of high pressure water	Loose fitting allows contact with high pressure water; not a tight connection	4	2	2	16	Design of fitting; instructions on coupling the fittings; seasonal inspection, periodic inspection	4	1	2	8	(3) Seasonal inspection plan - SP system test prior to drilling	Closed	
6		Loose fitting allows contact with high pressure water; fitting is loose with the hose	4	2	3	24	2000 psi factory test; pressure relief & torque limits on pumps to limit pressure output to < 1200 psi, periodic inspection. Heat hose in winter, training to help observe when hose is potentially damaged, Procedure for changing out software burst detection senses pressure drop and shuts system off	4	1	3	12	See item 8	Closed	Inspection criteria created and posted



**HAZARD ANALYSIS**

**Subsystem: Drill Head Supply Hose**

**Author: M. Zernick**

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
7		Hose failure due to pressure allows contact with high pressure water	4	2	3	24	2000 psi factory test; pressure relief & torque limits on pumps to limit pressure output to < 1200 psi; kevlar design of hose, training (lessons learned), 2 pressure reliefs added, and periodic inspection See item 6	4	1	3	12	See item 8	Closed	
8		Hose failure due to tensile load allows contact with high pressure water	4	2	3	24	2000 psi factory test; boot straps designed into hose; factory load test to 10,000 lbs, pressure reliefs, training, adding chamfers to deck plate of tower See item 6 Torque limit; safeties on wheel drive and wheel sensors Necking will occur at 3000 psi, damage will occur at 10000 psi	4	1	3	12	(8) 2000 psi factory test procedure - IV&T 6.1.1, tests passed (9) Verify use of pressure relief & torque limits on pumps - PMI 4.2 (10) Tensile load test results - IV&T 6.1.3, tests passed  Although the factory tests passed, the hose failed during IV&T during load testing; it was determined that the current hose could be used for season 1 w/ more frequent banding to the cable to transfer more load to the cable.  We reduced the operational drill load to 1000 lbs. tension on the hose. Tension load warnings are in software	Closed	Hauling hose from reel to TOS hoist may put stress on hose.
9		Hose damaged by cold storage results in cracks and leaks in fitting	4	3	2	24	Heat hose in winter, training to help observe when hose is potentially damaged, Procedure for changing out questionable hoses	4	2	1	8	Training records	Closed	Inspection criteria created and posted

**HAZARD ANALYSIS**

**Subsystem: Drill Head Supply Hose**

**Author: M. Zernick**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
10		Hose damaged (driven over by large equipment) allows contact with high pressure water	4	1	1	4	Hose suspended above ground; large equipment should not be present; contact with hose is readily seen, operations and safety training for IceCube and RPS personnel. Exposed hose covered by orange covering Hoses flagged at camp	4	1	1	4	None	Closed	
11	MECHANICAL - Trauma from hose movement	Leak in hose causes hose to whip or kick into staff	4	2	2	16	2000 psi factory test; pressure monitors; pressure test run without noticeable motion; guards on crescents, hose is EPDM and Kevlar	2	1	2	4	See item 8 (11) Verify use of pressure monitors in control system - Subsystem & system testing	Closed	May be more of an issue if a coupling fails near the crescent where the hose could kick onto the platform.
12		Motion caused by wind	3	2	2	12	Mean windspeed in summer is 5 mph; weight & stiffness of hose would minimize this effect	2	1	2	4	None	Closed	
13	MECHANICAL-Trauma strain relief	Improper installation of strain relief (90 degrees offset)	3	4	1	12	Add to operator training (proper installation of strain relief)	3	1	1	3	Training records	Closed	
14		Loose Screws	2	2	3	12	Use of self-locking screws during installation, training	2	1	3	6	Training records	Closed	
15	Mechanical - Trauma Improperly rated valve	Valve leak	2	3	1	6	Training, operators must verify the rating of the valve prior to use, safety factor Properly rated valves procured and installed by EHW engineering	2	1	1	2	Training records	Closed	

**HAZARD ANALYSIS**

**Subsystem: Drill Head Supply Hose**

**Author: M. Zernick**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
16		Valve Ruptures	4	3	1	12	Training, operators must verify the rating of the valve prior to use, safety factor Properly rated valves procured and installed by EHW engineering	4	1	1	4	Training records Pressure checking on system	Closed	Valves fail with slow leak, not catastrophic leak
17		Captures water, falls out over crescent, freeze on crescent, crescent belt breaks.	3	4	2	24	Regularly check crescent for ice build up. Add spacer to strain relief. Training.	3	1	1	3	Set-Up Checklist, check crescents, remove ice	Closed	
18	THERMAL - Burns	Contact with metal fittings	2	2	2	8	Gloves, protective clothing worn during drilling process	2	1	2	4	None	Closed	Most likely to occur in TOS
19		Contact with hose	1	2	2	4	Gloves, protective clothing worn during drilling process	1	1	2	2	None	Closed	Hose should not readily transfer heat.
20		Loose fitting allows contact with hot water: fitting is loose with another fitting	4	2	2	16	Design of fitting; instructions on coupling the fittings; seasonal inspection; protective clothing worn during drilling process and periodic inspection.	4	1	2	8	See item 5	Closed	(1) If coupling came off, worker could be drenched in hot water. (2) Eye injury would appear to have the highest injury potential.
21		Loose fitting allows contact with hot water: fitting is loose with the hose	4	2	3	24	2000 psi factory test: pressure relief & torque limits on pumps to limit pressure output to < 1200 psi, periodic inspection. Heat hose in winter, training to help observe when hose is potentially damaged, Procedure for changing out	4	1	3	12	See item 8	Closed	Inspection criteria created and posted

**HAZARD ANALYSIS**

**Subsystem: Drill Head Supply Hose**

**Author: M. Zernick**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
22		Hose failure due to pressure allows contact with hot water	4	2	3	24	2000 psi factory test; pressure relief & torque limits on pumps to limit pressure output to < 1200 psi; kevlar design of hose; protective clothing and periodic inspection. See item 6	4	1	3	12	See item 8	Closed	
23		Hose failure due to tensile load allows contact with hot water	4	2	3	24	2000 psi factory test; pressure relief & torque limits on pumps to limit pressure output to < 1200 psi; boot straps designed into hose; tensile load test > 14000 lbs; protective clothing and periodic inspection. See item 6	4	1	3	12	See item 8	Closed	
24		Hose damaged (driven over by large equipment)	4	1	1	4	Hose suspended above ground; lg. equip. should not be present; contact with hose is readily seen; signage, flagging	4	1	1	4	None	Closed	
25	USE - Tripping	Small leak in hose can make holes in ice that can be stepped in	3	2	3	18	Leaky hoses are removed from service	1	2	3	6	(12) Instructions for hose deployment - Discussed in Safety Training, Chapter 13	Closed	Policy exists to fill in all incidental holes
26		User error - trips on hose on ground	3	2	1	6	Hose suspended above ground & should be readily visible Hose on ground is flagged	2	2	1	4	None	Closed	
27		Improper installation allows hose to melt into snow.	3	3	2	18	Walk hose to ensure insulation is in place, train operators on proper installation techniques. Tape insulation or put orange fabric cover on insulation	3	1	2	6	Record hose inspection in log book, add to relocation checklist	Closed	

**HAZARD ANALYSIS**

**Subsystem: Drill Head Supply Hose**

**Author: M. Zernick**

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
28	Hose or strap wrench	Strap wrench is released accidentally, swings, and hits worker causing injury	3	3	3	27	Design change, rubber padding and protection on handle or end, longer wrench to provide better leverage, safety and operations training	2	2	3	12	Design change	Closed	Strap wrench has not been necessary since '04/'05 season
29	Strain Relief	Cutting of hose on drum at fitting joints	3	4	1	12	Add strain relief to joints, add empty layer of hose to soften bend	3	1	3	9	Inspect hose connection at beginning of season, and at last hole	Closed	
30	Hose Rupture	Reuse of retired hose	4	4	2	32	Only superficial surface damage qualifies a section of hose for reuse. Other hose failures are destroyed immediately.	4	1	2	8		Closed	Hose failures are reviewed by EHWD mgt/eng for potential reuse

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/9/02	See original
A		<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3-18; 20-30; 32; 35-36; 39-42; 44-52</li> <li>2 items open</li> <li>Removed Revision History on Page 2 (redundant)</li> <li>Added item 34 in reference to cable incident at SP</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment  Addition of Item 50, Running the reel unplugged from TOS	07/31/05	MAZ
C		Under mechanical trauma a hazard was changed from "cable backlash" to "hose backlash"	10/27/06	TCB
D		Probability of Item 35 reduced from 2 to 1 and item 55 from 4 to 3 as a result of new mitigations; Added "Overpressure relief sprays personnel," Failure Cause 51; Added "Plumbing Leak," Failure Cause 52	07/27/07	TCB
E		Annual review and revision	7/24/08	TCB
F		Annual review and revision	6/23/09	TR
G		Annual review and revision	4/19/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																				
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																				
		<b>MADISON, WISCONSIN</b>																				
TITLE		<b>ENHANCED HOT WATER DRILL          DRILL HOSE REEL          HAZARD ANALYSIS SUMMARY</b>																				
1	15	ORIGINATOR				DATE				ENGINEER				DATE				DRAFTSPERSON				DATE
2	16	Tim Rubino				4/19/10				T. Benson				4/19/10				NA				
3	17	CHECKER				DATE				PRODUCT ASSURANCE				DATE				PROJECT APPROVAL				DATE
4	18									M. Zernick				4/19/10								
5	19	FILENAME								PROJECT NO.												
6	20	8510-0107.RevG.doc								8510-0107.RevG.xls								8510				
7	21	DRAWING NO.				SCALE				SIZE				SHEET								
8	22	8510-0107				NA				A				Page 1 of 6								
9	23																					
10	24																					
11	25																					
12	26																					
13	27																					
14	28																					

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Hose Reel
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Hose Reel
<b>DOCUMENT #:</b>	8510-0107
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Drill Hose Reel for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Drill Hose Reel.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0104 – Requirements Specification for Hose Reel

Drawings for Hose Reel

- PSL drawings 5587E061, 5587E029, 5587E020
- PSL solid model renderings presented in Critical Design Review 11/01

8510-0107 – Hazard Analysis Table (FMEA) table

8510-0107 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns
- Use – e-stop, tripping



**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	59
Major Risk Reduced to Moderate:	0
Major to Minor:	3
Moderate to Moderate:	0
Moderate to Minor:	43
Minor to Minor:	13
# Mitigated to Minor:	51
# Justified:	
# Unmitigated:	8
# Eliminated:	0

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

<b>ITEM #</b>	<b>HAZARD/CAUSE</b>	<b>JUSTIFICATION</b>
	None	

**6.0 STATUS OF THE HAZARD ANALYSIS (choose one of the following)**

**CLOSED** – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

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**REOPEN** – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.1 The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Noise level measurement (around hose reel to determine if there is a noise concern)	PMI 1.1 – Supply cable reel uses the same motors & noise measurements were taken on the cable reel
2	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>• Ear plugs</li> <li>• Gloves</li> <li>• Outerwear</li> <li>• Hardhats</li> </ul>	Safety Training Chapter 1
3	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Exposed electrical connections</li> <li>• Test lab listing on motors</li> <li>• Sharp edges</li> <li>• Inadequate clearances</li> <li>• Sprocket guard</li> <li>• Integrity of reel cover</li> <li>• Presence of level wind reel stop</li> <li>• Weights marked on components</li> <li>• Valves to prevent spillage when disconnecting hose/r. union</li> <li>• Caution label on brake resistor enclosure</li> <li>• Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 2.2</li> <li>• PMI 2.3</li> <li>• PMI 3.1</li> <li>• PMI 3.1</li> <li>• PMI 3.1, 7.3</li> <li>• Cover inspected during IV&amp;T &amp; found to be acceptable</li> <li>• PMI 8.1</li> <li>• PMI 7.1</li> <li>• PMI 4.2</li> <li>• PMI 7.3</li> <li>• PMI 8.1</li> </ul>
4	Safety Training (including): <ul style="list-style-type: none"> <li>• Electrical safety review</li> <li>• Proper lockout/tagout</li> <li>• E-stop use, availability &amp; testing</li> <li>• Correcting failures in the e-stop circuit before continuing drilling</li> <li>• Level wind safety</li> <li>• Falling objects during assembly/minimize working over others</li> <li>• Trip hazards</li> <li>• Cable Hazards</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>• Chapters 8 &amp; 12</li> <li>• Chapter 4</li> <li>• Chapter 6</li> <li>• Chapter 6</li> <li>• Chapter 12</li> <li>• Chapter 7</li> <li>• Chapter 14</li> <li>• Safety trainings were completed at South Pole</li> </ul>
5	Warning label on sprocket cover (present & appropriate)	PMI 7.3
6	Warning label over level wind (present & appropriate)	PMI 7.3
7	Analysis of level wind mechanism (to ensure it will not bend or break unsafely)	Safety analysis 2
8	PM instructions (including): <ul style="list-style-type: none"> <li>• Reel brake check</li> <li>• Proper operation of e-stop</li> </ul>	Inspection of reels is included in the Startup & Weekly Safety Inspections, including operation of e-stop & brake

Item	Evidence	Completed/Attached
	<ul style="list-style-type: none"> <li>• Review of assembly of reel (including cover)</li> <li>• Check of ice/snow accumulation in level wind &amp; elsewhere</li> </ul>	
9	Ski analysis (to review impact of a ski coming loose & verify integrity of attachments of skis to reel)	Kammer Hose Reel analysis; IV&T load tests
10	Assembly instructions (including): <ul style="list-style-type: none"> <li>• Appropriate warnings</li> <li>• Appropriate assembly instructions &amp; drawings</li> <li>• Assembly inspection</li> <li>• Designation of pull/lift points</li> <li>• Lifting instructions</li> </ul>	Assembly drawings sent w/ hose reel; reels are inspected as part of Startup & Weekly Safety Inspections; lift points are obvious on components
11	Analysis on bearing block (to ensure it will not fail unsafely)	Kammer Hose Reel analysis; IV&T load tests
12	Analysis on lift points (to ensure they will not fail unsafely)	Verified during 2004/2005 deployment
13	Control system design review (including): <ul style="list-style-type: none"> <li>• Breakers</li> <li>• Proper grounding</li> <li>• Drives detect shorts to ground</li> <li>• Use of preheated, enclosed, nonventilated motor frame</li> <li>• Motor drives detect overloads</li> </ul>	Supply Hose Reel motors are on dedicated circuits with dedicated drives & circuit breakers; circuits are grounded; drives are designed to detect electrical faults; motors are totally enclosed, non-ventilated motors
14	Verification testing (including): <ul style="list-style-type: none"> <li>• System monitoring of payout</li> <li>• Watchdog timer in system triggers e-stop condition</li> <li>• E-stop works properly (shuts down appropriate subsystems; has to be cleared to restart; restarts from default condition)</li> </ul>	All tested during subsystem & system testing (IV&T)
15	Safety factor analyses on motors/gearbox	Safety analysis 4

## 6.2 Issues – None

## HAZARD ANALYSIS

Subsystem: Main Hose Reel

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	1	8	None	2	4	1	8	None	Closed	There will always be small amounts of grease present on bearing cases, lead screws, etc.
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	2	1	4	None	2	2	1	4	None	Closed	Lubricants & grease can be found on the lead screw mechanism, gear reducer, chain & main shaft bearings.
3	ELECTRICAL - Shock	Exposed terminals	4	3	2	24	Enclosed terminals; safety training; insulation guarding some terminals	4	2	1	8	(3) Post-mfg inspection - PMI 2.2 (4) Safety training - Chapters 8 & 12	Closed	Electrical power runs to the main motor, level wind motor, brake, level wind limit switches, motor encoder & level wind encoder. The first 3 are to operate at 480V & the last 2 are expected to be to 120V.
4		Inadequate insulation on conductors	4	3	2	24	No PVC insulation used	4	2	1	8	See item 3	Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on) check insulation on cables
5		Shorting of cables due to use, abuse or accident (i.e., run over by caterpillar)	4	3	2	24	Breaker; drives deenergize; armored cable; unit grounded	4	2	1	8	Motors are controlled through dedicated circuits w/ dedicated drives & circuit breakers, which will detect faults; all circuits grounded	Closed	
6		Inadequate ground	4	2	4	32	Design; drives detect shorts to ground; breakers; redundant ground connections to reel	4	1	2	8	See item 5	Closed	Requires a double fault condition where a carrier shorts to the chassis & the ground is inadequate
7		Motor shorts due to contact with water, condensation, ice	4	4	2	32	Preheated motor; enclosed non-ventilated motor frame; motor drive would detect a short	4	1	2	8	See item 5 TENV motor	Closed	Personnel not expected to be present while reel is running
8		Improper lockout/tagout allows power to reel during service	4	4	2	32	Safety training, field verification, cable lockout procedure, new single key red locks for lockout	4	2	1	8	(4) Safety training - Chapter 4, cable lockout procedure	Closed	Training comments (1) attach measurements leads to deenergized terminals (2) notification of surrounding staff when reenergizing

## HAZARD ANALYSIS

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
9		Shock from open circuit in electrical blanket	4	2	3	24	Inspect blanket and electrical connection before each installation. Power off when working near blankets. Training Breakers and GFIs	4	1	2	8		Closed	
10		Locks out wrong circuit	4	3	2	24	Safety training; labeling of breaker boxes & connections, field verification, cable lockout procedure, new single key red locks for lockout	4	2	1	8	See item 8	Closed	Training comments (1) probe circuit prior to starting work
11		Stored energy released from capacitor in drive after power down	4	2	2	16	Safety training, field verification, cable lockout procedure, new single key red locks for lockout	4	2	1	8	See item 8	Closed	Takes minutes to discharge; would need to contact electrical buss inside the drive box for this to occur. Training comments (1) probe DC bus prior to starting work.
12	ENVIRONMENTAL - Acoustic noise	Mechanical noise	3	6	1	18	Ear plugs; measure noise level	3	2	1	6	(1) Noise level measurement - PMI 1.1; supply cable reel uses same motors & noise measurements were taken on the cable reel (2) Personal protective equipment - Ear protection in Safety Training Chapter 1 & earmuffs. earplugs provided to SP staff	Closed	The use of ear plugs should be adequate to minimize potential noise hazard. If the noise level measurement yields a low result, the severity may be reduced as well. Measurements were < the 85 dBA OSHA threshold.
13	FIRE - Fire	Overheating of motor	3	1	3	9	Drives detect overloads; motors are enclosed; motors are UL listed	3	1	1	3	(3) Post-mfg inspection - PMI 2.3 See item 5	Closed	
14		Shorting of electrical blankets creates fire hazard	4	2	2	16	Overcurrent protection, temperature monitoring, weekly inspection by winter overs	4	1	1	4		Closed	
15		Shorting of cables due to use, abuse or accident (i.e., run over by caterpillar)	3	3	2	18	Breaker; drives deenergize; unit grounded	3	1	1	3	See item 13	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
16	MECHANICAL - Cuts	Sharp edges due to design	3	4	2	24	All edges are to be radiused during mfg.; users wearing protective clothing (gloves); post-mfg. inspection of reel	3	1	2	6	(2) Personal protective equipment - Safety Training Chapter 1 (3) Post-mfg inspection - PMI 3.1	Closed	
17		Sharp edges due to use or breakage	3	2	2	12	Users wearing protective clothing	3	2	2	12	(2) Personal protective equipment - Safety Training Chapter 1 - Safety training - Chapter 14	Closed	
18	MECHANICAL - Pinch/entrapment points	Inadequate clearances	3	3	2	18	Guards (cover) on reel; gloves; post-mfg inspection	3	2	2	12	- PMI 7.3 - Moving machinery & Do not operate w/o guard labels placed on sprocket guard & level wind - Safety training - Chapter 12	Closed	
19		Access to drive chain & sprocket	4	3	2	24	Sprocket guard; PPE; warning label; lockout/tagout instructions	4	2	1	8	See item 16	Closed	Safety training shall cover lockout/tagout. The guard shall have a warning label reading " Follow appropriate lockout/tagout procedures before removing this cover or serious injury may result."
20		Body part caught between rotating side of reel & stationary support	4	3	2	24	Tarp framework reduces risk	4	1	2	8		Closed	
21		Trapped under skis	4	2	1	8	None	4	2	1	8	None	Closed	
22		Person/clothes caught between hose/reel or hose/hose during rewind	4	3	2	24	Reel cover; support warning label on level wind area; training; pull cord	4	2	1	8	See item 16 - Reel stop trip wires on front & back of reel	Closed	A label shall be affixed to the reel cover near the level wind opening stating "Do not enter the level wind area during operation, serious injury may result".
23		Reel freely rotates due to motor/gearbox failure	4	2	4	32	estop applies brake; supported by cable winch; instrumenting payout of hose/cable; safety factor on motor & gearbox	1	1	2	2	(14) Verification testing - Subsystem & system testing (15) Safety factor analyses on motors/ gearboxes - Safety analysis 4	Closed	Redundant load supports tied off by strap during setup

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24		Reel freely rotates due to brake failure	4	2	3	24	Supported by cable winch; brake designed to be failsafe; brake application is checked via seasonal startup & between holes, new brake design	2	2	2	8	(8) PM instructions - Brake check included in Weekly Safety Inspection	Closed	Worst case - Loss of power and the brake fails could lead to a slow backdrive of the reel. The brake is applied when power is lost to the system. This will occur when the reel is moved from hole to hole.
25		Unrequested motion due to EMI	4	2	2	16	Shielded cables; shielded drives; estop stops motor motion & applies brake; system monitoring of payout	4	2	1	8	See item 23 (14) Verification testing - Subsystem & system testing	Closed	Issue should be obvious to persons around the reel.
26		Unrequested motion due to confused H/W or S/W state	4	3	2	24	estop; system monitoring of hose payout	4	2	1	8	See item 25	Closed	Reel stop
27		Loss of system monitoring of hose reel (i.e., computer crash)	4	4	2	32	estop; watchdog timer in system triggers estop condition	4	1	2	8	See item 25	Closed	
28		Improper lockout/tagout allows powered reel motion during service	4	3	2	24	Training	4	2	1	8	(4) Safety training - Chapter 4	Closed	Safety training shall cover lockout/tagout, including tag teaming & person doing servicing controls the lockout.
29		Bending or breaking of level wind due to use	4	3	2	24	Analysis of level wind mechanism; mounted each hole	4	1	2	8	(7) Analysis of level wind mechanism - Safety analysis 2	Closed	
30		Hand (or other body part) placed between hose & level wind	4	2	2	16	Training; level wind label	4	2	1	8	(4) Safety training - Chapter 12 (6) Warning label on level wind - Moving machinery label placed on level wind	Closed	
31		Cleaning snow or ice out of level wind during operation	4	2	2	16	Training; level wind label; PM inspection - Ice/water guard added over level wind to prevent ice	4	2	1	8	See item 29 (8) PM instructions - Reels inspected during Weekly Safety Inspection	Closed	
32		Hand caught in level wind mechanism	4	2	2	16	Training; level wind label	4	2	1	8	See item 29	Closed	
33		Reel is pulled toward hole due to tensile pull on hose	1	2	1	2	None	1	2	1	2	None	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
34		Loose or ill-fitting cover	2	4	2	16	Design: PM inspection	2	3	2	12	(3) Post-mfg inspection - Cover inspected during IV&T & found to be acceptable. (8) PM instructions - Reels inspected during Weekly Safety Inspection	Closed	Cover not used
35	MECHANICAL - Trauma	Hose backlash during rewind	2	2	1	4	None	2	2	1	4	None	Closed	
36		Loose cover panel blows around in wind	3	3	2	18	Design: PM inspection	3	2	1	6	see item 34	Closed	Cover not used
37		Personal injury caused by incorrect level wind limit switch logic - Incorrect assembly of connectors can contribute to problem	3	2	1	6	New plugs cannot be mismatched Only one connection now	3	1	1	3	System tested at beginning of season	Closed	
38		Equipment damage caused by incorrect level wind limit switch logic	3	2	3	18	Check limit switch operation with each logic change; specific training. New plugs cannot be mismatched	3	2	1	6	safety training, and inspections	Closed	See item 37
39		Hose reel not properly disabled before drill head removed.	4	2	3	24	Training, checklist, look at software changes, torque limit to hose reel. Tie hose off inside tower Torque "rate of change" alarm	4	1	2	8		Closed	Torque limit added to hose reel
40		Impact with CAT, person getting crushed while attaching hitch	4	2	1	8	Tow bar lifting mechanism	4	1	1	4	safety training, inspection, pre-season check	Closed	Rope system to lift tow bar
41	SUSPENDED MASS - Reel falls over	Ski break/becomes unmounted/ collapses	4	2	2	16	Analysis of ski integrity & result of ski coming loose - Preseason inspection	4	2	1	8	(9) Kammer Hose Reel analysis: IV&T load tests	Closed	
42		Reel becomes unbalanced on unlevel surface	4	1	1	4	None	4	1	1	4	None	Closed	
43		Tension from unreeled hose causes reel to move/fall over	4	1	1	4	None	4	1	1	4	None	Closed	



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44	SUSPENDED MASS - Heavy object falls on personnel	Improper assembly causes parts to fall off reel	4	2	3	24	Assembly instructions & checkout; analysis on bearing block	4	1	2	8	(10) Assembly instructions - Assembly instructions (11) Kammer Hose reel analysis; IV&T load tests - Reels inspected during Startup & Weekly Safety Inspections	Closed	The bearing block analysis is a review of data supplied by the vendor compared to its load under use.
45		Inadequate maintenance to check integrity of reel	4	2	2	16	PM inspection by qualified individual	4	2	1	8	Reels inspected during Startup & Weekly Safety Inspections	Closed	
46		Parts break or fail due to use or trauma	4	3	2	24	Operator experience; PM inspection; pull/lift points stated in assembly instructions	4	2	1	8	See item 45	Closed	
47	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device	4	2	2	16	Weights noted on parts; operator experience, field verification, crane operation by RPSC	4	1	1	4	(3) Post-mfg inspection - PMI 7.1; weights noted on the palletized components	Closed	
48		Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	4	3	4	48	Redundancy in lift points; operator experience; analysis on lift points; assembly instructions, field verification - Rigging training	4	1	2	8	(10) Assembly instructions (12) Analysis on lift points	Closed	
49		Tools, bolts, etc. accidentally dropped	4	4	4	64	Protective equipment (hard hats); assembly instructions; safety training, written operating procedures, field verification	4	2	1	8	(2) Personal protective equipment - Safety Training Chapter 1 (4) Safety training - Chapter 7 (10) Assembly instructions - Assembly drawings	Closed	Safety training - Do not work over others with heavy objects
50	THERMAL - Burn	Contact with rotary union & connection hose in reel during use	2	5	2	20	Protective clothing; valves to prevent water spills when disconnecting hoses, insulated parts	2	2	2	8	(2) Personal protective equipment - Safety Training Chapter 1 (3) Post-mfg inspection - PMI 4.2	Closed	
51		Contact with 600W brake resistor hot	3	3	3	27	Housed in an enclosure; caution label on enclosure, training	2	2	1	4	(3) Post-mfg inspection - PMI 7.3; Caution Hot labels placed by brake resistors enclosures	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
52		Contact with drive heat sink	3	1	3	9	None	3	1	3	9	Caution Hot labels placed by drive heat sinks	Closed	It is in electrical closet. The heat sinks have poor accessibility & there is nothing serviceable in the box.
53		Overpressure relief sprays personnel	4	2	4	32	Bypass connected during use, Flow directed away, Training	4	1	3	12	Inspection, Training records	Closed	
54		Electrical blanket burns	3	2	1	6	Blankets limited to 120F temp. display, turn blankets off when working around	3	2	1	6		Closed	
55		Plumbing Leak	2	3	2	12	Inspect before season; pressure test	2	1	2	4	Inspection.	Closed	
56	USE - e-stop	Problem in system such that estop does not stop motors or apply brakes	4	2	4	32	Tested often; failsafe system, field verification of system	4	2	1	8	(8) PM instructions - Included in Startup & Weekly Safety Inspection (14) Verification testing - Subsystem & system testing	Closed	E-stop system tested before start of each hole
57		Non-functional button (i.e., frozen)	4	3	3	36	Tested periodically; failsafe system; buttons are covered; redundant estop buttons, field verification of system	4	2	1	8	See item 56	Closed	
58		Not readily accessible to users	4	2	2	16	Redundant e-stops available to user; highly visible; safety training	4	2	1	8	(3) Post-mfg inspection - PMI 8.1 (4) Safety training - Chapter 6	Closed	Use of buddy system
59	USE - Tripping	Exposed electrical cables, hoses connecting to reel or skis	2	5	2	20	Obvious cables; cable routing away from reel controls to minimize tripping, combined signal cable reduces clutter	2	3	2	12	(4) Safety training - Chapter 14	Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/16/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3; 5; 8-10; 12-16; 18-19; 21-41; 43; 47-52</li> <li>All items closed except 42</li> <li>Removed Revision History on page 2 (redundant)</li> </ul>	2/4/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	08/01/06	TCB
D		Added mitigation to item 4; Added item 13; Removed 2 hazards due to "improper assembly"	08/21/07	TCB
E		Annual review	7/24/08	TCB
F		Deleted Item 12, Added new #7 for insulation on Return Water Pump Cable	7/9/09	TR
G		Annual review	5/10/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G	G											

CONTROLLED COPY DIST. LIST		THE UNIVERSITY OF WISCONSIN																
1	15	<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																
2	16	TITLE																
3	17	<b>ENHANCED HOT WATER DRILL TOWER &amp; TOS HAZARD ANALYSIS SUMMARY</b>																
4	18	ORIGINATOR      DATE      ENGINEER      DATE      DRAFTSPERSON      DATE																
5	19	Tim Rubino      5/10/10      T. Benson      5/10/10      NA																
6	20	CHECKER      DATE      PRODUCT ASSURANCE      DATE      PROJECT APPROVAL      DATE																
7	21	M. Zernick      5/10/10																
8	22	FILENAME      8510-0108.RevG.doc      PROJECT NO.      8510																
9	23	8510-0108.RevG.xls																
10	24	DRAWING NO.      8510-0108      SCALE      SIZE      SHEET																
11	25	NA      A      Page 1 of 6																
12	26																	
13	27																	
14	28																	

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Tower
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Tower
<b>DOCUMENT #:</b>	8510-0108
<b>REVISION:</b>	G
<b># OF PAGES:</b>	7
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the TOS Tower for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the TOS Tower. Note: This document does not include potential hazards specifically regarding the TOS MDS's to which the tower is attached for drilling, or the drill cable or hoses.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0101 – Requirements specification for TOS Tower

Draft 3D Rendering of Tower by Bit 7

8510-0108 – Hazard Analysis Table (FMEA) table

8510-0108 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Use – e-stop

#### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	54
Major Risk Reduced to Moderate:	2
Major to Minor:	4
Moderate to Moderate:	2
Moderate to Minor:	28
Minor to Minor:	18
# Mitigated to Minor:	32
# Justified:	4
# Unmitigated:	18
# Eliminated:	0

#### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
26	Tools/materials dropped by user	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Assembly instructions & training can reduce the potential for injury as a result of items being dropped. However, safety is dependent on the user wearing appropriate protective gear & not putting themselves/others in harm's way.

33	Ladder surface slippery due to ice or snow	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Periodic inspection of the ladder, design of the treads & boots with good traction will reduce the risk. However, use of ladders has some inherent risk that is readily identifiable to the user & is difficult to design out.
45	Equipment not placed out of way	<b>Issue should be obvious to workers in the tower.</b> A number of pieces of equipment may be in the tower, including drill head components, drill head rack, return water pump, DOM's, hole cover and hole ring. Although, these are to be stowed when not used, the work area is quite small, so there is the potential for equipment to be in the workflow. These are large pieces of equipment that should be easily seen. Avoidance is predicated on user compliance to stow equipment and avoid any equipment in the work areas.
50	Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> The tower will be shipped as pieces & built at the South Pole. Standard work practices are that person operating the lifting equipment verify the weight of the materials to be lifted & use equipment that can appropriately lift the materials. Weights are to be noted in the assembly documents. Following this process should adequately mitigate this issue.

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.1 The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Adequate exits present &amp; marked in MDS &amp; tower</li> <li>• GFI's installed on electrical outlets</li> <li>• Sharp edges</li> <li>• Presence of cable sheave guards, crescent brackets &amp; fairleads</li> <li>• Overall structural soundness of tower</li> <li>• Design of hitch points to secure tower to MDS to prevent chain from</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.2</li> <li>• NA for tower; PMI 2.2 for TOS</li> <li>• PMI 3.1</li> <li>• PMI 3.5</li> <li>• Tower Proof Test</li> <li>• PMI 3.5</li> </ul>

	<p>falling</p> <ul style="list-style-type: none"> <li>• Hoist present &amp; of appropriate design for tasks</li> <li>• Structural soundness of ladder, upper deck &amp; stairway</li> <li>• Construction of ladder &amp; stairway for anti-slip surfaces</li> <li>• Railings &amp; toeboards present &amp; structurally sound on upper deck, stairway &amp; holes (no railing planned for lower hole)</li> <li>• Anti-slip fiberglass grating on upper deck</li> <li>• Hole covers present</li> <li>• Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.5; Safety analysis 6</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 8.1</li> </ul>
2	<p>Safety Training (including):</p> <ul style="list-style-type: none"> <li>• Hole safety</li> <li>• E-stop use, availability &amp; testing</li> <li>• Falling objects during assembly/minimize working over others</li> <li>• Running into objects in work room</li> <li>• Do not block exits</li> <li>• Pinch/entrapment hazards around cable sheaves &amp; crescents</li> <li>• Securing tower to MDS with chains</li> </ul>	<p>Safety Training Manual:</p> <ul style="list-style-type: none"> <li>• Chapter 13</li> <li>• Chapter 6</li> <li>• Chapter 7</li> <li>• Not in training; obvious issue</li> <li>• Chapters 2 &amp; 11</li> <li>• Chapter 11 &amp; 14</li> <li>• Chapter 11</li> </ul>
3	<p>PM instructions (including): PM instructions have not been written; however, many of the inspections have been included in the Startup &amp; Weekly Safety Inspections.</p> <ul style="list-style-type: none"> <li>• Inspection of equipment used in/on tower, including hoist &amp; banding units</li> <li>• Check integrity of tower, railings, stairway, ladder</li> <li>• Check to ensure walking surfaces, stair/ladder treads are free from snow, ice &amp; debris</li> <li>• Check integrity of fall safety restraints (straps)</li> <li>• Check operation of e-stop system</li> </ul>	<ul style="list-style-type: none"> <li>• Banding unit NA; hoist in Startup &amp; Weekly Safety Inspections</li> <li>• Startup/Weekly Safety Inspections</li> <li>• Weekly Safety Inspections</li> <li>• Done at South Pole</li> <li>• Weekly Safety Inspections</li> </ul>
4	<p>Personal protective equipment (verify that the staff is to wear):</p> <ul style="list-style-type: none"> <li>• Gloves</li> <li>• Outerwear</li> <li>• Hardhats</li> <li>• Boots</li> <li>• Fall safety restraints (straps)</li> </ul>	<p>All PPE discussed in Safety Training Chapter 1; hardhat use described in Chapter 7</p>
5	<p>Assembly instructions (including): Assembly instructions were not created for the tower; however, a complete set of assembly drawings was taken to SP. Assembly is completed by staff responsible for the original assembly &amp; disassembly of the tower.</p> <ul style="list-style-type: none"> <li>• Securing tower to MDS with chains</li> <li>• Appropriate warnings</li> <li>• Appropriate assembly instructions &amp; drawings</li> <li>• Assembly inspection</li> <li>• Weights of tower components specified</li> </ul>	<ul style="list-style-type: none"> <li>• Designed by drill staff</li> <li>• Addressed in Safety Training</li> <li>• Assembly drawings</li> <li>• Startup Safety Inspections</li> <li>• Marked on component pallets</li> </ul>
6	<p>Final Bit 7 structural analysis on the tower</p>	<p>Tower Proof Test</p>
7	<p>Assessment of the safety margin on the hoist</p>	<p>Safety analysis 6</p>
8	<p>Verification testing (including):</p> <ul style="list-style-type: none"> <li>• E-stop works properly (shuts down appropriate subsystems; has to be cleared to restart; restarts from default condition)</li> </ul>	<ul style="list-style-type: none"> <li>• Subsystem &amp; system testing</li> </ul>

6.2 Issues – None



**HAZARD ANALYSIS**

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**Author: M. Zernick**

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	1	8	None	2	4	1	8	None		Closed	
2	CHEMICAL - Handling of lubricants & greases	Bearing cases not sealed due to inadequate design, manufacture or damage	2	2	1	4	None	2	2	1	4	None		Closed	
3	FIRE - Tower Design	Inadequate egress	4	2	2	16	Exit designed into TOS MDS's; exit to be designed into tower work room; exits marked	4	1	1	4	(1) Post-mfg inspection - PMI 3.2 (2) Safety training (not to block exits) - Chapter 2 & 11		Closed	This category can include not enough exits; no nearby exits; blocked exits. From a design standpoint, no one should be further than 25' from an exit.
4		Plywood interior of tower shack sustains fire	4	2	1	8	Fire Extinguisher	4	2	1	8	None		Closed	
5	FIRE - Ignition Sources	Electrical short from equipment used in/on tower	4	2	2	16	GFI's on non UPS outlets; inspect equipment	4	2	1	8	(1) Post-mfg inspection - No outlets in tower (3) PM instructions - Not done: only electrical devices are the hoist & return water pump, which are controlled through drives & circuit breakers in the TOS, both of which detect shorts in the cabling - GFIs installed on 120VAC outlets in TOS; 240VAC outlets to be connected through GFI cables (which were shipped to SP)		Closed	Include motor hoist, return water pump & any other accessories
6		Insulation on drill cable wears off due to continual rubbing on platform causing a short	4	1	1	4	Teflon scrubber Low abrasion	4	1	1	4	None		Closed	Low voltage cable: would lose sensor functionality

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7	ELECTRICAL - Shock	Exposed terminals	4	1	2	8	None	4	1	2	8	None		Closed	This would mainly apply to the hoist motor; the terminals of which are not accessible. Other items are cord connected & do not have exposed terminals.
8		Inadequate insulation on conductors	4	2	1	8	GFI's on outlets; inspect equipment, training	4	2	1	8	See item 5		Closed	
9		Shorting of cables due to use, abuse or accident	4	2	3	24	GFI's on outlets; inspect equipment, training	4	2	1	8	See item 5		Closed	
10		Inadequate ground	4	2	4	32	GFI's on outlets, training	4	1	3	12	See item 5		Closed	
11		Shock hazard due to integration of water and electrical closet	4	1	1	4	Train staff to keep fluids away from electrical closet	4	1	1	4	Training records		Closed	
12		Short circuit due to integration of water and electrical closet	4	1	1	4	Train staff to keep fluids away from electrical closet	4	1	1	4	Training records		Closed	
13		Disconnection of power supply before powering down	4	2	3	24	Training, Signage to power down before disconnecting power supply	4	1	1	4	Training records		Closed	
14	ENVIRONMENTAL - Acoustic noise	Noise levels > 85 dB	3	2	1	6	None	3	2	1	6	None		Closed	Noise levels are not expected to exceed 85 dB in the work room.
15	ENVIRONMENTAL - Cold working conditions	Exposed to cold while working on upper deck	3	3	1	9	Protective clothing, job rotation	3	2	1	6	(4) Personal protective equipment - Safety Training Chapter 1, job rotation		Closed	
16		Exposed to cold while working in TOS	3	2	1	6	Temperature is expected to be at least 40F in work room	3	2	1	6	None		Closed	Work room is solar heated & heated from furnace in MDS.
17	ENVIRONMENTAL - Diesel Fuel Spill	Fuel spill when connecting fuel tanks (not closing valve)	2	2	1	4	Valve, training	2	2	1	4				
18	MECHANICAL - Cuts	Sharp edges due to design	3	3	2	18	Radius sharp edges (note on drawings)	3	1	2	6	(1) Post-mfg inspection - PMI 3.1		Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
19		Sharp edges due to use or breakage	3	2	2	12	None	3	2	2	12	(1) Post-mfg inspection - PMI 3.1 (2) Safety Training - Chapter 14		Closed	
20	MECHANICAL - Pinch/entrapment points	Inadequate clearances	2	2	3	12	Training	2	2	3	12	Guards placed to prevent access to potential pinchpoints around sheaves & crescents		Closed	
21		Trapped under skis	4	2	1	8	None	4	2	1	8	None		Closed	
22		Caught between crescent/pulleys/tower hoist and hose/cable	3	4	2	24	Cable sheave guards; hose fairleads & bracket to keep hoses on crescent; personnel not routinely on upper deck; Training	3	2	1	6	(1) Post-mfg inspection - PMI 3.5 (2) Safety training - Chapter 14		Closed	
23		Caught between tower & MDS while attaching tower to MDS	4	1	1	4	None	4	1	1	4	None		Closed	
24		Hand caught in ratchet straps while attaching tower to MDS	3	4	2	24	Training procedure	3	2	1	6	(5) Assembly instructions - Safety Training Chapter 11		Closed	
25		Impact with CAT, person getting crushed	4	2	1	8	Add rope pulley system to support the tow bar for reel	4	1	1	4	safety training, inspection, pre-season check		Closed	
26	MECHANICAL - Trauma; falling objects	Tools/materials dropped by user	3	4	4	48	Protective equipment (hard hats); assembly instructions; safety training	3	2	3	18	(2) Safety training - Chapter 1 & 7 (4) Personal protective equipment - Safety Training Chapter 1; hardhats shipped to SP (5) Assembly instructions - Addressed through Safety Training		Closed	Addition of signs would be an improvement
27		Structural failure; breakage of support	4	2	3	24	Bit 7 analysis; ASTM material; inspection	4	1	2	8	(1) Post-mfg inspection - PMI 3.1 (6) Bit 7 structural analysis - Tower Operations Proof Test		Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
28		Inadequate maintenance to check integrity of tower	4	3	3	36	Periodic inspection, start up inspection	4	1	2	8	(3) PM instructions - Included in Startup & Weekly Safety Inspections, check tightness bolts on TOS start up and HPP		Closed	
29		Ratchet straps to secure tower to MDS come loose or are not secured	3	3	2	18	Design of hitch points; training; protective gear (safety glasses, hard hats)	3	1	1	3	(1) Post-mfg inspection - PMI 3.5 (2) Safety training - Chapter 11 (4) Personal protective equipment - Safety Training Chapter 1		Closed	
30		Hoses/cables falling off pulleys/crescents	3	4	3	36	Cable sheave guards; hose fairlead & bracket to keep hoses on crescent	3	1	1	3	(1) Post-mfg inspection - PMI 3.5		Closed	
31		Dropping drill head weights	3	3	2	18	Hoist provided to support weights; Training	3	1	2	6	(1) Post-mfg inspection - PMI 3.5		Closed	
32	MECHANICAL - Trauma; person falls off ladder	Structural failure; breakage of support	4	2	3	24	Purchased part to OSHA standards; inspection	4	1	2	8	(1) Post-mfg inspection - PMI 3.3 - Tower inspected by UW Safety; all issues addressed		Closed	
33		Ladder surface slippery due to ice or snow	4	4	2	32	Anti-slip tread; periodic inspection; protective clothing (boots)	4	2	2	16	(1) Post-mfg inspection - PMI 3.3 (3) PM instructions - Included in Weekly Safety Inspections (4) Personal protective equipment - FDX boots issued to drillers for better traction		Closed	
34		Improper assembly	4	2	2	16	Assembly/inspection procedures; assembly training	4	1	2	8	(5) Assembly instructions - Assembly checks included in Startup & Weekly Safety Inspections		Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
35	MECHANICAL - Trauma; person falls off upper deck	High wind	4	2	2	16	Railings around outside of platform & hole; kick plates	4	1	2	8	(1) Post-mfg inspection - PMI 3.3; access to upper hole largely occluded by equipment; toe board placed by opening to provide access to hole for workers		Closed	Railings & gates in place to prevent falling  High wind is considered unlikely in this environment.
36		Walking surface slippery due to ice or snow	4	3	2	24	Anti-slip walking surface	4	1	2	8	(1) Post-mfg inspection - PMI 3.3		Closed	
37		Structural failure; breakage of support	4	2	3	24	Bit 7 analysis; ASTM material; inspection	4	1	2	8	See item 27		Closed	
38		Inadequate guardrail/toe board on outside of top platform	4	2	2	16	Purchased part to OSHA standards; design inspection; periodic inspection	4	1	2	8	See item 27 (3) PM instructions - Included in Startup & Weekly Safety Inspections		Closed	
39		Falls through hole in upper deck due to inadequate guard	4	3	2	24	Toe board around hole	4	1	2	8	See item 27		Closed	
40	MECHANICAL - Trauma; person falls off stairway	Structural failure; breakage of support	4	2	3	24	Purchased part to OSHA standards; inspection	4	1	2	8	See item 27		Closed	
41		Stairway surface slippery due to ice or snow	3	4	2	24	Anti-slip tread; periodic inspection; protective clothing (boots)	3	1	2	6	See item 36		Closed	
42		Inadequate stair rail	4	3	3	36	Purchased part to OSHA standards; design inspection; periodic inspection	4	1	1	4	(1) Post-mfg inspection - PMI 3.3 (3) PM instructions - Included in Startup & Weekly Safety Inspections		Closed	
43	MECHANICAL - Trauma; person falls into drilled hole	Inadequate guard on drilled hole	4	3	2	24	Toe board & cover on hole; restraint straps	4	2	1	8	(1) Post-mfg inspection - PMI 3.3 (4) Personal protective equipment - PMI 3.5 (fall restraint connections); Safety Training Chapter 1; fall restraints shipped to SP		Closed	
44		Safety harness fails	4	2	3	24	Inspect periodically	4	1	2	8	(3) PM instructions , verified at South Pole		Closed	
45	MECHANICAL - Trauma; person runs into equip. inside TOS	Equipment not placed out of the way	2	4	2	16	Training, equipment location and design, PPE	2	4	2	16	(2) Safety training - Tight quarters; issue should be obvious to staff		Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
46	MECHANICAL - Trauma: tower falls over	Ski breaks/becomes unmounted/ collapses	4	1	3	12	None	4	1	3	12	None		Closed	
47		Tower becomes unbalanced on unlevel surface during transport	4	2	2	16	Road prepared & leveled prior to transport	4	1	2	8	Standard practice		Closed	The tower is designed to have a low center of gravity.
48		Run into by caterpillar or other large equipment	4	2	1	8	None	4	1	2	8	None		Closed	
49	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device, or bad rigging	4	2	3	24	Weights of materials listed: operator experience, SOPs, training	4	1	2	8	Weights of palletted materials noted on pallets - PMI 7.1		Closed	
50		Inadequate lifting points on equipment or lifting apparatus (I.e., strap) breaks	4	3	3	36	Weights of materials listed: operator experience, SOPs, training: annual sling inspection	4	2	2	16	See item 49		Closed	
51		Hose control not disabled during drill head disassembly, pulls tower	4	2	3	24	Training, torque limit added to Unico; software interface was changed; rate of load increase/decrease fault added to UNICO	4	1	2	8			Closed	
52		Hoist fails to hold drill weights and/or drill head	4	2	3	24	Design of motor: inspection; brake on hoist; assessment of safety margin, secondary safety harness, training, redundant support	4	1	2	8	(1) Post-mfg inspection - PMI 3.5 (7) Assessment of safety margin on hoist - Safety analysis 6		Closed	Added 3X giant carabiners, 5,000 lbs
53	USE - e-stop	Problem in system such that estop does not stop motors or apply brakes	4	2	4	32	Tested periodically; failsafe system, start-up inspection, inspection before each hole	4	2	1	8	(3) PM instructions - Included in Startup & Weekly Safety Inspections (8) Verification testing - Subsystem & system testing		Closed	

**HAZARD ANALYSIS**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
54		Non-functional (I.e., frozen)	4	3	3	36	Tested periodically; failsafe system; buttons are covered; redundant estop buttons, start up inspection, inspection before each hole	4	2	1	8	See item 53		Closed	
55		Readily accessible to users	4	2	2	16	Redundant e-stops available to user; highly visible; safety training	4	2	1	8	(1) Post-mfg inspection - PMI 8.1 (2) Safety training - Chapter 6		Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	9/17/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3-17; 22-32; 34-46; 48-52; 54-57; 59-62; 64-69</li> <li>1 item open</li> <li>Removed Revision History on page 2 (redundant)</li> </ul>	2/4/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment  Added items 69, 70, 71, 72, 73	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Item 5 probability reduced to 1; Added mitigation to items 24, 26, 32, 54, and 71; Added comment to item 42	08/21/07	TCB
E		Annual review	7/24/08	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	E	E	E	E	E	E	E	E										

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																		
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																		
		<b>TITLE</b>																		
		<b>ENHANCED HOT WATER DRILL MOBILE DRILLING STRUCTURES &amp; CONTAINED EQUIPMENT HAZARD ANALYSIS SUMMARY</b>																		
1	15	<b>ORIGINATOR</b>			<b>DATE</b>			<b>ENGINEER</b>			<b>DATE</b>			<b>DRAFTSPERSON</b>			<b>DATE</b>			
2	16	Tim Brenner			7/15/08			J. Cherwinka			7/24/08									
3	17	<b>CHECKER</b>			<b>DATE</b>			<b>PRODUCT ASSURANCE</b>			<b>DATE</b>			<b>PROJECT APPROVAL</b>			<b>DATE</b>			
4	18	D. Pernic			7/24/08			M. Zernick			7/17/08									
5	19	<b>FILENAME</b>						8510-0109.RevE.doc						<b>PROJECT NO.</b>			8510			
6	20							8510-0109.RevE.xls												
7	21	<b>DRAWING NO.</b>						8510-0109						<b>SCALE</b>		<b>SIZE</b>		<b>SHEET</b>		
8	22													NA		A		Page 1 of 8		
9	23																			
10	24																			
11	25																			
12	26																			
13	27																			
14	28																			



<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Mobile Drilling Structures
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Mobile Drilling Structures & Contained Equipment
<b>DOCUMENT #:</b>	8510-0109
<b>REVISION:</b>	E
<b># OF PAGES:</b>	8
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Mobile Drilling Structures (& contained equipment) for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Mobile Drilling Structures (& contained equipment).

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0030 – MDS Design Specifications

Drawings

- 8510-0002 (Drill site)
- 8510-0051 to 8510-0059 (individual MDS's)

8510-0109 – Hazard Analysis Table (FMEA) table

8510-0109 – Hazard Analysis, Meeting Notes

**3.0 SUMMARY OF POTENTIAL HAZARDS**

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns
- Use – e-stop, tripping

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	75
Major Risk Reduced to Moderate:	4
Major to Minor:	5
Moderate to Moderate:	2
Moderate to Minor:	41
Minor to Minor:	23
# Mitigated to Minor:	52
# Justified:	4
# Unmitigated (or Minor to Minor):	23
# Eliminated:	0

## 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
41	Fuel leak in MDS	<b>It may be technologically difficult to implement additional mitigation.</b> Although the mitigations were considered adequate, they do not mitigate the issue to a minor risk. This is because the probability of a fire starting from a fuel leak was considered to be highly unlikely, but not necessarily negligible (a score between 1 and 2). Using a conservative scoring method, the probability was given a 2.
68	(estop) Does not turn off pump or heaters, or cut off fuel	<b>It may be technologically difficult to implement additional mitigation.</b> The e-stop circuit is designed to be failsafe; a break in the circuit results in an e-stop condition. The e-stop circuit will be tested during verification testing prior to shipping the system to the South Pole. The e-stop circuit is planned to be checked periodically during the drilling season. Any failures of the e-stop circuit will need to be corrected before drilling can continue.
69	(estop button) Non-functional (i.e., frozen)	<b>It may be technologically difficult to implement additional mitigation.</b> The e-stop circuit is planned to be checked periodically during the drilling season. If a failure of an e-stop button should occur after testing or is not discovered during testing, there is sufficient redundancy of buttons at the drill site that others should be readily available in case of emergency.
73	Pressure relief device fails, vibration causes metal fatigue, fittings fail	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Periodic maintenance and inspection is conducted at the Pole and should alert us to any problems.
74	Pressure relief device freezes, lines freeze	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Periodic maintenance and inspection is conducted at the Pole and should alert us to any problems.

75	Improper maintenance and inspection	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Periodic maintenance and inspection is conducted at the Pole and should alert us to any problems.
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**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Verify that the EtOH is dyed blue	NA; EtOH not used
2	Assembly instructions (including): <ul style="list-style-type: none"> <li>• Ensure fittings/plumbing &amp; connectors/wiring are connected properly</li> <li>• Directions for burying hoses &amp; cables</li> </ul>	<ul style="list-style-type: none"> <li>• Systems pressure tested; staff experience assembling fittings</li> <li>• NA – Most hoses &amp; cables in utility alley away from normal workflow; see FMEA item 8</li> </ul>
3	PM instructions (including): <ul style="list-style-type: none"> <li>• Integrity of plumbing &amp; fittings</li> <li>• All doors can be opened</li> <li>• PM on pumps, heaters &amp; furnaces</li> <li>• Check of integrity of each MDS</li> <li>• Check for ice/snow accumulation &amp; integrity of MDS steps</li> <li>• Proper operation of e-stop</li> </ul>	PM instructions not done, other mitigations include: <ul style="list-style-type: none"> <li>• In weekly safety walkthrough</li> <li>• Redundant doors</li> <li>• In weekly safety walkthrough</li> <li>• In weekly safety walkthrough</li> <li>• In weekly safety walkthrough</li> </ul>
4	Define spill cleanup process for EtOH & fuel	Stated in emergency response binder
5	Verify that hose is compatible with antifreeze	PG used prior to shipping equipment to SP; no issues noted
6	Review design of fuel tanks	NA; tanks supplied by RPSC, not EHWD design
7	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Review secondary containment for fuel spills under fuel tanks</li> <li>• Review containment trays under manifolds &amp; heaters for fuel spill containment</li> <li>• Review of electrical boxes (appropriate for lockout/tagout)</li> </ul>	<ul style="list-style-type: none"> <li>• NA; RPSC supplied</li> <li>• Trays shipped; checked in weekly walkthrough</li> <li>• PMI 2.2</li> </ul>

	<ul style="list-style-type: none"> <li>Louvered openings available &amp; operational</li> <li>Battery backup on lighting</li> <li>CO monitors available &amp; operational</li> <li>Verify width of doorways meets OSHA</li> <li>Signage on low objects in egress path</li> <li>Exit signage at exit doors; no exit at electrical closets</li> <li>Do not obstruct doorways signage</li> <li>Review doors operational with appropriate latches &amp; handles</li> <li>Fire extinguishers or suppression system available</li> <li>Heat (possible ignition source &amp; contact burns) signage near hot components of heaters &amp; pumps</li> <li>Guards on rooftop windows</li> <li>Signage on MDS's with poor clearance</li> <li>Guards on pump motor mechanisms</li> <li>Placement &amp; assembly of cable plumbing trays</li> <li>Verify steps meet OSHA code &amp; made of non-slip material</li> <li>Sharp edges</li> <li>Weights marked on components</li> <li>Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>Forced air fans</li> <li>Continuous sunlight; windows; emergency lights in electrical closets; fluorescent exit signs</li> <li>PMI 5.1</li> <li>PMI 3.2</li> <li>Only RWS has "authorized personnel only" on it</li> <li>PMI 3.2</li> <li>In training</li> <li>PMI 3.2</li> <li>PMI 5.1</li> <li>PMI 6.1. &amp; 7.3</li> <li>PMI 3.5</li> <li>PMI 7.3</li> <li>PMI 3.1 &amp; 7.3</li> <li>PMI 3.1; trays not used, equipment directly mounted to ceiling</li> <li>Steps made by RPSC at SP per RPSC design</li> <li>PMI 3.1</li> <li>PMI 7.1</li> <li>PMI 8.1</li> </ul>
8	<p>Electrical inspection (review the built components at PSL for):</p> <ul style="list-style-type: none"> <li>Wired &amp; inspected per NEC</li> <li>Breakers</li> <li>GFI outlets inside &amp; outside</li> </ul>	<ul style="list-style-type: none"> <li>Inspected to NEC; all issues corrected</li> <li>GFI's for 120VAC; GFI cables for 240VAC</li> </ul>
9	<p>Safety Training (including):</p> <ul style="list-style-type: none"> <li>Electrical safety review</li> <li>Proper lockout/tagout</li> <li>Clearance between MDS &amp; pumps, heaters</li> <li>Do not obstruct exits</li> <li>Potential fire ignition sources</li> <li>No smoking</li> <li>Cleanup of EtOH &amp; fuel leaks; remove ignition sources</li> <li>Storage of combustible/hazardous materials</li> <li>Tagging &amp; repair of potentially injurious sharp objects</li> <li>Assembly safety; at least two people on ground when large objects are being lifted or lowered</li> <li>Removal of heaters or pumps</li> <li>Egress</li> <li>Potential burn hazards (water leaks, heater stacks)</li> <li>E-stop use, availability &amp; testing</li> <li>Burying of hoses &amp; cables</li> </ul>	<p>Safety Training Manual:</p> <ul style="list-style-type: none"> <li>Section 8</li> <li>Section 4</li> <li>Sections 2, 11 &amp; 14</li> <li>Section 2 &amp; 11</li> <li>Section 2</li> <li>Section 2</li> <li>Section 3; NA for EtOH</li> <li>Section 3</li> <li>Section 14</li> <li>Section 7</li> <li>Section 11</li> <li>Section 2 &amp; 11</li> <li>Section 11</li> <li>Section 6</li> <li>NA; Placed in utility alley; see FMEA item 8</li> </ul>
10	<p>Noise level measurements (in MDS's to determine if there is a noise concern)</p>	<p>PMI 1.1</p>
11	<p>Personal protective equipment (verify that the staff is to wear):</p> <ul style="list-style-type: none"> <li>Ear plugs</li> <li>Gloves</li> <li>Outerwear</li> </ul>	<p>Training Section 1</p> <ul style="list-style-type: none"> <li>Shipped to SP</li> <li>Shipped to SP</li> <li>Supplied by RPSC</li> </ul>
12	<p>Temperature measurements inside MDS's during operation</p>	<p>Temperature measurements taken in WI not applicable to SP; fans provided; furnace has thermostat; doors can be opened; equipment</p>

		MDS's not intended for continual occupancy
13	Ventilation analysis to ensure adequate staff ventilation	Safety analysis 14
14	Review of MDS design for adequate egress/exit paths	Redundant exits; small units
15	Set up fire inspection process with Raytheon	
16	Verification testing (including): <ul style="list-style-type: none"> <li>• Test thermal shutoffs &amp; torque limits on heaters, pumps &amp; furnaces</li> <li>• Verify proper operation of flow &amp; pressure sensors</li> <li>• E-stop works properly (shuts down appropriate subsystems)</li> </ul>	<ul style="list-style-type: none"> <li>• Tested during subsystem &amp; system testing</li> <li>• Tested during subsystem &amp; system testing</li> <li>• Tested during subsystem &amp; system testing</li> </ul>
17	Structural analysis of sleds to ensure that they can support the MDS's without failing unsafely	Safety analysis 15
18	Verify that all lifting & towing equipment is operated by experienced Raytheon staff	RPSC operators trained on equipment; IceCube staff would need to be approved to operate heavy equipment

6.2 Issues – No additional issues; EtOH no longer used

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	1	8	Safety and HazCom training, MSDS available	2	4	1	8	None	Closed	
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	3	1	6	HazCom training, MSDS available	2	3	1	6	None	Closed	
3	CHEMICAL - Antifreeze leaking out of plumbing	Hose defect	2	2	2	8	Propylene Glycol will melt the snow; Glycol smell, hose is EPDM and Kevlar	2	2	1	4	EIOH not used; Propylene Glycol used instead	Closed	
4		Loose fitting with hose or fitting leaks	2	4	1	8	seasonal inspection; assembly instructions; spill cleanup process, inspection before each hole	2	2	1	4	(1) EIOH not used; PG used instead (2) Assembly instructions - systems pressure tested; staff has experience assembling these fittings (3) PM instructions - NA (4) Spill cleanup process - spill cleanup instructions provided	Closed	
5		Interaction of Propylene Glycol with hose	3	1	4	12	Hose selection, hose is EPPM and Kelvar	2	1	1	2	(1) EIOH not used (5) Hose compatibility - Systems flushed w/ Propylene Glycol before shipping, no issues reported	Closed	
6	CHEMICAL - Fuel spill	Punctured fuel tank (TOS+)	3	3	2	18	Hardware protection for tanks, day tanks on skid and are towed, stainless steel, breakaway valve	3	1	2	6	(6) Review design of tanks - Local fuel tanks are provided byRPSC & not part of EHWD design	Closed	
7		Spilled during filling of tank (TOS+)	3	5	1	15	Use red buckets for fuel, operator experience, RPS fills tanks	3	3	1	9	(7) Post-mfg inspection - Filling of local fuel tanks completed by RPSC & not a part of EHWD team responsibility	Closed	Use red buckets for fuel



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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
8		Fuel supply line damaged	3	3	2	18	Placement: inspection	3	1	2	6	(3) PM instructions - Review of fuel lines included in Startup & Weekly Safety Inspections - Lines are run in utility alley (non-traffic area)	Closed	The original HA stated the fuel hoses would be buried. The potential risk of damage to the hoses is considered higher if the hoses are buried & then removed at the end of the season. Therefore, placing the hoses in the utility alley away from traffic was considered a safer alternative from a staff & equipment standpoint. Hoses covered in heavy traffic areas
9		Fuel leak/spill inside MDS, or during bleeding operation	3	3	2	18	Containment trays under wall manifolds & heaters, spill kits oil sorbent	3	3	1	9	(7) Post-mfg inspection - Trays shipped w/ units; fuel leaks to be checked during periodic inspections	Closed	
10		Fuel spill when hose is hooked up before plumbing is connected/checked	3	2	2	12	Leak check on plumbing	3	1	2	6	Inspection	Closed	
11	ELECTRICAL - Shock	Exposed terminals	4	3	2	24	Wired per NEC & inspected	4	1	1	4	(8) Electrical inspection - All MDS's inspected to NEC; all issues from inspections corrected	Closed	
12		Loose electrical fittings	4	2	2	16	Wired per NEC & inspected	4	1	1	4	See item 10	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
13		Inadequate insulation on conductors	4	3	2	24	Wired per NEC & inspected	4	1	1	4	See item 10	Closed	
14		Shorting of cables due use, abuse or accident	4	3	2	24	Wired per NEC & inspected; breakers; training	4	1	1	4	See item 10 (9) Training - Section 8 includes removing failed equipment	Closed	Training - Remove devices with frayed cables from use
15		Inadequate ground	4	2	4	32	Wired per NEC & inspected; breakers; GFI's, two separate grounds at main junction box/surface cables/DOM to surface cable connect to main station	4	1	2	8	See item 10 GFI's on 120VAC outlets in & out; GFI cables provided for 240VAC outlets Use of 240VAC GFI cables included in safety training section 8	Closed	GFI's inside & outside. UPS (red/labeled) outlets don't have GFI.
16		Water leak causes short	4	4	2	32	Wired per NEC & inspected; breakers; GFI's	4	1	2	8	See item 14	Closed	
17		Inadequate lockout/tagout	4	4	2	32	Design of electrical boxes; marking connections; training, field verification	4	2	1	8	(7) Post-mig inspection - Breaker boxes can be locked (PMI 2.2) (9) Training - Section 4	Closed	
18	ENVIRONMENTAL - Acoustic noise	Noise generated by pumps/heaters/other > 85 dB	4	6	1	24	Acoustic noise measurements; earplugs, signage, safety and operations training, field verification	4	2	1	8	(10) Acoustic noise measurements PMI 1.1: hearing protection signs placed on HPP & generators (11) Personal protective equipment - Hearing protection provided (9) PPE Training - Section 1	Closed	
19	ENVIRONMENTAL - Cold	Inadequate heating of inside of MDS	3	2	1	6	Furnaces present; furnace spares available; bullet heaters available; pumps/heaters radiate heat in equipment MDS's	3	1	1	3	None	Closed	
20		Loss of fuel source to furnace due to breach in fuel hosing	3	2	1	6	Electric heaters	3	2	1	6	None	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
21		Outer clothing inaccessible during evacuation	3	2	1	6	Clothes hangers near doors; Training	3	2	1	6	PPE, Training	Closed	
22		Inadequate sealing of windows, doors, vents or openings allows cold into MDS	1	4	1	4	Heavy duty gaskets	1	4	1	4	None	Closed	
23	ENVIRONMENTAL - Hot	Heat generated by pumps/heaters/other heats MDS > 110°F	3	4	1	12	Temperature measurements; louvered openings	3	2	1	6	(7) Post-mfg inspection (12) Temperature measurements - Temp measurements taken in WI not applicable to SP climate; fans provided; furnace has thermostat; doors can be opened; equipment MDS's not intended for continual occupancy	Closed	
24	ENVIRONMENTAL - Lighting	Lighting inadequate to facilitate evacuation	2	4	1	8	Battery backup	2	2	1	4	(7) Post-mfg inspection - Lighting stays on during e-stop; 24 hr sunlight during EHWD operation at SP; windows in MDS's; emergency lights in electrical closets; fluorescent exit signs (PMI 3.2)	Closed	
25	ENVIRONMENTAL - Ventilation	Inadequate airflow thru MDS for oxygenation of staff. Wind inversion occurs	4	3	3	36	Ventilation analysis, added additional computer controls, move MHP4 inline with MHPs; added air intake	4	1	2	8	(13) Ventilation analysis - Safety analysis 14	Closed	
26		Buildup of CO/CO2 due to space heaters, water heaters or pumps, wind inversion occurs	4	3	3	36	CO detector; ventilation analysis, added additional computer controls, move MHP4 inline with MHPs	4	2	1	8	(7) Post-mfg inspection - PMI 5.1 See item 24	Closed	
27		Inadequate combustion leads to drawing hot air into furnace and melting motor to fuel pump coupler	1	5	2	10	Pressure balancing system to be installed	1	5	2	10	TBD	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
28	FIRE - Inadequate egress	Doorways or pathways too narrow	4	2	1	8	Doorways designed to OSHA code and Life Safety Code	4	2	1	8	(7) Post-mfg inspection - PMI 3.2	Closed	
29		Fire blocks exit	4	2	2	16	Redundant exits; small facility; MDS design, exits designed to OSHA and Life Safety Codes	4	2	1	8	(14) Review of MDS design - Redundant exits; small units	Closed	
30		Inadequate headroom to allow personnel to pass	4	3	2	24	Training; signage on low objects in egress path; obstructions minimized in design	4	2	1	8	(7) Post-mfg inspection - Approved waivers 1 & 8 discuss clearance limited to 6'6" (9) Training - Section 2, 11 & 14	Closed	
31		Unable to find exit path (i.e., no exit through electrical closet)	4	2	2	16	Signage per OSHA code and Life Safety Code	4	1	1	4	(7) Post-mfg inspection - PMI 3.2	Closed	
32		Exit obstructed	4	4	2	32	Training; signage, inspections	4	2	1	8	(7) Post-mfg inspection - PMI 3.2 (9) Training - Section 11	Closed	
33		Unable to open door	4	2	3	24	Doors open outward; handle design; no internal door locks; PM instructions, inspections; new handles	4	2	1	8	(3) PM instructions - NA (7) Post-mfg inspection - PMI 3.2: doors open from inside when locked from outside; redundant doors	Closed	
34		Door is frozen shut	4	3	3	36	Doors open outward; handle design; no internal door locks; PM instructions, inspections	4	2	1	8	See item 32	Closed	
35		Trapped in electrical closet	4	2	1	8	None	4	2	1	8	None	Closed	
36		No fire extinguishing equipment available	4	2	2	16	MDS's to be supplied with fire extinguishers or fire suppression, inspections, use of metal cans not plastic, reduction of combustibles in area	4	1	1	4	(7) Post-mfg inspection - PMI 5.1; 26 extinguishers shipped	Closed	

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37		Fire extinguishing does not work	4	2	3	24	Periodic inspection of fire suppression & extinguishers	4	2	1	8	(15) Set up fire system inspection with Raytheon - OK for season 1, most extinguishers provided 7 months before season 1	Closed	
38		Trapped behind Model 75, no access to e-stop	4	4	1	16	Training: No one allowed behind Model 75 without someone with	4	2	1	8	Training	Closed	
39	FIRE - Ignition source/combustible material	Electrical discharge (spark) starts nearby item on fire	4	2	3	24	Wired per NEC & inspected; training, inspections, use of metal cans not plastic, reduction of combustibles in area	4	1	2	8	(8) Electrical inspection - PMI 2.1 (9) Training - Sections 2 & 3	Closed	Training - Do not place combustible materials near pumps, heaters or furnaces
40		Outer temp of pumps, water heaters or space heaters hot enough to ignite nearby material	4	3	2	24	Training: signage; test lab certification on pumps, heaters	4	2	1	8	(7) Post-mfg inspection - PMI 6.1; CAUTION-Hot labels placed by hot surfaces (9) Training - Section 11	Closed	
41		Fuel leak in MDS	4	4	3	48	Containment trays; shutoff valves; low pressure design; fuel lines are designed away from hot devices, inspections, use of metal cans not plastic, reduction of combustibles in area	4	2	2	16	See item 9 and 10	Closed	
42		Fuel leak outside MDS due to breach in fuel line or fuel tank	4	3	2	24	Hardware protection; away from ignition source; training, inspections	4	2	1	8	(7) Post-mfg inspection - Included in Startup & Weekly Safety inspections - Equipment would shutdown if leak was significant	Closed	
43		Storage of flammable or combustible materials	3	3	2	18	Stored in flameproof cabinets; training, use of metal cans not plastic, reduction of combustibles in area, inspections	3	2	2	12	(9) Training - Section 3	Closed	Buckets purchased

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
44		Overheating of pumps, water heaters or furnaces	4	4	2	32	Thermal shutoff; PM instructions; torque limits on pumps, inspections	4	2	1	8	(3) PM instructions - Not done (16) Verification testing - Subsystem & system testing; temperature sensors on plumbing lines; furnaces have thermostats	Closed	
45	MECHANICAL - Cuts	Sharp edges due to design	3	3	2	18	Adequate finishing, use of PPE	3	1	2	6	(7) Post-mfg inspection - PMI 3.1	Closed	
46		Sharp edges due to use or breakage	3	2	2	12	Repair of broken parts; tagging, use of PPE	3	2	1	6	(9) Training - Section 14 (7) PMI 3.1	Closed	Training - Tag broken parts for repair
47		Window breaks due to cold or trauma	3	3	2	18	Polycarbonate; guards on rooftop windows	3	2	2	12	(7) Post-mfg inspection - PMI 3.5	Closed	
48	MECHANICAL - Pinch/entrapment points	Inadequate clearances between equip. & MDS	3	4	2	24	Door placement; signage on MDS's with poor clearance; training	3	3	1	9	(7) Post-mfg inspection - PMI 3.1 (9) Training - 2, 11 & 14	Closed	Training - MDS's with poor clearance & use of cargo doors for better access. Note: Derivation of Probability - Rod Well & Pump plants will have poor clearance around the devices in the MDS's all the time (prob = 6); however, these are expected to have limited occupancy. The other MDS's are expected to have adequate clearance (prob = 1). Because of the difference in MDS's the final Probability was determined to be 4.
49		Trapped under skis	4	2	1	8	None	4	2	1	8	None	Closed	
50		Moving parts on equip.	3	3	2	18	Guards on motor mechanisms, inspections, training and field verification	3	2	2	12	(7) Post-mfg inspection - PMI 3.1 & 7.3	Closed	
51		Body part trapped between MDS & sled during assembly	4	2	1	8	Training	4	1	1	4	(9) Training - Section 7	Closed	Ratchet straps to be ordered

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
52	MECHANICAL - Trauma: falling objects	Equipment improperly attached to ceiling of MDS	3	3	3	27	Initial assembly; placement of trays not directly over egress paths	3	1	2	6	(7) Post-mfg inspection - PMI 3.1; trays not used; equipment directly mounted to ceiling; equipment over egress path minimized, but unavoidable	Closed	
53		Inadequate maintenance to check integrity of MDS	4	1	3	12	PM instructions	4	1	2	8	(3) PM instructions - new SOP	Closed	
54		Heater, pump falls on servicer while being removed for service	4	2	2	16	Training	4	1	2	8	(9) Training - Section 11	Closed	
55	MECHANICAL - Trauma: person falls	Falls off top of MDS	4	2	1	8	Add tie line; New fall protection system installed	4	2	1	8	Inspection	Closed	
56		Inadequate steps upon exiting MDS	3	4	2	24	Steps to OSHA code and Life Safety Code	3	1	1	3	(7) Post-mfg inspection - Steps made by RPSC at SP; presence confirmed in e-mail from SP; substitute steps used as needed during IV&T	Closed	No steps; steps too short; steps move away from building
57		Walking surface - slippery due to ice or snow	3	5	3	45	PM instructions; steps designed with gratings to prevent accumulation of snow	3	2	2	12	(3) PM instructions - Not done (7) Post-mfg inspection - Steps made by RPSC per RPSC design - Traction strips added to some MDS's	Closed	Floors, steps
58	MECHANICAL - Trauma: person runs into equip. hanging in a walkway	Inadequate clearance	3	4	2	24	Training; signage on low objects in egress path; obstructions minimized in design	3	2	1	6	(7) Post-mfg inspection - PMI 3.2 (9) Training - Section 2, 11 & 14; RWS marked for authorized personnel only	Closed	
59	MECHANICAL - Trauma: MDS unstable during transport	Ski breaks/becomes unmounted/ collapses	4	1	3	12	Sled analysis, inspection	4	1	2	8	(17) Sled analysis - Safety analysis 15	Closed	
60		MDS becomes unbalanced on unlevel surface	1	3	2	6	None	1	3	2	6	None	Closed	

## HAZARD ANALYSIS

### Subsystem: MDS's and Contained Equipment

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
61		Run into by caterpillar or other large equipment	3	2	3	18	Operator experience	3	2	1	6	(18) Equipment run by experienced operators; operators of heavy equipment need to be approved RPSC (RPSC-Ice <sup>2</sup> Safety minutes 9/9/04)	Closed	
62	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device	4	2	2	16	Operator experience; weights marked on parts, lifting device provided to assist, rigger training	4	2	1	8	(7) Post-mfg inspection - PMI 7.1	Closed	
63		Inadequate lifting points on equipment, lifting apparatus (i.e., strap) breaks or inadequately attached	4	3	4	48	Operator experience; ISO designed lifting corners	4	1	2	8	See item 61	Closed	
64	THERMAL - Burns	Outer enclosures of pumps, heaters, heater stacks too hot to contact	3	4	2	24	Signage; training PPE	3	2	1	6	(7) Post-mfg inspection - PMI 6.1 & 7.3; potential contact burn equipment labeled w/ CAUTION Hot signs (9) Training - Section 11 - The heater stacks were insulated.	Closed	
65		Outer enclosure or stack of furnace too hot to contact	2	2	2	8	Signage; training PPE	2	2	2	8	None	Closed	
66		Water leak during servicing	3	4	2	24	Plumbing design; lockout/tagout; training	3	2	2	12	(9) Training - Section 4	Closed	Potential lockout/tagout issue
67		Water leak during use due to pipe, hose, valve, etc. failure	3	3	3	27	Flow/pressure sensors; training; protective gear	3	2	2	12	(9) Training - Section 1 & 9 (11) Personal protective equipment - Gloves & goggles shipped to SP (16) Verification testing - Subsystem & system testing	Closed	Check to make sure water in pipe is not hot, not pressurized at DCC.



## HAZARD ANALYSIS

### Subsystem: MDS's and Contained Equipment

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
68	USE - e-stop	Does not turn off pump or heaters, or cut off fuel	4	2	4	32	Tested periodically; verification testing	4	2	2	16	(3) PM instructions - In startup & periodic safety inspection checklists (16) Verification testing - Checked during subsystem & system testing	Closed	
69		Non-functional (i.e., frozen)	4	3	3	36	Tested periodically; failsafe system; buttons are covered; redundant estop buttons	4	2	2	16	See item 67	Closed	
70		Readily accessible to users	4	2	2	16	Redundant estop buttons; highly visible; training	4	2	1	8	(7) Post-mfg inspection - PMI 8.1 (9) Training - Section 6	Closed	
71	Wiring	Wiring not phased correctly	2	4	2	16	Inspection before start-up. Use of Qualified personnel to do wiring, installers must use phase meter	2	3	2	12	New SOPs, use of RPS personnel as necessary	Closed	
72	Igniter	Igniter goes out, no ignition source produces excessive fuel in combustion chamber, could result in fire or explosion	4	2	3	24	Better igniters purchased; safeties implemented; automatic shutoff installed (after 15 seconds)	4	1	2	8	Purchase orders, inspection	Closed	
73	Pressure relief device	Pressure relief device fails, vibration causes metal fatigue, fittings fail	4	3	3	36	Connect pressure gauges to lines, retrofit of devices, inspection, operator training	4	2	2	16	Inspection	Closed	
74	Pressure relief device	Pressure relief device freezes, lines freeze	4	3	3	36	Connect pressure gauges to lines, retrofit of devices, inspection, operator training, add heat trace. Slow flow through HPP all season	4	2	2	16	Inspection	Closed	
75	High pressure lines and pumbing	Improper maintenance and inspection	4	2	3	24	Connect pressure gauges to lines, retrofit of devices, inspection, operator training.	4	2	2	16	Special training session for operator at UW during 2005	Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/9/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3-10; 13-14; 16-18; 22; 24; 27-28; 33; 37</li> <li>Updated table 4.0</li> <li>1 item open</li> <li>Removed Revision History on page 2 (redundant)</li> <li>Added item 29 in reference to cable incident at SP</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	07/31/05	MAZ
C		Spillage when capping end of hose after filling with antifreeze hazard has been eliminated.	10/27/06	TCB
D		Added mitigations of "insulation added" to item 11 and "collar around hole" to item 26	08/21/07	TCB
E		Annual review	7/24/08	TCB
F		Annual review	7/7/09	TR
G		Annual review, added hazards #20, 29, and 34	4/7/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G													

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																
		<b>MADISON, WISCONSIN</b>																
		TITLE																
		<b>ENHANCED HOT WATER DRILL</b>																
		<b>RODRIGUEZ WELL</b>																
		<b>HAZARD ANALYSIS SUMMARY</b>																
1	15	ORIGINATOR	DATE	ENGINEER	DATE	DRAFTSPERSON	DATE											
2	16	Tim Rubino	4/20/10	J. Cherwinka	4/20/10													
3	17	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE											
4	18	D. Duling	4/20/10	M. Zernick	4/20/10													
5	19	FILENAME	8510-0112.RevG.doc				PROJECT NO.	8510										
6	20		8510-0112.RevG.xls															
7	21	DRAWING NO.	8510-0112				SCALE	SIZE	SHEET									
8	22																	
9	23																	
10	24																	
11	25																	
12	26																	
13	27																	

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Rodriguez Well
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Rodriguez Well
<b>DOCUMENT #:</b>	8510-0112
<b>REVISION:</b>	G
<b># OF PAGES:</b>	5
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Rodriguez Well for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

The hazard analysis for the Rodriguez Well is split between two hazard analyses. 8510-0109, Hazard Analysis for MDS's, discusses the potential hazards for MDS enclosures in general. 8510-0112, Hazard Analysis for Rodriguez Well, discusses the potential hazards specific for the Rodriguez Well (beyond those described for the MDS's).

This document and 8510-0109, and their attachments document the hazard analysis completed for the Rodriguez Well.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0030 – MDS Design Specifications

Drawings for Rodriguez Well MDS

- 8510-0051
- 3D Rendering UWM723 MDS from Bit 7

8510-0112 – Hazard Analysis Table (FMEA) table

8510-0112 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Thermal – Burns
- Use – e-stop, tripping

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	39
Major Risk Reduced to Moderate:	0
Major to Minor:	3
Moderate to Moderate:	0
Moderate to Minor:	11
Minor to Minor:	25
# Mitigated to Minor:	14
# Justified:	0
# Unmitigated (or Minor to Minor):	25
# Eliminated:	0

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

<b>ITEM #</b>	<b>HAZARD/CAUSE</b>	<b>JUSTIFICATION</b>
None		

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

**CLOSED** – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

**IMPLEMENT** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

**REVIEW** – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

**REOPEN** – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.1 The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Verify EtOH is dyed blue	NA; EtOH not used
2	Instructions to attach fittings for hoses	Systems are pressure tested; staff experience assembling fittings
3	PM instructions (including): <ul style="list-style-type: none"> <li>Checking hose fittings</li> </ul>	PM instructions not done, other mitigations include: <ul style="list-style-type: none"> <li>In weekly safety walkthrough</li> </ul>
4	Instructions on capping Rod Well hoses during water/antifreeze exchange	NA – We plan to flush the system w/ PG & blow residual fluid out of the system w/ air; we do not plan to cap the hoses
5	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>Verify circuit breakers &amp; GFI's installed</li> <li>Test lab listing on motors</li> <li>Sharp edges</li> </ul>	<ul style="list-style-type: none"> <li>Inspected to NEC; all issues corrected; GFI's for 120VAC; GFI cables for 240 VAC</li> <li>PMI 2.3</li> <li>PMI 3.1</li> </ul>
6	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>Ear plugs</li> </ul>	Training Chapter 1 <ul style="list-style-type: none"> <li>Shipped to SP</li> </ul>
7	Verification testing (including): <ul style="list-style-type: none"> <li>To ensure water level sensors are present &amp; operational</li> </ul>	WT1 sensors tested during subsystem testing
8	Safety Training (including): <ul style="list-style-type: none"> <li>EtOH handling</li> <li>Proper lockout/tagout</li> <li>Covering Rod Well access hole during use</li> <li>Cover for Rod Well access hole after drill removed for the season</li> <li>Ensure that all serviced equipment is properly reassembled &amp; fastened in place prior to reenergizing the system</li> <li>Cable hazards</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>Chapter 3; NA for EtOH</li> <li>Chapter 4</li> <li>Chapter 10</li> <li>Chapter 10</li> <li>Part of LO/TO, Chapter 4</li> <li>Verified safety trainings were completed at SP</li> </ul>
9	Load analysis to determine whether there is enough pull by the hose to move the Rod Well hose reel if it is unmounted	Safety analysis 8

6.2 Issues – No additional issues; we do not plan on using EtOH.

## HAZARD ANALYSIS

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Author: M. Zernick

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
<b>The Rodriguez Well HA covers only those potential hazards not reviewed in the MDS HA. Potential hazards associated with the Rod Well MDS will be addressed in the MDS HA.</b>														
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	3	1	6	HazCom Training, MSDS available	2	3	1	6	None	Closed	
2	CHEMICAL - Diesel Fuel leaking	Fuel Leak	4	1	1	4	Inspections, training	4	1	1	4	None	Closed	
3	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	3	1	6	HazCom Training, MSDS available	2	3	1	6	None	Closed	
4	CHEMICAL - Anti-freeze leaking out of hose during startup or overwintering	Hose defect	2	2	2	8	Anti-freeze will melt the snow; Anti-freeze smell	2	2	1	4	EIOH not used; PG used instead	Closed	
5		Loose fitting between hose & hose or reel	2	2	1	4	Instructions on coupling the fittings; seasonal inspection	2	2	1	4	(1) EIOH not used; PG used instead (2) Assembly instructions - systems pressure tested; staff has experience assembling these fittings (3) PM instructions - NA (4) Spill cleanup process - spill cleanup instructions provided	Closed	
6		Valve fails/not closed & spills antifreeze	2	2	3	12	Design of end cap; safety and operations training	1	2	1	2	See item 4	Closed	
7		Interaction of antifreeze with hose	3	2	4	24	EPDM rubber resistant to antifreeze; melted snow	3	1	1	3	See item 4	Closed	
8	ELECTRICAL - Shock	Water leak in MDS causes short	4	3	2	24	Circuit breakers; GFI's; water is poorly conductive	2	2	2	8	(5) Post-mfg inspection - PMI 2.1 GFI's present for 120VAC outlets; 240VAC outlets require GFI cables	Closed	
9		Cable to water pumps damaged	4	2	2	16	Circuit breakers; GFI's; water is poorly conductive, Unicon drives protect pumps	4	1	2	8	See item 8	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
10	ENVIRONMENTAL - Acoustic noise	Noise generated by pumps/heaters/other > 85 dB	2	6	1	12	Ear plugs	3	2	2	12	PMI 1.1 (6) Personal protective equipment - Ear plugs & muffs sent to SP	Closed	No longer relevant, pumps no longer inside
11	ENVIRONMENTAL - Cold	Cold air enters through hose slot near reel	1	3	1	3	Insulation added	1	3	1	3	None	Closed	
12	ENVIRONMENTAL - Water	Water tank overflows	3	2	1	6	Water level sensors in tanks, overflow pipes on tank 1.	3	2	1	6	(7) Verification testing - Subsystem & system testing; no issues reported of overflowing tank	Closed	Overflowing of water could cause pitting in snow around tank
13	FIRE - Ignition source	Reel motor overheats	4	2	3	24	Design of motor; current limit on drives; motor certified to test lab standards; no combustibles near motor	4	1	2	8	(5) Post-mfg inspection - PMI 2.3; motor is only operated a few times per season	Closed	
14	FIRE - Combustible material	Hose sustains fire	4	2	1	8	Hose is tested to withstand 350°F; would require an outside ignition source to start hose on fire	4	2	1	8	None	Closed	
15	MECHANICAL - Cuts	Sharp edges due to design	3	4	2	24	Edges radiused	3	1	2	6	(5) Post-mfg inspection - PMI 3.1	Closed	
16		Sharp edges due to use or breakage	3	2	2	12	None	3	2	2	12	(5) Post-mfg inspection - PMI 3.1	Closed	
17	MECHANICAL - Pinch/entrapment points	Hand/other pinched between hose & hose slot in MDS wall	2	3	1	6	Manual Level Wind is outside of MDS and chain guards.	2	3	1	6	None	Closed	
18		Hand caught in hose reel	4	2	1	8	Training	4	2	1	8	None	Closed	
19		Hand caught between crescent & hose	3	2	2	12	Training	3	2	2	12	None	Closed	
20		Body part caught between hose reel and wall of MDS	4	2	2	16	Make sure brakes are engaged and reel is offline; procedure	4	1	1	4		Closed	



## HAZARD ANALYSIS

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
21		Reel moves under use due to inadequate mounting to MDS floor	4	2	2	16	Load analysis, operations inspection, adding brake to reel, combo cable is backup; people are kept away	4	1	2	8	(8) Safety training - Analysis recommends making sure reel is bolted down before use; this is standard LOTO procedure, Chapter 4 (9) Load analysis - Safety analysis 8	Closed	
22		Runaway cable reel motion	2	2	2	8	Reel Stop/ Training	2	2	2	8	None	Closed	
23		User activates reel during servicing	4	3	4	48	Lockout/tagout, field verification	4	1	1	4	(8) Safety Training - Chapter 4	Closed	
24	MECHANICAL - Trauma; falling objects	Uncontrolled falling of hoses due to hose reel motor/gearbox failure	2	1	4	8	Brake independent of drive train, combo cable is backup	2	1	4	8	None	Closed	
25	MECHANICAL - Trauma; person falls	Hole collapses under weight of personnel or equipment, due to hole becoming undermined.	4	1	4	16	Standard practice; operator experience; collar around hole	4	1	2	8	None	Closed	The firm does not support the well at less than 50m from the surface (the water is absorbed into the firm). The Rod Well is planned to be drilled from 50 - 100m. Hole collapse is considered negligible risk with a hole drilled to this depth. Assure there is no undermine.
26		Person falls into access hole during use	4	3	2	24	Cover provided to prevent access	4	1	1	4	(8) Safety Training - Chapter 10; crescent covers hole; crescent shipped to SP	Closed	Access hole may be 12 -24"
27		Person falls into access hole after drill removed for the season	4	3	3	36	Permanent cover for hole	4	1	2	8	(8) Safety Training - Chapter 10 In MDS end-of-season checklist	Closed	
28		Cable backlash during unrequested movement of cable back down into hole. Cable could smack or pull someone.	4	3	3	36	Hazards and Safety Training were conducted, Brake present, redesign of brake in 2005 and addition of combo cable, cable carries load	4	1	2	8	(1) Safety Training Records.	Closed	

**HAZARD ANALYSIS**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
29		Crescent shifts because of tension of cable/hose	2	3	3	18	Secure crescent; training	2	1	2	4		Closed	
30	MECHANICAL - Trauma: spraying water	Water not contained in hose due to use or abuse	2	2	2	8	Hose inspections, low pressure.	2	2	2	8	None	Closed	Low pressure, 50 gpm.
31		Loose fitting	2	2	2	8	Hose inspections, and low pressure.	2	2	2	8	None	Closed	
32	MECHANICAL - Trauma: person runs into hose or cable	Inattentiveness	2	3	1	6	Hardhats	2	3	1	6	None	Closed	
33	THERMAL - Burns	Reel motor casing too hot	3	2	2	12	Design of motor; current limit on drives; motor certified to test lab standards, and PPE	3	1	1	3	See Item 13	Closed	Heaters could also be hot
34		Body part burned on hot heater	2	3	1	6	Training, gloves	2	2	1	4			
35		Exposure to hot water	2	3	1	6	PPE, gloves and eye protection provided	1	3	1	3	None	Closed	Possible 190F
36		Touch hot hose, coupling or valve	1	4	2	8	PPE, gloves and eye protection provided	1	4	2	8	None	Closed	
37	USE - e-stop	Does not stop reel	2	2	2	8	Tested periodically; failsafe system; buttons are covered; redundant estop buttons, inspected at start up and before use at each hole; reel stop system.	2	2	2	8	None	Closed	
38	USE - Tripping	Trips on hose or cable	2	3	1	6	None	2	3	1	6	(8) Safety Training - Chapter 14	Closed	
39	Combo Cable Reel	Fails to hold load	4	4	2	32	Brake redesign, double brake. Training	2	2	2	8	Inspection	Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	9/9/02	See original
A		<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3-10; 12-14; 16-19; 21-32; 35-36; 39-42; 44-46; 48-52</li> <li>1 item open</li> <li>Removed Revision History on Page 2 (redundant)/Typographical corrections</li> <li>Added item 34 in reference to cable incident at SP</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment  Added items 54, 55, 56	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Added "Cable pinched in rollers," Failure cause 60, Added "Bundling" to mitigation of item 55 reducing probability from 4 to 3	8/21/07	TCB
E		Annual review	7/24/08	TCB
F		Re-opened Item 23 to include "Tag and tape hydraulic brake bypass valve". Added new number 58 for stepping over cable	6/25/09	TR
G		Annual review	5/11/10	TR

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

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1	15	ORIGINATOR	DATE	ENGINEER	DATE	DRAFTSPERSON	DATE												
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3	17	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE												
4	18	D. Duling	5/11/10	M. Zernick	5/11/10														
5	19	FILENAME	8510-0114.RevG.doc				PROJECT NO.	8510											
6	20		8510-0114.RevG.xls																
7	21	DRAWING NO.	8510-0114			SCALE	SIZE	SHEET											
8	22					NA	A	Page 1 of 6											
9	23																		
10	24																		
11	25																		
12	26																		
13	27																		
14	28																		

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Cable Reel
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Cable Reel
<b>DOCUMENT #:</b>	8510-0114
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Cable Reel for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Cable Reel.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0114 – Hazard Analysis Table (FMEA) table

8510-0114 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns
- Use – e-stop, tripping

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	62
Major Risk Reduced to Moderate:	0
Major to Minor:	4
Moderate to Moderate:	1
Moderate to Minor:	39
Minor to Minor:	18
# Mitigated to Minor:	43
# Justified:	1
# Unmitigated (or Minor to Minor):	18
# Eliminated:	0

## 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
59	Pendant is unplugged or changed	<b>It may be technologically difficult to implement additional mitigation.</b> The pendant is planned to be redesigned to prevent it from changing stages. The break is also designed to automatically engage.

## 6.0 STATUS OF THE HAZARD ANALYSIS (choose one of the following)

**CLOSED** – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

**IMPLEMENT** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

**REVIEW** – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

**REOPEN** – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>Exposed electrical connections</li> <li>Test lab listing on motors</li> <li>Sharp edges</li> <li>Inadequate clearances</li> <li>Covers on sheaves on tower</li> <li>Weights marked on components</li> <li>Caution label on brake resistor enclosure</li> <li>Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>PMI 2.2</li> <li>PMI 2.3</li> <li>PMI 3.1</li> <li>PMI 3.1</li> <li>PMI 3.5</li> <li>PMI 7.1</li> <li>PMI 7.3</li> <li>PMI 8.1</li> </ul>
2	Safety Training (including): <ul style="list-style-type: none"> <li>Electrical safety review</li> <li>Proper lockout/tagout</li> <li>E-stop use, availability &amp; testing</li> <li>Correcting failures in the e-stop circuit before continuing drilling</li> <li>Level wind safety</li> <li>Falling objects during assembly/minimize working over others</li> <li>Trip hazards</li> <li>Anchoring cable reel</li> <li>Cable Hazards</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>Chapter 8</li> <li>Chapter 4</li> <li>Chapter 6</li> <li>Chapter 6</li> <li>Chapter 12</li> <li>Chapter 7</li> <li>Chapter 14</li> <li>Noted in Weekly Safety Inspection</li> <li>Verified safety trainings were completed at South Pole</li> </ul>
3	Control system design review (including): <ul style="list-style-type: none"> <li>Breakers</li> <li>Proper grounding</li> <li>Drives detect shorts to ground</li> <li>Use of preheated, enclosed, nonventilated motor frame</li> <li>Motor drives detect overloads</li> </ul>	Supply Cable Reel motors are on dedicated circuits with dedicated drives & circuit breakers; circuits are grounded; drives are designed to detect electrical faults; motors are totally enclosed, non-ventilated motors
4	Noise level measurement (to determine if there is a noise concern)	PMI 1.1
5	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>Ear plugs</li> <li>Gloves</li> <li>Outerwear</li> <li>Hardhats</li> </ul>	Safety Training Chapter 1
6	Verification testing (including): <ul style="list-style-type: none"> <li>System monitoring of payout</li> <li>Watchdog timer in system triggers e-stop condition</li> <li>E-stop works properly (shuts down appropriate subsystems; has to be cleared to restart; restarts from default condition)</li> </ul>	All tested during subsystem & system testing (IV&T)
7	Safety factor analyses on motors/gearbox	Safety Analysis 10
8	PM instructions (including): <ul style="list-style-type: none"> <li>Reel brake check</li> <li>Proper operation of e-stop</li> <li>Review assembly of reel</li> <li>Check of ice/snow accumulation in level wind &amp; elsewhere</li> </ul>	Inspection of reels is included in the Startup & Weekly Safety Inspections, including operation of e-stop & brake
9	Analysis of level wind mechanism (to ensure it will not bend or break unsafely)	Safety Analysis 11
10	Load analysis of cable	Safety Analysis 12; Cortland test results
11	Ski analysis (to review impact of a ski coming loose & verify integrity of attachments of skis to reel)	Safety Analysis 13
12	Assembly instructions (including): <ul style="list-style-type: none"> <li>Appropriate warnings</li> <li>Appropriate assembly instructions &amp; drawings</li> <li>Assembly inspection</li> </ul>	Cable reel was sent assembled; reels are inspected as part of Startup & Weekly Safety Inspections; lift/pull points are obvious; warning labels

	<ul style="list-style-type: none"><li>• Designation of pull/lift points</li><li>• Lifting instructions</li></ul>	were affixed to reel prior to shipping
13	Analysis on lift points (to ensure they will not fail unsafely)	Safety Analysis 13

6.2 Issues – None



## HAZARD ANALYSIS

Subsystem: Cable Reel

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic

Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual

Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor

13-35 Yellow- moderate

≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	1	8	None	2	4	1	8	None		Closed	There will always be small amounts of grease present on bearing cases, lead screws, etc.
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	2	1	4	None	2	2	1	4	None		Closed	Lubricants & grease can be found on the lead screw mechanism, gear reducer, chain & main shaft bearings.
3	ELECTRICAL - Shock	Exposed terminals	4	3	2	24	Enclosed terminals; safety training; insulation guarding some terminals	4	2	1	8	(1) Post-mfg inspection - PMI 2.2 (2) Safety training - Chapter 8 Wired to code		Closed	Electrical power runs to the main motor, level wind motor, brake, level wind limit switches, motor encoder & level wind encoder. The first 2 are to operate at 460V, the brake at 120V & the last 3 are to V.
4		Inadequate insulation on conductors	4	3	2	24	Strain relief on connections; no PVC insulation used, periodic inspection	4	2	1	8	See item 3		Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on)
5		Shorting of cables due to use, abuse or accident (i.e., run over by caterpillar)	4	3	2	24	Breaker; drives deenergize; unit grounded	4	2	1	8	Motors are controlled through dedicated circuits w/ dedicated drives & circuit breakers, which will detect faults; all circuits grounded		Closed	
6		Inadequate ground	4	2	4	32	Design; drives detect shorts to ground; breakers; redundant ground connections to reel	4	1	2	8	See item 5		Closed	Requires a double fault condition where a carrier shorts to the chassis & the ground is inadequate
7		Motor shorts due to contact with water, condensation, ice	4	4	2	32	Preheated motor; enclosed non-ventilated motor frame; motor drive would detect a short	4	1	2	8	See item 5 TENV motor		Closed	Personnel not expected to be present if this occurs
8		Improper lockout/tagout allows power to reel during service	4	4	2	32	Safety training, Field verification	4	2	1	8	(2) Safety training - Chapter 4		Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on)

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
9		Locks out wrong circuit	4	3	2	24	Safety training: labeling of breaker boxes & connections, field verification	4	2	1	8	See item 8		Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on)
10		Stored energy released from capacitor in drive after power down	4	2	2	16	Safety training, Field verification	4	2	1	8	See item 8		Closed	Takes minutes to discharge; would need to contact electrical buss inside the drive box for this to occur. Training comments (1) probe DC bus prior to starting work.
11		Low voltage short from drill head cable	2	3	2	12	Monitoring readout from power supply, shut down capabilities	2	3	2	12	None		Closed	Cable carries 30V DC nominal., not a risk to personel
12	ENVIRONMENTAL - Acoustic noise	Mechanical noise	3	6	1	18	Ear plugs; measure noise level, training	3	2	1	6	(4) Noise level measurement - PMI 1.1 (5) Personal protective equipment - Safety Training Chapter 1 & earmuffs, earplugs provided to staff		Closed	Noise measurements < 85 dBA; motor located outside
13	FIRE - Fire	Overheating of motor	3	2	3	18	Drives detect overloads; motors are enclosed; motors are listed	3	2	1	6	(1) Post-mfg inspection - PMI 2.3 See item 5		Closed	Motors are outside, little chance of overheating
14		Shorting of cables due to use, abuse or accident (i.e., run over by caterpillar)	4	3	2	24	Breaker; drives deenergize; armored cable; unit grounded	4	1	1	4	See item 5		Closed	
15		Cable burns	3	2	2	12	None	3	2	2	12	None		Closed	This requires an outside ignition source.
16	MECHANICAL - Cuts	Sharp edges due to design	3	4	2	24	All edges are to be radiused during mfg.; users wearing protective clothing (gloves); post-mfg. inspection of reel	3	1	2	6	(1) Post-mfg inspection - PMI 3.1 (5) Personal protective equipment - Safety Training Chapter 1		Closed	
17		Sharp edges due to use or breakage	3	2	2	12	Users wearing protective clothing, periodic inspection	3	2	2	12	(5) Personal protective equipment - Safety Training Chapter 1 - Safety Training Chapter 14		Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
18	MECHANICAL - Pinch/entrapment points	Inadequate clearances	3	3	2	18	Protective clothing; post-mfg inspection, signage - Trip wires on both sides	3	2	2	12	See item 16 - PMI 7.3 Moving machinery label placed on level wind - Safety Training Chapter 12		Closed	
19		Body part caught between rotating side of reel & stationary support	4	3	2	24	Review of clearances - trip wires on both sides	4	1	2	8	See item 18		Closed	
20		Trapped under skis	4	2	1	8	None	4	2	1	8	None		Closed	
21		Person/clothes caught between cable/reel during rewind	4	3	2	24	Training: e-stop, reel stop button and trip wire	4	2	1	8	See item 16 - e-stop - PMI 8.1 - Safety Training Chapter 6		Closed	
22		Reel freely rotates due to motor/gearbox failure	4	2	4	32	estop applies brake; instrumenting payout of hose/cable; safety factor on motor & gearbox	4	1	2	8	(6) Verification testing - Subsystem & system testing (7) Safety factor analyses on motors/ gearboxes - Safety Analysis 10		Closed	Worst case - The hose is mostly rewound, but still in a completely drilled hole. If the motor or gearbox fails, the drill head could drop back into the hole (probably slowly).
23		Reel freely rotates due to brake failure	4	2	3	24	Brake designed to be failsafe; brake application is checked via seasonal startup & between holes, redesign of brake in 2005, hose redesigned to carry load	4	1	2	8	(8) PM instructions - Brake check included in Weekly Safety Inspections		Open	Worst case - Loss of power and the brake fails could lead to a slow backdrive of the reel. The brake is applied when power is lost to the system. This will occur when the reel is moved from hole to hole. - Tag and tape hydraulic brake bypass valve
24		Unrequested motion due to EMI	4	2	3	24	Shielded cables; shielded drives; estop stops motor motion & applies brake; system monitoring of payout	4	2	1	8	See item 22 See item 23		Closed	Issue should be obvious to persons around the reel.
25		Unrequested motion due to confused H/W or S/W state	4	2	3	24	estop; system monitoring of hose/cable payout	4	2	1	8	See item 22 See item 23		Closed	

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
26		Loss of system monitoring of reel (i.e., computer crash)	4	4	2	32	estop; watchdog timer in system triggers estop condition, redesign of brake in 2005, redesign of hose, load transfers to hose, loss of power to Unico drives engages brake, modifying load monitoring software - Training	4	1	2	8	See item 22 See item 23		Open	Watchdog timers need to be looked at
27		Improper lockout/tagout allows powered reel motion during service	4	3	2	24	Training, field verification	4	2	1	8	(2) Safety training - Chapter 4		Closed	Safety training shall cover lockout/tagout, including tag teaming & person doing servicing controls the lockout.
28		Bending or breaking of level wind due to use	3	3	2	18	Analysis of level wind mechanism, limit switch change, reel stop tested between holes	3	1	2	6	(9) Analysis of level wind mechanism - Safety Analysis 11		Closed	
29		Hand (or other body part) placed between cable & level wind	3	2	2	12	Training, field verification	3	2	1	6	(2) Safety training - Chapter 12: Warning label placed on level wind		Closed	
30		Cleaning snow or ice out of level wind during operation	4	2	2	16	Training; PM inspection	4	2	1	8	See item 29 (8) PM instructions - Reels inspected during Weekly Safety Inspection		Closed	Snow/ice in cable level wind is unlikely/rare
31		Hand caught in level wind mechanism	4	2	2	16	Training, field verification	4	2	1	8	See item 29		Closed	
32		Reel is pulled toward hole due to pull on cable	4	3	3	36	Anchoring the reel	4	1	2	8	Reels inspected during Weekly Safety Inspection, when assembling the anchors, make sure that chains are tight		Closed	
33	MECHANICAL - Trauma	Cable backlash during rewind	2	2	1	4	None	2	2	1	4	None		Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
34		Cable backlash during unrequested movement of cable back down into hole. Cable could smack or pull someone.	4	3	3	36	Hazards and Safety Training were conducted, redesign of brake in 2005, redesign of hose, load transfers to hose, loss of power to Unico drives engages brake, modifying load monitoring software	4	1	2	8	(2) Safety Training Records		Closed	
35		Personal injury caused by incorrect level wind limit switch logic	3	2	1	6	Limit switch cannot be plugged in backwards, reel stop tested between holes	3	2	1	6	None		Closed	
36		Equipment damage caused by incorrect level wind limit switch logic	3	2	3	18	Check limit switch operation with each logic change; specific training, reel stop tested between holes	3	2	1	6	safety training, and inspections		Closed	
37		Impact with CAT, person getting crushed	4	2	1	8	Tow chain instead of tow bar, operator training	4	1	1	4	safety training, inspection, pre-season check		Closed	Chain is hooked up after CAT is in position
38		Cable breakage causes recoiling of cable	4	2	3	24	Antiwhips on sheaves; load analysis of cable	4	1	3	12	(1) Post-mfg inspection - PMI 3.5 (10) Load analysis on cable - Safety Analysis 12; Cortland test results		Closed	
39		Tow chain breaks during cable reel movement	4	2	3	24	Driller and operator training, rated chains	3	2	2	12	safety training		Closed	
40	SUSPENDED MASS - Reel falls over	Ski break/becomes unmounted/ collapses	4	2	2	16	Analysis of ski integrity & result of ski coming loose	4	2	1	8	(11) Ski analysis - Safety Analysis 13		Closed	
41		Reel becomes unbalanced on unlevel surface	4	1	1	4	None	4	1	1	4	None		Closed	
42		Tension from unreeled cable causes reel to move/fall over	4	1	1	4	None	4	1	1	4	None		Closed	
43	SUSPENDED MASS - Heavy object falls on personnel	Improper assembly causes parts to fall off reel	4	2	2	16	Seasonal startup inspection	4	1	2	8	Reels inspected during Startup & Weekly Safety Inspections		Closed	

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
44		Inadequate maintenance to check integrity of reel	4	2	2	16	Seasonal startup inspection	4	2	1	8	See item 43		Closed	
45		Parts break or fail due to use or fatigue	4	3	2	24	Operator experience; PM inspection	4	2	1	8	See item 43		Closed	
46	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device	4	2	2	16	Weights noted on parts; operator experience - Rigging training	4	1	1	4	(1) Post-mfg inspection - PMI 7.1		Closed	
47		Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	4	3	4	48	Redundancy in lift points; operator experience; analysis on lift points; assembly instructions - Rigging training	4	1	2	8	(12) Assembly instructions - See comments for item 44 (13) Analysis on lift points - Safety analysis 13		Closed	
48		Tools, bolts, etc. accidentally dropped	3	2	2	12	Protective equipment (hard hats); assembly instructions; safety training	3	1	2	6	(5) Personal protective equipment - Safety Training Chapter 1 (2) Safety training - Chapter 7 (12) Assembly instructions - Reel is not very high; low potential for staff working over one another		Closed	The reel was assembled during transportation; little assembly should be needed at the Pole. The reel is smaller than the main hose reel and there should be little need for people to be working over one another.
49	THERMAL - Burn	Motor casing very hot	3	2	3	18	Cold outside temperature; protective clothing; drive will shut down if too hot or if drawing too much current	3	1	3	9	(5) Personal protective equipment - Safety Training Chapter 1		Closed	
50		Contact with hot brake resistor	3	3	3	27	Housed in an enclosure; caution label on enclosure	2	2	1	4	(1) Post-mfg inspection - PMI 7.3 Caution Hot labels placed by brake resistor enclosures		Closed	
51		Contact with drive heat sink	3	1	3	9	None	3	1	3	9	None		Closed	It is in electrical closet. The heat sinks have poor accessibility & there is nothing serviceable in the box.
52	THERMAL - Cold	Contact with cold metal	3	3	1	9	Protective clothing	3	2	1	6	See item 49		Closed	

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
53	USE - e-stop	Problem in system such that estop does not stop motors or apply brakes	4	2	4	32	Tested periodically; failsafe system, field verification and testing on each hole	4	1	2	8	(6) Verification testing - Subsystem & system testing (8) PM instructions - Included in Startup & Weekly Safety Inspection		Closed	
54		Non-functional button (i.e., frozen)	4	3	3	36	Tested periodically; failsafe system; buttons are covered; redundant estop buttons, field verification and testing on each hole	4	1	2	8	See item 53		Closed	
55		Not readily accessible to users	4	2	2	16	Redundant e-stops available to user; highly visible; safety training	4	2	1	8	(1) Post-mfg inspection - PMI 8.1 (2) Safety training - Chapter 6		Closed	Use of buddy system
56	USE - Tripping	Exposed electrical cables connecting to reel	2	5	2	20	Obvious cables; cable routing away from reel controls to minimize tripping, bundling	2	3	2	12	(2) Safety training - Chapter 14		Closed	
57		Runs into suspended cable	2	4	1	8	None	2	4	1	8	None		Closed	
58		Steps over cable	3	2	1	6	None	3	2	1	6	None			
59	Pendant switch	Pendant switch is incorrectly set or changed	3	4	2	24	Training, redesign to prevent predant from changing states, plus automatic engage of reel brake; dedicated pendant for each reel - Labeling	3	2	2	12	Field verification required.		Closed	
60	Pendant	Pendant is unplugged or changed	3	4	2	24	Training, redesign to prevent predant from changing states, plus automatic engage of reel brake - Labeling	3	3	2	18	Field verification required		Closed	
61	Cable	Cable jumps sheave	4	4	1	16	Redesigned sheave, guard installed	4	2	1	8	Field verification required		Closed	
62		Cable pinched in rollers on level wind	2	3	2	12	New design for rollers	2	1	2	4	Field verification required		Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/29/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3-13; 15-18; 20-24; 26; 33; 36-43; 46-48</li> <li>Added new items: 30 (cable incident at SP) and 31</li> <li>2 items open</li> <li>Removed Revision History on Page 2 (redundant)</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment  Added item 50 to HA	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Added mitigation to Item 27; Eliminated potential hazard "putting hose back into service"	08/21/07	TCB
E		Annual review	7/24/08	TCB
F		Annual review, Removed #18	7/3/09	TR
G		Annual review, Added #38	4/28/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																	
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																	
		<b>MADISON, WISCONSIN</b>																	
TITLE		<b>ENHANCED HOT WATER DRILL  RETURN WATER HOSE REEL  HAZARD ANALYSIS SUMMARY</b>																	
1	15	ORIGINATOR	DATE	ENGINEER	DATE	DRAFTSPERSON	DATE												
2	16	Tim Rubino	4/28/10	T. Benson	4/28/10														
3	17	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE												
4	18	D. Pernic	4/28/10	M. Zernick	4/28/10														
5	19	FILENAME	8510-0115.RevG.doc				PROJECT NO.	8510											
6	20		8510-0115.RevG.xls																
7	21	DRAWING NO.	8510-0115			SCALE	SIZE	SHEET											
8	22					NA	A	Page 1 of 6											
9	23																		
10	24																		
11	25																		
12	26																		
13	27																		
14	28																		



<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Return Water Hose Reel
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Return Water Hose Reel
<b>DOCUMENT #:</b>	8510-0115
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Return Water Hose Reel for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Return Water Hose Reel.

Note: The Return Water Hose Reel is a refurbishment/update of one of the drilling reels used in AMANDA.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0115 – Hazard Analysis Table (FMEA) table

8510-0115 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns
- Use – e-stop, tripping

#### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	48
Major Risk Reduced to Moderate:	0
Major to Minor:	3
Moderate to Moderate:	2
Moderate to Minor:	27
Minor to Minor:	16
# Mitigated to Minor:	30
# Justified:	2
# Unmitigated (or Minor to Minor):	16
# Eliminated:	0

#### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
8	Improper lockout/tagout allows power to reel during service	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Design & training can reduce the potential for injury as a result of improper lockout/tagout. However, appropriate lockout/tagout is dependent on the user applying it prior to servicing equipment.
9	Locks out wrong circuit	See item 8

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Exposed electrical connections</li> <li>• Strain relief on connections</li> <li>• Test lab listing on motors</li> <li>• Sharp edges</li> <li>• Inadequate clearances</li> <li>• Weights marked on components</li> <li>• Caution label on brake resistor enclosure</li> <li>• Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 2.2</li> <li>• Not needed</li> <li>• PMI 2.3</li> <li>• PMI 3.1</li> <li>• PMI 3.1</li> <li>• PMI 7.1</li> <li>• NA; manually applied brake</li> <li>• PMI 8.1</li> </ul>
2	Safety Training (including): <ul style="list-style-type: none"> <li>• Electrical safety review</li> <li>• Proper lockout/tagout</li> <li>• E-stop use, availability &amp; testing</li> <li>• Falling objects during assembly/minimize working around others</li> <li>• Trip hazards</li> <li>• Cable Hazards</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>• Chapter 8</li> <li>• Chapter 4</li> <li>• Chapter 6</li> <li>• Chapter 7</li> <li>• Chapter 14</li> <li>• Verified safety trainings were completed at South Pole</li> </ul>

3	Control system design review (including): <ul style="list-style-type: none"> <li>• Breakers</li> <li>• Proper grounding</li> <li>• Drives detect shorts to ground</li> <li>• Use of preheated, enclosed, nonventilated motor frame</li> <li>• Motor drives detect overloads</li> </ul>	The Return Water Hose Reel motor is on a dedicated circuit with dedicated drive & circuit breaker; all circuits are grounded; drives are designed to detect electrical faults; the motor is a totally enclosed, non-ventilated motor
4	Noise level measurement (around hose reel to determine if there is a noise concern)	The noise reading at 2" from the motor was 91 dBA, but was < 85 dBA at 1'. It is unlikely that anyone would be working any extended period of time 2" from this motor while it is operating. Also, the motor is only operated at the beginning & end of drilling. Lastly, this motor is located outside.
5	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>• Ear plugs</li> <li>• Gloves</li> <li>• Outerwear</li> <li>• Hardhats</li> </ul>	Safety Training Chapter 1 (&7)
6	Verification testing (including): <ul style="list-style-type: none"> <li>• Drive shuts down if too hot or drawing too much current</li> <li>• E-stop works properly (shuts down appropriate subsystems; has to be cleared to restart; restarts from default condition)</li> </ul>	<ul style="list-style-type: none"> <li>• System testing</li> </ul>
7	PM instructions (including): <ul style="list-style-type: none"> <li>• Reel brake check</li> <li>• Proper operation of e-stop</li> <li>• Review of assembly of reel</li> <li>• Check of ice/snow accumulation</li> </ul>	<ul style="list-style-type: none"> <li>• Used during operation; manual brake</li> <li>• Startup &amp; Weekly Safety Inspections</li> <li>• Startup &amp; Weekly Safety Inspections</li> <li>• Startup &amp; Weekly Safety Inspections</li> </ul>
8	Structural analysis of reel	Reel was used as the substitute Supply Hose Reel during the latter parts of IV&T w/o issue; only 400' of hose will be on the reel
9	Assembly instructions (including): <ul style="list-style-type: none"> <li>• Appropriate warnings</li> <li>• Appropriate assembly instructions &amp; drawings</li> <li>• Assembly inspection</li> <li>• Designation of pull/lift points</li> <li>• Lifting instructions</li> </ul>	<ul style="list-style-type: none"> <li>• Moving Machinery labels affixed to reel</li> <li>• Reel was shipped assembled</li> <li>• Applicable drawings shipped</li> <li>• Lift/pull points should be obvious</li> <li>• Trained RPSC staff</li> </ul>
10	Analysis on lift points (to ensure they will not fail unsafely)	See items 8 & 9 – This was an old AMANDA reel; it does not have lift points (just tow points)
11	Analysis regarding what keep the hose from sliding off the top side of the drum	

## 6.2 Issues – None

## HAZARD ANALYSIS

### Subsystem: Return Hose Reel

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	1	8	HazCom training, MSDS available	2	3	1	6	None	Closed	There will always be small amounts of grease present on bearing cases, etc.
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	2	1	4	HazCom training, MSDS available	2	2	1	4	None	Closed	Lubricants & grease can be found on the gear reducer & main shaft bearings.
3	ELECTRICAL - Shock	Exposed terminals	4	3	2	24	Enclosed terminals; safety training; insulation guarding terminals	4	2	1	8	(1) Post-mfg inspection - PMI 2.2 (2) Safety training - Chapter 8	Closed	Elec power runs to the main motor
4		Inadequate insulation on conductors	4	3	2	24	Strain relief on connections; no PVC insulation used, periodic inspection	4	2	1	8	See item 3; strain relief not needed	Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on)
5		Shorting of cables due to use, abuse or accident (i.e., run over by caterpillar)	4	3	2	24	Breaker; drives deenergize; unit grounded	4	2	1	8	Motors are controlled through dedicated circuits w/ dedicated drives & circuit breakers, which will detect faults; all circuits grounded	Closed	
6		Inadequate ground	4	2	4	32	Design; drives detect shorts to gnd; breakers; redundant gnd connections to reel	4	1	2	8	See item 5	Closed	Requires a double fault condition where a carrier shorts to the chassis & the ground is inadequate
7		Motor shorts due to contact with water, condensation, ice	4	4	2	32	Preheated motor; enclosed non-ventilated motor frame; motor drive would detect a short	4	1	2	8	See item 5; TENV motor used	Closed	Personnel not expected to be present if this occurs
8		Improper lockout/tagout allows power to reel during service	4	4	2	32	Safety training, field verification	4	2	2	16	(2) Safety training - Chapter 4	Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on)
9		Locks out wrong circuit	4	3	2	24	Safety training; labeling of breaker boxes & connections, field verification	4	2	2	16	See item 8	Closed	Safety training is to include who can work on hi V equipment (i.e., persons with electrical training & knowledge of the circuit to be worked on)

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
10		Stored energy released from capacitor in drive after power down	4	2	2	16	Safety training, field verification	3	2	2	12	See item 8	Closed	Takes minutes to discharge; would need to contact electrical buss inside the drive box for this to occur. Training comments (1) probe DC bus prior to starting work.
11	ENVIRONMENTAL - Acoustic noise	Mechanical noise	1	1	2	2	Ear plugs; measure noise level, safety and operations training	1	1	1	1	(4) Noise level measurement - PMI 1.1 (5) Personal protective equipment - Safety Training Chapter 1; earmuffs, earplugs provided to staff	Closed	Reading 2" from motor was 91 dBA, but was < 85 dBA at 1'. It is unlikely that anyone would be working any extended period of time 2" from this motor while it is operating. Also, the motor is only operated at the beginning & end of drilling. Lastly, this motor is located outside.
12	FIRE - Fire	Overheating of motor	3	2	3	18	Drives detect overloads; motors are enclosed; motors are listed	3	2	1	6	(1) Post-mfg inspection - PMI 2.3 (3) Control system design review - See item 5	Closed	
13		Shorting of cables due use, abuse or accident (i.e., run over by caterpillar)	4	3	2	24	Breaker; drives deenergize; unit grounded	4	1	1	4	See item 12	Closed	
14		Hose burns	3	2	2	12	None	3	2	2	12	None	Closed	
15	MECHANICAL - Cuts	Sharp edges due to design	3	4	2	24	All edges are to be radiused during mfg; users wearing protective clothing (gloves); post-mfg. inspection of reel, seasonal inspection	3	2	2	12	(1) Post-mfg inspection - PMI 3.1 (5) Personal protective equipment - Safety Training Chapter 1	Closed	
16		Sharp edges due to use or breakage	3	2	2	12	Users wearing protective clothing, seasonal inspection	3	2	2	12	(5) Personal protective equipment - Safety Training Chapter 1 - Safety Training - Chapter 14	Closed	
17	MECHANICAL - Pinch/entrapment points	Inadequate clearances	3	3	2	18	Protective clothing; post-mfg inspection	3	2	2	12	See item 15	Closed	
18		Trapped under skis	4	2	1	8	None	4	2	1	8	None	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
19		Person/clothes caught between hose/reel or hose/hose during rewind	4	3	2	24	Training: e-stop on reel, buddy system	4	2	1	8	See item 15; Safety Training Chapter 12	Closed	
20		Reel freely rotates due to motor/gearbox failure	2	2	4	16	Brake present: safety factor on motor & gearbox, redesign adding combo cable in 2005, cable carries load	2	1	2	4	(6) Verification testing - Subsystem & system testing - Safety Analysis 10 - Manually applied brake	Closed	
21		Reel freely rotates due to brake failure	2	2	3	12	Brake present, redesign of brake in 2005 and addition of combo cable, cable carries load	2	1	2	4	(7) PM instructions - Manual brake present; applied after pump is deployed & released after pump is removed from hole	Closed	Worst case - Loss of power and the brake fails could lead to a slow backdrive of the reel, which is a double fault condition.
22		Unrequested motion due to EMI	4	2	3	24	Shielded cables; shielded drives; estop stops motor motion	4	2	1	8	(6) Verification testing - Subsystem & system testing (7) PM instructions - Included in Startup & Weekly Safety Inspections - Manual brake present	Closed	Issue should be obvious to persons monitoring the reel.
23		Unrequested motion due to confused H/W or S/W state	4	2	3	24	estop; system monitoring of hose payout, buddy system during operation	4	2	1	8	See item 23	Closed	Issue should be obvious to persons monitoring the reel.
24		Loss of system monitoring of hose reel (i.e., computer crash)	1	3	1	3	None	1	3	1	3	None	Closed	Very little monitoring; possibly a pressure monitor. Activity could be done manually without a monitor; injury is not considered a likely outcome. Computers are not tied in to system
25		Improper lockout/tagout allows powered reel motion during service	4	3	2	24	Training, field verification	4	2	1	8	(2) Safety training - Chapter 4	Closed	Safety training shall cover lockout/tagout, including tag teaming & person doing servicing controls the lockout.
26		Reel is pulled toward hole due to tensile pull on hose	1	2	1	2	Reel is anchored	1	2	1	2	None	Closed	
27	MECHANICAL - Trauma	Hose backlash during rewind	2	2	1	4	None	2	2	1	4	None	Closed	
28		Reel freely rotates due to improper brake setting	2	3	3	18	Training, labeling	2	2	2	8		Open	Add labels



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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
29		Hose backlash during unrequested movement of hose back down into hole. Hose could smack or pull someone.	4	3	3	36	Hazards and Safety Training were conducted, Brake present, redesign of brake in 2005 and addition of combo cable, cable carries load, keep hose suspended	4	1	2	8	(2) Safety Training Records, design drawings	Closed	
30		Hose slides off of drum sideways (side of drum is not flanged to retain hose)	4	2	3	24	Verification testing; engineering analysis of what retains the hose on the reel, training, buddy system	4	1	2	8	(6) Verification testing	Closed	Someone always present when reeling up
31	SUSPENDED MASS - Reel falls over	Ski break/becomes unmounted/ collapses	4	2	2	16	Structural analysis of reel	4	1	2	8	(8) Structural analysis - Reel was used as the substitute Supply Hose Reel during the latter parts of IV&T w/o issue; only 400' of hose will be on the reel; previous used AMANDA reel	Closed	
32		Reel becomes unbalanced on unlevel surface	4	1	1	4	None	4	1	1	4	reel anchored	Closed	
33		Tension from unreeled hose causes reel to move/fall over	4	1	1	4	None	4	1	1	4	reel anchored	Closed	
34	SUSPENDED MASS - Heavy object falls on personnel	Improper assembly causes parts to fall off reel	4	2	2	16	Assembly instructions & checkout, seasonal inspection	4	1	2	8	(9) Assembly instructions - Reel was shipped assembled	Closed	
35		Inadequate maintenance to check integrity of reel	4	2	2	16	PM inspection, seasonal inspection	4	2	1	8	(7) PM instructions - Included in Startup & Weekly Safety Inspections	Closed	
36		Parts break or fail due to use or trauma	4	3	2	24	Operator experience; PM inspection; pull/lift points slated in assembly instructions	4	2	1	8	See item 35 (9) Assembly instructions - Lift/pull points obvious on equipment	Closed	
37	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device	4	2	2	16	Weights noted on parts; operator experience	4	1	1	4	(1) Post-mfg inspection - PMI 7.1	Closed	Assembly completed

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
38		Hose falls during installation into/out of tower	4	3	1	12	Training, Rated rope, buddy system, onsite communication	4	2	1	8			
39		Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	4	3	3	36	Redundancy in lift points; operator experience; analysis on lift points; assembly instructions	4	1	2	8	(9) Assembly instructions - Reel was shipped assembled See item 33	Closed	Assembly completed
40		Tools, bolts, etc. accidentally dropped	3	2	2	12	Protective equipment; assembly instructions; safety training	3	1	2	6	(2) Safety training - Chapter 7 (5) Personal protective equipment - Safety Training Chapters 1 & 7 (9) Assembly instructions - Drawings sent; little assembly needed	Closed	Little assembly of the reel is needed; staff should not be working over one another
41	THERMAL - Burn	Motor casing very hot	3	2	3	18	Cold outside temperature; protective clothing; drive will shut down if too hot or if drawing too much current	3	1	3	9	(5) Personal protective equipment - Safety Training Chapter 1 (6) Verification testing - Motor is outside, any contact heat should dissipate quickly	Closed	Heat buildup is not expected to be an issue with this motor, because: 1) It is outside & the heat will dissipate quickly 2) Users will be wearing outerwear 3) The motor is run intermittantly
42		Contact with hot brake resistor	3	3	3	27	Housed in an enclosure; caution label on enclosure	3	2	2	12	(1) Post-mfg inspection - CAUTION Hot labels placed by all brake resistors	Closed	
43		Contact with drive heat sink	3	1	3	9	None	3	1	3	9	None	Closed	It is in electrical closet. The heat sinks have poor accessibility & there is nothing serviceable in the box.
44	THERMAL - Cold	Contact with cold metal	3	3	1	9	None	3	1	3	9	None	Closed	
45	USE - Reel-stop	Non-functional button (i.e., frozen)	4	3	3	36	Tested periodically; failsafe system; buttons are covered; redundant reel-stop buttons, inspected at start up and before use at each hole	4	2	1	8	(6) Verification testing - System testing (7) PM instructions - Included in Startup & Weekly Safety Inspections	Closed	
46		Readily accessible to users	4	2	2	16	Redundant reel-stop available to user; highly visible; safety training	4	2	1	8	(1) Post-mfg inspection - PMI 8.1 (2) Safety training - Chapter 6	Closed	Use of buddy system

**HAZARD ANALYSIS**

**Subsystem: Return Hose Reel**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
47	USE - Tripping	Exposed elec cables, hoses connecting to reel	2	5	2	20	Obvious cables: cable routing away from reel controls to minimize tripping, safety and operations training	2	4	1	8	(2) Safety training - Chapter 14	Closed	
48		Running into suspended hose	2	4	1	8	Obvious, safety and operations training, hardhats	2	4	1	8	None	Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	12/6/02	See original
A		<ul style="list-style-type: none"> <li>Updated mitigation information for items: 1; 3; 7-13; 16; 19-21; 28-30; 32; 34-35; 40-42; 44; 46-47; 49; 53</li> <li>3 items open</li> <li>Removed Revision History on page 2 (redundant)</li> </ul>	1/31/05	MAZ
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Reduced items 26 and 27 probabilities from 2 to 1; Increased items 36 and 38 severities from 3 to 4 and item 53 probability from 5 to 6; Reduced item 54 probabilities from 3 to 2; Added item 55	08/21/07	TCB
E		Annual revision	7/24/08	TCB
F		Item #25 increased from 2 to 4 on probability, Annual review and revision	6/25/09	TR
G		Annual review and revision	4/26/10	TR

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

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		<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																
		<b>MADISON, WISCONSIN</b>																
		TITLE																
		<b>ENHANCED HOT WATER DRILL POWER DISTRIBUTION SYSTEM HAZARD ANALYSIS SUMMARY</b>																
1	15	ORIGINATOR	DATE	ENGINEER	DATE	CHECKER	DATE											
2	16	Tim Rubino	5/3/10	T. Matt	5/3/10	J. Kalin	5/3/10											
3	17	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE											
4	18	M. Thoma	5/3/10	M. Zernick	5/3/10													
5	19	FILENAME	8510-0120.RevG.doc				PROJECT NO.	8510										
6	20		8510-0120.RevG.xls															
7	21	DRAWING NO.	8510-0120			SCALE	SIZE	SHEET										
8	22					NA	A	Page 1 of 6										
9	23																	
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<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Power Distribution System
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Power Distribution System
<b>DOCUMENT #:</b>	8510-0120
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

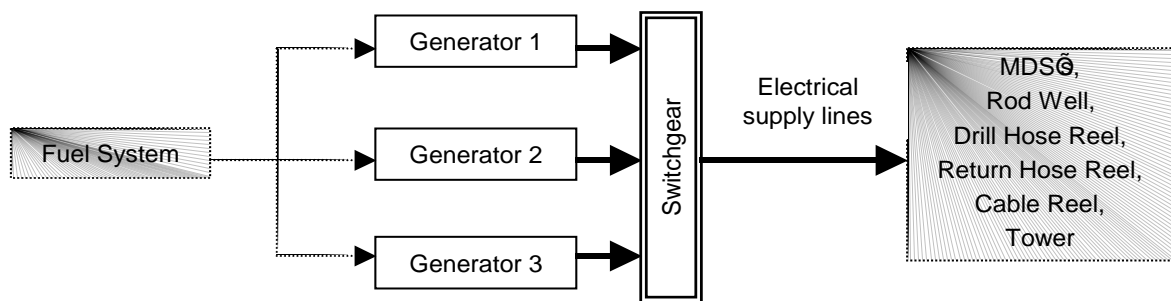
## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Power Distribution System for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Power Distribution System.

***The components of the power distribution system addressed in this document are:***

- ***Generators***
- ***Switchgear***
- ***Electrical supply lines to the drill devices***



See HA for Fuel System

See HA for each component

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0120 – Hazard Analysis Table (FMEA) table

8510-0120 – Hazard Analysis, Meeting Notes

Generator Request For Proposal

### 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns
- Use – tripping

### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	56
Major Risk Reduced to Moderate:	0
Major to Minor:	3
Moderate to Moderate:	0
Moderate to Minor:	18
Minor to Minor:	35
# Mitigated to Minor:	21
# Justified:	0
# Unmitigated (or Minor to Minor):	35
# Eliminated:	0

### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
22	All generators non-functional	Although generator malfunctions have occurred frequently, the availability of maintenance personnel along with securing equipment and training should minimize this hazard.

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Spill pan under genset</li> <li>• Use of dry connect couplings on fuel lines</li> <li>• No exposed terminals on genset</li> <li>• Strain relief on cables connecting to switchgear</li> <li>• Breakers</li> <li>• Labeling on switchgear connections</li> </ul>	<ul style="list-style-type: none"> <li>• Not specifically noted in PMI; however, gensets are in dedicated containers &amp; the floor should contain any spills</li> <li>• PMI 9.1</li> <li>• Not specifically noted in PMI; however, no exposed terminals were noted during other inspections of the generators &amp; PDM</li> <li>• PMI 10.1; NA due to connectors &amp; angle of connections</li> <li>• All services protected by circuit breakers</li> <li>• One-line power schematic</li> </ul>



Item	Evidence	Completed/Attached
	<ul style="list-style-type: none"> <li>• Finger safe electrical connectors of supply cables</li> <li>• Cable caps</li> <li>• Lockout capacity on switchgear</li>   <li>• Test lab listing on breakers</li> <li>• Noise measurements</li> <li>• Temperature &amp; CO detectors present</li> <li>• Ventilation available</li> <li>• Fire suppression installed</li> <li>• Sharp edges</li> <li>• Weights marked on components</li> <li>• Caution label on hot components of genset &amp; switchgear</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 10.1</li> <li>• PMI 10.1</li> <li>• Output connectors are contained in panels with doors that can be locked out; individual services to MDS's can be locked out by disconnecting &amp; locking out the service cable</li> <li>• PMI 2.3</li> <li>• PMI 1.1</li> <li>• PMI 5.1</li> <li>• Yes, plus doors can be opened</li> <li>• PMI 5.1</li> <li>• PMI 3.1</li> <li>• PMI 7.1</li> <li>• PMI 7.3 on genset</li> </ul>
2	<p>Safety Training (including):</p> <ul style="list-style-type: none"> <li>• Servicing batteries including washing hands after handling</li> <li>• Breaker safety (do not reset multiple times)</li> <li>• Proper lockout/tagout</li> <li>• Chocking skies on generator &amp; PDM buildings</li> <li>• Repair of broken parts or tagging</li> <li>• Hot items (generators &amp; transformer on switchgear)</li> <li>• Trip hazards</li> </ul>	<p>Safety Training Manual:</p> <ul style="list-style-type: none"> <li>• Chapter 8</li> <li>• Chapter 8</li> <li>• Chapters 4 &amp; 8</li> <li>• Chapter 8</li> <li>• Chapter 14</li>   <li>• Chapter 14</li> </ul>
3	<p>Personal protective equipment (verify that the staff is to wear):</p> <ul style="list-style-type: none"> <li>• Ear plugs</li> <li>• Gloves</li> <li>• Outerwear</li> <li>• Hardhats</li> <li>• Face shields or safety glasses</li> </ul>	<p>Described in Safety Training Manual Chapter 1. All items shipped to SP.</p>
4	<p>PM instructions (including):</p> <ul style="list-style-type: none"> <li>• Check cables &amp; connectors; replace accordingly</li> </ul>	<p>Field verification at South Pole</p>
5	<p>Verification testing (including):</p> <ul style="list-style-type: none"> <li>• Verify fuel sensors operate correctly</li> </ul>	<p>Field verification at South Pole</p>
6	<p>Electrical inspection</p>	<p>Units were assembled by a contract vendor &amp; are the responsibility of RPSC; all units were tested during IV&amp;T</p>
7	<p>Lifting equipment operated by experienced operators</p>	<p>All lifting devices operated by qualified RPSC staff or IceCube staff approved by RPSC</p>

6.2 Issues – None

## HAZARD ANALYSIS

### Subsystem: Power Distribution System

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	1	4	1	4	Genset comes with pan under generator	1	4	1	4	1) Post-mfg inspection - Genset in dedicated container; floor should contain spillage; training	Closed	There will always be small amounts of grease present on bearing cases, etc.
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	2	1	4	MSDS available	2	2	1	4	None	Closed	Lubricants & grease can be found on the gear reducer & main shaft bearings.
3	CHEMICAL - Environmental	Fuel spilled when disconnecting fuel supply from generator	2	2	2	8	Dry disconnect couplings, oil sorbent pads, spill kits	2	1	2	4	1) Post-mfg inspection - PMI 9.1	Closed	Inspect gaskets yearly
4	CHEMICAL - Toxicity	Antifreeze leaks out of generator or heat exchanger	3	1	1	3	MSDS available, oil sorbent pads, spill kits	3	1	1	3	None	Closed	
5		Contact with antifreeze during PM from generator or heat exchanger	3	1	1	3	MSDS available, oil sorbent pads, spill kits	3	1	1	3	None	Closed	
6	CHEMICAL - Contact with acid	Contact with acid during installation, deinstallation, charging or PM of lead acid battery bank	2	4	1	8	Washing hands; gloves available, safety glasses available, MSDS available, RPS does the work	2	2	1	4	See item 7	Closed	
7		Splash acid during servicing	4	2	1	8	Eye glasses; gloves; washing hands, MSDS available, RPS does the work	4	1	1	4	2) Training - Chapter 1 & 8 3) Personal protective equipment - Safety Training Chapter 1	Closed	
8	ELECTRICAL - Shock	Exposed terminals on generators or switchgear	4	2	2	16	Terminals not accessible; lockout/tagout training, field verification	4	2	1	8	1) Post-mfg inspection - Not specifically noted in PMI, but no exposed terminals noted during other inspections of generators & PDM 2) Training - Chapter 4	Closed	
9		Damaged terminals on generators or switchgear	4	2	1	8	Strain relief on cables; RPS involvement	4	2	1	8	1) Post-mfg inspection - PMI 10.1: NA due to angle of connections & connectors	Closed	

## HAZARD ANALYSIS

### Subsystem: Power Distribution System

Author: M. Zernick

Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
10		Terminals damaged due to movement of generator or switchgear buildings	4	2	2	16	Stationary buildings	4	1	1	4	2) Training - Chapter 8	Closed	
11		Shorting of cables or damage to terminals due to use, abuse or accident (i.e., run over by caterpillar)	4	4	2	32	Cables in utility alley; breakers, safety training	4	2	1	8	Power schematic - All services protected by circuit breakers Training - Chapter 2: cables run in utility alley	Closed	
12		Generator phases wired incorrectly to switchgear	4	2	3	24	Labeling on switchgear; breakers, qualified electrician does the wiring; RPS electrician involvement	4	1	1	4	See item 11 All generators tested w/ PDM during IV&T	Closed	The possibility of misconnection is high, but shock is unlikely.
13		Inadequate ground	4	2	4	32	Circuit breakers, training	4	1	2	8	See item 12	Closed	Requires a double fault condition where a carrier shorts to the chassis & the ground is inadequate
14		Contact with battery terminals	4	2	1	8	None	4	2	1	8	None	Closed	
15		Generator shorts due to contact with water, condensation, ice	4	2	1	8	Generators inside buildings	4	1	1	4	None; generator design	Closed	Possible if a flood occurs (most likely from a coolant leak) in a building; however, personnel not expected to be present if this occurs
16		Disconnected hot cables	4	2	2	16	Finger safe connectors; cable caps; lockout/tagout, training	4	1	1	4	1) Post-mfg inspection - PMI 10.1 2) Training - Chapter 4 & 8	Closed	RPS involvement
17		Transferring a locked out cable to a non-locked out connection	4	3	3	36	Lockout cable at switchgear, operations training, lockout training, end of cable "bagged"	4	1	2	8	Lockout capacity verified in #19 Lockout training addressed in #16	Closed	
18		Insulation physically fails on cables due to use, bending or fatigue	4	3	1	12	PM on cables; periodic replacement; conductors dual insulated; Circuit breakers	4	1	1	4	4) PM inspection Breakers verified in #11&12, field verification	Closed	

## HAZARD ANALYSIS

### Subsystem: Power Distribution System

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13-35 Yellow- moderate  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
19		Inadequate lock out capacity on switchgear	4	1	2	8	Lockout capacity in switchgear, lockout training, field verification	4	1	1	4	1) Post-mfg inspection - Not specifically reviewed during PMI; however, output connectors are contained in panels with doors that can be locked out; individual services to MDS's can be locked out by disconnecting & locking out the cable	Closed	
20		Locks out wrong circuit	4	3	3	36	Checking circuit prior to use, operations training, lockout training, field verification; labeling	4	1	1	4	2) Training - Chapter 4	Closed	
21	ELECTRICAL - Explosion	Breaker explodes due to excessive power or failure	4	2	4	32	Face shields; gloves; clothing; test lab listing, left hand rule Arc Flash rated clothing	4	1	3	12	1) Post-mfg inspection - PMI 2.3 2) Training - Chapter 1 & 8 3) Personal protective equipment - Safety Training Chapter 1	Closed	
22	ELECTRICAL - No power	All generators non-functional	2	2	1	4	Maintenance Personnel Available, securing equipment, training.	2	2	1	4	None	Closed	
23		Switchgear non-functional	4	2	1	8	Inspection	4	2	1	8	None	Closed	
24		System runs out of fuel	4	3	1	12	Fuel level sensors	4	1	1	4	5) System verification, field verification	Closed	
25	ELECTRICAL - Inadequate power to run drill	Generator non-functional or poorly functioning, or switchgear poorly functional	2	2	1	4	Back up generator available - Testing and load testing of generators prior to service	2	2	1	4	Training	Closed	
26	ELECTRICAL - Output voltage too high	Generator failure	4	1	1	4	Generator has output detection that will shut down output from generator; periodic checks	4	1	1	4	None; generator design	Closed	Could lead to arcing, which could be a fire hazard also
27	ELECTRICAL - Output voltage too low	Generator failure	4	1	1	4	Generator has output detection that will shut down output from generator	4	1	1	4	None; generator design	Closed	

## HAZARD ANALYSIS

### Subsystem: Power Distribution System

Author: M. Zernick

Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

13-35 Yellow- moderate  
 ≥36 Red-Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
28	ENVIRONMENTAL - Acoustic noise	Mechanical noise	4	6	1	24	Silencer on exhaust; noise measurement; hearing protection; signage	4	3	1	12	1) Post-mfg inspection - PMI 1.1 3) Personal protective equipment - Safety Training Chapter 1 - Hearing protection recommended signs posted on Gen 1-3	Closed	
29	ENVIRONMENTAL - Heat	Excessively high temperatures inside generator building due to generator operation	3	4	1	12	Temp sensor; ventilation	3	2	1	6	1) Post-mfg inspection - Temperature measurements at IV&T are NA for SP; units can be cooled by opening doors	Closed	
30	ENVIRONMENTAL - Respiratory	CO buildup due to inadequate venting or faulty exhaust	4	2	4	32	CO detectors, periodic field testing of CO monitors	4	2	1	8	1) Post-mfg inspection - PMI 5.1	Closed	
31		Inhalation of exhaust from gensets outside of genset buildings	2	3	1	6	Exhaust located near top of buildings	2	3	1	6	None	Closed	
32	FIRE - Fire	Overheating of generators	4	2	2	16	Temperature monitor; fire suppression; automatic shutdown	4	1	1	4	1) Post-mfg inspection - 5.1; fire, CO/smoke detectors & fire suppression systems	Closed	
33		Overheating of engine	4	2	2	16	Temperature monitor; fire suppression; automatic shutdown	4	1	1	4	See item 32	Closed	
34		Overheating of transformer in switchgear	4	1	3	12	Temperature monitor; fire suppression	4	1	2	8	See item 32	Closed	
35		Overheating conductors	4	2	3	24	NEC code (using right wires, breakers, # of wires that can be in conduit), correct specification of wiring, qualified personnel doing PM and inspection and installation	4	1	2	8	6) Electrical inspection - Units were assembled by a contract vendor & are the responsibility of RPSC - Generators & PDM were tested during IV&T	Closed	
36		Shorting of connectors due to use, abuse, or accident	4	2	2	16	Circuit breakers	4	2	1	8	See items 11 & 12	Closed	

## HAZARD ANALYSIS

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
37		Fuel leak or other combustible ignites	4	2	3	24	No fuel storage in buildings; fire suppression; temperature sensor; pan under generator; use of diesel fuel	4	2	1	8	See items 1 & 32	Closed	
38		Space heater starts combustible on fire	4	2	1	8	Isolation of flammables from heaters, training	4	2	1	8	None	Closed	This should be a more localized event if a fire did occur.
39		Switchgear failure	4	1	2	8	Face shields; gloves; clothing; test lab listing; fire suppression, inspection	4	1	2	8	Inspection, training & PPE verified under #21; fire suppression verified in #34	Closed	
40		Batteries can start on fire or explode	4	2	2	16	Face shields; gloves; clothing; baking soda, MSDS available	4	1	2	8	2) Training - Chapter 1 & 8 3) Personal protective equipment - Safety Training Chapter 1	Closed	
41	MECHANICAL - Cuts	Sharp edges due to design	3	2	2	12	Adequate finishing; Gloves, hard hats	3	1	2	6	1) Post-mfg inspection - PMI 3.1	Closed	
42		Sharp edges due to use or breakage	3	2	2	12	Repair of broken parts; tagging; Gloves, hard hats	3	2	1	6	2) Training - Chapter 14	Closed	
43	MECHANICAL - Pinch/entrapment points	Body part caught in moving member of generator	4	2	1	8	Generator design; guards	4	2	1	8	None, generator design	Closed	Potential during service
44	MECHANICAL - Trauma	Hits head on exhaust pipe or other low hanging items	2	4	1	8	Hardhats; training	2	2	1	4	See item 40	Closed	
45		Engine or generator forcibly ejects parts upon failure	4	1	2	8	Generator design, enclosed	4	1	2	8	None, generator design	Closed	Very noticeable failure, but little potential reaction time
46	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device	4	2	2	16	Weights marked on devices, training	4	1	1	4	1) Post-mfg inspection - PMI 7.1	Closed	Total weight of components to be stenciled on each piece. RPS involvement
47		Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	4	3	4	48	Operator experience; ISO designed corners, training	4	1	2	8	7) Equipment run by experienced operators - Forklift pockets & ISO corners supplied on each unit	Closed	RPS Involvement
48		Removing genset from building for service	4	2	1	8	Genset made to be forked	4	2	1	8	None, generator design	Closed	RPS Involvement

**HAZARD ANALYSIS**

**Subsystem: Power Distribution System**

**Author: M. Zernick**

Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

13-35 Yellow- moderate  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
49		CO2 tanks could fall if not installed correctly during switch outs	4	2	1	8	Inspection; Hardhats, PPE	4	1	1	4	Inspection	Closed	
50	THERMAL - Burn	Exposure to generator housing, engine, exhaust pipe, heat recovery very hot	3	3	2	18	Signage; Insulated covers, training	3	2	1	6	1) Post-mfg inspection - PMI 6.1 & 7.3	Closed	
51		Transformer in switchgear very hot	2	2	1	4	Training; signage; Circuit breakers	2	2	1	4	1) Post-mfg inspection 2) Training, Field verification	Closed	
52		Cables very hot	2	1	2	4	Oversized cables used	2	1	2	4	None	Closed	
53		Contact with space heaters	3	2	1	6	Covers	3	2	1	6	None	Closed	
54	USE - Tripping	Exposed electric cables	2	6	2	24	Training; utility alley; suspended cables	2	3	2	12	2) Training - Chapter 14	Closed	
55		Running into suspended cable	2	2	1	4	Hardhats	2	2	1	4	None	Closed	
56	USE - Slippage	Oil on floor of generator room	2	2	1	4	Oil Dry available; housekeeping practices, oil sorbent pads	2	2	1	4	None	Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	10/25/02	See original
A	1024	<ul style="list-style-type: none"> <li>Update document to reflect changes in FMEA. The FMEA changes were due to changes in the design of the water tanks &amp; elimination of ethanol as an anti-freeze agent.</li> <li>Remove revision history on p.2</li> </ul>	6/19/03	TAD
B		<ul style="list-style-type: none"> <li>Updated mitigation information for items: 8-10; 14-15; 18-19; 21-28; 30-31; 33; 35; 37; 39-43</li> </ul>	2/4/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Eliminated hazard "EtOH incompatible with tank"; Item 11 severity reduced from 3 to 2 and items 15 and 18 probabilities reduced from 3 to 2 due to new mitigations; Added item 16; Item 36 probability and detectability reduced from 2 to 1	08/21/07	TCB
E		Annual review and revision	6/25/08	TCB
F		Annual review and revision	7/2/09	TR
G		Annual review and revision	5/10/10	TR

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

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		<b>ANTIFREEZE &amp; WATER TANKS</b>																	
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<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Anti-Freeze & Water Tanks
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Anti-Freeze & Water Tanks
<b>DOCUMENT #:</b>	8510-0121
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Closed (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Anti-Freeze & Water Tanks for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Anti-Freeze & Water Tanks.

***This hazard analysis includes the tanks for the drill water (tanks 1 & 2) and antifreeze. The original choice for anti-freeze was ethanol and hazards were based off of that choice. Since Rev. -, the anti-freeze method has been changed to compressed air with propylene glycol. They will now serve as the baseline anti-freeze method for this document. Note: There is no similarity between the tanks used for anti-freeze and water. They were combined in this HA for convenience.***

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0121 – Hazard Analysis Table (FMEA) table

8510-0121 – Hazard Analysis, Meeting Notes

8510-0017 – Water Tank Drawings

McMaster-Carr catalog information for model 3664K15

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Fire
- Mechanical – cuts, pinchpoints, trauma
- Suspended Mass
- Use – water, tripping

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	40
Major Risk Reduced to Moderate:	0
Major to Minor:	1
Moderate to Moderate:	0
Moderate to Minor:	19
Minor to Minor:	20
# Mitigated to Minor:	40
# Justified:	0
# Unmitigated (or Minor to Minor):	20
# Eliminated:	0

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
None		

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

**CLOSED – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.**

**IMPLEMENT –** The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

**REVIEW –** The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

**REOPEN –** This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	e-mail from Raytheon verifying that tank to be used for the antifreeze is acceptable for use	DONE 10/7/02 from E. Jensen
2	Safety Training (including): <ul style="list-style-type: none"> <li>• Electrical safety around water tanks</li> <li>• Propylene glycol is a slight fire hazard</li> <li>• Lowering/lifting of submersible pump</li> <li>• Hatch/opening safety on top of water tank (hatch falling on hand)</li> <li>• Use of non-submersible pumps for anti-freeze</li> <li>• How to address potentially injurious broken objects</li> <li>• Water tank hazards (drowning, electrical hazards, lifting hinged hatch covers)</li> <li>• Hose/cable placement</li> <li>• Acceptable behavior while on top of water tank</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>• Chapter 17</li> <li>• Chapter 3</li> <li>• Chapter 17</li> <li>• Chapter 17</li> <li>• Chapter 17</li> <li>• Chapter 14</li> <li>• Chapter 17</li> <li>• Chapter 14</li> <li>• Chapter 17</li> </ul>
3	Post-manufacturing inspection (including): <ul style="list-style-type: none"> <li>• Inspect tanks for sharp corners or edges</li> <li>• Liner used in water tank</li> <li>• Weights marked on tanks</li> <li>• Hinged hatch covers (&amp; handles)</li> <li>• Hose entry covers</li> <li>• Grated walkways</li> <li>• Railings</li> <li>• Toeboards</li> <li>• Landings at top of stairways</li> <li>• Stairways</li> <li>• Anti-slip tread on stairways</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.1</li> <li>• PMI 3.5</li> <li>• PMI 7.1</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> <li>• PMI 3.4</li> </ul>
4	Review of electrical design to ensure breakers available on water & anti-freeze pumps	Breakers present for pumps

5	Review DCS system to ensure that: <ul style="list-style-type: none"> <li>Flow sensors are available on the submersible pumps</li> <li>Water level (for water tanks) &amp; water temperature sensors integrated into DCS system</li> </ul>	<ul style="list-style-type: none"> <li>IV&amp;T subsystem &amp; system testing</li> <li>IV&amp;T subsystem &amp; system testing</li> </ul>
6	PM instructions (including): <ul style="list-style-type: none"> <li>Water tank railings attachment</li> <li>Water tank stairways attachment</li> <li>Stairways free from debris, snow, ice, etc.</li> </ul>	<ul style="list-style-type: none"> <li>Startup &amp; weekly safety walkthrough</li> <li>Startup &amp; weekly safety walkthrough</li> <li>Startup &amp; weekly safety walkthrough</li> </ul>
7	Sled analysis to verify that the MDS sleds can support the water tanks filled with water	Safety analysis 15
8	Determine lifting mechanism for pumps & water tank covers	Utility crane to lift pumps – PMI 3.4
9	Force analysis on water tanks by SeaBox	Completed by SeaBox; water tanks used during IV&T w/ no failures due to water load
10	Anti-freeze tank designed with lifting pockets	DONE 10/7/02 – catalog description shows lifting pockets
11	Assembly instructions for fastening stairways to tanks	No instructions; EHWD team experienced at mounting the stairways; startup & weekly safety walkthrough contain checks for stairways
12	Personal protective equipment: <ul style="list-style-type: none"> <li>Boots</li> </ul>	FDX boots ordered for drill team
13	Develop procedure for entering water tank empty or with water	Entrants are to follow RPSC confined space procedure & lockout/tagout procedure
14	Verify that the propylene glycol has been dyed & what color	Reddish-brown

## 6.2 Issues – None

## HAZARD ANALYSIS

Subsystem: Antifreeze and Water Tanks

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Reactivity	Reactive item dropped in propylene glycol (oxidizer, acid)	2	1	3	6	Contact with other chemicals is not a foreseen issue	2	1	3	6	None	Closed	
2	CHEMICAL - Toxicity	ingestion of propylene glycol	3	2	2	12	There is no particular reason for anyone to ingest a significant amount of PG. HazCom Training. MSDS available	3	2	2	12	None	Closed	
3	ELECTRICAL - Shock	Water pump shorts	4	2	3	24	Safety and operations training; submersible pump used; breakers; sensors	4	1	2	8	(2) Safety Training - LO/TO training, Chapter 4 (4) Review of electrical design - Pumps & drives test lab listed (5) Review of DCS - Flow sensors would indicate loss of pump	Closed	Shorting of pump should result in pump failure, which should be seen by the pump drive
4		Shock from electrical submersion heaters	4	2	3	24	Safety training	4	1	3	12	See item 3		
5		Anti-freeze pump shorts	4	2	3	24	Submersible pump used	4	1	2	8	See item 3	Closed	
6	FIRE - Fire	Anti-freeze tank leaks near ignition source	4	1	2	8	PG is slight fire hazard	4	1	2	8	(2) Safety Training - Chapter 3	Closed	
7		Anti-freeze tank overflows or PG spilled during filling	4	1	2	8	PG is slight fire hazard	4	1	2	8	See 6	Closed	
8		Anti-freeze tank starts on fire	4	1	2	8	PG is slight fire hazard	4	1	2	8	See 6	Closed	
9	MECHANICAL - Cuts	Sharp edges due to design	3	3	3	27	Inspect units for sharp corners; protective clothing; add "radiusing corners" to shop drawings	3	1	2	6	(3) Post-mfg inspection - PMI 3.1	Closed	
10		Sharp edges due to use or breakage	3	2	2	12	Operations Training	3	2	1	6	(2) Safety Training - Chapter 14	Closed	Training should describe that all broken items should be tagged, covered or fixed

## HAZARD ANALYSIS

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
11	MECHANICAL - Pinch/entrapment points	Trapped under skis	4	2	1	8	Training	4	2	1	8	None	Closed	
12		Hands trapped between hinged covers or covers & tank top	3	3	1	9	New Covers	2	3	1	6	None	Closed	Cover lighter and counterweighted on one tank which is open/closed most often
13		Hinged cover falls on hand	3	3	1	9	New Covers, Operations Training	3	2	1	6	(2) Safety Training - Chapter 17	Closed	Cover lighter and counterweighted on one tank which is open/closed most often
14	MECHANICAL - Trauma	Sled cannot support filled water tank	3	1	3	9	Sled analysis	3	1	3	9	(7) Sled analysis - Safety analysis 15	Closed	
15		Sled cannot support filled anti-freeze tank	1	2	3	6	Pallet used	1	2	3	6	None	Closed	Lack of support is not expected to result in injury.
16		Pumps being lowered into or raised from water tank	3	3	2	18	Training: means of lifting pumps, mechanical assist, implementation of lighter components	3	2	1	6	(2) Safety Training - Chapter 17 (8) Lifting mechanism for pumps - Utility crane made to lift pumps, PMI 3.4	Closed	
17		Screens being lowered into or raised from water tank	3	2	2	12	Training, means of lifting screens, mechanical assist	3	2	2	12	(2) Safety Training - Chapter 17 (8) Lifting mechanism for pumps - Utility crane made to lift pumps, PMI 3.4	Closed	
18		Water tank bursts due to inadequate design	3	2	3	18	Liner: force analysis by SeaBox	3	1	2	6	(9) Force analysis for water tanks by SeaBox - Analysis conducted by Seabox: tanks used during IV&T w/o incident of this nature	Closed	
19		Water freezes in tank causing tank failure	3	2	2	12	Temperature sensors: liner should contain water even in the case of a structural failure	3	2	1	6	(3) Post-mig inspection - PMI 3.5 (5) Review of DCS - Subsystem & system testing	Closed	
20		Muscle strain due to lifting hinged door	3	3	1	9	Ergonomics and lifting training, implementation of lighter covers counterweighted	3	2	1	6	(2) Safety Training - Chapter 17	Closed	See item 12

## HAZARD ANALYSIS

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
21	MECHANICAL - Trauma: person falls off top of tank	Person falls into empty water tank	4	2	2	16	Hatch covers; hose entry covers; training, added safety ladder to inside of tank	4	1	2	8	(2) Safety Training - Chapter 17 (3) Post-mfg inspection - PMI 3.4, hatch covers, doghouses, grating on walking surface	Closed	
22		Walking surfaces slippery due to ice or snow	4	3	2	24	Grated walkways; railings; landing at top of stairways, snow removal	4	1	2	8	(3) Post-mfg inspection - PMI 3.4	Closed	
23		Inadequate guardrail/toeboard on outside of tank top	4	2	2	16	Purchased part to OSHA standards; inspection	4	1	2	8	(3) Post-mfg inspection - PMI 3.4; water tanks reviewed for OSHA compliance by UW safety (no issues noted) (6) PM instructions - Included in startup & weekly safety walkthrough	Closed	
24		Irresponsible action (i.e., horseplay, running, jumping off tank )	4	3	2	24	Training	4	1	2	8	(2) Safety Training - Chapter 17	Closed	
25		Person trips while on top of tank	2	3	2	12	Snow removal Railings; doors are usually closed	2	3	2	12	None	Closed	
26	MECHANICAL - Trauma: person falls off stairway	Stairway breaks	4	2	3	24	Purchased part to OSHA standards; inspection	4	1	2	8	(3) Post-mfg inspection - PMI 3.4 (6) PM instructions - Included in startup & weekly safety walkthrough	Closed	
27		Stairway becomes detached from tank	4	2	2	16	Assembly/Inspection procedures; assembly training	4	1	2	8	(11) Assembly instructions- Included in startup & weekly safety walkthrough	Closed	
28		Inadequate stair rail	4	2	3	24	Purchased part to OSHA standards; inspection	4	1	2	8	See item 27	Closed	



## HAZARD ANALYSIS

Subsystem: Antifreeze and Water Tanks

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
29		Stairway surface slippery due to ice or snow	3	4	2	24	Anti-slip tread; periodic inspection; protective clothing (boots), snow removal	3	2	2	12	(3) Post-mfg inspection - PMI 3.4 (6) PM instructions - Included in startup & weekly safety walkthrough (12) Personal protective equipment - FDX boots w/ better traction bought for drillers	Closed	
30	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device (Propylene Glycol Tank)	1	1	2	2	None	1	1	2	2	None	Closed	Empty tank weighs -800 lbs. Per a discussion with the manufacturer on 10/1/02.
31		Inadequate lifting device (water tank)	4	2	2	16	Operator experience; weights marked on parts	4	1	1	4	(3) Post-mfg inspection - PMI 7.1	Closed	Total weight of components to be stenciled on each piece.
32		Inadequate lifting points on equipment or lifting apparatus (I.e., strap) breaks (anti-freeze tank)	4	2	1	8	Forklift pockets designed in tank; equipment at Pole	4	1	1	4	(10) Design of tank	Closed	Tank supplied with frame with fork lift pockets; empty tank weighs only 800 lbs.
33		Inadequate lifting points on equipment or lifting apparatus (I.e., strap) breaks (water tank)	4	3	3	36	Operator experience; weights marked on parts; ISO corners. Towed into position, training.	4	1	2	8	See item 31	Closed	
34	USE - Water	Person falls into water tank	4	2	2	16	Training; covers, safety ladder	4	1	1	4	(2) Safety Training - Chapter 17 Add safety ladder to inside of tank	Closed	Safety Ladder added
35		Person enters tank with water	4	2	1	8	Tank entry procedure, SOPS developed in 2005, safety ladder	4	2	1	8	(13) Develop procedure for entering tank wet or dry - Confined space entry, Safety Training Chapter 17; follow RPSC confined space entry process & LO/TO procedure Add safety ladder to inside of tank	Closed	Potential drowning or electrocution issue

**HAZARD ANALYSIS**

Subsystem: Antifreeze and Water Tanks

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
36	USE - Hose	Strain from lifting heated hose to top of water tank	3	2	1	6	Design change, lighter hose	2	1	1	2	Inspection	Closed	
37	USE - Tripping	Water leaks from tank & forms holes in snow	3	2	3	18	New liner; design of containers, cover holes and backfill as necessary	3	1	2	6	Inspection	Closed	
38		Anti-freeze leaks from tank & forms holes in snow	3	2	3	18	Cover holes and back fill as necessary, Training, IceCube spill clean-up plan	3	1	1	3	Training Records	Closed	
39		Tripping on hoses & cables	2	3	2	12	Camp redesign; redesign of support for cables/hoses; hoses/cables obvious to users	2	2	1	4	(2) Safety Training - Chapter 14	Closed	
40	USE - Tank safety	Person enters empty tank	4	2	2	16	Tank entry procedure, confined space training	4	2	1	8	See item 34	Closed	Potential suffocation issue

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	10/16/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 1-6; 8-10; 13; 15-17; 32-38; 40-44; 46-48; 50-51</li> <li>2 items open</li> <li>Removed Revision History on Page 2 (redundant)</li> <li>Added item 52 in reference to cable incident at SP</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Increased item 3 severity from 1 to 3 and item 13 severities from 2 to 3; Reduced item 14 probability from 6 to 4; Increased item 30 severities from 2 to 3; Combined hazards related to monitoring; Removed hazard related to pump on/off/speed; Reduced item 34 probabilities from 3 to 2 and item 36 detectability from 4 to 2; removed hazards related to E-Stop inadequacies	08/21/07	TCB
E		Annual review	7/24/08	TCB
F		Combined all hazards for inaccurate and non-functioning monitoring	7/30/09	TR
G		Annual review	4/21/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																
		<b>MADISON, WISCONSIN</b>																
		TITLE																
		<b>ENHANCED HOT WATER DRILL</b>																
		<b>DRILL CONTROL SYSTEM</b>																
		<b>HAZARD ANALYSIS SUMMARY</b>																
1	15	ORIGINATOR		DATE		ENGINEER		DATE		CHECKER		DATE						
2	16	Tim Rubino		4/28/10		T. Matt		4/28/10		J. Kalin		4/28/10						
3	17	CHECKER		DATE		PRODUCT ASSURANCE		DATE		PROJECT APPROVAL		DATE						
4	18	M. Thoma		4/28/10		M. Zernick		4/28/10										
5	19	FILENAME				8510-0122.RevG.doc				PROJECT NO.				8510				
6	20					8510-0122.RevG.xls												
7	21	DRAWING NO.				8510-0122				SCALE		SIZE		SHEET				
8	22									NA		A		Page 1 of 6				
9	23																	
10	24																	
11	25																	
12	26																	
13	27																	
14	28																	

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Drill Control System
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Drill Control System
<b>DOCUMENT #:</b>	8510-0122
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Drill Control System for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Drill Control System.

The Drill Control System monitors the following parameters:

- Water pressure
- Water temperature
- Water flow
- Water or fuel detector (for presence of)
- CO, smoke or heat detectors
- Fuel flow
- Level of water in water tanks
- Drill hose & cable payout & tension
- Downhole monitoring (angle & hole size)

The Drill Control System controls the actuation of the following parameters:

- Pump on/off & speed
  - Air intake
  - Heater burner on/off
  - Fuel line open/close
  - Drill hose & cable velocity
  - Motor & mechanical brakes
- e-stop system

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0122 – Hazard Analysis Table (FMEA) table

8510-0122 – Hazard Analysis, Meeting Notes

Control System Input/Output from 9/4/02 NSF Meeting

### 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Use – Monitoring, actuation, e-stop, tripping

### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	24
Major Risk Reduced to Moderate:	0
Major to Minor:	3
Moderate to Moderate:	2
Moderate to Minor:	9
Minor to Minor:	10
# Mitigated to Minor:	12
# Justified:	2
# Unmitigated (or Minor to Minor):	10
# Eliminated:	0

### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- Additional mitigation may introduce additional or more serious risk.
- It may be cost prohibitive to implement additional mitigation.
- It may be technologically difficult to implement additional mitigation.
- Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
3	Water pressure monitoring inaccurate down hole, pump damage hazard	<b>It may be technologically difficult to implement additional mitigation.</b> Range of water pressure has defined boundaries
33	Brakes not actuated correctly	<b>It may be technologically difficult to implement additional mitigation.</b> The brake is designed to be failsafe; if power is cut to the system, the brake is applied. This will occur during e-stops & during normal powerdowns, such as moving the reel to the next hole. The application of the brake will be checked during PM inspections also. The brake may be applied manually for operational use. For this issue to result in a potentially hazardous condition, the following conditions would need to be present: (1) power is removed from the reel motor or the gear box/driveshaft has broken (2) the drill hose is not being supported by the cable reel (3) the drill hose is in a position where it could drop/fall (4) brake does not apply (5) someone in harm's path.

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

**CLOSED** – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

**IMPLEMENT** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

**REVIEW** – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

**REOPEN** – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Review DCS design for: <ul style="list-style-type: none"> <li>• Redundant pressure, flow &amp; temperature sensors</li> <li>• Limit checking</li>   <li>• Fuel flow sensors</li> <li>• Localizing mechanism for determining where e-stop was activated</li> </ul>	<ul style="list-style-type: none"> <li>• Redundant sensors present</li> <li>• Limit checking not instituted for pressure sensors; user definable underflow &amp; over-temperature alarms &amp; shutoffs instituted (checked during IV&amp;T)</li> <li>• Present</li> <li>• Checked during IV&amp;T</li> </ul>
2	Hose testing	NA

3	<p>Verification testing (including):</p> <ul style="list-style-type: none"> <li>• All flow, pressure, temperature &amp; fluid sensors work &amp; reflect accurate readings</li> <li>• Payout monitoring works &amp; accurately measures payout</li> <li>• Environmental sensors (CO, fire, smoke) work correctly</li> <li>• Actuation parameters controlled accurately (pump on/off, pump speed, burner on/off, ventilation, fuel line open/close,</li> <li>• Brakes actuated properly</li> <li>• System resets to safe state after e-stop</li> <li>• E-stop system operates properly</li> <li>• Localization of e-stop activation</li> </ul>	<ul style="list-style-type: none"> <li>• All items checked during IV&amp;T, except environmental sensors</li> <li>• Operation of environmental sensors verified at South Pole</li> </ul>
4	<p>Safety Training (including):</p> <ul style="list-style-type: none"> <li>• Tag teams when entering/working on equip. MDS's</li>   <li>• Conduct "all clear" notification prior to restarting system after e-stop</li> <li>• Trip hazards</li> <li>• Burying cables</li>   <li>• Cable Hazards</li> </ul>	<p>Safety Training Manual:</p> <ul style="list-style-type: none"> <li>• Discussed during trainings &amp; meetings, but not stated in safety training manual</li> <li>• Chapter 6</li> <li>• Chapter 14</li> <li>• No plan to bury control system cables; cables should be noticeable on snow; cables run in utility alley in SES to minimize trip hazard; see trip hazard above</li> <li>• Verify safety trainings were completed at SP</li> </ul>
5	<p>PM instructions (including):</p> <ul style="list-style-type: none"> <li>• Proper operation of environmental monitors (CO, smoke, fire)</li> <li>• Proper operation of fluid monitors</li> <li>• Brake actuation</li> <li>• System resets to safe state after e-stop</li> <li>• E-stop system operates properly</li> <li>• Localization of e-stop activation</li> </ul>	<ul style="list-style-type: none"> <li>• All included in Startup &amp; Weekly Safety Inspections except fluid sensors</li> <li>• Operation of fluid monitors needs to be added to walk-thru inspections</li> </ul>
6	Review of ventilation design	Safety Analysis 14

6.2 Issues – None



## HAZARD ANALYSIS

Subsystem: Drill Control System

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
1	USE - Monitoring inaccurate/ non-functional	Water pressure monitoring inaccurate/non-functional in heater MDS's, causing equipment problem	3	2	3	18	Redundant pressure & flow monitors; limit checking on sensor values; verification testing, Pressure relief devices in HPP, torque limits in pump motor controller	3	1	1	3	1) DCS design - redundant sensors; ranges indicated on-screen 3) Verification testing - System & subsystem testing		Closed	
2		Water pressure monitoring inaccurate/non-functional in pump MDS	3	2	3	18	Redundant pressure & flow monitors; limit checking on sensor values; verification testing, Pressure relief devices in HPP, torque limits in pump motor controller	3	1	1	3	See item 1		Closed	
3		Water pressure monitoring inaccurate/non-functional down hole, pump damage hazard	3	3	2	18	Repeated limit checking, training, spares for pressure sensor	3	3	2	18	1) DCS design - ranges indicated on-screen		Closed	
4		Water temperature monitoring inaccurate/non-functional in heater MDS's, overhear noise hazard, heater could burn	3	2	2	12	Redundant temperature monitors; limit checking on sensor values; verification testing, automatic shutdown	3	1	1	3	1) DCS design - redundant sensors; over-temperature alarm & automatic shutoff designed into software 3) Verification testing - Subsystem testing		Closed	
5		Water temperature inaccurate/non-functional in pump MDS	2	2	2	8	Redundant temperature monitors; limit checking on sensor values; verification testing	2	1	1	2	See item 4		Closed	
6		Water temperature monitoring inaccurate/non-functional in drill head	1	4	2	8	Verification testing	1	4	2	8	1) DCS design - redundant sensors; - Drill head tests		Closed	If water temperature monitoring becomes inaccurate software will slow drill down
7		Water temperature monitoring inaccurate/non-functional in water tanks	1	3	2	6	None	1	3	2	6	None		Closed	

## HAZARD ANALYSIS

Subsystem: Drill Control System

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic

Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual

Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor

13-35 Yellow- moderate

≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
8		Water flow monitoring inaccurate/non-functional in heater MDS's, burn hazard	3	2	3	18	Redundant pressure & flow monitors; limit checking on sensor values; hose tests; verification testing, Pressure relief devices in HPP, torque limits in pump motor controller	3	1	1	3	1) DCS design - redundant sensors; underflow alarm & shutoff designed into software 3) Verification testing - Subsystem testing, gages on stacks, visual temperature gage, shut off sensors		Closed	
9		Water flow monitoring inaccurate/non-functional in pump MDS	3	2	3	18	Redundant pressure & flow monitors; limit checking on sensor values; hose tests; verification testing, Pressure relief devices in HPP, torque limits in pump motor controller	3	1	1	3	See item 1, gages on stacks, visual temperature gage, shut off sensors		Closed	Automatic shut-off system when pressure/torque in system drops
10		Fuel flow monitoring inaccurate/non-functional	1	2	3	6	None	1	2	3	6	None		Closed	There are no fuel flow monitors
11		Water level monitoring in water tanks inaccurate/non-functional	1	3	2	6	None	1	3	2	6	None		Closed	Vane pumps lowered to reduce risk
12		Payout/tensioning monitoring inaccurate/non-functional for drill hose & cable	3	3	1	9	Visually detectable; verification testing	3	3	1	9	3) Verification testing - Subsystem & system testing		Closed	
13		Down hole monitoring inaccurate/non-functional	1	4	1	4	Pressure/temp monitoring	1	4	1	4	Training Records		Closed	Includes hole diameter, drill angle. The inclinometer is normally slightly inaccurate.
14		CO detectors monitoring incorrectly or malfunctioning	4	4	3	48	Tag team; PM instructions; verification testing, periodic and start-up check of batteries, redundant detectors	4	3	1	12	3) Verification testing - Operation verified at South Pole 4) Training - Chapter 2 5) PM instructions - Included in Startup & Weekly Safety Inspections		Closed	Changing position of CO detectors

## HAZARD ANALYSIS

### Subsystem: Drill Control System

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
15		Smoke or fire detectors monitoring incorrectly or malfunctioning	4	4	3	48	Visually/smell detectable; PM instructions; verification testing, periodic and start-up check of batteries, redundant detectors	4	3	1	12	3) Verification testing - Operation verified at South Pole 4) Training - Chapter 2 5) PM instructions - Included in Startup & Weekly Safety Inspections		Closed	
16		Fluid detectors (water and fuel) monitoring incorrectly or malfunctioning	4	5	2	40	Visually/smell detectable; PM instructions; verification testing	4	2	1	8	3) Verification testing 5) PM instructions - Needed		Closed	Fluid detectors to be replaced 09/10
17	USE - Actuation incorrect	Air intake not controlled correctly	4	2	2	16	Ventilation redesigned, monitors	4	2	1	8	3) Verification testing - Subsystem & system testing 6) Ventilation design - Safety Analysis 14		Closed	Redesigned for personnel reasons
18		Heater burner on/off not controlled correctly	4	2	2	16	Temperature and flow valves need to be verified; verification testing, sensors	4	2	1	8	1) DCS design - Redundant sensors; underflow & over-temperature alarms & shutoffs in software 3) Verification testing - Subsystem testing		Closed	Rodwell has some computer controlled valves; heaters are manually controlled for flow
19		Fuel line open/close not controlled correctly	3	2	3	18	Fuel flow sensors; verification testing	3	2	1	6	E-Stop design 3) Verification testing - Subsystem testing		Closed	No computer control of fuel lines
20		Drill hose & cable velocity not controlled correctly	2	3	1	6	Manually measure and compare to sensor	2	3	1	6	None		Closed	Calibration before drilling
21		Brakes not actuated correctly	4	2	2	16	Verification testing; PM instructions, redesign of brakes	4	2	2	16	3) Verification testing - Subsystem & system testing 5) PM instructions - Startup & Weekly Safety Inspections		Closed	
22	USE - e-stop	Cannot localize where estop was tripped causing delay getting to injured party	4	2	2	16	Localizing mechanism; verification testing; PM, software upgrade	4	1	1	4	1) DCS design - Position of e-stop can be located		Closed	

**HAZARD ANALYSIS**

**Subsystem: Drill Control System**

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
23	USE - Tripping	Exposed cables and hoses	2	5	1	10	Training; Covers	2	2	1	4	4) Training - Chapter 14		Closed	Avoid high risk areas
24	MECHANICAL-Trauma	Cable backlash during unrequested movement of cable back down into hole. Cable could strike or pull someone.	4	2	3	24	Hazards and Safety Training	4	1	2	8	(4) Safety Training Records.		Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	7/09/09	TR
A		Annual Review	3/31/10	TR

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	A	A	A	A														

CONTROLLED COPY DIST. LIST		THE UNIVERSITY OF WISCONSIN																	
1	15	<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																	
2	16	<b>TITLE</b> <b>ENHANCED HOT WATER DRILL CABLE TENSIONER HAZARD ANALYSIS SUMMARY</b>																	
3	17																		
4	18	<b>ORIGINATOR</b> <b>DATE</b> <b>ENGINEER</b> <b>DATE</b> <b>DRAFTSPERSON</b> <b>DATE</b>																	
5	19	Tim Rubino      3/14/10      T. Benson																	
6	20																		
7	21	<b>CHECKER</b> <b>DATE</b> <b>PRODUCT ASSURANCE</b> <b>DATE</b> <b>PROJECT APPROVAL</b> <b>DATE</b>																	
8	22	Dennis Duling																	
9	23	<b>FILENAME</b> 8510-0123.RevA.doc <b>PROJECT NO.</b> 8510																	
10	24	8510-0123.RevA.xls																	
11	25	<b>DRAWING NO.</b> 8510-0123 <b>SCALE</b> <b>SIZE</b> <b>SHEET</b>																	
12	26	NA      A																	
13	27	Page 1 of 4																	
14	28																		

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube

<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Cable Tensioner
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Cable Tensioner
<b>DOCUMENT #:</b>	8510-0123
<b>REVISION:</b>	A
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Cable Tensioner for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Cable Tensioner.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0114 – Hazard Analysis Table (FMEA) table

8510-0114 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Mechanical – Cuts, pinchpoints, trauma
- Thermal – Burns
- Use –tripping

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	15
Major Risk Reduced to Moderate:	0
Major to Minor:	0
Moderate to Moderate:	0
Moderate to Minor:	3
Minor to Minor:	12
# Mitigated to Minor:	3
# Justified:	0
# Unmitigated (or Minor to Minor):	12
# Eliminated:	0

## 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
None		

## 6.0 STATUS OF THE HAZARD ANALYSIS (choose one of the following)

**CLOSED** – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

**IMPLEMENT** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

**REVIEW** – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

**REOPEN** – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.



**HAZARD ANALYSIS**

Subsystem: Cable Tensioner

Author: T. Rubino

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Lubricants leaking out of equipment	Grease spilling from equipment	1	2	1	2	None	1	2	1	2			
2	MECHANICAL - Cuts	Splinters from plywood	2	2	3	12	Gloves, Training, PPE	2	1	3	6			
3	MECHANICAL - Pinch/entrapment points	Body part caught in sprocket chain/ECW	3	2	2	12	Training, Partial Guarding	3	1	1	3			Small "fingers caught in gears" sign
4		Body part caught in cable/ECW	4	2	2	16	Training, Signage, Guarding	4	1	1	4			Loose clothing sign
5		Body part caught in fairlead/ECW	3	2	2	12	Training, Signage	3	1	1	3			Small "fingers caught in gears" sign
6		Body part caught in disc brake/ECW	3	1	2	6	Training, Signage	3	1	1	3			
7		Trapped under skis	3	2	2	12	Training	3	1	1	3			
8	MECHANICAL - Trauma	Tensioner tips and falls on person	4	1	2	8	Training, barcade, anchored	4	1	1	4			
9		Rating exceeded and tensioner fails	4	2	3	24	1) Monitor Torque 2) Periodic Inspection 3) Torque Limit	4	1	1	4			
10		Cable slips off reel and strikes person and/or damages cable	4	3	2	24	Training, continuous monitoring	4	1	1	4			
11		Mounting bolts shear, tensioner slides of skid	4	1	3	12	Setup inspection, rated bolts	4	1	3	12			
12	Thermal - Burn	Burn from touching disc brake	2	2	3	12	Signage, gloves, training	2	1	2	4			Hot temp signage
13	Use - Tripping	Trip on cables	2	3	1	6	Training, barcade, signage	2	2	1	4			

**HAZARD ANALYSIS**

Subsystem: Cable Tensioner

Author: T. Rubino

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
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 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
14		Trip on anchor	2	3	1	6	Training, barricade	2	2	1	4			
15		Slipping on tensioner platform	2	3	2	12	anti-skid, training	2	2	2	8			



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	12/9/02	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for: 2-3; 6; 8-9; 17-18; 20-23; 27; 30-33; 37-38; 42</li> <li>6 items open</li> <li>Removed Revision History on page 2 (redundant)</li> <li>Updated schematic to eliminate pre-heat water line</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB
D		Added mitigations of "alarm system, Containment" to item 9, "use of conduit" to item 18, and "fuel meter" to item 36	08/21/07	TCB
E		Annual review	7/24/08	TCB
F		Annual review	7/7/09	TR
G		Annual review	4/16/10	TR

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	G	G	G	G	G	G												

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																				
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																				
1	15	<b>TITLE</b>																				
2	16	<b>ENHANCED HOT WATER DRILL</b>																				
3	17	<b>FUEL SYSTEM</b>																				
4	18	<b>HAZARD ANALYSIS SUMMARY</b>																				
5	19	<b>ORIGINATOR</b>				<b>DATE</b>				<b>ENGINEER</b>				<b>DATE</b>				<b>CHECKER</b>		<b>DATE</b>		
6	20	Tim Rubino				4/20/10				T. Matt				4/20/10				D. Pernic		4/20/10		
7	21	<b>CHECKER</b>				<b>DATE</b>				<b>PRODUCT ASSURANCE</b>				<b>DATE</b>				<b>PROJECT APPROVAL</b>		<b>DATE</b>		
8	22	T. Matt				4/20/10				M. Zernick				4/20/10								
9	23	<b>FILENAME</b>						8510-0123.RevG.doc						<b>PROJECT NO.</b>						8510		
10	24							8510-0123.RevG.xls														
11	25	<b>DRAWING NO.</b>						8510-0123						<b>SCALE</b>		<b>SIZE</b>		<b>SHEET</b>				
12	26													NA		A		Page 1 of 6				
13	27																					
14	28																					

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<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Fuel System
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Fuel System
<b>DOCUMENT #:</b>	8510-0123
<b>REVISION:</b>	G
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

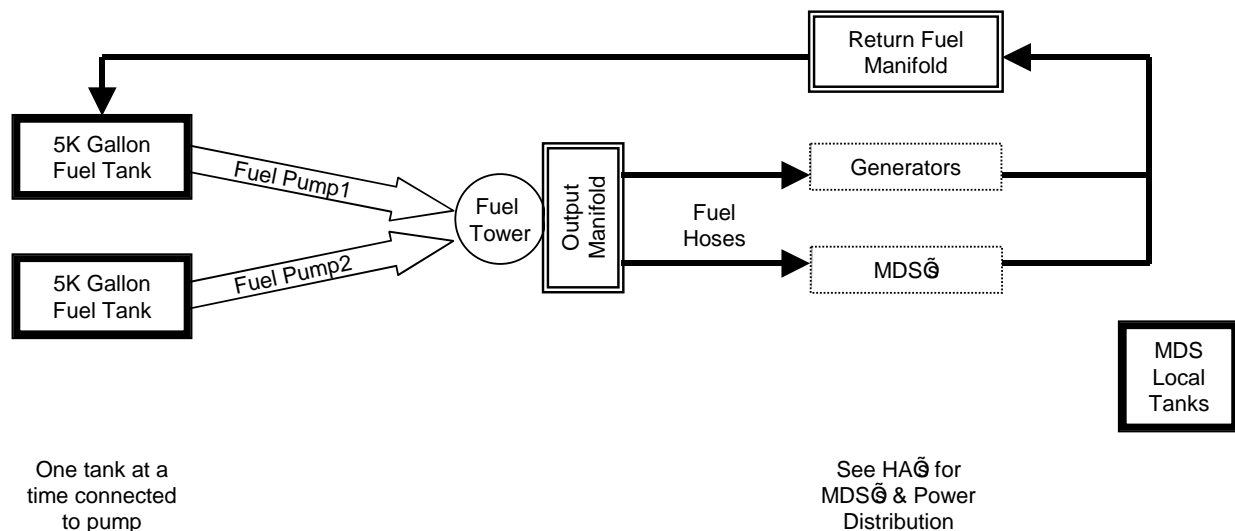
## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Fuel System for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Fuel System.

***The components of the fuel system addressed in this document are:***

- ***Main fuel tanks (5K)***
- ***Local fuel tanks at TOS, TOW & SEW***



- ***Fuel lines & manifolds to MDS's & generators***

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0123 – Hazard Analysis Table (FMEA) table

8510-0123 – Hazard Analysis, Meeting Notes

8510-0002 – Drill Camp Drawing

### 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Fire
- Mechanical – Cuts, trauma
- Use – Tripping, water leakage, fuel feed to MDS's/generators

### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	38
Major Risk Reduced to Moderate:	0
Major to Minor:	1
Moderate to Moderate:	0
Moderate to Minor:	4
Minor to Minor:	33
# Mitigated to Minor:	5
# Justified:	0
# Unmitigated (or Minor to Minor):	33
# Eliminated:	0

### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.

- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
	None	

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Tower spill pan present</li> <li>• Spill pans available for fuel connections to 5K tanks (since the 5K tanks are at the South Pole, we cannot verify the use of their spill pans during testing, just the availability of the spill pans)</li> <li>• Dry disconnects used on fuel hoses</li> <li>• Overflow drain built into tower</li> <li>• Breakers on all fuel &amp; water pumps</li> <li>•</li> <li>• GFI's on all fuel pumps</li> <li>• No exposed conductors or terminals on fuel or water pumps</li> <li>• Enclosed (TENV) motors used for fuel pumps</li> <li>• Verify self-extinguishing hoses used for fuel</li> <li>• Sharp edges</li> <li>• Verify pumps do not have entrapment points</li> <li>• Verify use of two fuel pumps</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 9.1</li> <li>• PMI 9.1</li> <li>• PMI 9.1</li> <li>• Each pump is on its own dedicated circuit &amp; circuit breaker</li> <li>• PMI 2.2</li> <li>• PMI 9.1</li> <li>• PMI 9.1</li> <li>• PMI 3.1</li> <li>• PMI 3.1</li> <li>• PMI 9.1</li> </ul>

2	Safety Training (including): <ul style="list-style-type: none"> <li>No smoking areas</li> <li>Location of fuel system components</li> <li>Disconnect procedure for hoses</li> <li>Repairing, tagging broken items</li> <li>Suspending hoses in hose trays</li> <li>Trip hazards</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>Chapter 2</li> <li>Chapter 2</li> <li>To do</li> <li>Chapter 14</li> <li>Chapter 14</li> <li>Chapter 14</li> </ul>
3	Develop chemical spill kit	Pre-made spill kits shipped with safety equipment; chemical spill response quick guide included in emergency response binder
4	PM instructions (including): <ul style="list-style-type: none"> <li>Check local tanks for leaks</li> <li>Monitor fuel spill pans on tower</li> <li>No exposed conductors or terminals on fuel pumps (water pumps used to pre-heat fuel were originally included in this item; the pre-heat loop with the water pumps was eliminated)</li> <li>Broken equipment or sharp edges</li> <li>Fuel level daily</li> </ul>	<ul style="list-style-type: none"> <li>Included in Startup &amp; Weekly Safety Inspections</li> <li>Included in Startup &amp; Weekly Safety Inspections</li> <li>Included in Startup &amp; Weekly Safety Inspections on fuel pumps</li> <li>Included in Startup &amp; Weekly Safety Inspections on fuel pumps</li> </ul>
5	Structural analysis on fuel tower	
6	<ul style="list-style-type: none"> <li>Verify double-walled tanks are used</li> <li>Verify whether the space between the walls will be monitored for fluid</li> </ul>	
7	Develop process for collecting fuel when draining the hose	
8	Verify that the mountings on the MDS's to support the local tanks are effective	NA – tanks are free-standing (not mounted to MDS's)

## 6.2 Issues – None



## HAZARD ANALYSIS

Subsystem: Fuel System

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	CHEMICAL - Environmental hazard (fuel leaks)	Fuel tank leaks	3	2	2	12	Fuel tank containment (catch basin)	2	2	2	8		Closed	Puncture due to trauma; cracking of tank material due to sunlight or cold; detectability may not be obvious if the tanks leak underneath
2		Local tanks leak (near TOS)	2	2	2	8	Inspection	2	2	2	8	4) PM inspection - Included in Startup & Weekly Safety Inspections -Double walled -Painted	Closed	Puncture due to trauma; cracking of tank material due to sunlight or cold;
3		Day tank leaks	2	2	2	8	Spill pan; monitor pans periodically, sensors in pan	2	2	1	4	1) Post-mfg inspection - PMI 9.1 4) PM inspection - Included in Startup & Weekly Safety Inspections	Closed	Breakaway valves may be installed
4		Manifold leaks	2	3	2	12	Spill pan; monitor pans periodically	2	2	1	4	See item 3	Closed	
5		Hose breaks	2	2	2	8	Inspections	2	2	2	8	None	Closed	No hose breaks were reported for AMANDA
6		Hose connectors leak	2	3	2	12	Quick, dry disconnects used on fuel hoses, spill pans	1	2	2	4	1) Post-mfg inspection - PMI 9.1 4) PM inspection - Included in Startup & Weekly Safety Inspections	Closed	We would expect to see a few drips; a large volume is not anticipated
7	CHEMICAL - Environmental hazard (fuel spills)	5K fuel tanks overflow during filling	3	2	2	12	Not done on our premises; RPSC fills tanks at SP station; person should be present during refueling	2	2	2	8	None	Closed	
8		Local tanks overflow during filling	2	2	2	8	Spill kit, RPS fills tanks	2	2	2	8	3) Develop chemical spill kit - Shipped w/ safety equipment along w/ chemical spill response quick guide	Closed	
9		Day tank overflows - input fuel rate too high	2	2	2	8	Float valve connected to pump switch; tower has overflow drain if fuel level gets too high; alarm system; containment -Spill Plan	2	1	2	4	1) Post-mfg inspection - PMI 9.1	Closed	

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
10		Fuel lost when switching hoses between 5K tanks	3	3	1	9	Dry disconnects on hoses	2	2	1	4	1) Post-mfg inspection	Closed	Get Drip pans
11		Fuel lost during hose draining	2	3	1	6	Capture fuel during draining	1	2	1	2	7) Developed practice for capturing fuel when emptying hose	Closed	5 Gallon Buckets ordered
12		Fuel lost when disconnecting hoses for year end	2	3	1	6	Dry disconnects	1	2	1	2	See item 11	Closed	5 Gallon Buckets ordered
13	CHEMICAL - Reactivity	Fuel incompatible with tanks	3	1	3	9	One type of fuel in use at South Pole, UL approved tanks	1	1	3	3	None	Closed	
14		Fuel incompatible with hoses & fittings	3	1	3	9	One type of fuel in use at South Pole, fuel rated hoses	1	1	3	3	None	Closed	
15	CHEMICAL - Toxicity	Breathing of fumes or ingestion of fuel	4	2	1	8	HazCom Training, MSDS available	2	2	1	4	None	Closed	
16		Dermal contact	4	2	1	8	HazCom Training, MSDS available, PPE	2	2	1	4	None	Closed	
17	ELECTRICAL - Shock	Fuel pump shorts (2 fuel pumps used)	3	2	2	12	Breakers	3	1	2	6	1) Post-mfg inspection - Each pump is on its own dedicated circuit & circuit breaker	Closed	480 VAC pumps
18		Fuel pump has exposed conductors	4	3	3	36	Inspection; use of conduit, wired to code	4	2	1	8	1) Post-mfg inspection - PMI 2.2 4) PM inspection - Review fuel tower for damage is included in Startup & Weekly Safety Inspections	Closed	
19		Fuel pump has poor ground	2	3	2	12	Circuit breaker	2	2	2	8	1) Post-mfg inspection - verified circuit breakers on all fuel system pumps	Closed	
20	FIRE - Fire	Leak/spillage from tanks, manifold or day tank near ignition source	4	2	2	16	No smoking zones; fuel system located away from ignition sources	4	1	1	4	2) Training - no smoking & location of fuel system components - Chapter 2	Closed	Not near an ignition source, except fuel pumps
21		Tanks, manifold or day tank near ignition source	4	1	2	8	No smoking zones; fuel system located away from ignition sources	4	1	1	4	See item 20	Closed	

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
22		Smoking or user error ignites component of fuel system	4	2	2	16	No smoking zones, operations and safety training	4	2	1	8	See item 20	Closed	
23		Fuel spills/leaks onto operating fuel pump	4	1	2	8	Enclosed (TENV) motors	4	1	2	8	1) Post-mfg inspection - PMI 9.1	Closed	
24		Hose/connector break near ignition source	4	1	2	8	Utility alley is a non-smoking area	3	1	2	6	See item 20	Closed	No ignition sources in utility alley
25		Fuel pump shorts with exposure to fuel	4	1	2	8	Breakers; terminals covered	4	1	2	8	See item 17	Closed	
26		Fire in MDS starts fire in a fuel feeder hose	4	1	2	8	Disconnect procedure for hoses; fire resistant hoses, fire extinguisher	4	1	2	8	1) Post-mfg inspection - PMI 9.1; fusamatic valves on inputs; manual & solenoid valves on each fuel input to a MDS; shutoff valves on fuel tower 2) Training - Chapters 2 & 6; fire & e-stop procedures	Closed	
27	MECHANICAL - Cuts	Sharp edges due to design	3	3	3	27	Inspection PPE - Gloves	3	1	2	6	1) Post-mfg inspection - PMI 3.1	Closed	
28		Sharp edges due to use or breakage	3	2	2	12	Periodic inspection; repairing broken items PPE - Gloves	3	2	1	6	1) Post-mfg inspection - PMI 3.1 2) Training - Chapter 14 4) PM inspection - Included in Startup & Weekly Safety Inspections	Closed	
29	MECHANICAL - Entrapment	Body or clothes caught in rotating member of pump	4	1	2	8	Design shields of pump	3	1	2	6		Closed	
30	MECHANICAL - Trauma	Day tank collapses	4	2	1	8	Design; training	4	1	1	4	5) Structural analysis on tower	Closed	This is expected to require force from an outside source such as impact from a caterpillar.
31		Day tank tips over	4	2	1	8	Design; training	4	1	1	4	See item 30	Closed	
32		5K tank tips over (i.e., hit by caterpillar)	4	1	1	4	Designed not to tip easily, training	3	1	1	3	See item 30	Closed	

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
33	USE - Tripping	Exposed hoses	2	5	2	20	Routed hoses; walkways covered, training	2	3	2	12	2) Training - Chapter 14	Closed	
34		Fuel leaks from tank & forms holes in snow	2	2	2	8	Drip pan under tower, holes are covered or backfilled, containment	2	1	2	4	See item 3	Closed	
35	USE - Water leakage	Water leaks from preheat hose or connector into fuel tower	2	2	3	12	UL approved vents - Don't allow H2O to get into tank	2	2	3	12	None	Closed	
36	USE - No fuel	5K tanks empty	2	2	2	8	Check fuel level periodically, fuel meter	2	2	1	4	4) PM inspection	Closed	5K tanks are dipped every shift
37		Fuel pumps non-functional or fuel pump hose blocked	2	2	2	8	2 pumps (redundant)	2	2	2	8	1) Post-mfg inspection - PMI 9.1	Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	5/5/03	See original
A		<ul style="list-style-type: none"> <li>Updated mitigation information for items: 9-16; 18; 20; 22-25; 28; 35; 37; 40; 42-44; 49-50</li> <li>7 items open</li> <li>Removed Revision History on page 2 (redundant)</li> <li>Added item 31 as per the cable incident at SP</li> </ul>	2/7/05	
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/2006	TCB
D		Removed 5 hazards related to 4" drill; Item 13 probability reduced from 2 to 1 due to new mitigation; Failure cause 21 changed to include "banding", initial probability reduced from 4 to 2, initial detectability and residual probability reduced from 3 to 2; Item 22 severities reduced from 6 to 4 and 5 to 4; Item 27 severities reduced from 5 to 4; Added item 37; Item 39 severity reduced from 5 to 4; Added item 48	08/21/07	TCB
E		Annual review	7/24/08	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	E	E	E	E	E	E												

CONTROLLED COPY DIST. LIST		THE UNIVERSITY OF WISCONSIN																												
1	15	<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																												
2	16	TITLE																												
3	17	<b>ENHANCED HOT WATER DRILL DRILLING OPERATIONS HAZARD ANALYSIS SUMMARY</b>																												
4	18	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>ORIGINATOR</td> <td>DATE</td> <td>ENGINEER</td> <td>DATE</td> <td>DRAFTSPERSON</td> <td>DATE</td> </tr> <tr> <td>Tim Brenner</td> <td>7/15/08</td> <td>T. Benson</td> <td>7/24/08</td> <td></td> <td></td> </tr> </table>																	ORIGINATOR	DATE	ENGINEER	DATE	DRAFTSPERSON	DATE	Tim Brenner	7/15/08	T. Benson	7/24/08		
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<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Drilling Operations
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Drilling Operations
<b>DOCUMENT #:</b>	8510-0124
<b>REVISION:</b>	E
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with Drilling Operations for the Enhanced Hot Water Drill (EHWD); develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for Drilling Operations.

This hazard analysis covers those issues that are not a part of the larger equipment HA's and, therefore, not previously covered in those HA's. The topics covered in this HA are:

- Mechanical Drill
- Firm Drill Head (~250 lbs.)
  - Connecting/disconnecting from drill hose
  - Assembling weights to firm drill head
  - Storage
- Main Drill Head (~1200 lbs.)
  - Connecting/disconnecting from drill hose
  - Assembling weights to firm drill head
  - Storage
- Drilling
- Hole Safety
- Drill Hose and Return Water Hose maintenance between holes (to prevent freezing of water or water from running out of hose)

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0124 – Hazard Analysis Table (FMEA) table

8510-0124 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Electrical
- Environmental
- Mechanical – Lifting, pinchpoints, trauma

- Suspended Mass
- Thermal – Burns, cold
- Use – e-stop, holes, leaks, tripping, water

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	47
Major Risk Reduced to Moderate:	0
Major to Minor:	1
Moderate to Moderate:	0
Moderate to Minor:	15
Minor to Minor:	31
# Mitigated to Minor:	16
# Justified:	0
# Unmitigated (or Minor to Minor):	31
# Eliminated:	0

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

<b>ITEM #</b>	<b>HAZARD/CAUSE</b>	<b>JUSTIFICATION</b>
	None	



**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Electrical inspection: <ul style="list-style-type: none"> <li>• Verify use of fingersafe connectors on e-stop circuit</li> <li>• Verify circuit breakers on exterior outlets to power 4" drill</li> </ul>	<ul style="list-style-type: none"> <li>• Done-8510-0019</li> </ul>
2	Safety Training (including): <ul style="list-style-type: none"> <li>• Lifting                             <ul style="list-style-type: none"> <li>• Cables, hoses</li> <li>• Drill head weights</li> <li>• Positioning drill head, firm drill or pump</li> <li>• Lifting 4" drill</li> </ul> </li> <li>• Pinchpoints                             <ul style="list-style-type: none"> <li>• Connecting cables or hoses</li> <li>• Between heads/pump &amp; wall during storage</li> <li>• Between drill head components</li> </ul> </li> <li>• TOS/tower unoccupied during transport</li> <li>• Potential cargo strap injuries</li> <li>• Do not stand in a loop of cable or hose</li> <li>• Do not stand under 4" drill tower during installation</li> <li>• Do not occupy equipment buildings for extended periods</li> <li>• Covering holes                             <ul style="list-style-type: none"> <li>• Completed hole</li> <li>• Pre-drilled firm holes</li> <li>• 4" mechanical hole</li> </ul> </li> <li>• Fluid leaks (water, chemicals) causing holes in snow</li> <li>• Tripping on ridges or holes in snow</li> <li>• Placing flags on cables for better visibility</li> <li>• Cabling Hazards</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>• Chapter 14 – all 4 items</li>   <li>• Chapter 14 – all 3 items</li>   <li>• Chapter 14</li> <li>• Chapter 14</li> <li>• Chapter 14</li> <li>• Chapter 14</li> <li>• Chapter 14</li> <li>• Chapter 13 – all 3 items</li>   <li>• Chapter 13</li> <li>• Chapter 13</li> <li>• Chapter 14</li> <li>• Safety trainings were completed at South Pole</li> </ul>
3	Post manufacturing inspection (including): <ul style="list-style-type: none"> <li>• Means to secure drill head, firm head &amp; return pump in TOS during interhole transport</li>   <li>• Means to secure return water hose to Tank 1</li> <li>• Attachments for drill head support straps in tower</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.5 – Drill head &amp; return water pump placed on carrier &amp; secured to unistrut</li> <li>• Firm drill</li> <li>• PMI 3.5</li> <li>• Completed at South Pole</li> </ul>
4	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>• Gloves - Contact with cold surfaces, handling 4" drill, removing cargo straps</li> </ul>	Safety Training Chapter 1

Item	Evidence	Completed/Attached
	<ul style="list-style-type: none"> <li>• Eye protection - Removing cargo straps</li> <li>• Outerwear - Splashing water</li> </ul>	
5	Verify availability of the following items: <ul style="list-style-type: none"> <li>• Kevlar keepers to secure hose sections when blowing water out of hoses</li> <li>• Slips to secure drill sections</li> </ul>	<ul style="list-style-type: none"> <li>• Verified at South Pole during operations</li> </ul>
6	User instructions (including): <ul style="list-style-type: none"> <li>• Secure hose/cable with rope prior to mounting or dismounting from tower (to prevent hose or cable from falling off tower)</li> </ul>	In draft procedures for firm drilling & sub pump installation/removal
7	PM inspection: <ul style="list-style-type: none"> <li>• Inspections of equipment &amp; MDS's to verify proper operation &amp; no incipient failures</li> </ul>	Included in Startup & Weekly Safety Inspections

6.2 Issues – None

**HAZARD ANALYSIS**

Subsystem: Drilling Operations

Author: M. Zernick

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN		
1	ELECTRICAL-Shock	Disconnecting/reconnecting power to TOS's	4	2	2	16	Fingersafe connectors; Training	4	1	1	4	Training records	Closed
2		Disconnecting/reconnecting e-stop to TOS's	3	2	2	12	Operates at < 48VDC; fingersafe connectors	2	1	1	2	1) Electrical inspection	Closed
3		Disconnecting/reconnecting communications to TOS's	1	2	2	4	None	1	2	2	4	None	Closed
4		Cut or drill into power lines	4	2	1	8	Cables obvious in work areas; elevated in drill camp; on snow in areas where drilling will not occur	4	1	1	4	None	Closed
5	ENVIRONMENTAL - Fatigue	Initial adjustment to altitude & climate	2	6	1	12	Awareness, change to work schedule to reduce hours on duty, increased crew size, operations training; Diomox and initial day off	2	5	1	10	None	Closed
6		General fatigue due to altitude	2	6	1	12	Awareness, change to work schedule to reduce hours on duty, increased crew size, operations training	2	6	1	12	None	Closed
7	ENVIRONMENTAL - Cold	Frostbite or exposure to SP climate	4	5	1	20	Awareness, change to work schedule to reduce hours on duty, increased crew size, operations training, PPE	2	5	1	10	None	Closed
8	MECHANICAL - Lifting	Person hurt lifting, moving or holding hoses or cables	4	3	1	12	Awareness, change to work schedule to reduce hours on duty, increased crew size, mechanical assists, operations training, buddy system, don't be a hero	4	2	1	8	2) Training - Chapter 14	Closed
9		Person hurt lifting weights to install or uninstall them on the drill head	4	2	1	8	Awareness, mechanical assists, operations training, PPE	4	2	1	8	See item 8	Closed

**HAZARD ANALYSIS**

Subsystem: Drilling Operations

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
10		Person hurt positioning firm drill head or return water pump	4	2	1	8	Awareness, increased crew size, mechanical assists, operations training, redundant attachments	4	2	1	8	See item 8	Closed	
11	MECHANICAL - Pinch/entrapment points	Hand/finger caught while connecting cables/hoses	4	2	1	8	Awareness, mechanical assists, operations training, communication	4	2	1	8	See item 8	Closed	
12		Hands caught between drill head/pump & storage cart or wall during storage	4	2	1	8	Awareness, mechanical assists, operations training	4	2	1	8	See item 8	Closed	
13		Hands/fingers caught between drill head components and weight stack	4	2	1	8	Awareness, mechanical assists, operations training; welded lifting ring to prevent pinch; clamped	4	1	1	4	See item 8	Closed	
14	MECHANICAL - Trauma	Drill head components fall from storage position	3	2	3	18	Clamps in TOS to hold head components (or stored on floor of MDS), inspection at startup, PPE	3	1	2	6	3) Post-mfg inspection - PMI 3.5; placed on carrier which is to be secured to unistrut	Closed	
15		Firm head components fall from storage position	3	2	3	18	Clamps in TOS to hold head components (or stored on floor of MDS), inspection at startup and at the beginning of each hole	3	1	2	6	3) Post-mfg inspection	Closed	Not currently in TOS

**HAZARD ANALYSIS**

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
16		Drill head moves during TOS/tower transport	1	2	2	4	Hoist and straps in TOS to hold head components; no personnel in units during transport, inspection at startup and at the beginning of each hole	1	1	2	2	2) Training - Chapter 14 See item 15	Closed	
17		Firm head moves during TOS/tower transport	1	2	2	4	Hoist and straps in TOS to hold head components or (stored on floor of tower); no personnel in units during transport, inspection at startup and at the beginning of each hole	1	1	2	2	2) Training - Chapter 14 3) Post-mfg inspection	Closed	Not currently in TOS
18		Return water pump moves during TOS/tower transport	1	2	2	4	Stored on floor of tower, no personnel in units during transport, inspection at startup and at the beginning of each hole	1	1	2	2	See item 17	Closed	
19		Return water hose leaks due to obstruction, ice, poor fittings	1	1	1	1	None	1	1	1	1	None	Closed	
20		Return water hose falls off Tank 1	3	2	2	12	Secure hose, tied off	3	1	1	3	3) Post-mfg inspection - PMI 3.5	Closed	Purging of air in hose at startup could cause a whipping motion
21		Removal or placement of banding straps on cargo	3	2	2	12	PPE: training	3	2	1	6	2) Training - Chapter 14 4) Personal protective equipment - Safety Training Chapter 1	Closed	Broken tooth or scratched eye
22		Person standing in loop of hose/cable that straightens out	4	1	4	16	Awareness, mechanical assists, operations training, communication	4	1	2	8	2) Training - Chapter 14	Closed	

## HAZARD ANALYSIS

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
23		Run over by heavy equipment	4	1	1	4	Awareness, operations training, communication	4	1	1	4	None	Closed	
24		Compressed air evacuation of water blows apart hose sections or plumbing fittings	3	2	2	12	Verify proper fittings, awareness, operations testing, verify open circuit Chinese fingers	3	1	2	6	Verify proper fittings	Closed	
25		Cable falls off sheave	4	2	2	16	Keepers, design change in 2005, deeper grove on sheave, new fairlead on lower sheave in tower	4	1	1	4	(1) Post-mfg inspection - PMI 3.5	Open	
26	MECHANICAL-Trauma: person falls	Steps poorly attached to MDS or tower	3	2	1	6	Weekly inspections: Permanent steps	3	2	1	6	None	Closed	
27		Cable backlash during unrequested movement of cable back down into hole. Cable could smack or pull someone.	4	3	3	36	Hazards and Safety Training were conducted, Awareness, change to work schedule to reduce hours on duty, increased crew size, mechanical assists, operations training, inspections at South Pole during operations, new SOP, brake redesigned in 2005	4	1	2	8	(2) Safety Training Records	Closed	Brake redesign in 2008
28	SUSPENDED MASS - Object falls on personnel	Drill head falls on staff during connection or disconnection to hose	3	3	2	18	Hoist provided to support weights; safety straps provided, redundant safetys, PPE	3	1	2	6	(1) Post-mfg inspection - PMI 3.5	Closed	
29		Weight from main drill head weight stack dropped during assembly or disassembly of head	3	3	2	18	Redundant safety straps are in use, clamps & elevators used to secure drill	3	1	2	6	Used at South Pole during operations	Closed	
30		Return water pump dropped	3	3	2	18	Hoist provided to support pump, two means of support, new SOP	3	1	2	6	(1) Post-mfg inspection - PMI 3.5	Closed	

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31		Hose/cable dropped from tower before or after drilling completed	3	2	2	12	Rope & capstan winch used to pull rope, hose secured with sling during mounting & dismounting, communication	3	1	1	3	6) User instructions - In draft procedures for firm drilling & sub pump installation/ removal	Closed	
32		Cable/hose pallets, spools, crates etc. dropped during transit	3	2	2	12	Skid loader used; procedure for installing, operator training, rigger training, communication	3	2	1	6	None	Closed	
33	THERMAL - Burn	Staff splashed with hot water during drilling	4	2	2	16	Inspection; training; PPE	4	1	1	4	2) Training - Chapter 14 4) Personal protective equipment - Safety Training Chapter 1 7) PM Inspection - Included in Startup & Weekly Safety Inspections	Closed	
34		Staff splashed with pressurized, hot water when removing drill heads (system not off before removing head)	3	2	2	12	Flow cut off before removing hose; water outlet low in tower - procedural issue	2	1	1	2	None	Closed	
35	THERMAL - Cold	Staff splashed with cold water during drilling	1	2	2	4	None	1	2	2	4	None	Closed	
36		Frostbite from contact with cold drill surfaces	2	3	1	6	PPE	1	3	1	3	4) Personal protective equipment - Safety Training Chapter 1	Closed	
37		Use of damaged lifting straps	4	3	2	24	Training; Inspections; availability of good straps	4	2	1	8	None	Closed	
38	USE - e-stop	e-stop does not work after reconnecting to TOS	1	1	1	1	Inspection at start up and at the beginning of each hole	1	1	1	1	None	Closed	Add to PM
39	USE - Holes	Person falls into completed hole after tower is moved	4	2	2	16	Timber & covers; training, fall protection	4	1	1	4	2) Training - Chapter 13; hole cover developed by RPSC for use w/ IceCube	Closed	

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			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
40		Person falls into pre-drilled firn holes	4	2	2	16	Timber & covers; training, procedure	4	1	1	4	See item 39	Closed	
41	USE - Leaks (fluids)	Water leaks from disconnected drill & return water hoses & forms holes in the snow	3	2	2	12	Training regarding handling of fluid leaks, fill holes	3	1	1	3	See item 45	Closed	
42		Antifreeze leaks from vehicles & equipment forms holes	3	2	3	18	Training regarding handling of fluid leaks	3	1	1	3	See item 45	Closed	Should flag all spills and holes
43		Water drained from tanks or overflow forms holes in snow	3	2	2	12	Training regarding handling of fluid leaks, holes are covered or backfilled and flagged, software alarms	3	1	1	3	See item 45	Closed	
44	USE - Tripping	Exposed cables, hoses used for drilling or deployment; other ground obstacles; & snow	2	5	2	20	Training; utility alley; suspended cables	2	3	2	12	2) Training - Chapter 14	Closed	Whiteout days keep detectability at a 2
45		Running into suspended hoses & cables	2	3	1	6	Flags on cables	2	1	1	2	See item 45	Closed	
46	USE - Water	Standing water or flooding in tower	2	2	1	4	None	2	2	1	4	None	Closed	
47		Ice forms around kick plate	4	2	1	8	Black rubber mats; Shake mats when ice forms	4	1	1	4	None	Closed	



REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/15/03	See original
A	SSEC	<ul style="list-style-type: none"> <li>Updated mitigation information for items: 3-5; 9; 14; 17-20; 22; 26-27; 29; 33; 39-40; 42; 46-48</li> <li>1 item open</li> <li>Updated description of change to reel in section 1 of the summary</li> <li>Added item 31 in reference to cable incident at SP</li> </ul>	2/7/05	TAD
B		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment  Addition of Item 50, Running the reel unplugged from TOS	07/31/05	MAZ
C		Annual review and revision based on actual operating experience at South Pole and modifications to equipment and operating procedures after return from initial deployment	10/27/06	TCB

**SHEET REVISION STATUS**

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	C	C	C	C	C	C												

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		<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																		
TITLE																				
<b>ENHANCED HOT WATER DRILL RETURN WATER CABLE REEL HAZARD ANALYSIS SUMMARY</b>																				
ORIGINATOR			DATE			ENGINEER			DATE			DRAFTSPERSON			DATE					
TCB			08/01/06			JJC			08/01/06			NA								
CHECKER			DATE			PRODUCT ASSURANCE			DATE			PROJECT APPROVAL			DATE					
NA						MAZ			08/01/06			BP								
FILENAME						8510-0219.RevC.doc						PROJECT NO.						8510		
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												NA			A			Page 1 of 6		

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<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Return Water Cable Reel
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Return Water Cable Reel
<b>DOCUMENT #:</b>	8510-0219
<b>REVISION:</b>	C
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Mike Zernick
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Return Water Cable Reel for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for the Return Water Cable Reel.

***Note: The Return Water Cable Reel was planned to be a refurbishment/ update of one of the reels used in AMANDA. However, that plan was changed in fall 2004 just prior to shipping equipment to SP. At that point, the green reel that had been the return water hose reel was commissioned as the return water cable reel (it was determined during IV&T that the drum diameter of this reel was too small for the hose, so it was decommissioned as the return water hose reel). This reel had been originally inspected as the return water hose reel; however, it was not reinspected prior to shipment as the return water cable reel. The motor that will be used on this reel is the backup motor for the return water hose reel, which is the same model motor that was used on the green reel previously. The motor will be controlled by the hoist drive.***

***Note2: Modifications to the reel brake design have been made and will be installed at the South Pole at the beginning of 2005/2006 season to ensure that the brake is always in a positive state.***

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0219 – Hazard Analysis Table (FMEA) table

8510-0219 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Environmental
- Fire

- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns, cold
- Use – e-stop, tripping

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	53
Major Risk Reduced to Moderate:	0
Major to Minor:	2
Moderate to Moderate:	1
Moderate to Minor:	16
Minor to Minor:	34
# Mitigated to Minor:	18
# Justified:	1
# Unmitigated (or Minor to Minor):	34
# Eliminated:	3

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
9	Improper lockout/tagout allows power to reel during service	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Design & training can reduce the potential for injury as a result of improper lockout/tagout. However, appropriate lockout/tagout is dependent on the user applying it prior to servicing equipment.
10	Locks out wrong circuit	See item 9
48	(Tripping on) Exposed electric cables connecting to reel	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Appropriate routing of cables/hoses & training can reduce the potential for injury. However, safety is dependent on the user vigilance.

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

**IMPLEMENT** – **The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.**

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Exposed electrical connections</li>   <li>• Test lab listing on motors</li> <li>• Verify cable rating to 600 VAC</li> <li>• Inadequate clearances</li> <li>• Slip clutch on motor (if a motor is used)</li>   <li>• Weights marked on components</li> </ul>	<ul style="list-style-type: none"> <li>• No exposed connectors; submersible connector on pump end; standard EHWD connectors used between TOS umbilical &amp; pump cable; reel motor to be connected similar to other powered reels in system</li> <li>• PMI 2.3</li> <li>• PMI 2.3</li> <li>• PMI 3.1</li> <li>• NA; motor drive under manual control</li> <li>• PMI 7.1</li> </ul>

2	<p>Safety Training (including):</p> <ul style="list-style-type: none"> <li>• Electrical safety review</li> <li>• Proper lockout/tagout</li> <li>• Addressing equipment breakage</li> <li>• Falling objects during assembly/minimize working around others</li> <li>• Trip hazards</li> <li>• Cable Hazards</li> </ul>	<p>Safety Training Manual:</p> <ul style="list-style-type: none"> <li>• Chapter 8</li> <li>• Chapter 4</li> <li>• Chapter 14</li> <li>• Chapter 7</li> <li>• Chapter 14</li> <li>• Verify safety trainings were completed at SP</li> </ul>
3	<p>Control system design review (including):</p> <ul style="list-style-type: none"> <li>• Breakers</li> <li>• Proper grounding</li> <li>• Cable grounded</li> </ul>	<p>Reel motor controlled by hoist drive &amp; circuit breaker; pump motor controlled by a dedicated circuit drive &amp; circuit breaker; all circuits grounded</p>
4	<p>Personal protective equipment (verify that the staff is to wear):</p> <ul style="list-style-type: none"> <li>• Gloves</li> <li>• Outerwear</li> </ul>	<p>PPE discussed in Safety Training Chapter 1</p>

6.2 Issues – None

HAZARD ANALYSIS

Subsystem: Return Water Cable Reel

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK		MITIGATION	RESIDUAL RISK		EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Det		Sev	Det				
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	None	2	4	None		Closed	There will always be small amounts of grease present on bearing cases, etc.
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	1	None	2	2	None		Closed	Lubricants & grease can be found on the gear reducer & main shaft bearings.
3	ELECTRICAL - Shock	Exposed terminals	4	2	Enclosed terminals; safety training	4	2	(1) Post-mpg inspection - Cabling was not inspected prior to shipment due to the reel being changed shortly before shipping; no exposed terminals; submersible connector used on pump end; standard EHWI connectors used to connect downhole cable to TOS umbilical (2) Safety training - Chapter 8		Closed	Reel would use tower hoist cable, unless a dedicated cable is made (spare cable is available from which to make a dedicated cable)
4		Inadequate insulation on conductors	4	2	Return water cable rated to 600VAC	4	2	(1) Post-mpg inspection - Standard EHWI electrical connectors used		Closed	
5		Shorting of reel or pump cables due use, abuse or accident (i.e., run over by caterpillar)	4	2	Breaker; cable & reel grounded	4	2	(3) Control system design review - Motor controlled by drive & circuit breaker which will detect shorts; pump is powered from a dedicated circuit in the TOS w/ its own drive & circuit breaker		Closed	
6		Inadequate ground	4	2	Breaker; cable & reel grounded	4	2	See Item 5		Closed	
7		Pump motor shorts due to contact with water, condensation, ice	4	2	Breaker; cable & reel grounded	4	2	See Item 5		Closed	
8		Reel motor shorts due to contact with water, condensation, ice	4	2	Breaker; cable & reel grounded	4	2	See Item 5		Closed	

**HAZARD ANALYSIS**

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			Sev	Prob		Det	RPN					Sev
9		Improper lockout/tagout allows power to reel during service	4	2	2	16	4	1	1	4	(2) Safety training - Chapter 4	Closed
10		Locks out wrong circuit	4	2	2	16	4	1	1	4	See item 9	Closed
11		Stored energy released from capacitor in drive after power down	4	1	1	4	4	1	1	4	None	Closed
12		Lo voltage short from water level sensor cable	2	2	2	8	2	2	2	8	None	Closed
13		Potential exposure to 480 V if reel is operated while cable is plugged in	4	2	2	16	4	1	1	4	Training records; check for signs at pole	Closed
14	ENVIRONMENTAL - Acoustic noise	Mechanical noise	2	6	1	12	2	4	1	8	None	Closed
15	FIRE - Fire	Overheating of motor	3	2	3	18	3	2	1	6	(1) Post-mfg inspection - PMI 2.3; see description in summary	Closed
16		Shorting of cables due use, abuse or accident (i.e., run over by caterpillar)	3	3	2	18	3	1	1	3	See item 5	Closed
17		Cable burns	3	2	2	12	3	2	2	12	None	Closed
18	MECHANICAL - Cuts	Sharp edges due to design	3	2	2	12	3	2	2	12	PMI 3.1	Closed
19		Sharp edges due to use or breakage	3	2	2	12	3	2	2	12	(2) Safety training - Chapter 14 (4) Personal protective equipment Safety Training Chapter 1	Closed



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			Sev	Det		Sev	Det				
20	MECHANICAL - Pinch/entrapment points	Inadequate clearances	3	2	Protective clothing, post-mg inspection	3	2	(1) Post-mg inspection - PMI 3.1 (4) Personal protective equipment Safety Training Chapter 1 - Moving machinery labels affixed to reel		Closed	
21		Body part caught between rotating side of reel & stationary support	3	2	Safety training	3	2	Moving machinery labels affixed to reel		Closed	
22		Trapped under skis	4	2	None	4	2	None		Closed	
23		Person/clothes caught between cable/reel or cable/cable during rewind	3	2	Safety training, slow winding operation	3	2	(2) Safety training - Chapter 14 - Moving machinery labels affixed to reel		Closed	
24		Reel freely rotates due to motor/gearbox failure	2	2	Cable & spooling supported by return water hose reel	2	2	Field verification		Closed	
25		Reel freely rotates due to brake failure	1	1	New brake design	1	1	Field verification		Closed	
26		Unrequested motion due to EMI	2	1	Cable & spooling supported by return water hose reel	2	1	Field verification		Closed	
27		Unrequested motion due to confused HW or SW state	2	1	None; pump is supported by hose; issue is not expected to result in injury	2	1	Field verification		Closed	
28		Loss of system monitoring of hose reel (i.e., computer crash)	2	1	Position of pump is not critical; depth can be estimated by the number of wraps of cable unwrapped from the reel	2	1	Field verification		Closed	
29		Improper lockout/tagout allows powered reel motion during service	3	2	Training; motor has slip clutch; field verification	3	2	See item 9		Closed	
30		Reel is pulled toward hole due to tensile pull on cable	4	2	Pump is supported by hose; reel has ~400' of cable; reel is 2 tons; issue unlikely to result in injury, anchored to hole, anchors in snow	4	2	Field verification		Closed	

HAZARD ANALYSIS

Subsystem: Return Water Cable Reel

≤12 Green- minor  
13-35 Yellow- moderate  
≥36 Red- Major

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK		MITIGATION	RESIDUAL RISK		EVIDENCE	REQUIREMENTS	STATUS	COMMENTS	
			Sev	Prob		Det	RPN					Sev
31	MECHANICAL - Trauma	Cable backlash during rewind	2	2	1	4	2	2	1	4	Closed	
32		Cable backlash during unrequested movement of cable back down into hole. Cable could smack or pull someone.	4	3	3	36	4	1	2	8	Closed	(2) Safety Training Records. (5) Verification of Equipment Mods. Verification of new brake design.
33		Cable breakage causes recoiling of cable	2	2	3	12	2	2	2	8	Closed	None
34		Potential cable breakage could strike user if reel is operated while cable is plugged in	3	2	2	12	3	1	1	3	Closed	Training records, check for signs at pole
35		Impact with CAT while attaching hitch	4	2	1	8	4	1	1	4	Closed	safety training, inspection, pre-season check
36	SUSPENDED MASS - Reel falls over	Slit break/becomes unmounted/ collapses	2	2	2	8	2	2	2	8	Closed	None
37		Reel becomes unbalanced on unlevel surface	4	1	1	4	4	1	1	4	Closed	None
38		Tension from unreel cable causes reel to move/fall over	4	1	1	4	4	1	1	4	Closed	None
39	SUSPENDED MASS - Heavy object falls on personnel	Improper assembly causes parts to fall off reel	3	2	2	12	3	2	2	12	Closed	None
40		Inadequate maintenance to check integrity of reel	3	1	2	6	3	1	2	6	Closed	None
41		Parts break or fall due to use or trauma	3	2	2	12	3	2	1	6	Closed	See item 18

HAZARD ANALYSIS

Subsystem: Return Water Cable Reel

≤12 Green- minor  
13-35 Yellow- moderate  
≥36 Red- Major

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK		MITIGATION	RESIDUAL RISK		EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Det		Sev	Det				
42	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device	4	2	Weights noted on parts; operator experience	4	1	(1) Post-mpg inspection - PMI 7.1		Closed	
43		Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	4	3	Weights noted on parts; operator experience	4	1	See item 39		Closed	
44		Tools, bolts, etc. accidentally dropped	3	2	Pre-assembled reel	3	1	None		Closed	
45	THERMAL - Burn	Motor casing very hot	3	2	Cold outside temperature; protective clothing	3	1	(4) Personal protective equipment Safety Training Chapter 1		Closed	
46		Contact with brake resistor hot	1	1	None	1	1	None		Closed	
47		Contact with drive heat sink	1	1	None	1	1	None		Closed	
48	THERMAL - Cold	Contact with cold metal	3	3	Safety training, gloves	3	3	Training		Closed	
49	USE - e-stop (reel stop)	Non-functional button (i.e., frozen)	3	2	Motion under manual control; position of pump controlled by return water hose reel which has a reel stop, independent manual stop, testing at beginning of each hole	3	2	Field verification		Closed	
50		Readily accessible to users	3	2	Motion under manual control; position of pump controlled by return water hose reel which has a reel stop	3	2	See item 46		Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/21/07	TCB
A		Annual review and revision	6/16/08	TCB
B		Annual review and revision	6/18/09	TR
C		Annual review and revision	4/5/10	TR

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	C	C	C	C	C	C												

CONTROLLED COPY DIST. LIST		THE UNIVERSITY OF WISCONSIN																
1	15	<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																
2	16	<b>MADISON, WISCONSIN</b>																
3	17	TITLE																
4	18	<b>ENHANCED HOT WATER DRILL</b>																
5	19	<b>TESTBED TOWER</b>																
6	20	<b>HAZARD ANALYSIS SUMMARY</b>																
7	21	ORIGINATOR	DATE	ENGINEER	DATE	CHECKER	DATE											
8	22	Tim Rubino	4/5/10	Terry Benson	4/5/10													
9	23	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE											
10	24	Terry Hannaford	4/5/10	Mike Zernick	4/5/10													
11	25	FILENAME	8510-0435.RevC.doc				PROJECT NO.	8510										
12	26		8510-0435.RevC.xls															
13	27	DRAWING NO.	8510-0435			SCALE	SIZE	SHEET										
14	28					NA	A	Page 1 of 6										

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Testbed Tower
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Tower
<b>DOCUMENT #:</b>	8510-0435
<b>REVISION:</b>	C
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Tim Brenner
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Testbed Tower for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities

This document and its attachments document the hazard analysis completed for the Testbed Tower.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0101 – Requirements specification for TOS Tower

8510-0108 – Hazard Analysis Table (FMEA) table

8510-0108 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Use – e-stop

#### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	32
Major Risk Reduced to Moderate:	2
Major to Minor:	3
Moderate to Moderate:	0
Moderate to Minor:	18
Minor to Minor:	9
# Mitigated to Minor:	29
# Justified:	3
# Unmitigated:	3
# Eliminated:	0

#### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
13	Tools/materials dropped by user	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Assembly instructions & training can reduce the potential for injury as a result of items being dropped. However, safety is dependent on the user wearing appropriate protective gear & not putting themselves/others in harm's way.

26	Equipment not placed out of way	<b>Issue should be obvious to workers in the tower.</b> A number of pieces of equipment may be in the tower, including drill head components, drill head rack, return water pump, DOM's, hole cover and hole ring. Although, these are to be stowed when not used, the work area is quite small, so there is the potential for equipment to be in the workflow. These are large pieces of equipment that should be easily seen. Avoidance is predicated on user compliance to stow equipment and avoid any equipment in the work areas.
28	Inadequate lifting points on equipment or lifting apparatus (i.e., strap) breaks	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Standard work practices are that person operating the lifting equipment verify the weight of the materials to be lifted & use equipment that can appropriately lift the materials. Weights are to be noted in the assembly documents. Following this process should adequately mitigate this issue.

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.1 The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Adequate exits present &amp; marked in MDS &amp; tower</li> <li>• GFI's installed on electrical outlets</li> <li>• Sharp edges</li> <li>• Presence of cable sheave guards, crescent brackets &amp; fairleads</li> <li>• Overall structural soundness of tower</li> <li>• Design of hitch points to secure tower to MDS to prevent chain from falling</li> <li>• Hoist present &amp; of appropriate design for tasks</li> <li>• Structural soundness of ladder, upper deck &amp; stairway</li> <li>• Construction of ladder &amp; stairway for anti-slip surfaces</li> <li>• Railings &amp; toeboards present &amp; structurally sound on upper deck, stairway &amp; holes (no railing planned for lower hole)</li> <li>• Anti-slip fiberglass grating on upper deck</li> <li>• Hole covers present</li> <li>• Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.2</li> <li>• NA for tower; PMI 2.2 for TOS</li> <li>• PMI 3.1</li> <li>• PMI 3.5</li> <li>• Tower Proof Test</li> <li>• PMI 3.5</li> <li>• PMI 3.5; Safety analysis 6</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 3.3</li> <li>• PMI 8.1</li> </ul>



2	<p>Safety Training (including):</p> <ul style="list-style-type: none"> <li>• Hole safety</li> <li>• E-stop use, availability &amp; testing</li> <li>• Falling objects during assembly/minimize working over others</li> <li>• Running into objects in work room</li> <li>• Do not block exits</li> <li>• Pinch/entrapment hazards around cable sheaves &amp; crescents</li> <li>• Securing tower to MDS with chains</li> </ul>	<p>Safety Training Manual:</p> <ul style="list-style-type: none"> <li>• Chapter 13</li> <li>• Chapter 6</li> <li>• Chapter 7</li> <li>• Not in training; obvious issue</li> <li>• Chapters 2 &amp; 11</li> <li>• Chapter 11 &amp; 14</li> <li>• Chapter 11</li> </ul>
3	<p>PM instructions (including): PM instructions have not been written; however, many of the inspections have been included in the Startup &amp; Weekly Safety Inspections.</p> <ul style="list-style-type: none"> <li>• Inspection of equipment used in/on tower, including hoist &amp; banding units</li> <li>• Check integrity of tower, railings, stairway, ladder</li> <li>• Check to ensure walking surfaces, stair/ladder treads are free from snow, ice &amp; debris</li> <li>• Check integrity of fall safety restraints (straps)</li> <li>• Check operation of e-stop system</li> </ul>	<ul style="list-style-type: none"> <li>• Banding unit NA; hoist in Startup &amp; Weekly Safety Inspections</li> <li>• Startup/Weekly Safety Inspections</li> <li>• Weekly Safety Inspections</li> <li>• Done at South Pole</li> <li>• Weekly Safety Inspections</li> </ul>
4	<p>Personal protective equipment (verify that the staff is to wear):</p> <ul style="list-style-type: none"> <li>• Hardhats</li> <li>• Closed toe shoes</li> <li>• Eye protection</li> <li>• Fall safety restraints (straps)</li> </ul>	<p>All PPE discussed in Safety Training Chapter 1; hardhat use described in Chapter 7</p>
5	<p>Assessment of the safety margin on the hoist</p>	<p>Safety analysis 6</p>
6	<p>Verification testing (including):</p> <ul style="list-style-type: none"> <li>• E-stop works properly (shuts down appropriate subsystems; has to be cleared to restart; restarts from default condition)</li> </ul>	<ul style="list-style-type: none"> <li>• Subsystem &amp; system testing</li> </ul>

6.2 Issues – None

## HAZARD ANALYSIS

Subsystem: Testbed Tower

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
1	CHEMICAL - Lubricants leaking out of equipment	Bearing cases not sealed due to inadequate design, manufacture or damage	2	4	1	8	None	2	4	1	8	None		Closed	Spill Kits Available
2	CHEMICAL - Handling of lubricants & greases	Lubricants or grease may need to be added as part of the periodic maintenance	2	2	1	4	None	2	2	1	4	None		Closed	Spill Kits Available
3	FIRE - Tower Design	Inadequate egress	4	1	1	4	Training	4	1	1	4	(1) Post-mfg inspection - PMI 3.2 (2) Safety training (not to block exits) - Chapter 2 & 11		Closed	Fence gates should be kept open.
4	FIRE - Ignition Sources	Electrical short from equipment used in/on tower	4	2	1	8	GFI's on outlets; inspect equipment on 120 V; test procedures	4	2	1	8	Seasonal Inspection		Closed	Fire extinguishers brought out of lower area due to procedures.
5	ELECTRICAL - Shock	Exposed terminals	4	1	2	8	480V failsafe disconnect.	4	1	2	8	None		Closed	This would mainly apply to the hoist motor; the terminals of which are not accessible. Other items are cord connected & do not have exposed terminals.
6		Inadequate insulation on conductors	4	2	1	8	GFI's on outlets; inspect equipment	4	2	1	8	See item 4		Closed	
7		Shorting of cables due to use, abuse or accident	4	2	3	24	GFI's on outlets; inspect equipment	4	2	1	8	See item 4		Closed	
8		Inadequate ground	4	2	4	32	GFI's on outlets, earth ground	4	1	3	12	See item 4		Closed	
9	MECHANICAL - Cuts	Sharp edges due to design	3	3	2	18	Radius sharp edges (note on drawings)	3	1	2	6	(1) Post-mfg inspection - PMI 3.1		Closed	
10		Sharp edges due to use or breakage	2	1	2	4	None	2	1	2	4	(1) Post-mfg inspection - PMI 3.1 (2) Safety Training - Chapter 14 (3) Seasonal Inspection		Closed	
11	MECHANICAL - Pinch/entrapment points	Inadequate clearances	2	2	3	12	Guards, Training	2	2	3	12	Guards placed to prevent access to potential pinchpoints around sheaves & crescents		Closed	Reevaluate rollers at fairlead assembly for future use

## HAZARD ANALYSIS

Subsystem: Testbed Tower

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
12		Caught between crescent/pulleys/tower hoist and hose/cable	3	4	2	24	Hose fairleads & bracket to keep hoses on crescent; personnel not routinely on upper deck	3	2	1	6	(1) Post-mfg inspection - PMI 3.5 (2) Safety training - Chapter 14		Closed	
13	MECHANICAL - Trauma; falling objects	Tools/materials dropped by user	3	4	4	48	Protective equipment (hard hats); toe guards; assembly instructions; safety training, signage	3	2	3	18	(2) Safety training - Chapter 1 & 7 (4) Personal protective equipment - Safety Training Chapter 1;		Closed	Hard hats required
14		Structural failure; breakage of support	4	2	3	24	Bit 7 analysis; ASTM material; inspection	4	1	2	8	(1) Post-mfg inspection - PMI 3.1 (6) Bit 7 structural analysis - Tower Operations Proof Test		Closed	
15		Improper assembly	4	3	3	36	Assembly/inspection procedures; assembly training seasonal check of hoist mounting	4	1	2	8	(5) Assembly instructions - Assembly drawings		Closed	Testbed commissioning test
16		Hoses/cables falling off pulley crescents	3	2	3	18	Hose fairleads to keep hoses on crescent, sideplates on pulleys; training to applicable procedure	3	2	1	6	(1) Post-mfg inspection - PMI 3.5		Closed	
17		Dropping load	3	3	2	18	Hoist provided to support load, PPE	3	1	2	6	(1) Post-mfg inspection - PMI 3.5		Closed	Redundant support at all times
18	MECHANICAL - Trauma; person falls off ladder	Structural failure; breakage of support	4	2	3	24	Purchased part to OSHA standards; seasonal inspection	4	1	2	8	(1) Post-mfg inspection - PMI 3.3 - Tower inspected by UW Safety; all issues addressed		Closed	
19		Ladder surface slippery due to rain	4	4	2	32	Anti-slip tread; periodic inspection; protective clothing (boots). Open grid floor. Tower will not be used in winter.	4	1	1	4	(1) Post-mfg inspection - PMI 3.3		Closed	

## HAZARD ANALYSIS

Subsystem: Testbed Tower

Author: M. Zernick

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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
20		Improper assembly	4	2	2	16	Assembly/inspection procedures; assembly training	4	1	2	8	(5) Assembly instructions - Assembly checks included in Startup Inspections		Closed	
21	MECHANICAL - Trauma; person falls off upper deck	High wind	4	2	2	16	Railings around outside of platform & hole	4	1	2	8	(1) Post-mfg inspection - PMI 3.3; access to upper hole largely occluded by equipment; toe board placed by opening to provide access to hole for workers		Closed	
22		Inadequate maintenance to check integrity of tower	4	3	3	36	Periodic inspection, start up inspection	4	1	2	8	(3) PM instructions - Included in Startup & Safety Inspections gates at tower - inspect at beginning of training / test		Closed	
23		Structural failure; breakage of support	4	2	3	24	Bit 7 analysis; ASTM material; inspection	4	1	2	8	(1) Post-mfg inspection - PMI 3.1 (6) Bit 7 structural analysis - Tower Operations Proof Test		Closed	
24		Falls through hole in upper deck due to inadequate guard	4	3	2	24	Toe board around hole/guard rail	4	1	2	8	See item 21		Closed	
25	MECHANICAL - Trauma; person falls into hole	Inadequate guard on hole	4	3	2	24	Metal rim & cover on hole	4	2	1	8	(1) Post-mfg inspection - PMI 3.3		Closed	Hole is 18" throughout
26	MECHANICAL - Trauma; person runs into equip. under tower	Equipment not placed out of the way	2	4	2	16	Training, equipment location, design and PPE	2	2	2	8	(2) Safety training - Tight quarters; issue should be obvious to staff		Closed	
27	SUSPENDED MASS - Object falls on personnel during assembly	Inadequate lifting device, or bad rigging	4	2	3	24	Weights of materials known	4	1	2	8	Training and SOPs		Closed	Double Securing
28		Inadequate lifting points on equipment or lifting apparatus (i.e., strap breaks)	4	3	3	36	Weights of materials known; operator experience, SOPs	4	2	2	16	See item 27		Closed	Redundant support

**HAZARD ANALYSIS**

**Subsystem: Testbed Tower**

**Author: M. Zernick**

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
29		Hoist fails to hold weights	4	2	3	24	Design of motor; inspection; brake on hoist; assessment of safety margin, secondary safety harness, and rigging training	4	1	2	8	(1) Post-mfg inspection - PMI 3.5 (5) Assessment of safety margin on hoist - Safety analysis 6		Closed	Seasonal Inspection
30	USE - e-stop	No e-stop on tower	4	2	4	32	Local reel stop & remote testbed e-stop	4	2	1	8	(3) PM instructions - Included in Startup & Inspections (5) Verification testing - Subsystem & system testing		Closed	
31		Non-functional (i.e., frozen)	4	3	3	36	Tested periodically; failsafe system; buttons are covered; redundant estop buttons, start up inspection, inspection before each test	4	2	1	8	See item 30		Closed	



<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Testbed
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Tower
<b>DOCUMENT #:</b>	8510-0437
<b>REVISION:</b>	C
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Tim Brenner
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Testbed for the Enhanced Hot Water Drill (EHWD) for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities

This document and its attachments document the hazard analysis completed for the Testbed.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

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8510-0108 – Hazard Analysis Table (FMEA) table

8510-0108 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Electrical
- Fire
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Use – e-stop



#### 4.0 STATISTICAL SUMMARY OF RISK MITIGATION

RISK REDUCTION	# OF HAZARDS
Total Potential Hazard/Cause Combinations	23
Major Risk Reduced to Moderate:	0
Major to Minor:	0
Moderate to Moderate:	1
Moderate to Minor:	9
Minor to Minor:	13
# Mitigated to Minor:	22
# Justified:	1
# Unmitigated:	0
# Eliminated:	0

#### 5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

ITEM #	HAZARD/CAUSE	JUSTIFICATION
13	Person falls off ladder	<b>Standard work practices should be adequate to identify the hazard prior to its manifestation.</b> Assembly instructions & training can reduce the potential for injury as a result of items being dropped. However, safety is dependent on the user using the ladder correctly.

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.1 The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Post-mfg inspection (review the built components at PSL for): <ul style="list-style-type: none"> <li>• Adequate exits present</li> <li>• GFI's installed on electrical outlets</li> <li>• Sharp edges</li> <li>• Hoist present &amp; of appropriate design for tasks</li> <li>• Redundant e-stops</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.2</li> <li>• NA for tower; PMI 2.2 for TOS</li> <li>• PMI 3.1</li> <li>• PMI 3.5; Safety analysis 6</li> <li>• PMI 8.1</li> </ul>
2	Safety Training (including): <ul style="list-style-type: none"> <li>• E-stop use, availability &amp; testing</li> <li>• Falling objects during assembly/minimize working over others</li> <li>• Running into objects in work room</li> <li>• Do not block exits</li> </ul>	Safety Training Manual: <ul style="list-style-type: none"> <li>• Chapter 6</li> <li>• Chapter 7</li> <li>• Not in training; obvious issue</li> <li>• Chapters 2 &amp; 11</li> </ul>
3	PM instructions (including): PM instructions have not been written; however, many of the inspections have been included in the Startup & Weekly Safety Inspections. <ul style="list-style-type: none"> <li>• Inspection of equipment used in/on testbed</li> <li>• Check integrity of fall safety restraints (straps)</li> <li>• Check operation of e-stop system</li> </ul>	<ul style="list-style-type: none"> <li>• Safety Inspections</li> <li>• Safety Inspections</li> <li>• Safety Inspections</li> </ul>
4	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>• Hardhats</li> <li>• Closed toe shoes</li> <li>• Eye protection</li> <li>• Fall safety restraints (straps)</li> </ul>	All PPE discussed in Safety Training Chapter 1; hardhat use described in Chapter 7
5	Verification testing (including): <ul style="list-style-type: none"> <li>• E-stop works properly (shuts down appropriate subsystems; has to be cleared to restart; restarts from default condition)</li> </ul>	<ul style="list-style-type: none"> <li>• Subsystem &amp; system testing</li> </ul>

6.2 Issues – None

## HAZARD ANALYSIS

Subsystem: Testbed

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL	FAILURE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
	HAZARD	CAUSE	Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
1	CHEMICAL -Lubricants	Exposure to Oil leak	2	1	2	4	Spill Kits Available	2	1	2	4	None		Closed	
2	FIRE -Ignition source	Electrical short from equipment used in testbed area	4	1	2	8	GFI's on outdoor receptacles; equipment inspections; Training; Lockout/Tagout Procedures	4	1	1	4	Periodic Assessment, Startup Inspection		Closed	
3		Electrical spark from solenoid valve power cord on fuel tank	4	2	2	16	Electrical Conduit	4	1	1	4	Startup Inspection		Closed	
4	FIRE - Fuel source	Fuel sources not properly stored in approved containers	4	2	2	16	Approved containers and safety cans available; Labeling; Materials stored outside testbed area, or in flammable storage cabinet	4	1	1	4	Periodic Assessment		Closed	All fuel properly stored
5	ELECTRICAL - Shock	Exposure to high pressure pump test fixture, dynamometer, power pallet, field station	4	2	2	16	Hazard labeling; Training; Lockout/Tagout procedures;	4	1	1	4	Training Records, Startup Inspection		Closed	logbook tagging process
6		Water escaping system into environment	2	2	1	4	Closed water circulation system, training, procedures. GPIs in all wet locations	2	1	1	2	Startup Inspection		Closed	logbook tagging process
7		Exposure to unico drive	4	2	2	16	Lockout/Tagout procedures; Hazard labeling; Training; Keep doors closed	4	1	1	4	Start-up Inspection; Training Records		Closed	logbook tagging process
8	ENVIRONMENTAL - Acoustic noise	Noise levels > 85 dB in HPP	2	4	1	8	Hearing protection available, signage	2	2	1	4	None		Closed	Audiometric survey annually on start-up checklist
9	ENVIRONMENTAL-Spill	Diesel fuel spill from tank	4	2	1	8	Double wall tank; Barriers; Safety devices	4	1	1	4	None		Closed	Spill tray for manifold
10		Oil Leak	2	1	2	4	Spill kits available	2	1	2	4	None		Closed	

## HAZARD ANALYSIS

Subsystem: Testbed

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL	FAILURE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
	HAZARD	CAUSE	Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
11	MECHANICAL -Cuts	Laceration from spinning fan blade on heat exchanger	3	2	1	6	Guards	3	1	1	3	None		Closed	logbook tagging process
12	MECHANICAL - Pinch/entrapment points	Belt on high pressure pump or dynamometer	3	2	1	6	Machine guard; Training	3	1	1	3	None		Closed	Add signage Apply Lockout tag logbook tagging process ALL DONE
13		Clothing/Jewelry caught in rotary equipment	4	2	2	16	Guards; Training	4	2	1	8	None		Closed	logbook tagging process
14	MECHANICAL - Trauma; person falls off ladder	Ladder slips due to improper placement/use	4	3	2	24	Training; Knowledge of proper work practices	4	2	2	16	Training records		Closed	logbook tagging process
15	MECHANICAL -Trauma, person hit by equipment	Fittings disconnect from piping when a blow occurs	3	2	3	18	Reposition manifold	2	1	2	4	None		Closed	Remount high pressure manifold, logbook tagging process (DONE)
16	SUSPENDED MASS - Object falls on personnel	Inadequate lifting device, or bad rigging	3	2	1	6	Operator experience; Personal protective equipment; Training	3	2	1	6	None		Closed	
17	THERMAL-Burn	Hot water sprays from heat exchanger if blow occurs	3	2	3	18	Signage; Pressure relief valve; Painted red	3	1	2	6	Startup Inspection		Closed	Repipe pressure relief discharge (DONE)
18		Hot water sprays from heater skid	3	2	3	18	Signage, painted red	3	1	2	6	Startup inspection		Closed	Signage added
19		Discharged hot water from y-strainer purge	3	2	2	12	Training procedure	3	1	2	6	Startup inspection		Closed	Process is being redesigned, training to occur, y-strainer needs to be installed

**HAZARD ANALYSIS**

**Subsystem: Testbed**

**Author: M. Zernick**

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL	FAILURE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS	COMMENTS
	HAZARD	CAUSE	Sev	Prob	Det	RPN		Sev	Prob	Det	RPN				
20	USE - e-stop	E-Stop Inoperable	4	1	4	16	Tested periodically; failsafe system, Commissioning Inspection, Startup Inspection	4	1	3	12	Commissioning Inspection; Periodic tests, Startup Inspection		Closed	
21	USE-Tripping	Conduit line to fuel tank	2	3	2	12	Wooden cover	2	1	1	2	None		Closed	
22		Fuel lines	2	3	2	12	Wooden cover, Cord protectors	2	1	1	2	None		Closed	
23		Fire extinguishers on floor	2	2	2	8	Mount extinguishers, signage	2	1	1	2	None		Closed	

REVISIONS				
LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/28/07	TCB
A		Annual review	7/24/08	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
REVISION	A	A	A	A	A														
<b>CONTROLLED COPY DIST. LIST</b>			<b>THE UNIVERSITY OF WISCONSIN</b>																
1	15	<b>SPACE SCIENCE &amp; ENGINEERING CENTER</b>																	
2	16	<b>MADISON, WISCONSIN</b>																	
3	17	TITLE																	
4	18	<b>ENHANCED HOT WATER DRILL</b>																	
5	19	<b>INDEPENDENT FIRN DRILL OPERATIONS</b>																	
6	20	<b>HAZARD ANALYSIS SUMMARY</b>																	
7	21	ORIGINATOR	DATE	ENGINEER	DATE	DRAFTSPERSON	DATE												
8	22	Tim Brenner	7/17/08	L. Greenler	7/17/08	NA													
9	23	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE												
10	24	D. Wahl	7/24/08	M. Zernick	7/17/08														
11	25	FILENAME	8510-0438.RevA.doc				PROJECT NO.	8510											
12	26		8510-0438.RevA.xls																
13	27	DRAWING NO.	8510-0438			SCALE	SIZE	SHEET											
14	28					NA	A	Page 1 of 5											

<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Drill / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	Independent Firm Drill Operations
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary For Drilling Operations
<b>DOCUMENT #:</b>	8510-0438
<b>REVISION:</b>	A
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Tim Brenner
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>

## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with Independent Firm Drill Operations, develop a plan to mitigate those hazards, and track the mitigations to closure and document those activities.

This document and its attachments document the hazard analysis completed for Independent Firm Drill Operations.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

8510-0124 – Hazard Analysis Table (FMEA) table

8510-0124 – Hazard Analysis, Meeting Notes

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Electrical
- Environmental
- Mechanical – Lifting, pinchpoints, trauma
- Suspended Mass
- Thermal – Burns, cold
- Use – e-stop, holes, leaks, tripping, water



**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	25
Major Risk Reduced to Moderate:	0
Major to Minor:	0
Moderate to Moderate:	0
Moderate to Minor:	12
Minor to Minor:	13
# Mitigated to Minor:	25
# Justified:	0
# Unmitigated (or Minor to Minor):	13
# Eliminated:	0

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

<b>ITEM #</b>	<b>HAZARD/CAUSE</b>	<b>JUSTIFICATION</b>
	None	

**6.0 STATUS OF THE HAZARD ANALYSIS** (choose one of the following)

*CLOSED* – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

**6.1** The following information needs to be compiled as evidence that the hazards described in this hazard analysis have been appropriately mitigated.

Item	Evidence	Completed/Attached
1	Electrical inspection: <ul style="list-style-type: none"> <li>• Verify use of fingersafe connectors on e-stop circuit</li> </ul>	None
2	Safety Training (including): <ul style="list-style-type: none"> <li>• Lifting                             <ul style="list-style-type: none"> <li>• Cables, hoses</li> <li>• Drill head weights</li> <li>• Positioning firm drill</li> </ul> </li> <li>• Pinchpoints                             <ul style="list-style-type: none"> <li>• Connecting cables or hoses</li> <li>• Between heads/pump &amp; wall during storage</li> <li>• Between drill head components</li> </ul> </li> <li>• Potential cargo strap injuries</li> <li>• Do not stand in a loop of cable or hose</li> <li>• Do not occupy equipment buildings for extended periods</li> <li>• Covering holes</li> <li>• Fluid leaks (water, chemicals) causing holes in snow</li> <li>• Tripping on ridges or holes in snow</li> <li>• Placing flags on cables for better visibility</li> <li>• Cabling Hazards</li> </ul>	Safety Training Manual
3	Post manufacturing inspection (including): <ul style="list-style-type: none"> <li>• Means to secure firm head during interhole transport</li> <li>• Means to secure return water hose to Tank 1</li> <li>• Attachments for drill head support straps in tower</li> </ul>	<ul style="list-style-type: none"> <li>• PMI 3.5 – Drill head &amp; return water pump placed on carrier &amp; secured to unistrut</li> <li>• Firm drill</li> <li>• PMI 3.5</li> <li>• Completed at South Pole</li> </ul>
4	Personal protective equipment (verify that the staff is to wear): <ul style="list-style-type: none"> <li>• Gloves - Contact with cold surfaces, handling 4" drill, removing cargo straps</li> <li>• Eye protection - Removing cargo straps</li> <li>• Outerwear - Splashing water</li> </ul>	Safety Training Chapter 1
5	PM inspection: <ul style="list-style-type: none"> <li>• E-stop testing</li> </ul>	Included in Startup & Weekly Safety Inspections

**6.2** Issues – None

## HAZARD ANALYSIS

Subsystem: Firm Drill

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
 Detectability Assessment 1-Obvious 2-Noticeable 3-Obscure 4-Undetectable

≤12 Green- minor  
 13-35 Yellow- moderate  
 ≥36 Red- Major

ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
1	ELECTRICAL-Shock	Disconnecting/reconnecting power	4	2	2	16	Fingersafe connectors; Training; Signage; Power down	4	1	1	4	1) Post-mfg inspection - PMI 10.1 2) Training - Chapter 4 & 8	Closed	
2		Cut or drill into power lines	4	1	1	4	Cables obvious in work areas; elevated in drill camp; on snow in areas where drilling will not occur	4	1	1	4	None	Closed	
3		Shock from failure in Firm Drill	4	2	2	16	Professional electricians; Conduit; Circuit breakers; Training	4	2	1	8	All outlets & circuits protected with circuit breakers per 8510-0019	Closed	Signage to be added
4		Shock from failure in Crel generator	4	2	2	16	Awareness, training, signage, preventative maintenance by RPS	4	1	2	8	Training records	Closed	
5	ENVIRONMENTAL - Fatigue	Initial adjustment to altitude & climate	2	6	1	12	Awareness, operations training	2	5	1	10	Training records	Closed	Buddy System
6		General fatigue due to altitude	2	6	1	12	Awareness, operations training	2	6	1	12	Training records	Closed	
7	ENVIRONMENTAL - Cold	Frostbite or exposure to SP climate	4	5	1	20	Awareness, operations training, PPE	2	5	1	10	Training records	Closed	
8	MECHANICAL - Lifting	Person hurt lifting, moving or holding hoses or cables	3	3	1	9	Awareness, mechanical assists, operations training	3	2	1	6	2) Training - Chapter 14	Closed	

## HAZARD ANALYSIS

Subsystem: Firm Drill

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
 Probability Assessment 1-Negligible 2-Remote 3-Occasional 4-Periodic 5-Frequent 6-Continual  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
9	MECHANICAL - Pinch/entrapment points	Hand/finger caught while raising/lowering drill head	4	2	1	8	Awareness, mechanical assists, operations training	4	2	1	8	See item 7	Closed	
10	MECHANICAL - Trauma	Drill head components fall from storage position	2	1	1	2	Drill head hangs over hole	2	1	1	2	3) Post-mfg inspection - PMI 3.5; placed on carrier which is to be secured to unistrut	Closed	Hard hat area
11		Firm head moves during transport	1	2	2	4	No personnel in units during transport, inspection at startup and at the beginning of each hole	1	1	2	2	2) Training - Chapter 14 3) Post-mfg inspection	Closed	Firm head secured in shack
12		Run over by heavy equipment	4	2	2	16	Awareness, mechanical assists, operations training	4	2	1	8	None	Closed	
13		Hose falls off spool	3	1	1	3	Groove around idle wheel	3	1	1	3	Inspection	Closed	Edges on sheave
14		Sheave wheel falls from roof	4	2	3	24	Training; Steel reinforcement on roof	4	1	2	8	Inspection	Closed	

## HAZARD ANALYSIS

Subsystem: Firm Drill

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
15	MECHANICAL-Trauma: person falls	Cable backlash during unrequested movement of cable back down into hole. Cable could smack or pull someone.	4	1	1	4	Training; Awareness; Brakes; Connected to motor	4	1	1	4	(2) Safety Training Records	Closed	
16	THERMAL - Burn	Staff splashed with hot water during drilling	4	2	2	16	Inspection; training; PPE	4	1	1	4	2) Training - Chapter 14 4) Personal protective equipment - Safety Training Chapter 1 7) PM Inspection - Included in Startup & Weekly Safety Inspections	Closed	
17	THERMAL - Cold	Staff splashed with propylene glycol during drilling	3	2	3	18	Personal Protective Equipment	3	1	3	9	None	Closed	
18		Frostbite from contact with cold drill surfaces	2	3	1	6	Personal Protective Equipment	1	3	1	3	4) Personal protective equipment - Safety Training Chapter 1	Closed	
19	USE - E-Stop	E-Stop fails	4	2	3	24	E-stop incorporated into normal use	4	1	2	8	(3) PM instructions - Included in Startup & Weekly Safety Inspections (8) Verification testing - Subsystem & system testing	Closed	E-stop not connected to camp
20	USE - Holes	Person falls into completed hole after firm drill is moved	4	2	2	16	Metal grate used; training, fall protection	4	1	1	4	2) Training - Chapter 13; hole cover developed by RPSC for use w/ IceCube	Closed	24" diameter hole
21		Person falls into firm holes pre-drilled w/ end of season water	4	2	2	16	Metal grate covers hole after completion; training	4	1	1	4	See item 20	Closed	
22		Firm drill moved prior to removing drill head from hole	4	2	1	8	Training, check harness prior to moving	4	1	1	4	Training	Closed	

**HAZARD ANALYSIS**

Subsystem: Firm Drill

Author: M. Zernick

Severity Assessment 1-Negligible 2-Moderate 3-Critical 4-Catastrophic  
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ITEM	POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	STATUS	
			Sev	Prob	Det	RPN		Sev	Prob	Det	RPN			
23	USE - Leaks (fluids)	Propylene glycol leaks from disconnected drill & return water hoses & forms holes in the snow	3	2	2	12	Training regarding handling of fluid leaks	3	1	1	3	Training - Chapter 13	Closed	
24		Antifreeze leaks from vehicle equipment systems and forms holes	3	2	3	18	Training regarding handling of fluid leaks; daily inspection	3	1	1	3	See item 22	Closed	
25	USE - Tripping	Exposed cables, hoses used for drilling or deployment; other ground obstacles; & snow	2	3	2	12	Training; utility alley; suspended cables	2	3	2	12	2) Training - Chapter 14	Closed	Whiteout days keep detectability at a 2
26		Person falls while filling PG tank	3	2	1	6	Ladder, training	3	1	1	3	Training records	Closed	

**REVISIONS**

LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original version	10/28/10	TCB

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION																		

<b>CONTROLLED COPY DIST. LIST</b>		<b>THE UNIVERSITY OF WISCONSIN</b>																		
		<b>SPACE SCIENCE &amp; ENGINEERING CENTER MADISON, WISCONSIN</b>																		
1	15	<b>TITLE</b>																		
2	16	<b>ENHANCED HOT WATER TRENCHER</b>																		
3	17	<b>HAZARD ANALYSIS SUMMARY</b>																		
4	18																			
5	19																			
6	20																			
7	21	ORIGINATOR	DATE	ENGINEER	DATE	DRAFTSPERSON	DATE													
8	22	Jessica Larson	10/28/2010	Terry Benson	10/28/2010	NA														
9	23	CHECKER	DATE	PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE													
10	24	Terry Hannaford	10/28/2010	Mike Zernick	10/28/2010	Terry Benson	10/28/2010													
11	25	FILENAME	8510-0499 Original.doc										PROJECT NO.	8510						
12	26		8510-0499 Original.xls																	
13	27	DRAWING NO.	8510-0499					SCALE	NA		SIZE	A		SHEET	Page 1 of 5					
14	28																			

Document #: 8510-0499

Revision: Original

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<b>DOCUMENT IDENTIFICATION &amp; STATUS</b>	
<b>PROJECT:</b>	Enhanced Hot Water Trencher / IceCube
<b>SYSTEM/SUBSYSTEM/COMPONENT:</b>	
<b>DOCUMENT NAME:</b>	Hazard Analysis Summary
<b>DOCUMENT #:</b>	8510-0499
<b>REVISION:</b>	Original
<b># OF PAGES:</b>	6
<b>AUTHOR:</b>	Tim Brenner
<b>STATUS OF HAZARD ANALYSIS</b>	<b>Implement (see Section 6)</b>



## 1.0 PURPOSE

This hazard analysis was conducted to review potential hazards associated with the Enhanced Hot Water Trencher for IceCube; develop a plan to mitigate those hazards; track the mitigations to closure and document those activities

This document and its attachments document the hazard analysis completed for the Enhanced Hot Water Trencher.

## 2.0 REFERENCES

The following documents were used to identify hazard analysis reviews, define the system/subsystem/component operation/use, potential hazards, assess the severity/probability/detectability of the hazards, determine mitigations or justify analysis. This hazard analysis was conducted as described in the IceCube Project Safety Manual.

## 3.0 SUMMARY OF POTENTIAL HAZARDS

The following potential hazards were reviewed as a part of this analysis:

- Chemical
- Fire
- Electrical
- Environmental
- Mechanical – Cuts, pinchpoints, trauma
- Suspended Mass
- Thermal
- Use – E-stop

**4.0 STATISTICAL SUMMARY OF RISK MITIGATION**

<b>RISK REDUCTION</b>	<b># OF HAZARDS</b>
Total Potential Hazard/Cause Combinations	29
Major Risk Reduced to Moderate:	0
Major to Minor:	1
Moderate to Moderate:	1
Moderate to Minor:	12
Minor to Minor:	15
# Mitigated to Minor:	0
# Justified:	0
# Unmitigated:	0
# Eliminated:	0

**5.0 JUSTIFICATIONS FOR NOT REDUCING THE RISK ON MODERATE RISK ISSUES**

The following potential hazards were assessed as having moderate risk to users, assemblers or collateral staff. Review of these potential hazards indicated that no additional mitigation was required as described below. Justifications for not mitigating a potential moderate hazard can include:

- a) Additional mitigation may introduce additional or more serious risk.
- b) It may be cost prohibitive to implement additional mitigation.
- c) It may be technologically difficult to implement additional mitigation.
- d) Standard work practices should be adequate to identify the hazard prior to its manifestation.

**6.0 STATUS OF THE HAZARD ANALYSIS (choose one of the following)**

**CLOSED** – The potential hazards have been assessed, actions determined and all mitigations/rationale have been completed.

***IMPLEMENT*** – The potential hazards have been assessed, actions determined, but not all mitigations/rationale have been completed.

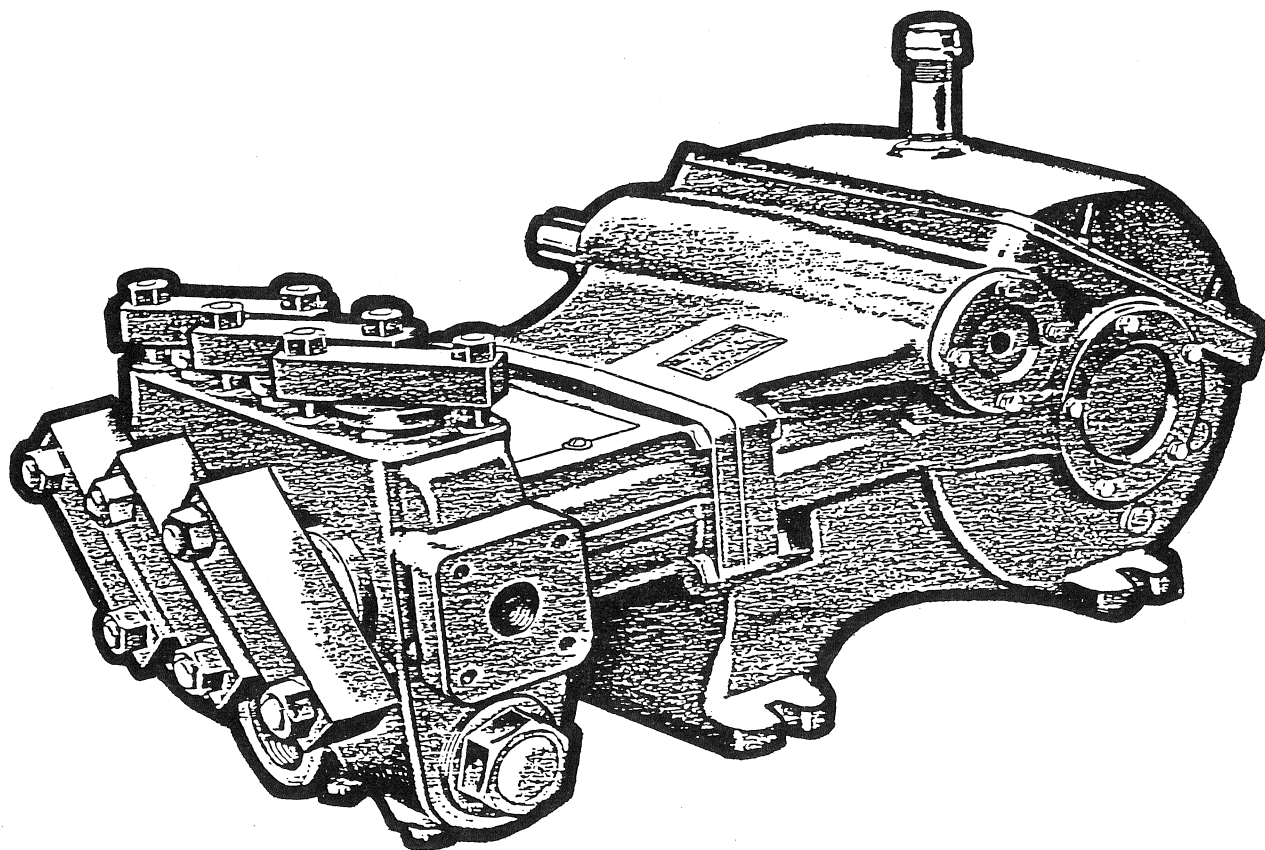
*REVIEW* – The assessment has been started, but not all hazards or mitigations have been identified, or the scoring has not been completed.

*REOPEN* – This analysis has been previously closed. However, design change or new information has been made available that necessitates reevaluation of the potential hazards associated with this system, subsystem or component.

6.2 Issues – None

# D65-16AVD Industrial Pump Instructions & Service Manual

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**SPECIFICATIONS**

Type	Triplex - Single Acting
*Rated Capacity	68.5 GPM @ 398 Strokes/Minute*
Gear Reduction Ratio	3.95
*Discharge Capacity	4.37 GPM per 100 Pinion RPM*
Rated Pressure	1600 PSI Max.
Temperature Rating	160°F Max.
Cylinder Bore & Stroke	2 1/8" x 3 3/4"
Suction Size	3" NPT
Discharge Size	1 1/4" NPT
Cylinder Body Mtl.	Ductile Iron
Cylinder Mtl.	Ceramic
Piston Packing Mtl.	Coated Stainless Steel Molded Composition V-Rings
Piston Assembly Mtls.	Stainless Steel
Valve Mtl.	Stainless Steel, Stamped
Valve Seat Mtl.	Stainless Steel, Hardened
Pump Drive End	Helical Gear Single Reduction
Pinion Shaft Speed at Rated Capacity	1570 RPM Max.
Pinion Shaft Exten. Dia.	1 5/8"
Keyway	3/8" x 3/16" Straight
Pinion and Crankshaft Main Bearings	Tapered Roller
Crankshaft Journ. Bearings	Steel/Babbit Inserts
Crosshead Pin Bearing	Bronze Bushing
Recommended Regulator	15696C5
Cylinder Removal Tool Kit	17539B1
Valve Seat Removal Tool Kit	7297A3
Allen Wrench for Packing Capscrew	8574A11
Valve Seat Installation Tool	18999B

\*Based on 100% Volumetric Efficiency - Allow 5 to 7% for Valve Slippage.

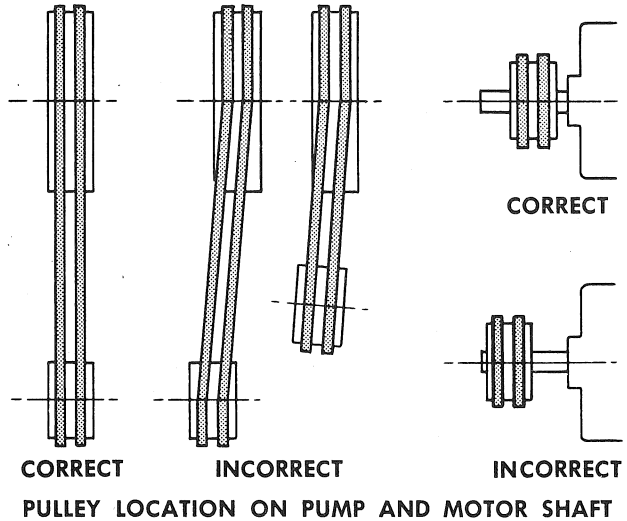
**GENERAL INSTRUCTIONS**

**CAUTION:** Positive Displacement Pumps must have a proper size and operable type of pressure regulating valve or pressure relief valve piped into the discharge line. This is mandatory to prevent damage to pump and piping or possible injury to personnel. Do not install any valves or shutoff devices in the by-pass line from pressure regulator to tank or supply.

**BELT DRIVE**

With belt drives, pulley on both engine and pump should be located as closely as possible to bearing to reduce bearing and shaft bending loads.

Make sure that all bolts, nuts, set screws, and keys are properly tightened.



**STARTING PUMP**

**A. Before starting**

1. Read all instructions carefully.
2. Fill pump crankcase with recommended oil to level mark on oil sabet. Oil recommendations are covered in lubrication section of pump instructions.
3. Replace all drain plugs in pump and piping.
4. Inspect tank to be sure that no foreign material is in tank or suction line.
5. Fill tank at least half full or connect suction to water supply. Open valve (if present) in suction line. **Avoid prolonged dry operation which may cause excessive wear on cylinders and piston packing. Be sure that an operating pressure gauge is located in discharge line.**
6. Make sure all valves, including spray gun or nozzles, are open in discharge line. Spray gun may be anchored to discharge back into tank.
7. Completely back off pressure adjusting screw on pressure regulating valve.

**B. Starting the Unit**

1. After starting, close discharge valve or spray gun slowly while watching pressure gauge to make sure relief valve or unloader is operating properly.
2. Adjust relief valve or unloader to desired pressure. See regulator instructions.
3. Cycle nozzles or gun on and off to be sure that pressure adjustment and regulator operation is satisfactory.

**NOTE:** Nozzle capacity should not exceed 90% of pump capacity for satisfactory regulator operation. **AVOID FREEZING** by draining all water from pump and system in cold weather.

### SUGGESTED MAINTENANCE SCHEDULE

OPERATION	INTERVAL
Check oil level	Daily
Drain & change oil	300 hr. (1)
Replace piston packing	500 hr.(2)
Inspect valves and springs	500 hr. (3)
Inspect connecting link bearing inserts	1000 hr. (4)
Inspect crankshaft tapered roller bearings	2000 hr.

- (1) Drain at operating temperature to prevent contamination from settling.
- (2) Inspect frequently for leakage; replace before 500 hours if any cylinder exceeds 10 drops per minute leakage. Packing may not look badly worn but will often be shiny and hard and won't seal well.
- (3) Replace if cracks and heavy wear are present.
- (4) Replace at first signs of fatigue or wear to prevent damage to crankshaft.

### LUBRICATION

Fill gear case with Mobilgear 630 or equal additive to capacity listed in chart. Maintain oil level at mark on oil dipstick.

**NOTE:** After first 30 hours of operation drain oil from gear case (preferably drain at operating temperature), replace plug and refill crankcase with new oil as above. Change oil every 300 hours thereafter. Check oil level daily and add oil as needed.

### ADDITIVES FOR CRANKCASE OIL

Use of Molybdenum Disulfide ( $MoS_2$ ) is highly recommended by Myers as an additive to the gear case oil in back geared pumps and speed reducers manufactured by Myers. The additive is compatible with all known oils. It appears to be so effective in reducing wear and friction that power train life may be doubled between overhauls.

The chart below gives volume of  $MoS_2$  concentrate for Myers Industrial and Spray Pumps.

PUMP	GEAR CASE CAPACITY OIL	VOLUME $MoS_2$ CONCENTRATE OR DISPERSION "M" FOR 5%	VOLUME $MoS_2$ CONCENTRATE OR DISPERSION "M" FOR 10%
D65-16	5½ Qts.	9 Fl. Oz.	18 Fl. Oz.

The  $MoS_2$  fluid concentrate is marketed by Dow Corning Greensboro Ph., 2914 Patterson St., Greensboro, NC 27407 under the designation "Molykote M Gear Guard."

Several other brands are available. Follow instructions of manufacturer.

### SERVICE

**CAUTION:** Disengage clutch, disconnect electrical leads to motor, or remove spark plug leads on engine.

Following work on any internal pump parts, it is important to tighten all clamps, caps and assemblies to specific torque ratings, refer to Recommended Torque chart.

### REMOVING PACKING

Move assembly to front end of cylinder (top dead center). Remove valve assembly if required to provide clearance. Remove cap screw with an Allen wrench. (Allen wrench, Part No. 8574A11). Retract piston rod and insert tool as shown. Pull packing assembly out or push by rotating crankshaft by hand.

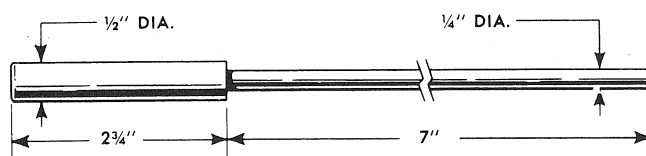
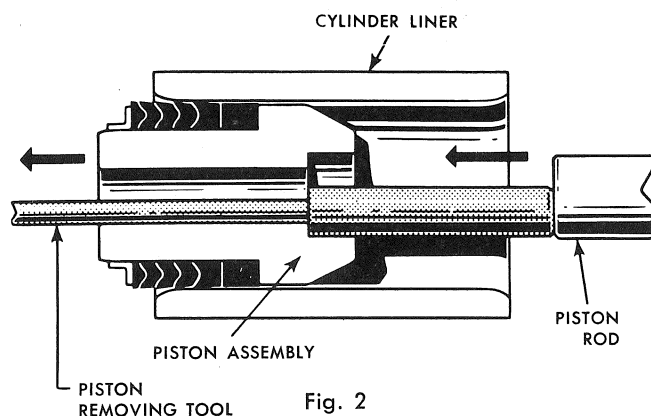


Fig. 3. Suggested tool for removing V-Ring Piston assembly.

**CAUTION:** Also inspect cylinders for linear grooving by running your thumbnail circumferentially around bore of cylinder. If any grooving is detected also replace cylinders. New packing will rapidly cut or wear out in grooved cylinders.

### V-RING PISTON ASSEMBLY

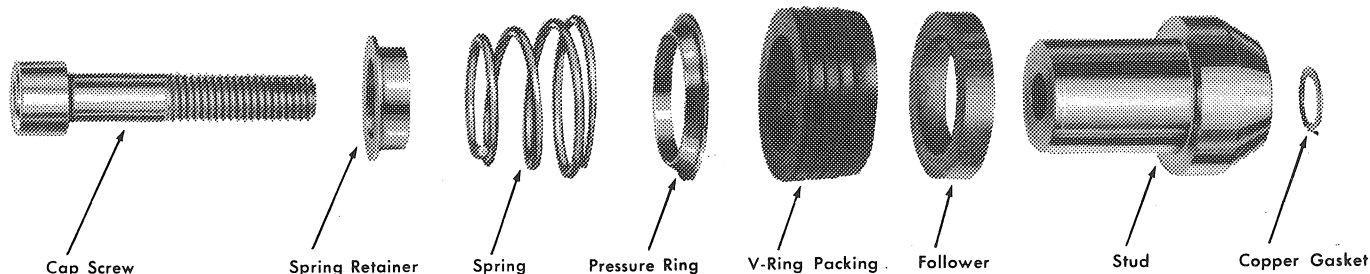


Fig. 1

### INSTALLING PACKING

Assemble V-Rings onto stud as shown. Lubricate the outside of the assembly with Molykote or other grease for ease in insertion - do not use a graphite type grease.

When installing each V-Ring assembly, rotate crankshaft until piston rod is at forward position. Place copper gasket 5030A128 in position in stud using a small amount of Permatex to hold in place.

Assemble capscrew, etc., into piston assembly and push into cylinder. Torque the capscrew to 50 ft. lb. using a hexagonal socket attachment  $\frac{3}{8}$ " across flats.

### REMOVING CYLINDERS

1. First remove packing as outlined previously.
2. Rotate crankshaft until piston rod is in rear position.
3. Insert puller (3) through inside of cylinder and pilot over piston rod.
4. Insert disc (4) into slots on puller (3).
5. Slip plate (2) over threads on puller (3) as shown.
6. Screw nut (1) on thread on puller (3) and snug up.
7. Tighten nut (1) until cylinder breaks loose.
8. Loosen nut (1) and slip disc (4) out of slots.
9. Remove puller (3) and repeat to remove other cylinders.

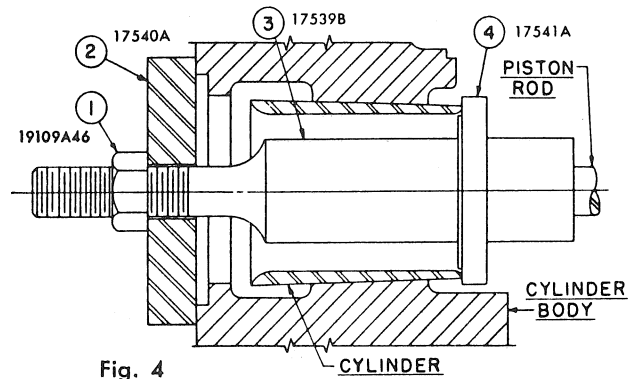


Fig. 4

### INSTALLATION

Reasonable care and judgment should be used when installing the new cylinder. Clean out any accumulation of loose rust or corrosion in cylinder body. Install a new O-Ring in groove on tapered portion of cylinder; lubricate with oil or grease for ease in insertion. Position cylinder carefully by hand to avoid cutting the O-Ring. Drive into position firmly with a wooden block and mallet. Never use a hydraulic press; excessive force can cause damage and make cylinders very difficult to remove for later replacement.

### REMOVING VALVE SEATS

First remove spring retaining bar, spring, and flat valve. When removing upper valve seat, pass head of puller through hole in valve seat before sliding wedge is

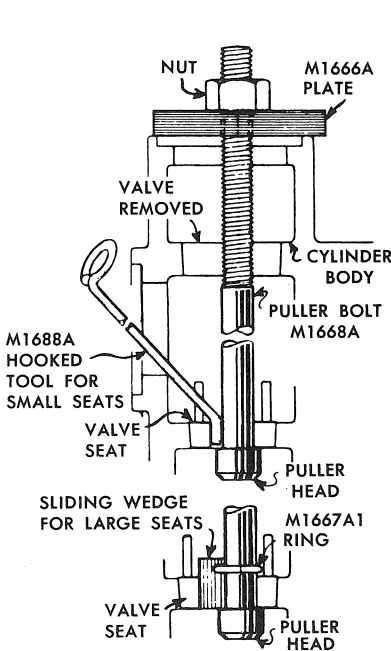


Fig. 5A

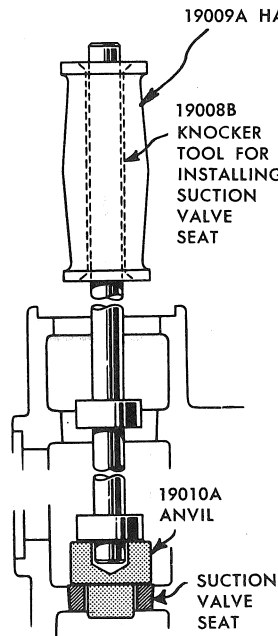


Fig. 5B

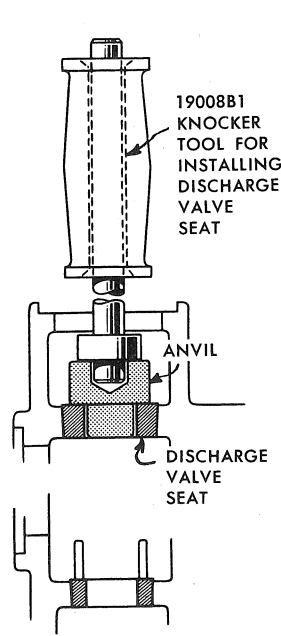


Fig. 5C

inserted alongside puller bolt. Draw down on nut at top of bolt. When removing lower seats drop puller bolt through opening for upper seat and remove in same manner as described above, using sliding wedge on pumps where lower seats are same size as upper seats. Use hooked tool M1668A as a wedge where lower seats are smaller.

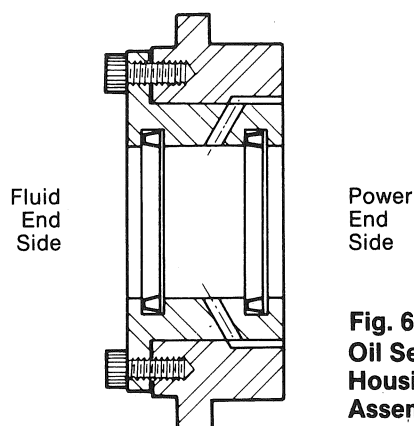
#### Replacement:

Place new lower seat in tapered hole in cylinder body. Hold a soft brass or hardwood round bar (with square flat end) against seat and drive into place with a hammer. A special seating tool 18999B as shown in Figs. 5B and 5C can be used for installing new seats. The knocker stem is in two pieces so that it can be shortened for installing discharge seats after suction seats have been installed (useful where working clearance above pump is limited).

**Caution:** Do not use a hand or arbor press to install valve seats. With excessive pressure it is possible to crack cylinder body.

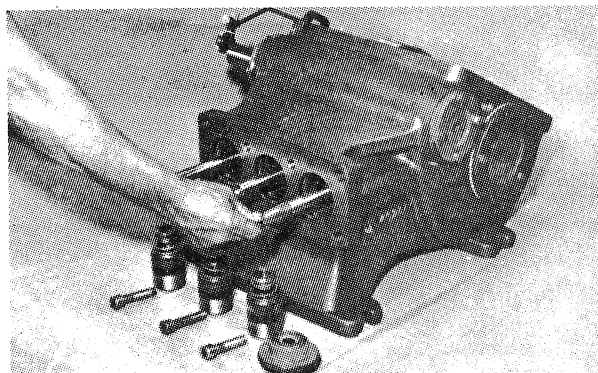
**NOTE:** Reassemble valve springs in correct location. When upper and lower valve seats are the same size, the heavier spring (larger diameter wire) is always installed on upper or discharge valve.

## REPLACING PISTON ROD SEALS



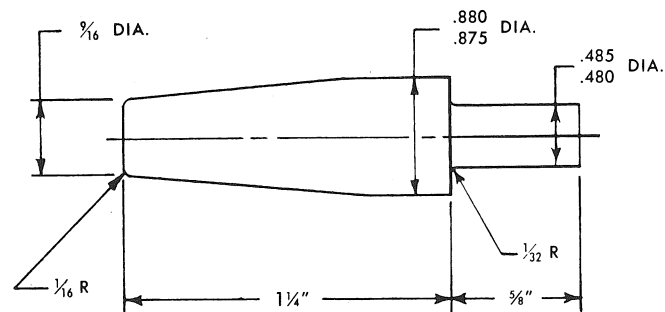
**Fig. 6  
Oil Seal  
Housing  
Assembly**

The rod seal assembly contains two seals, two oil seals with lips facing power end. The oil seal can be replaced without taking the fluid end off by removing the cylinder and piston to allow access for oil seal housing. Unscrew two Allen screws and place into the other two tapped holes. Gradually screw them in to push oil seal housing off the retainer. After assembling new seals in oil seal housing an assembly thimble should be used on end of crosshead rod for sliding oil seal housing back into retainer. Check gasket, replace if damaged.



**Fig. 7**

An assembly thimble should be used on small end of the piston rod to expand sealing edge as it is pushed on. Figure 7 illustrates an assembly thimble being placed on the end of the rod. Figure 8 shows a recommended thimble for installation of oil seals. The thimble should be machined from high carbon steel and polished on the exterior to reduce possibility of seal lip damage.



**Fig. 8**

## REMOVING CRANKSHAFT AND PINION SHAFT

Remove packing assemblies. Remove connecting link caps and move the link-crosshead assembly as far forward as possible. On some models, it may be necessary to remove the fluid cylinder body to obtain clearance for crankshaft removal. **IMPORTANT:** Note the markings on the connecting links and caps; these parts are not interchangeable and must be reassembled in their original positions.

Wedge a 3/4" board between crankshaft gear and gear case so that crankshaft will be held in place against pinion shaft. Remove both crankshaft bearing caps. (See Fig. 9). Hold crankshaft at ring gear and left-hand link journal (to prevent dropping into bearing bores), remove from gear case by moving crankshaft to right until left end can be swung free.



To remove pinion shaft, observe inside of gear case, to see if small sheet metal plates are in front of each bearing. These plates must be removed. Then remove bearing caps.

Next, using a lead or rawhide hammer, tap the end of pinion shaft extension to remove bearing cup at opposite end. After removing pinion shaft, the remaining bearing cup can be removed by gently tapping against the peripheral edge of the cup with a brass rod.

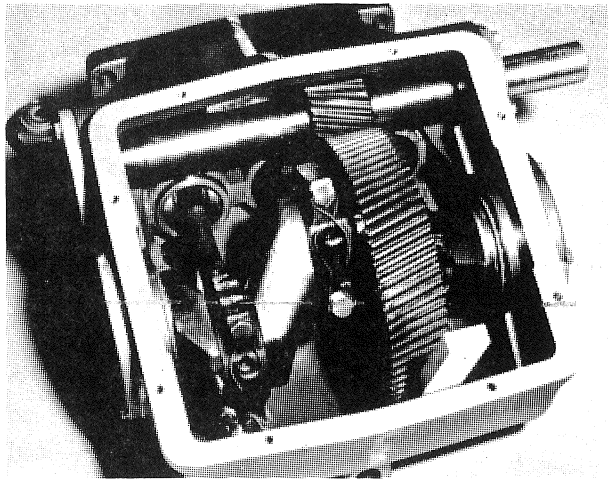


Fig. 9

### REPLACING PINION SHAFT AND SHIMMING BEARINGS

After installing the link-crosshead assemblies and moving them toward the fluid end as far as possible, tap right-hand pinion shaft bearing cup into position using the bearing cap. Make sure that the spacer is properly seated on drive end of pinion shaft (the curve side should match the fillet radius of pinion shaft). Place pinion shaft in position and tap left-hand bearing cup into place.

- A. Cover shaft keyway with vinyl tape to protect lip of oil seal, slide on the open bearing cap to which has been added approximately .030 shim, tighten the four cap screws to recommended torque.
- B. Put on other cap using total shim thickness known to be more than needed so that resulting end play is greater than required. Tighten cap screws holding pinion or crankshaft caps to gear case. Rotate pinion shaft back and forth and apply about 15 lbs. axial force to properly seat tapered rollers. Measure end play by using an indicating gage in a manner shown in Fig. 10.
- C. Subtract recommended end play (.005-.009) from actual end play as found above. This is the amount of shim that must be removed. After excess shim thickness has been removed, replace caps and retighten cap screws. Again measure end play. If end play is not within limits recommended, add or subtract shims as required.

**NOTE:** Pinion bearing shims are made of .002" layers bonded together. Start separation of layers by heating edge, then peel back.

### REPLACING CRANKSHAFT AND SHIMMING BEARINGS

Press the bearing cups into the caps. Place one cap into position on the right side with cap screws engaged about one turn; install crankshaft (left end first), then push both bearing caps into place. Extreme care should be exercised to avoid damage to gear teeth, bearings, and link journals.

Good performance of tapered roller bearings on a shaft require that correct shaft end play first be made by shimming. This insures that uneven heating, as encountered during warm-up, will not overload the bearings, and that after all parts are heated to approximately the same temperature the resulting end play will be correct. Shouldered roller bearings also require correct shimming to insure that the shoulder will properly locate the shaft and yet not bind.

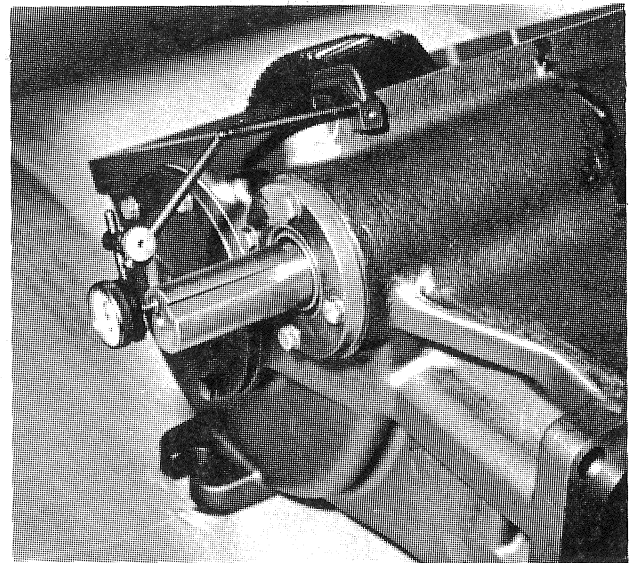


Fig. 10

For quiet operation and long life, the crankshaft and bearings must be installed with .003 to .005" preload; the following procedure will provide an accurate adjustment. Before starting, loosen the four cap screws on the pinion shaft bearing cap.

- A. Place about .045 shim on the right crankshaft bearing cap, tighten the five cap screws.
- B. Install the left cap without shims, secure with two cap screws positioned exactly as shown in Fig. 11. Torque the two cap screws at 13 ft.-lbs., rotate the crankshaft, retorque the cap screws. Do this three times to properly seat the tapered roller bearings.

- C. Measure (adjacent to the cap screws) the shim gap remaining between the bearing cap and the gear case.
- D. The required shim thickness for this cap is equal to the average gap measurement plus .022".
- E. Insert correct shim thickness under left bearing cap and tighten cap screws.
- F. Install connecting links and caps; note the markings; torque cap screws to 40 ft.-lbs.
- G. **IMPORTANT:** Check for adequate side clearance of links on crankshaft. Some shims must be moved from one end of the crankshaft to the other until sideways movement of all links can be seen.
- H. Check torque of cap screws on all bearing caps.

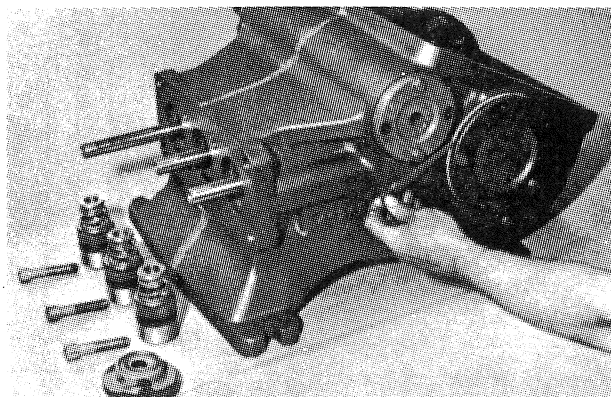


Fig. 11

### RECONDITIONED CRANKSHAFTS

When the crank throws are only slightly damaged, such as small surface grooves cut part way around the bearing surface, they can sometimes be reconditioned for further use. This can be done by sandpapering and polishing until all ridges are completely removed. The final polishing operation should be with very fine emery cloth. If the surface is badly damaged, the crankshaft can often be salvaged by "metalizing" the crank throw and then regrinding and polishing to the original diameter of 3.1240-3.1245". Contact Engineering Department for detail.

### SERVICING CONNECTING LINKS

The connecting rod link is furnished with replaceable split sleeve bearing inserts at the crank throw. It is never practical to attempt to re-fit connecting links to the crankshaft bearings by filing or grinding the mating faces of the link cap where it contacts the link. **Always be sure that the proper side of the link is placed upward when attaching it to the crankshaft.** The upper side contains an oil hole at the crosshead end of the link. This oil hole must be up to allow proper oil feeding to the crosshead pin bushing. The wrist pin is press-fitted into the crosshead and slip-fitted through the bronze bushing. Use arbor press instead of hammering to force in the wrist pin. Check to see if link is free to rotate after the wrist pin is pressed in. Make sure that either side of the wrist pin does **not** protrude beyond the crosshead.

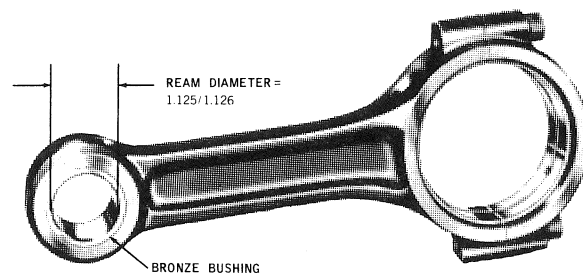


Fig. 12

The crosshead end of the connecting link is fitted with a bronze bushing. When new replacement links are obtained, these bushings are reamed to the proper size for immediate installation. If the bushing only is replaced, it may be necessary to ream the new bushing to the proper inside diameter after it is pressed into the link. When placing the bushing on the link be sure that the oil holes in the bushing and link will be in line after the bushing is pressed into position. Fig. 12 shows the proper diameter to which the bushing must be reamed for proper seating of the crosshead pin.

### CROSSHEAD AND PISTON RODS

Repair parts for the crosshead and piston rod are supplied only as a complete unit. If either of these parts becomes worn it is necessary to replace both the crosshead and piston rod. Under normal conditions a crosshead will not wear nor will the bore of the crankcase wear to the extent that oversize crossheads will be required. If extreme wear does occur, it will be due to severe damage from the lack of oil or a fairly large metal object scoring the crosshead bore. A clearance of .002" to .004" is standard for the crosshead. The parts can wear until considerably more clearance than this exists before harmful operation will occur.

### RECOMMENDED TORQUE (foot-pounds)

FASTENER LOCATION	D65-16
Link Bearing Caps	40
Crankshaft End Caps	20
Pinion Bearing End Caps	20
Cap Screw, Piston Assembly to Piston Rod	50
Valve Cover Clamps	100
Cylinder Cover Clamps	175

— WARNING —

THIS PUMP MUST BE INSTALLED WITH A PRESSURE RELIEF VALVE IN DISCHARGE LINE.

## SERVICE CHART

### SERVICE PROBLEM

	E	D	C	B	A
A Failure of pump to build pressure with discharge closed					X
B Failure to hold pressure with discharge open					X
C Pump is noisy					X
D Pump gets hot					X
E Pressure gauge shows abnormal fluctuation					X
POSSIBLE CAUSE OF PROBLEM	E	D	C	B	A
1. Pump not primed					X
2. Valve closed in suction line			X		X
3. Suction line or sediment chamber clogged			X	X	X
4. Air leak in suction line			X	X	X
5. Pressure regulator valve badly worn or not properly adjusted				X	X
6. Broken valves or springs	X		X	X	
7. Pump packing or valves badly worn	X		X	X	
8. Pressure regulator bypassed by open #1 valve				X	X
9. Pump cylinder body cracked			X	X	X
10. Water in crankcase		X			
11. Worn connecting link inserts or wrist pin bushings		X	X		
12. Lack of oil in crankcase		X	X		
13. Foaming mixture in tank	X		X	X	
14. Regulator plunger sticking	X				
15. Foreign matter under pump valve	X		X	X	
16. Loose piston rod			X		
17. Improper preload of crankshaft bearings		X	X		

### Explanation of the Service Chart

1. Pump priming is usually not necessary when the pump is installed correctly. However, there are certain unusual conditions which may make it necessary to prime the pump to get the pumping action started. Priming will be required under conditions where it is impossible for the piston to displace the air in the pump and replace it with water. This could be caused by a high suction lift (high from the water supply to the pump), the valves being stuck on the seat, such as after pumping a sticky fluid, or it might be caused by valves sticking due to extreme corrosion of the valves and seats. A pump will not prime readily if someone has tampered with the valve springs causing them to exert undue pressure of the valve plates against the valve seats. When the pump appears to need priming this condition can be checked by pouring water into the cylinder body through one of the valve cap openings or into the pump discharge opening at the same time operating the pump to work the water into the cylinder and valve passages.

2. Frequently a gate valve is installed in the suction line between a tank or pressure line and pump sediment chamber. This valve is usually installed in the line to shut off the supply source for cleaning sediment chamber or for pump repairs.

If this valve is closed or even partially closed it will interfere with the flow of water to the pump suction to such an extent that the pump will not perform to full capacity. If the valve is partially closed it may cause severe knocking and vibration of the pump because the water cannot flow into the cylinder cavities fast enough.

3. A sediment chamber should be installed in the suction line between the gate valve and the pump suction. The strainers in these sediment chambers are of more than adequate capacity to allow a free flow of the liquid to the pump. However, because of its normal function of collecting sediment the strainer may become severely clogged and in some cases, it will com-

pletely stop the flow of liquid to the pump. The length of time the pump may operate before it is necessary to clean the strainer will depend upon the type of liquid pumped. After the pump has been used a short period the operator will soon become familiar with the amount of running time between strainer cleanings.

4. Any piston pump, when operated at high pressure will not operate satisfactorily or quietly if a mixture of air and water is allowed to enter the pump suction. For this reason, a small air leak in the suction line will cause the pump to knock and vibrate excessively. This holds true only for a small air leak which allows the pump to draw a certain amount of water mixed with air on each stroke of the piston. A large air leak will cause the pump to lose prime after which it cannot be reprimed until the air leak is stopped. Air leaks may occur at the joints of the suction line piping, at the gate valve in the suction line, at the gasket sealing the cap on the sediment chamber or by a crack in the suction wall of the cylinder body, such as might be caused by freezing if the pump is not properly drained in freezing weather. There is also a definite possibility of air drawing past the packing on the suction stroke if the packing is badly worn.

5. If the pressure regulator internal bypass valve is badly worn it will allow too much of the pump capacity to be by-passed and recirculated back to the tank. By examining the flow from this valve with the discharge turned on, it can be determined whether or not the valve is worn. If a heavy flow continues when the discharge is turned on, it is usually a good indication that the valve is badly worn and should be replaced or that something is lodged under the valve holding it open.

6. A broken pump valve or spring will often prevent one cylinder from functioning properly. Very rough pulsing discharge, a knocking sound, and a loss of capacity will result. If not repaired promptly, the rough running pump can cause mechanical damage to itself or other system components.

7. Badly worn packing or valves and valve seats will cause a serious drop in pump capacity. This will be indicated by a drop in pressure when guns are turned on. Worn packing is very easy to detect because of the water leakage. The packing should be replaced just as soon as this leakage is noticed. If it is allowed to continue some of the water may work past the piston rod seals into the pump crankcase. Water in the pump crankcase will cause severe corrosion of the bearings causing rapid wear. Worn valves can only be detected by visual examination of each valve assembly. The most prevalent cause of valve wear is the use of highly abrasive liquids which will cause the valve and valve seat to wire cut. The cut starts as a very small groove

but increases rapidly once the valve starts to leak through this groove. If the valves are replaced as soon as they start to show this cutting action it will prevent the valve seat from becoming cut in a similar manner and keep the cost of replacement parts to a minimum.

8. If a portion of the pump delivery is allowed to bypass because the #1 control valve is not completely closed there may not be adequate flow to develop full pressure. This also will cause rapid wear in the control valve; any excess flow should be bypassed only by the pressure regulator.

9. Pump cylinder bodies must withstand an extreme amount of shock and pulsation while the pump is in operation. If the pump is allowed to freeze, due to not being drained, the freezing may crack the cylinder body walls in almost any location. If the crack should occur on the suction valve or cylinder portion of the body it may allow a small amount of air to enter on the suction stroke and cause noisy operation or a decrease in pumping capacity. If the crack develops in the walls between the cylinder cavities or discharge valve cavity it may allow the water to flow from one cavity to the adjacent cavity and rob the pump of its effective displacement. This will not cause noisy operation but will reduce the pump capacity and may show up as a drop in pressure when the discharge is open.

10. Water may accumulate in the pump crankcase from two sources; the most prevalent being leakage of the packing as explained in Paragraph 7. The other means of accumulation being a condensation of moisture inside the crankcase due to changes in weather or the repeated heating and cooling of the pump due to its normal usage. Pumps that are used rather consistently and run for a considerable period of time to heat the oil and other working parts will not normally accumulate water by condensation. If the packing is replaced as soon as it starts to leak it will be impossible for water to enter the crankcase from this cause.

11. Worn connecting link bearings will only develop because of unusual or adverse operating conditions. They will, however, be seriously affected by corrosion if water is present in the crankcase and they will wear out from overheating if the oil is not clean and of good quality. For this reason we recommend thorough draining, cleaning and refilling with new oil at the specified interval and prior to any storage period. Replace link inserts as soon as any wear is noticed to avoid damage to crankshaft journals. See also Paragraph 17 and Lubrication instructions.

12. Lack of sufficient oil in crankcase can quickly cause failure of pump power end and result in extensive re-

pairs. Oil level should be checked periodically during normal operation as well as when maintenance work of any nature is performed. Insufficient oil will first be indicated by excessive heat and should be corrected immediately.

13. A foaming mixture will sometimes have the same effect as a small air leak in the suction line. This is because various quantities of the foam is drawn through the suction line into the pump disrupting the normal flow of water.

14. Pressure regulators may become sluggish in action due to the plunger sticking or fitting too tightly in its cylinder. This condition may be caused by an accumulation of chemicals collecting in and around the plunger, or may be due to excessive corrosion of the plunger parts. To check this condition, remove and clean the plunger. After cleaning the plunger, parts should be covered with a waterproof grease before assembling. In some cases there is a tendency for the pressure regulator to chatter or vibrate excessively. This is an indication of unstable operation due to nozzling in the high or low capacity range of the regulator; the nozzling requirements should be at least 50% and not exceed 90% of pump capacity.

Due to nozzle wear, the system requirements may exceed the 90% limit, resulting in cycling or hammering of the regulator. This can readily be checked by replacing the worn nozzle.

15. If a large piece of foreign matter becomes lodged between a pump valve and valve seat or if something of this kind becomes wedged in so that it prevents the valve from operating normally we can expect drastic drop in capacity and considerable surge or pulsation will be noticed in the discharge line. To correct a condition of this kind it is usually necessary to examine each valve in the pump until the offending condition is located. The use of clean liquid and seeing that the suction strainer is in proper condition will prevent trouble of this kind.

16. Noisy pump operation will sometimes be caused by a piston rod being loose in the crosshead.

This will only become evident after the rod becomes so extremely loose that some end motion can be found between the rod and crosshead. A noise of this kind usually has a regular cadence timed with each stroke. When this condition occurs it is always necessary to replace both the rod and the crosshead.

17. More than the recommended amount of preload to the crankshaft bearings will reduce bearing life, require more power, and generate more heat. Less than the recommended preload may cause a knock timed with the crankshaft rotation. Check for loose bolts on the crankshaft end caps or adjust shims to obtain proper bearing preload.

Worn roller bearings will continue to run for a long time but will introduce wear particles into the oil (which can cause other damage), may cause overheating, and may or may not cause a noticeable noise. Check oil regularly, check for wear particles when changing oil.

#### **UNUSUAL CONDITIONS WHICH MAY CAUSE TROUBLE**

Pinion shaft breakage on the drive side of the pump may be caused by having the pulley or sprocket positioned too far away from the pump bearing. It may also be caused by a loose drive chain if the pump is chain driven.

If the V-belts have a tendency to wear rapidly, it may be due to having the belt tightener pulley adjusted too far into the belt, throwing a reverse bend in the belt where it passes over the pulley. If very much reverse angle seems necessary to keep the belt tight, other provisions should be made for tightening, such as placing shims under the pump base or otherwise spreading the drive centers enough to take up the belt length. On multiple V-belt drives, a complete set of belts should be installed when making a replacement. Further, all the belts in one set should be checked for length and accurately matched to avoid placing an undue load on any one belt.

# Myers®

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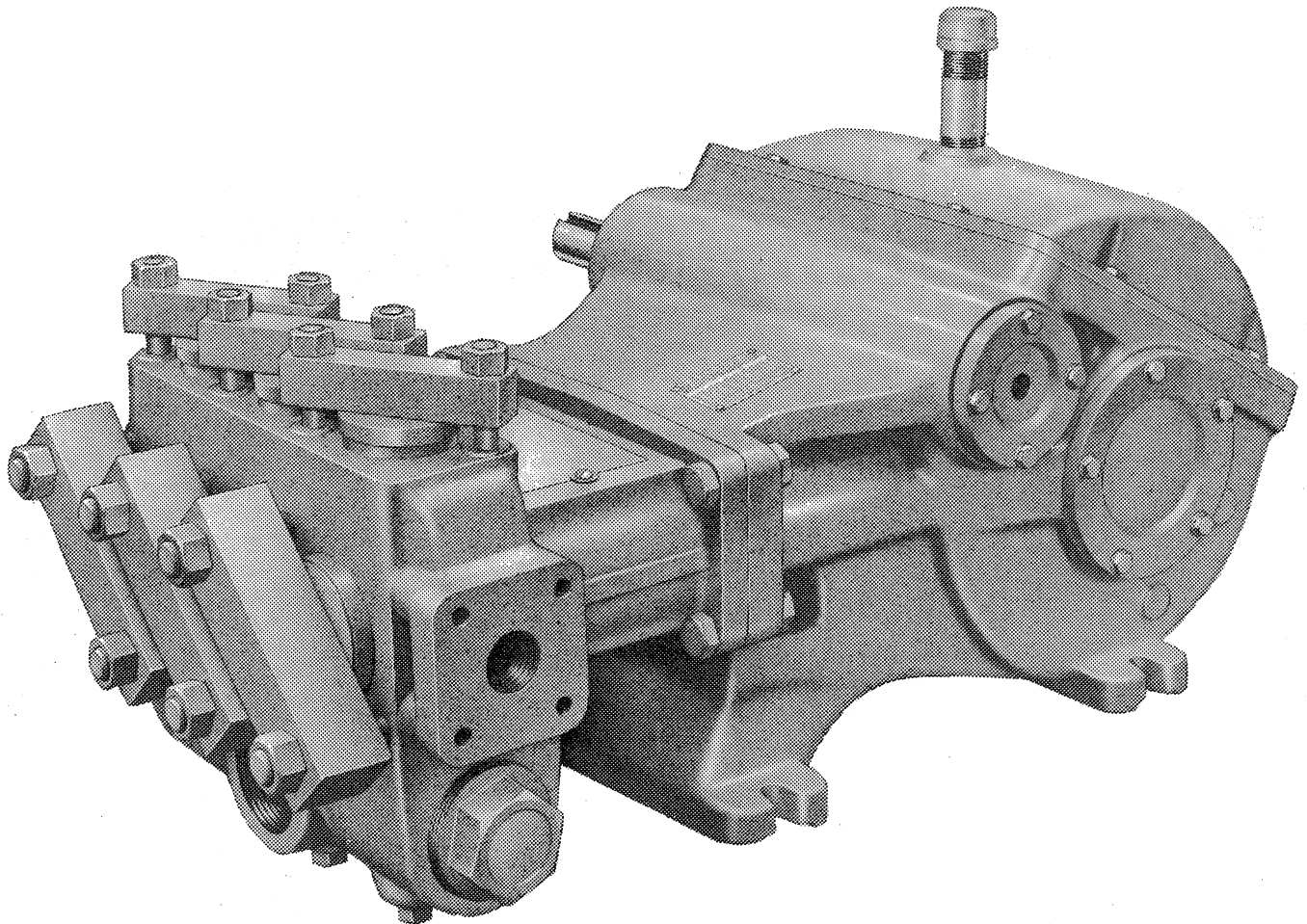
**D65-16AVD, D65-16AVDL,  
D65-16AVD-CP, D65-16AVAB,  
D65-16AVAB-CP**

**Myers®**

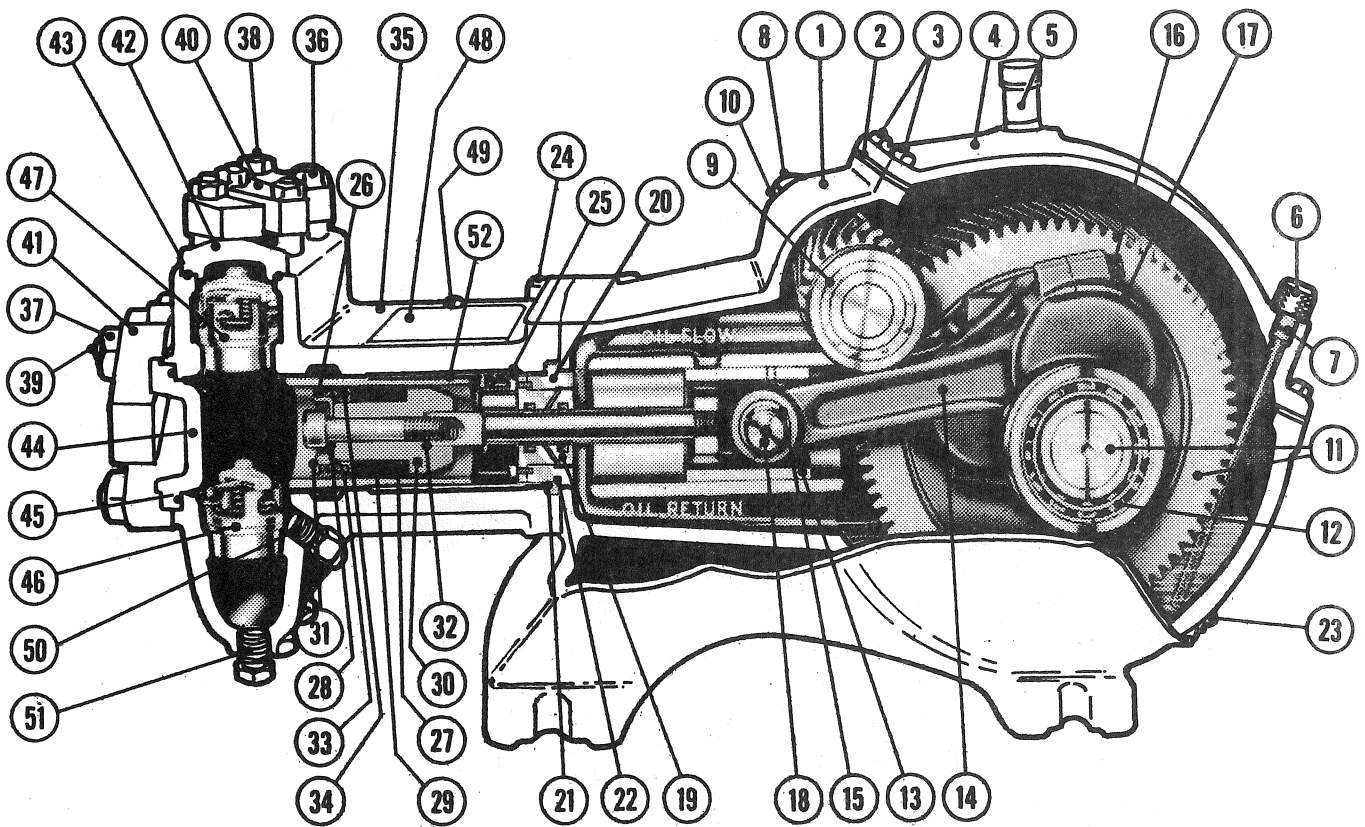
Pentair Pump Group

## Industrial Pumps Parts List

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# D65-16AVD, D65-16AVDL, D65-16AVD-CP, D65-16AVAB, D65-16AVAB-CP Industrial Pumps Parts List



# D65-16AVD, D65-16AVDL, D65-16AVD-CP, D65-16AVAB, D65-16AVAB-CP Industrial Pumps Parts List

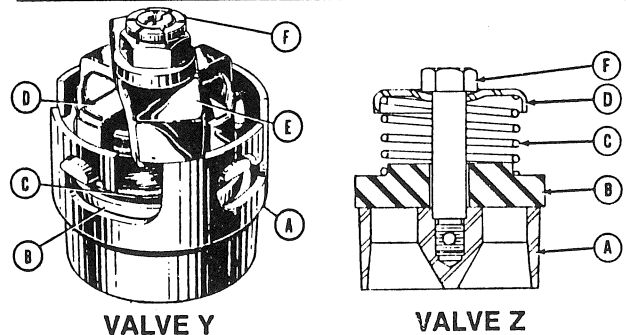
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Ref. No.	Description	Qty. Req'd.	Part No.
1	Case, Gear	1	04625E001
2	Gasket, Lid	1	06201C000
3	Screw, Cap, 5/16"-18 UNC x 7/8", Steel	8	19100A005
4	Lid	1	04561B000
5	Nipple, Special Vent	1	17995A000
	Cap, Pipe	1	05737A002
6	Gauge, Oil, with "O" Ring	1	17360A010
7	"O" Ring, 3/8" I.D., 9/16" O.D., 1/16" Thick	1	110-000110-201
8	Shaft, Pinion	1	20164B000
	Spacer	1	20164B002A
	Shim	4	05231A074
	Shim	4	05231A075
9	Cone, Bearing	2	05674A013
	Cup, Bearing	2	05675A009
10	Cap, Open	1	04563A001
	Cap, Closed	1	04741B001
	Oil Seal	1	05710A017
	Screw, Cap, 3/8"-16 UNC x 1", Steel	18	19101A013
	Washer, Seal	18	14946A003
11	Crankshaft	1	20355C010
12	Cone, Bearing	2	05674A018
	Cup, Bearing	2	05675A013
	Cap, Bearing	2	04624B004
	Shim, Plastic, Green, 6-7/32" x 5-1/32" x .0115"	6	05068A016
	Shim, Plastic, Pink, 6-7/32" x 5-1/32" x .003"	6	05068A018
	"O" Ring, 5" I.D., 5-1/8" O.D., 1/16" Thick	2	05876A098
13	Crosshead	3	06211B041
14	Link, Ductile Iron	3	17042C002
15	Bushing	3	B01619A000
16	Screw, Cap	6	19103A016
	Lock Washer	6	05454A004
17	Bearing, Two Halves	3	15245A101
18	Wrist Pin	3	M01525A001
19	Housing, Oil Seal	3	24959A001
	Oil Seal	6	22835A004
20	Retainer, Oil Seal Housing	3	24958A000
	Screw, Allen	6	06106A034
	Gasket, Seal Housing	3	05059A434
	Kit for Ref. No. 19 & 20	1	24648A000
21	Spring	3	M1643A000
22	Gasket	3	05059A058
23	Plug, Pipe, Magnetic	1	17481A002
24	Screw, Cap, 3/4"-10 UNC x 3", Steel	4	06106A038
	Nut, Hex 3/4"-10 UNC, Steel	4	19109A050
	Lockwasher	4	05454A003
25	Screw, Cap, 5/8"-11 UNC x 2", Steel	4	19105A008
26	Screw, Cap, .551"-14 METRIC x 2-3/4"	3	16654A006
26	Screw, Cap, .551"-14 METRIC x 3" 316 SST for AVAB-CP Pump	3	16654A008
27	Follower	3	20855A000
29	Packing "V" Rings	3	18922A004
30	Stud, 2-9/16" x 2-1/16" x 1-1/2" SST	3	20850A000
30	Stud, 2-9/16" x 2-1/16" x 1-1/2", 316 SST for AVAB-CP Pump	3	20850A010

Ref. No.	Description	Qty. Req'd.	Part No.
31	Retainer	3	20852A000
31	Retainer	3	20852A001
32	Washer	3	05030A128
33	Spring	3	20853A000
34	Ring	3	20854A000
34	Ring 316 SST for AVAB-CP Pump	3	20854A001
35	Body, Cylinder	1	18639F002
35	Body, Cylinder, Alum. Bronze for AVAB & AVAB-CP Pump	1	18639F004
	"O" Ring, 2-3/4" x 2-15/16" x 3/32"	3	05876A095
36	Nut, Hex, 5/8"-11 UNC, Steel	6	19109A046
37	Nut, Hex, 7/8"-14 UNF, Steel	6	19109A072
38	Stud, 5/8"-11 UNC x 3-5/16"	6	05659A560
39	Stud, 7/8"-14 UNF x 4-1/2"	6	05659A089
40	Clamp, Valve Cap	3	20848A000
41	Clamp, Cylinder Cap	3	20856A000
42	Cap, Valve	3	17390A000
42	Cap, Valve, Alum. Bronze for AVAB & AVAB-CP Pump	3	17390A002
43	"O" Ring, 2-3/8" x 2-9/16" x 3/32"	3	05876A064
44	Cap, Cylinder	3	20849A000
44	Cap, Cylinder, Alum. Bronze for AVAB & AVAB-CP Pump	3	20849A001
45	"O" Ring, 3-1/4" x 3-1/2" x 1/8"	3	05876A096
46	Assembly, Valve, Suction: D65-16AVD, D65-16AVD-L & D65-16AVAB "Y"	3	11903A004
46	Assembly, Valve, Suction: D65-16AVD-CP "Z"	3	18925A003
46	Assembly, Valve, Suction: D65-16AVAB-CP "Z" 316	3	18925A013
47	Assembly, Valve, Discharge: D65-16AVD, D65-16AVD-L & D65-16AVAB "Y"	3	11903A003
47	Assembly, Valve, Discharge: D65-16AVD-CP "Z"	3	18925A004
47	Assembly, Valve, Discharge: D65-16AVAB-CP "Z" 316	3	18925A014
48	Lid, Cylinder	1	M01520A000
49	Screw, Machine 1/4"-20 UNC x 1/2"	2	05028A002
	Washer	2	05030A020
50	Plug, Pipe, 1/2"	3	05022A015
50	Plug, Pipe 1/2" for AVAB Pump	3	05022A035
50	Plug, Pipe, 1/2" 316 SST for AVAB & AVAB-CP Pump	3	05022A063
51	Plug, Pipe, 1"	3	05022A043
51	Plug, Pipe, 1" for AVAB Pump	3	06206A000
51	Plug, Pipe, 1" Alum. Bronze for AVAB & AVAB-CP Pump	3	05022A064
52	Liner, Cylinder, 316 SST	3	20851A002
	"O" Ring, Cylinder (incl. w/liner)	3	05876A095
	Washer, Splash	3	05059A418
	Plug, Pipe, 1-1/4"	1	05022A047
	Plug, Pipe, 3"	2	03210A000
52	Liner, Cylinder 316 SST for AVAB-CP Pump	3	20851A002
	"O" Ring, Cylinder (incl. w/liner)	3	05876A095
	Washer, Splash	3	05059A418
	Plug, Pipe, 1-1/4" Alum. Bronze for AVAB & AVAB-CP Pump	1	05022A065
	Plug, Pipe, 3" Alum. Bronze for AVAB & AVAB-CP Pump	2	03210A010

Style Valve Assembly		Y	Z	Z	
Suction Valve Assembly		11903A4	18925A3	18925A13	
Discharge Valve Assembly		11903A3	18925A4	18925A14	
Seat Material		420F	420F	316	
Ref. No.	Name of Part*	No. Req.	Part No.	Part No.	Part No.
A	Seat, Valve	6	6271A	18835A2	18835A4
B	Valve	6	17553A2	18834A1	18834A1
C	Spring, Valve, Suction	3	18463A	18463A	18463A
C	Spring, Valve, Discharge	3	11829A	11829A	11829A
D	Retainer, Spring, Valve	6	11827A	18833A1	18833A1
E	Clamp, Retainer, Spring	6	11828A	—	—
F	Lock Nut or Cap Screw	6	11904A1	18832A	18832A1

\*NOTE: Except where Noted — Parts for suction and discharge are interchangeable.



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# AF/AFG

## Oil Burner Manual

Beckett™

RESIDENTIAL BURNERS



### **WARNING** Potential for Fire, Smoke and Asphyxiation Hazards



*Incorrect installation, adjustment, or misuse of this burner could result in death, severe personal injury, or substantial property damage.*

#### **To the Homeowner or Equipment Owner:**

- Please read and carefully follow all instructions provided in this manual regarding your responsibilities in caring for your heating equipment.
- Contact a professional, qualified service agency for installation, start-up or service work.
- Save this manual for future reference.

#### **To the Professional, Qualified Installer or Service Agency:**

- Please read and carefully follow all instructions provided in this manual before installing, starting, or servicing this burner or heating system.
- The Installation must be made in accordance with all state and local codes having jurisdiction.

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## Hazard Definitions

**⚠ DANGER** Indicates a hazardous situation, which, if not avoided, will result in death or serious injury.

**⚠ WARNING** Indicates a hazardous situation, which, if not avoided, could result in death or serious injury.

**⚠ CAUTION** Indicates a hazardous situation, which, if not avoided, could result in minor or moderate injury.

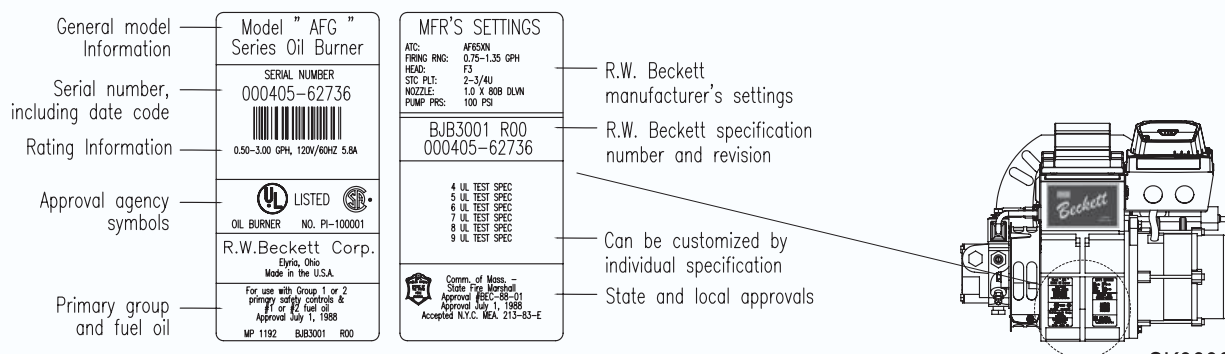
Within the boundaries of the hazard warning, there will be information presented describing consequences if the warning is not heeded and instructions on how to avoid the hazard.

**NOTICE** Intended to bring special attention to information, but not related to personal injury or property damage.

**NOTICE** This manual contains information that applies to both AF and AFG burners. These burners may appear to be basically identical, but there are differences in design and performance. Please review the comparison chart below:

Feature	AF	AFG
Static Pressure Capability	Conventional - Low range	Enhanced - Medium range
Blower Wheel Design	Standard strip	Special tablock
Inlet Airflow Design	Standard inlet bell	Special airguide
UL Air Tube Combinations	"F" Series ONLY	"F" or "M" Series
Igniter Gaskets Baseplate/Barrier	Optional, as specified	Required, always specified
Low Firing Rate Baffle	Not required	Required, per specification

**Figure 1. Burner label location**



**⚠ WARNING** **Owner's Responsibility**

**Incorrect installation, adjustment, and use of this burner could result in severe personal injury, death, or substantial property damage from fire, carbon monoxide poisoning, soot or explosion.**

Contact a professional, qualified service agency for the installation, adjustment and service of your oil heating system. This work requires technical training, trade experience, licensing or certification in some states and the proper use of special combustion test instruments.

Please carefully read and comply with the following instructions:

- Never store or use gasoline or other flammable liquids or vapors near this burner or appliance.
- Never attempt to burn garbage or refuse in this appliance.
- Never attempt to light the burner/appliance by throwing burning material into the appliance.
- Never attempt to burn any fuel not specified and approved for use in this burner.
- Never restrict the air inlet openings to the burner or the combustion air ventilation openings in the room.

# General Information

## To the Owner:

**Thank you for purchasing a Beckett burner** for use with your heating appliance. Please pay attention to the Safety Warnings contained within this instruction manual. Keep this manual for your records and provide it to your qualified service agency for use in professionally setting up and maintaining your oil burner.

Your Beckett burner will provide years of efficient operation if it is professionally installed and maintained by a qualified service technician. If at any time the burner does not appear to be operating properly, **immediately contact your qualified service agency** for consultation.

**We recommend annual inspection/service of your oil heating system by a qualified service agency.**

**Daily** – Check the room in which your burner/appliance is installed. Make sure:

- Air ventilation openings are clean and unobstructed
- Nothing is blocking burner inlet air openings
- No combustible materials are stored near the heating appliance
- There are no signs of oil or water leaking around the burner or appliance

### Weekly


- Check your oil tank level. Always keep your oil tank full, especially during the summer, in order to prevent condensation of moisture on the inside surface of the tank.

## **WARNING** Impaired Burner Performance and Fire Hazard.

**Do NOT operate the burner beyond specifications outlined in the following Table.**

- For applications beyond these limits, consult Beckett Technical Service at 1-800-645-2876.
- NOTE: Some packaged appliances with burners may be agency listed as a unit to operate beyond these limits. Consult the appliance manufacturer's specifications and agency approvals for verification.

**Table 1 – Burner Specifications**

Capacity (Note 1)	'F' Head (AF & AFG) Firing rate range: ..... 0.40 – 3.00 GPH Input: ..... 56,000 – 420,000 Btu
	'L1' Head (AFG Only) Firing rate range: ..... 0.40 - 1.10 GPH Input: ..... 56,000 – 154,000 Btu/h
	'L2' Head (AFG Only) Firing rate range: ..... 0.50 - 1.00 GPH Input: ..... 70,000 – 140,000 Btu/h
	'V1' Head (AFG Only) Firing rate range: ..... 0.75 - 2.75 GPH Input: ..... 105,000 – 385,000 Btu/h
Certifications/ Approvals	UL listed to comply with ANSI/UL296 and CSA-B140.0
Fuels	U. S No. 1 or No. 2 heating oil only (ASTM D396) Canada No. 1 stove oil or No. 2 furnace oil only   <b>CAUTION</b>  <b>DO NOT USE GASOLINE, CRANKCASE OIL, OR ANY OIL CONTAINING GASOLINE.</b>
Electrical	Power supply:..... 120 volts AC, 60 Hz single phase Operating load: ..... Amps max Motor: .....1/7 hp, 3450 rpm, NEMA 48M frame PSC rotation CCW when facing shaft end Ignition: .....Continuous duty solid-state igniter
Fuel pump	Outlet pressure: .....Note 2
Air tube	ATC code: .....See Table 2
Dimensions (with cover)	Height (maximum) ..... 12.5 inches Width (maximum) ..... 15 inches Depth ..... 9.25 inches Air tube diameter ..... 4.00 inches
Ambient Operating Temperature	+32° F. (0 C.) Minimum +115° F. (+46 C.) Maximum (See above Warning)
Moisture	5% to 95% RH, non-condensing and non-crystallizing

*Note 1: Approval agency listed rating for these burners is 0.40 to 3.00 gph. However, the firing rate range is limited by the specific air tube combination being used. Refer to Table 2.*

*Note 2: See appliance manufacturer's burner specifications for recommended pump discharge pressure.*

## **WARNING** Do NOT Alter the Original Burner Design

**Tampering with or altering the burner design could seriously impair performance, resulting in loss of static pressure, damage to the system components, reduced air volume, heavy smoke, flame impingement, appliance sooting, hot gas puff-back, and asphyxiation or fire hazards.**

Maintain the design to its original configuration.

Only use parts specified for AF or AFG Burners

Do NOT remove the air guide from the AFG chassis.

Do NOT use 'M' Series air tube combinations on AF Burners.

Never try to convert an AF to an AFG or vice versa

Any design alteration will:

- Void UL Listing
- Void manufacturer's warranties
- Seriously impact burner performance
- Greatly increase your liability risk

**Table 2 – Air Tube Combination (ATC) codes**

Firing Rate (gph)	Head	Static plate size (inches)	Venturi	ATC Codes for usable air tube lengths ('A' in inches; See Figure 3.)									
				4-1/2	5	5-3/8	6-5/8	7	7-1/4	9	10-1/2	13	16
0.50-0.75	F0	3-3/8U	None	AF44XR	-	AF53XR	AF65XR	-	AF72XR	AF90XR	AF104XR	AF130XR	A160XR
0.75-1.25	F3	2-3/4U	None	AF44XN	-	AF53XN	AF65XN	-	AF72XN	AF90XN	AF104XN	AF130XN	AF160XN
0.85-1.35	F4	2-3/4U	None	AF44WH	-	AF53WH	AF65WH	-	AF72WH	AF90WH	AF104WH	AF130WH	AF160WH
0.85-1.65	F6	2-3/4U	None	AF44YB	-	AF53YB	AF65YB	-	AF72YB	AF90YB	AF104YB	AF130YB	AF160YB
1.10-2.00	F12	2-3/4U	None	AF44XO	-	AF53XO	AF65XO	-	AF72XO	AF90XO	AF104XO	AF130XO	AF160XO
1.65-2.50	F22	2-3/4U	None	AF44XP	-	AF53XP	AF65XP	-	AF72XP	AF90XP	AF104XP	AF130XP	AF160XP
2.50-3.00	F31	None	None	AF44XS	-	AF53XS	AF65XS	-	AF72XS	AF90XS	AF104XS	AF130XS	AF160XS
0.50-1.10	L1	3-3/8U	8hole	-	AFG50MB	-	-	AFG70MB	-	AFG90MB	-	-	-
0.50-1.00	L2	2-3/4U	8hole	-	AFG50MP	-	-	AFG70MP	-	AFG90MP	-	-	-
0.75-2.75	V1	2-3/4U	8hole	-	AFG50MD	-	-	AFG70MD	-	AFG90MD	-	-	-
0.40-0.75	F0	3-1/2U	None	AF44WG	-	AF53WG	AF65WG	-	AF72WG	AF90WG	AF104WG	AF130WG	A160WG

**Notice Special Requirements**

- THE INSTALLATION OF A BURNER SHALL BE IN ACCORDANCE WITH THE REGULATIONS OF AUTHORITIES HAVING JURISDICTION.
- For recommended installation practices in the U.S. refer to the latest edition of NFPA 31. (CSA-B139 and CSA-B140 in Canada).
- Concealed damage — If you discover damage to the burner or controls during unpacking, notify the carrier at once and file the appropriate claim.
- When contacting Beckett for service information — Please record the burner serial number (and have available when calling or writing). You will find the serial number on the silver label located on the left rear of the burner. Refer to Figure 1.

**! WARNING Professional Service Required**

***Incorrect installation, adjustment, and use of this burner could result in severe personal injury, death, or substantial property damage from fire, carbon monoxide poisoning, soot or explosion.***

Please read and understand the manual supplied with this equipment. This equipment must be installed, adjusted and put into operation only by a qualified individual or service agency that is:

- Licensed or certified to install and provide technical service to oil heating systems.
- Experienced with all applicable codes, standards and ordinances.
- Responsible for the correct installation and commission of this equipment.
- Skilled in the adjustment of oil burners using combustion test instruments.

The installation must strictly comply with all applicable codes, authorities having jurisdiction and the latest revision of the National Fire Protection Association Standard for the installation of Oil-burning Equipment, NFPA 31 (or CSA-B139 and CSA-B140 in Canada).

Regulation by these authorities take precedence over the general instructions provided in this installation

# Inspect/Prepare Installation Site

## Inspect Chimney or Direct Vent System

### **WARNING** Fire, Smoke & Asphyxiation Hazard

- Carefully inspect the chimney or exhaust vent system.
  - Make sure it is properly sized and in good working condition.
  - Follow the instructions supplied by the appliance manufacturer.
  - The installation must strictly comply with all applicable codes, authorities having jurisdiction and the latest revision of the National Fire Protection Association Standard NFPA 31 for the installation of chimneys and vent sizing, (or CSA-B139 and CSA-B140 in Canada).
  - Regulation by these authorities take precedence over the general instructions provided in this installation manual.
1. Starting with minimum gph firing rate, the minimum size recommended is 6" flue pipe with 8" X 8" inside chimney, unless specified otherwise by the appliance manufacturer.
  2. A chimney flue shall extend at least 3 feet above the highest point at which the chimney comes in contact with the roof, and not less than 2 feet above the highest roof surface or structure within 10 feet horizontally of the chimney. Refer to Figure 2.
  3. Any accumulation of soot or debris in chimney offsets should be removed
  4. Any obstructions such as a protruding joint or a piece of broken tile wedged in the chimney should be removed.

5. No other appliance connection should be made to the same flue pipe.
6. The flue pipe should have an upward pitch toward the chimney of at least 1/4" per foot of length. It should fit tightly and should not project into the chimney.
7. Any leakage between tiles, around clean-out doors, or around the vent pipe should be sealed.

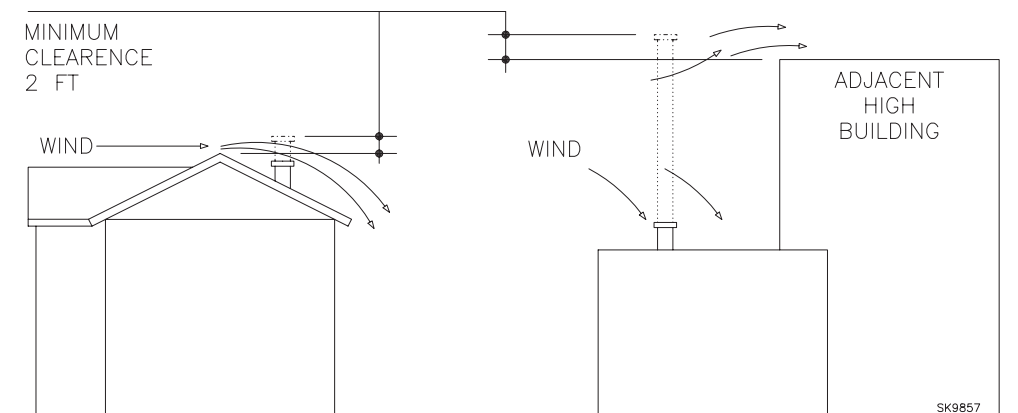
### INSULATED STAINLESS STEEL CHIMNEY LINERS

The new designs of high efficiency oil furnaces and boilers in conjunction with flame retention oil burners are more efficient. One result of increased efficiency is lower flue gas temperatures. As flue gases rise in the chimney, they will cool and condense when they reach the dew point. The condensation will mix with the sulphur in the flue gases creating sulphuric acid. The acid will attack the chimney mortar, brick and clay liners causing corrosion, deterioration and blockage of the chimney. Eventually the blockage could prevent exhausting the flue gases. Instead, the flue gases could vent out the barometric damper into the living space.

Therefore, it is strongly recommended that an approved insulated stainless steel liner be installed.

- For those installations not requiring a chimney, such as through-the-wall vented appliances, follow the instructions given by the appliance and power venter (if used) manufacturers.

**Figure 2 – Chimney Design - Above the Roof**



**NOTE:** Correct chimney design is shown by dotted lines. Incorrect chimney design, as shown by the solid lines, may result in down-drafts.

## Combustion air supply



**WARNING**

### Adequate Combustion and Ventilation Air Supply Required

**Failure to provide adequate air supply could seriously affect the burner performance and result in damage to the equipment, asphyxiation, explosion or fire hazards.**

- The burner cannot properly burn the fuel if it is not supplied with a reliable combustion air source.
- Follow the guidelines in the latest editions of the NFPA 31 and CSA-B139 regarding providing adequate air for combustion and ventilation.

#### Appliance located in confined space

The confined space should have two (2) permanent openings: one near the top of the enclosure and one near the bottom of the enclosure. Each opening shall have a free area of not less than (1) one square inch per 1,000 BTU's per hour of the total input rating of all appliances within the enclosure. The openings shall have free access to the building interior, which should have adequate infiltration from the outside.

#### Exhaust fans and other air-using devices

Size air openings large enough to allow for all air-using devices in addition to the minimum area required for combustion air. If there is any possibility of the equipment room developing negative pressure (because of exhaust fans or clothes dryers, for example), either pipe combustion air directly to the burner or provide a sealed enclosure for the burner and supply it with its own combustion air supply.

#### Direct air supply and sidewall venting

- Some AFG burners are equipped with combustion air boots to allow use of outside air for combustion.
- When sidewall venting appliances, carefully follow appliance and power venter instructions for installation and wiring.



**WARNING**

### Follow the Outside Air Kit Instructions Exactly

**Failure to comply could result in impaired combustion, appliance soot-up, puffback of smoke, and fire or asphyxiation hazards.**

- Do not attempt to install outside air piping to the burner without using the outside air kit and instructions.

#### Outside air kit applications

Refer to separate instruction sheet supplied with AF/AFG outside air kit for installation. This optional kit allows combustion air to be piped directly to the burner (Beckett part number 51747).

#### Clearances to burner and appliance

- Provide space around burner and appliance for easy service and maintenance.
- Check minimum clearances against those shown by the appliance manufacturer and by applicable building codes.



**WARNING**

### Protect Steel Combustion Chamber From Burnout

**Failure to comply could result in damage to the heating equipment and result in fire or asphyxiation hazards.**

- When retrofitting appliances that have unlined stainless steel combustion chambers, protect the chamber by lining the inside surfaces with a ceramic fiber blanket, such as a wet-pac or other suitable refractory material.
- Some steel chambers may not require liners because the appliance was designed and tested for use with flame retention burners. Refer to the manufacturer's instructions.

#### Combustion chamber — Burner retrofitting

Verify that the appliance combustion chamber provides at least the minimum dimensions given in Table 3.

**Table 3. Chamber Dimensions**

Chamber Dimensions (inches)					
Firing Rate (GPH)	Round I.D.	Rectangular		Height	Floor to nozzle
		Width	Length		
0.50	8	7	8	12	5-6
0.75	9	8	9	12	5-6
1.00	10	9	10	12.5	5-6
1.25	11	10	11	12.5	5-6
1.50	12	11	12	13	6-7
2.00	14	12	15	13.5	6-7
2.50	16	13	17	14	7-8
3.00	18	14	18	15	7-8



# Inspect/Prepare Installation Site

## Prepare the Burner

### Low Firing Rate Baffle

The AFG Low Firing Rate Baffle (LFRB) reduces the air flow and pressure. The LFRB is sometimes used for firing rates under 1.00 gph as listed in Table 4. Refer to the appliance manufacturer's instructions. Do not omit the LFRB when specified. Omitting the baffle when specified or installing the baffle when not specified could result in impaired burner performance.

### Burner fuel unit


- Verify that the burner fuel unit is compatible with the oil supply system. For more details, refer to the pump manufacturer's instructions provided with the burner.

### Attach air tube (if not already installed)

If using a flange and gasket, slide them onto the air tube. Then attach the air tube to the burner chassis using the four sheet metal screws provided. Refer to Figure 4 for details.

### Nozzle and Pump Pressure

#### **WARNING** Correct Nozzle and Flow Rate Required

 **Incorrect nozzles and flow rates could result in impaired combustion, under-firing, over-firing, soot-ing, puff-back of hot gases, smoke and potential fire or asphyxiation hazards.**

Use only nozzles having the brand, flow rate (gph), spray angle and pattern specified by the appliance manufacturer.

Follow the appliance manufacturer's specifications for the required pump outlet pressure for the nozzle, since this affects the flow rate.

- Nozzle manufacturers calibrate nozzle flow rates at 100 psig.
- When pump pressures are higher than 100 psig, the actual nozzle flow rate will be greater than the gph stamped on the nozzle body. (Example: A 1.00 gph nozzle at 140 psig = 1.18 gph)

Securely tighten the nozzle (90 torque inch pounds). For typical nozzle flow rates at various pressures refer to Table 5.

**Table 4. AFG Reduced Firing Rates (with LFRB)**

Burner head type	Low Firing Rate Baffle installed
F0	up to 0.65 gph
F3 or L1	up to 0.85 gph
F4 or F6	up to 0.90 gph
V1	up to 1.00 gph

**Table 5. Nozzle Flow Rate by Size**

Nozzle flow rate U. S. gallons per hour of No. 2 fuel oil when pump pressure (psig) is:					
Nozzle size (rated at 100 psig)	125 psi	140 psi	150 psi	175 psi	200 psi
0.40	0.45	0.47	0.49	0.53	0.56
0.50	0.56	0.59	0.61	0.66	0.71
0.60	0.67	0.71	0.74	0.79	0.85
0.65	0.73	0.77	0.80	0.86	0.92
0.75	0.84	0.89	0.92	0.99	1.06
0.85	0.95	1.01	1.04	1.13	1.20
0.90	1.01	1.07	1.10	1.19	1.27
1.00	1.12	1.18	1.23	1.32	1.41
1.10	1.23	1.30	1.35	1.46	1.56
1.20	1.34	1.42	1.47	1.59	1.70
1.25	1.39	1.48	1.53	1.65	1.77
1.35	1.51	1.60	1.65	1.79	1.91
1.50	1.68	1.77	1.84	1.98	2.12
1.65	1.84	1.95	2.02	2.18	2.33
1.75	1.96	2.07	2.14	2.32	2.48
2.00	2.24	2.37	2.45	2.65	2.83
2.25	2.52	2.66	2.76	2.98	-
2.50	2.80	2.96	-	-	-

### Install burner nozzle (if not already installed)

1. Remove the plastic plug protecting the nozzle adapter threads
2. Place a 3/4" open-end wrench on the nozzle adapter. Insert the nozzle into the adapter and finger tighten. Finish tightening with a 5/8" open-end wrench. Use care to avoid bending the burner head support legs or electrodes. If you remove the head to replace the nozzle (type "L1"/"L2" or "V1" heads), carefully reconnect the head to the nozzle adapter, making sure that the head support makes contact with the nozzle adapter shoulder. Refer to Figure 5 or 6.

3. If the nozzle is already installed, remove the nozzle line assembly to verify that the nozzle size and spray pattern are correct for the application (per appliance manufacturer's information). Verify that the electrode tip settings comply with Figure 3.
4. If the nozzle is not installed, obtain a nozzle from the manufacturer, having the capacity and spray angle specified in the appliance manufacturer's information. For conversions or upgrades, when information is not available for the application:
  - Refer to Table 6 to select the mid-range nozzle spray angle for the head type being used.
  - Fire the burner and make sure the combustion is acceptable and the flame is not impinging on chamber surfaces.
  - If a shorter flame is needed, select a wider spray angle. If a longer flame is needed, select a narrower spray angle.
  - Either hollow or solid spray patterns may be used. If combustion results are not satisfactory with the selected spray pattern, try the other pattern.

**Table 6. Nozzle Spray Angles**

Recommended nozzle spray angles	
"F" head	70° or 80° nozzle
"L1" & "L2" head	45°, 60°, or 70° nozzle
"V1" head	45°, 60°, or 70° nozzle

### Check/adjust electrodes

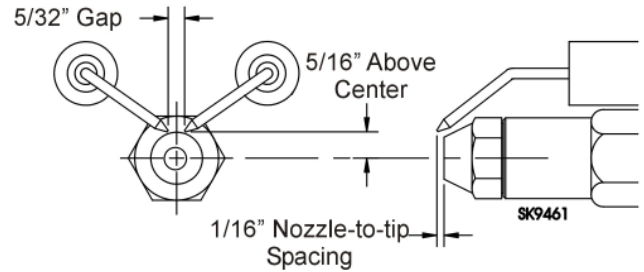
Check the electrode tip settings. Adjust if necessary to comply with the dimensions shown in Figure 3. To adjust, loosen the electrode clamp screw and slide/rotate electrodes as necessary. Securely tighten the clamp screw when finished.

### Servicing nozzle line assembly

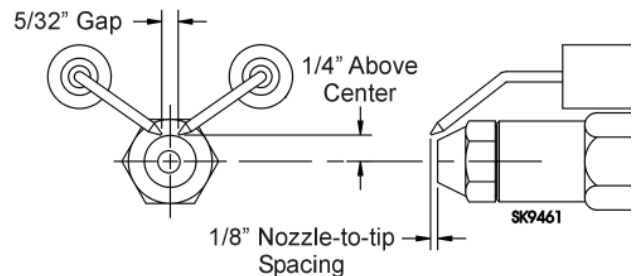
1. Turn off power to burner before proceeding.
2. Disconnect oil connector tube from nozzle line.
3. Loosen the two screws securing igniter retaining clips and rotate both clips to release igniter baseplate. Then tilt igniter back on its hinge.
4. Remove splined nut.
5. "F" head air tube. - Remove nozzle line assembly from burner, being careful not to damage the electrodes or insulators while handling. To ease removal of long assemblies (over 9 inches), rotate assembly 180° from installed position after pulling partially out of tube.
6. "L1", "L2", and "V1" head air tubes. - Slide nozzle line assembly forward (further into air tube) so the head clears the venturi opening. Then rotate the nozzle line assembly 90° so the nozzle line end points up. Pull the nozzle line assembly toward you and remove assembly from burner.
7. To replace the nozzle assembly, reverse the above steps.

### Figure 3. – Electrode Tip Adjustment

Standard Dimensions for F, L1, and V1 Heads.



The Dimensions shown below are for use with L2 heads and M series air tube combinations ending with an 'N' suffix (example: AFG70MDAQN)



### Mount burner on appliance

#### Mounting options

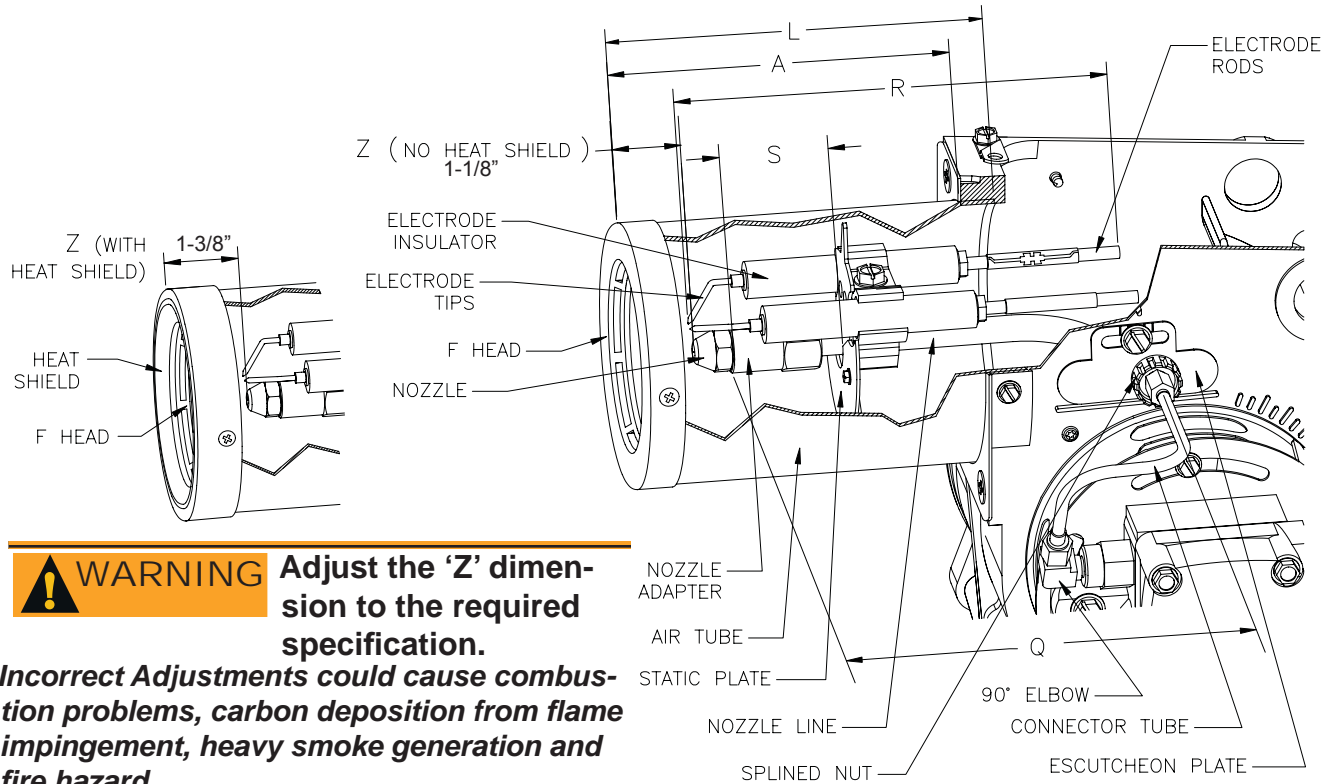
1. Bolt the burner to the appliance using the factory-mounted flange or an adjustable flange.

#### Mounting dimensions

1. When using the Beckett universal adjustable flange, mount the air tube at a 2° downward pitch unless otherwise specified by the appliance manufacturer.
2. Verify that the air tube installed on the burner provides the correct insertion depth. See Figure 7.
3. The end of the air tube should normally be 1/4" back from the inside wall of the combustion chamber. Never allow the leading edge of the head assembly to extend into the chamber, unless otherwise specified by the heating appliance manufacturer. Carefully measure the insertion depth when using an adjustable flange. Verify the insertion depth when using a welded flange.

# Prepare the Burner

**Figure 4. Check/Adjust 'Z' Dimension for 'F' Heads**



**WARNING** Adjust the 'Z' dimension to the required specification.

**Incorrect Adjustments could cause combustion problems, carbon deposition from flame impingement, heavy smoke generation and fire hazard.**

- Make all adjustments exactly as outlined in the following information.

## Check/Adjust 'Z' Dimension - 'F' heads

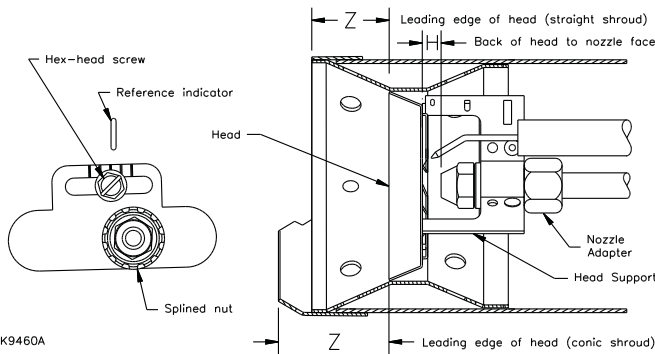
1. The important 'Z' dimension is the distance from the face of the nozzle to the flat face of the head (or heat shield, if applicable). This distance for F heads is 1-1/8" (1-3/8" if the air tube has a heat shield). The "Z" dimension is factory set for burners shipped with the air tube installed. Even if factory set, verify that the "Z" dimension has not been changed.
2. Use the following procedure to adjust the "Z" dimension, if it is not correct:
  - Turn off power to the burner.
  - Disconnect the oil connector tube from the nozzle line
  - See above figure. Loosen the splined nut from the nozzle line. Loosen the hex head screw securing the escutcheon plate to the burner housing.
  - Place the end of a ruler at the face of the nozzle and, using a straight edge across the head, measure the distance to the face of the head. A Beckett T501 gauge may also be used.
  - Slide the nozzle line forward or back until this dimension for F heads is 1-1/8" (1-3/8" to the face of the heat shield, if applicable).
  - Tighten the hex head screw to secure the escutcheon plate to the burner chassis. Then tighten the splined nut and attach the oil connector tube.
3. Recheck the "Z" dimension periodically when servicing to ensure the escutcheon plate has not been moved. You will need to reset the "Z" dimension if you replace the air tube or nozzle line assembly. The Beckett Z gauge (part number Z-2000) is available to permit checking the F head "Z" dimension without removing the burner from the appliance.

## Burner Dimensions

Dimension (inches)	For usable length A (inches)			
	F Head	L1 Head	L2 Head	V1 Head
H (nozzle to head), $\pm 1/32$	N/A	1/4	7/32	1/4
L (Total tube length)	A+1/2	A+1/2	A+1/2	A+1/2
R (electrode length), $\pm 1/4$	A+2-1/4	A+1-1/8	A+1-1/8	A+1-1/8
S (adapter to static plate), $\pm 1/16$	(Note 1)	1-3/8	1-3/8	1-3/8
Q (nozzle line length),	A+ 15/16	A+ 3/16	A+ 3/16	A+ 3/16
Z (F head-no heat shield)	1-1/8	N/A	N/A	N/A
Z (F head-with heat shield)	1-3/8	N/A	N/A	N/A
Z (L1 head w/straight shroud) (L1/L2/V1 head w/conic shroud)	N/A	1-3/8	N/A	N/A
	N/A	1-3/4	1-3/4	1-3/4

Note 1: 1-3/8 for dimension A less than 4"; 1-5/8 for dimension A from 4" through 4-1/2 " , 2-13/32 for dimension A greater than 4-1/2".

**Figure 5. Check/Adjust 'Z' Dimension - L1 & L2 Heads**



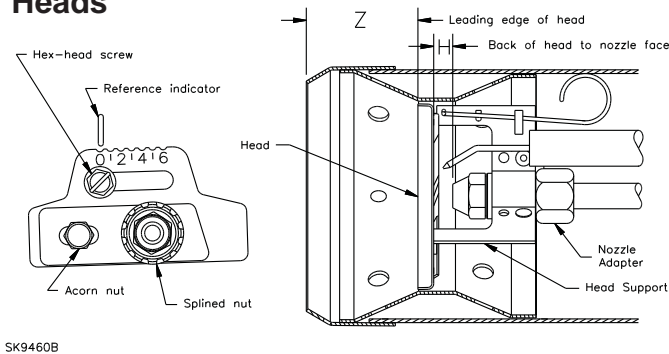
L1/L2 heads (see Table 7 and Figure 3 for dimensions)

1. See figure above. The important "Z" dimension is the distance from the leading edge of the head to the end of the air tube. This distance for L1 & L2 heads is 1-3/8" if the tube has a straight shroud or 1-3/4" if the air tube has a conic shroud. The "Z" dimension is factory set for

burners shipped with the air tube installed. Even if factory set, verify that the "Z" dimension has not been changed.

2. Use the following procedure to adjust the "Z" dimension, if it is not correct:
  - Turn off power to the burner.
  - Disconnect the oil connector tube from the nozzle line.
  - Refer to figure. Loosen the splined nut from the nozzle line. Loosen the hex head screw securing the escutcheon plate to the burner housing.
  - Place the end of a ruler at the leading edge of the head and, using a straight edge across the end of the air tube, measure the distance to the end of the tube. A Beckett T501 gauge may also be used.
  - Slide the nozzle line forward or back until this dimension is 1-3/8" for L1 & L2 heads if the tube has a straight shroud, or 1-3/4" if the air tube has a conic shroud.
  - Tighten the hex head screw to secure the escutcheon plate to the burner chassis. Then tighten the splined nut and attach the oil connector tube.
3. Recheck the "Z" dimension periodically when servicing to ensure the escutcheon plate has not been moved. You will need to reset the "Z" dimension if you replace the air tube or nozzle line assembly.

**Figure 6. Check/Adjust 'Z' Dimension - V1 Heads**



V1 heads (see Table below and Figure above for dimensions)

1. See figure above. The important "Z" dimension is the distance from the leading edge of the head to the end of the air tube. This distance for V1 heads is 1-3/4". The "Z" dimension is factory set for burners shipped with the air tube installed. Even if factory set, verify that the "Z" dimension has not been changed.

2. Use the following procedure to adjust the "Z" dimension, if it is not correct:
  - Turn off power to the burner.
  - Disconnect the oil connector tube from the nozzle line.
  - See figure above. Loosen the splined nut from the nozzle line. Loosen the hex head screw securing the head adjusting plate to the burner housing.
  - Loosen the acorn nut. Move the head adjusting plate until the "0" lines up with the reference indicator on the housing, and retighten the hex head screw. Place the end of a ruler at the leading edge of the head and, using a straight edge across the end of the air tube, measure the distance to the end of the tube. A Beckett T501 gauge may also be used.
  - Slide the nozzle line forward or back until this dimension is 1-3/4" for V1 heads. Tighten the acorn nut.
  - Tighten the hex head screw to secure the head adjusting plate to the burner chassis. Then tighten the splined nut and attach the oil connector tube.
3. Recheck the "Z" dimension periodically when servicing to ensure the escutcheon plate has not been moved. You will need to reset the "Z" dimension if you replace the air tube or nozzle line assembly.

**Set head position adjusting plate (V1 head only)**

1. After setting "Z" dimension, loosen head adjusting plate hex head screw and nozzle line splined nut. Move the nozzle line assembly until the burner reference indicator lines up with the head adjusting plate setting number given in Table shown below.
2. Tighten the hex head screw and splined nut. (DO NOT loosen the acorn nut when setting head position.) Refer to the manufacturer's instructions for OEM settings.
3. The position of the head affects air flow volume and pattern. For most applications, the burner will perform satisfactorily with the air adjustment plate setting of Table shown below.
4. If combustion results indicate the need for change, adjust the head position adjusting plate forward or back one position at a time to optimize combustion.

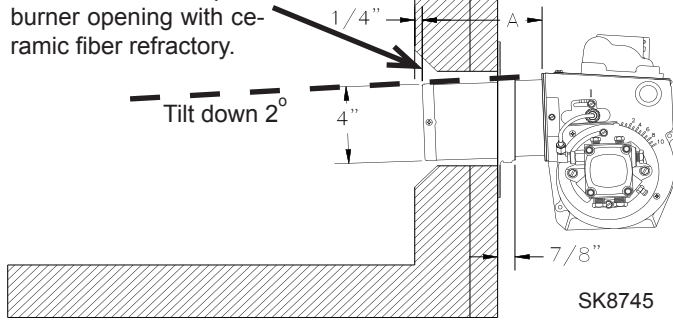
**Table for initial adjusting plate settings for V1 Head**

V1 Adjusting Plate Setting	AFG with V1 Head Burner Firing Rates
0	0.75-1.00
1	1.00-1.50
2	1.50-1.75
3	1.75-2.00
4	2.00-2.25
5	2.25-2.50
6	2.50-2.75

# Mount burner on appliance

**Figure 7. – Mounting Burner in Appliance**

If space between burner air tube and opening exceeds 1/2 inch, pack burner opening with ceramic fiber refractory.



## Installing the Oil Tank and Supply System

### **WARNING** Oil Leak and Fire Hazard

*Install the oil tank following applicable standards in the U.S. by referring to the latest edition of NFPA 31 or CSA-B139 & CSA-B140 in Canada, and all authorities having jurisdiction.*

### **CAUTION** Do Not Use Teflon Tape

*Damage to the pump could cause impaired burner operation, oil leakage and appliance soot-up.*

- Never use Teflon tape on fuel oil fittings.
- Tape fragments can lodge in fuel line components and fuel unit, damaging the equipment and preventing proper operation.
- Use oil-resistant pipe sealant compounds.

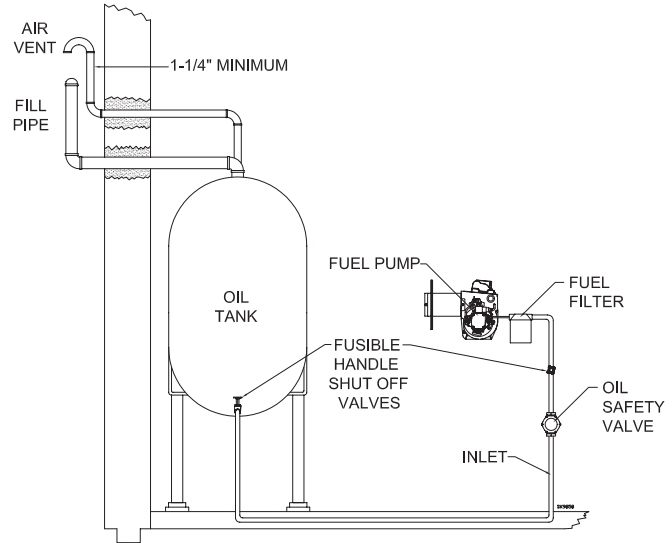
**Note:** to determine the proper fuel line size, refer to the fuel pump manufacturer's instructions provided with the burner. Refer to Figure 8 or Figure 9 for typical installation layouts.

### Fuel Line Valves and Filter

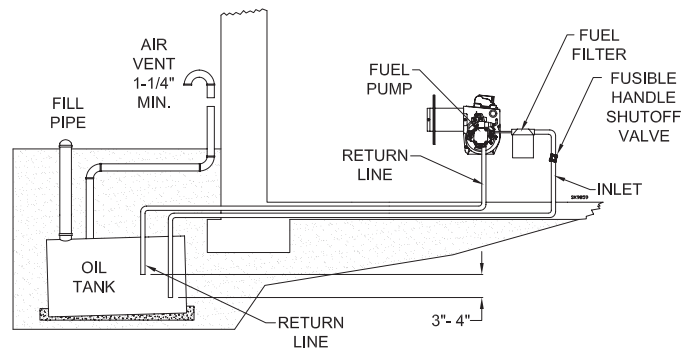
Install two high quality, oil duty rated, fusible handle design shutoff valves in accessible locations on the oil supply line. Locate one close to the tank and the other close to the burner, upstream of the filter for service access.

Install a generous capacity filter inside the building between the fuel tank shutoff valve and the burner, locating both the filter and the valve close to the burner for ease of servicing. Filter should be rated for 50 microns or less.

**Figure 8. – Inside Tank Gravity Feed System**



**Figure 9. – Outside Buried Tank-Lift System**



**NOTICE** To further protect the fuel supply system and reduce nozzle orifice plugging with firing rates below 0.75 gph, a dual filtration system can be installed. This typically consists of a 50 micron primary filter, located near the fuel tank and a secondary filter rated for at least 10 microns located near the burner.

### Fuel supply level with or above burner –

### **WARNING** Do Not Install By-pass Plug with 1-Pipe System

*Failure to comply could cause immediate pump seal failure, pressurized oil leakage and the potential for a fire and injury hazard.*

- The burner is shipped without the by-pass plug installed.
- Install the by-pass plug in two-pipe oil supply systems ONLY.

**CAUTION****Oil Supply Pressure Control Required**

**Damage to the filter or pump seals could cause oil leakage and a fire hazard.**

- The oil supply inlet pressure to the burner **cannot exceed 3 psig**.
- Insure that a pressure limiting device is installed in accordance with the latest edition of NFPA 31.
- **Do NOT install valves in the return line.** (NFPA 31, Chapter 8.)
- **Gravity Feed Systems:** Always install an anti-siphon valve in the oil supply line or a solenoid valve (RWB Part # 2182602U) in the pump/nozzle discharge tubing to provide backup oil flow cut-off protection.

The burner may be equipped with a single-stage fuel unit for these installations. Connect the fuel supply to the burner with a single supply line if you want a one-pipe system (making sure the bypass plug is NOT installed in the fuel unit.) Manual bleeding of the fuel unit is required on initial start-up. If connecting a two-pipe fuel supply, install the fuel unit bypass plug.

**Fuel supply below the level of the burner –**

When the fuel supply is more than eight feet below the level of the burner, a two-pipe fuel supply system is required. Depending on the fuel line diameter and horizontal and vertical length, the installation may also require a two-stage pump. Consult the fuel unit manufacturer's literature, included with the burner, for lift and vacuum capability.

**Fuel line installation –**

- Continuous lengths of heavy wall copper tubing are recommended. **Always use flare fittings. Never use compression fittings.**
- Always install fittings in accessible locations. Proper routing of fuel lines is required to prevent air cavitation and vibration.

**CAUTION****Frozen Plumbing and Water Damage Hazard**

***If the residence is unattended in severely cold weather, burner primary control safety lockout, heating system component failures, power outages or other electrical system failures could result in frozen plumbing and water damage in a matter of hours. For protection, take preventive actions such as having a security system installed that operates during power outages, senses low temperature and initiates an effective action. Consult with your heating contractor or a home security agency.***

## Wire burner

**Burner packaged with appliance****WARNING****Electrical Shock Hazard**

***Electrical shock can cause severe personal injury or death.***

- Disconnect electrical power before installing or servicing the burner.
- Provide ground wiring to the burner, metal control enclosures and accessories. (This may also be required to aid proper control system operation.)
- Perform all wiring in compliance with the National Electrical Code ANSI/NFPA 70 (Canada CSA C22.1)

- Refer to appliance manufacturer's wiring diagram for electrical connections.

**Burner installed at jobsite**

- Refer to Figures 11a and 11b, for typical burner wiring, showing cad cell primary controls. Burner wiring may vary, depending on primary control actually used.
- Refer to the appliance manufacturer's wiring diagram prior to connecting the burner wiring. All wiring must be in accordance with the latest revision of National Electric Code NFPA 70 and all local codes and regulations. In Canada, all wiring is to be in accordance with the Canadian Electrical Code, Part 1.

The 7505 primary control with valve-on delay (pre-purge) and burner motor-off delay (postpurge) requires a constant 120 volts AC power source supplied to the BLACK wire on the control. The RED wire goes to the appliance limit circuit. Please note that other control manufacturers may use different wire colors for power and limit connections.

**Special wiring required with covered burners**

The mounting plate is not a conduit connection point. Pass conduit and attached connector through the opening in the mounting plate and attach it directly to the burner-mounted 4x4 electrical box.

If attaching a burner cover to a previously installed burner, attach the mounting plate and then slide the conduit into the "J" shaped conduit slot.

# Burner Controls

## GeniSys Model 7505 Control

# Wiring

### **WARNING** Fire or Explosion Hazard



**Can cause severe injury, death, or property damage.**

- The control can malfunction if it gets wet, leading to accumulation of oil or explosive oil vapors.
- Never install where water can flood, drip or condense on the control.
- Never use a control that has been wet - replace it.

### Features

- Thermostat / Operating and Limit Control Compatible
- Welded Relay Protection
- Limited Recycle
- Limited Reset
- 3 Status Lights
- Valve-On Delay / Motor-Off Delay (Field programmable with 52067 GeniSys Display)
- 15 Second Lockout Time
- Interrupted or Intermittent Duty Ignition
- Technician Pump Priming Mode
- Disable Function
- Cad Cell Resistance Indicator
- Communication Ports

### **WARNING** Explosion, Fire, Scald, and Burn Hazard



**All heating appliances must have HIGH LIMIT protection to interrupt electrical power and shutdown the burner if operating or safety controls fail and cause a runaway condition.**

- Follow the appliance manufacturer's wiring diagrams and note all required safety controls.
- Typical safety controls include high temperature or pressure limits, low water cutoffs, pressure relief valves and blocked flue sensing switches.
- Verify all limit and safety controls are installed and functioning correctly, as specified by the manufacturer, applicable safety standards, codes and all authorities having jurisdiction.
- Ensure that the appliance is free of oil and oil vapor before starting or resetting the burner.

### **CAUTION** Incorrect Wiring Will Result in Improper Control Operation

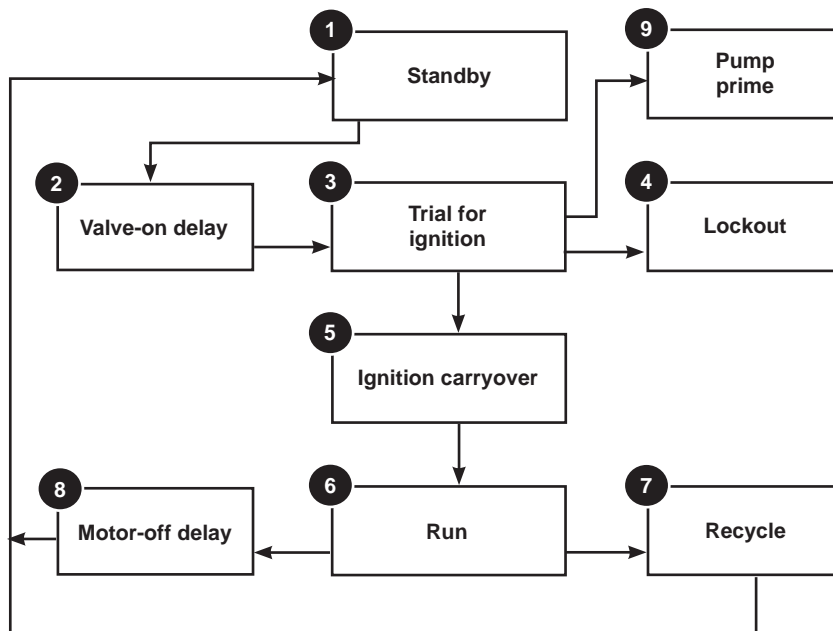
- GeniSys wiring label colors may not match the wire colors of the burner or other manufacturers' controls.
- The GeniSys Control should be wired according to the appliance manufacturer's instructions.

Figure 10.



### Typical Burner Sequence of Operation for GeniSys 7505 Control.

Refer to the appliance manufacturer's wiring diagram for actual specifications.



1. **Standby:** The burner is idle, waiting for a call for heat.
2. **Valve-On Delay:** The igniter and motor are on while the control delays turning on the oil solenoid valve for the programmed time.
3. **Trial For Ignition:** The oil solenoid valve is energized. A flame should be established within the factory set trial for ignition time ("lockout time").
4. **Lockout:** The control has shut the burner down for one of the following safety reasons:

- The trial for ignition (lockout) time expired without flame being established.
- The cad cell detected flame at the end of the Valve-On Delay.
- The Recycle mode 30-second time budget expired (see "Recycle" section for complete explanation of recycle time budget).

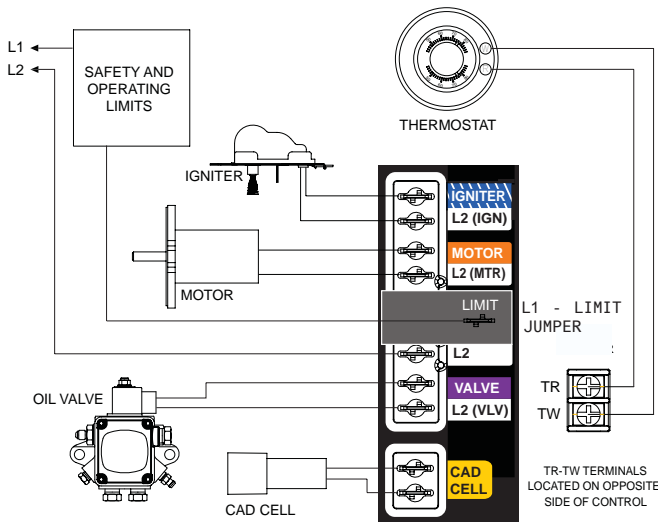
Click the reset button to reset the control from lockout. If the control locks out three times without completing a successful call for heat, or if the control fails the welded relay check, the control enters Restricted (Hard) Lockout and must be reset by a technician. Hold the reset button for 15 seconds until the yellow light turns on, to reset from Restricted Lockout.

5. **Ignition Carryover:** Once flame is established, the igniter remains on for 10 additional seconds to ensure flame stability.
6. **Run:** The flame is sustained until the call for heat is satisfied. The burner is then sent to Motor-Off Delay, if applicable, or it is shut down and sent to Standby.
7. **Recycle:** If the flame is lost while the burner is firing, the control shuts down the burner, enters a 60 second recycle delay, and then repeats the ignition sequence. The control will continue to Recycle each time the flame is lost until the accumulated oil-flow-without-flame time reaches 30 seconds, at which point the control will go into lockout instead of recycle if the flame is lost again during run. This feature prevents excessive accumulation of oil in the appliance firing chamber.
8. **Motor-Off Delay:** If applicable, the oil solenoid valve is turned off and the control delays turning the motor off for the set motor-off delay time before the control returns to standby.
9. **Pump Prime:** The igniter and motor are on with the oil solenoid valve energized for 4 minutes. During Pump Prime mode, the cad cell is disregarded, allowing the technician to prime the pump without

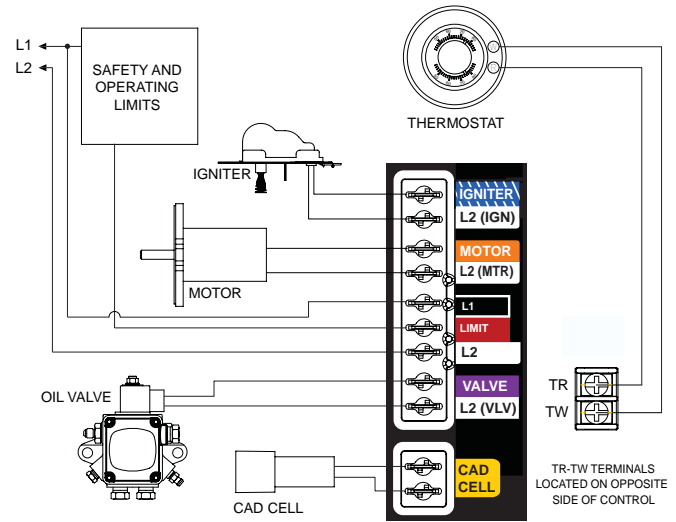


# Burner Controls

**Figure 11a. – Interrupted ignition, valve-on delay only (no motor-off delay)**



**Figure 11b. – Interrupted ignition, valve-on delay and motor-off delay**



## Reset Button Operation

Table 2 explains what action the control will take when the reset button is pressed for different lengths of time during the various burner operating states.

**Table 2 - Reset Button Operation**

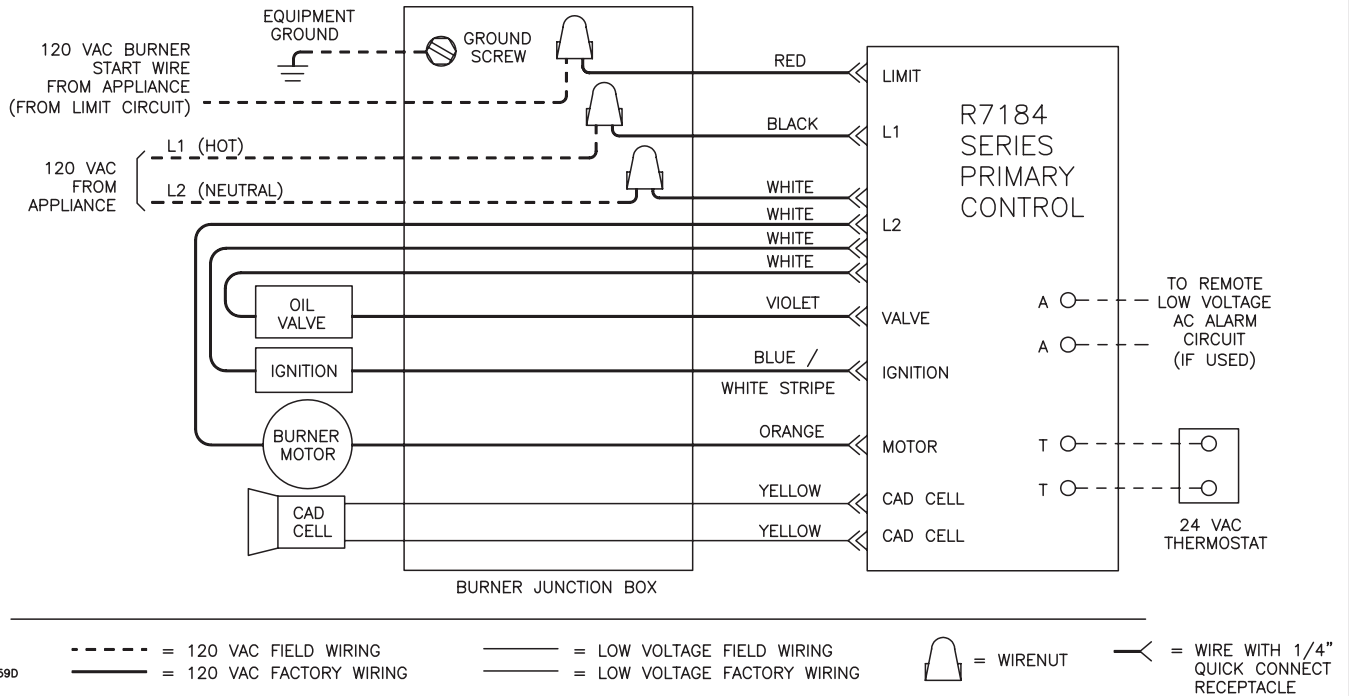
If the burner is in the below state:	Pushing the reset button will:		
	Button Click (press < 1 second)	Button Hold (press > 1 second)	Button Hold (press 15+ seconds)
Lockout	Reset from Soft Lockout		Reset from Restricted (Hard) Lockout
Valve-on Delay, Trial for Ignition, Ignition Carryover	Go to Pump Prime (see "Priming the Pump" above)	Disable the Burner: Any time the burner is running, press and hold the reset button to disable the burner. The burner will remain off as long as the button is held.	Enables Pump Priming: After the reset button has been held for 15 seconds, the button can then be clicked during the next ignition sequence to enter Pump Prime mode.
Run (igniter is shut off)	Yellow light flashes to indicate cad cell resistance. See "Cad Cell Resistance Indicator" for table of resistance values.		
Motor-Off Delay, Standby	No action		
Pump Prime	No action	Exit Pump Prime mode and return to Standby	

**Table 3 - Status Lights**

Light Color	On Continuously	Flashing
Red	Restricted (Hard) Lockout	Soft Lockout
Green	Flame Sensed during normal operation (Could be stray light during standby)	Recycle
Yellow	Control is in Pump Prime mode <b>or</b> Reset button currently held for 15+ seconds.	Cad Cell resistance. See "Cad Cell Resistance Indicator" on page 8 for a table of resistance values.

### Typical Burner Wiring & Burner Sequence of Operation for R7184P Control.

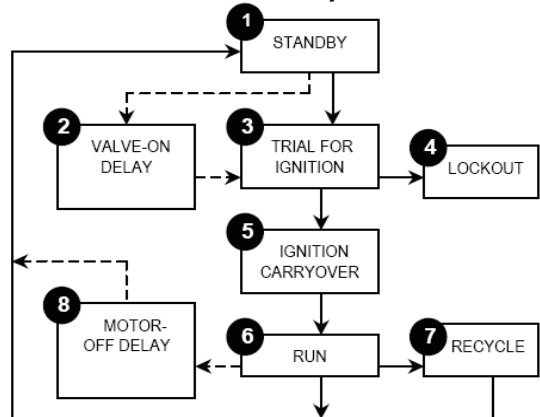
Refer to the appliance manufacturer's wiring diagram for actual specifications.



**Figure 10. – Typical Burner Wiring**

1. **STANDBY.** The burner is idle, waiting for a call for heat. When a call for heat is initiated, there is a 3-10 second delay while the control performs a safe start check.
2. **VALVE-ON DELAY.** The ignition and motor are turned on for a 15 second valve-on delay.
3. **TRIAL FOR IGNITION (TFI).** The fuel valve is opened. A flame should be established within the 15 second lockout time.
4. **LOCKOUT.** If flame is not sensed by the end of the TFI, the control shuts down on safety lockout and must be manually reset. If the control locks out three times in a row, the control enters restricted lockout.
5. **IGNITION CARRYOVER.** Once flame is established, the ignition remains on for 10 seconds to ensure flame stability before turning off. If the control is wired for intermittent duty ignition, the ignition unit stays on the entire time the motor is running.
6. **RUN.** The burner runs until the call for heat is satisfied. The burner is then sent to burner motor off delay, if applicable, or it is shut down and sent to standby.

7. **RECYCLE.** If the flame is lost while the burner is firing, the control shuts down the burner, enters a 60 second recycle delay, and then repeats the above ignition sequence. If flame is lost three times in a row, the control locks out to prevent cycling with repetitious flame loss due to poor combustion.
8. **BURNER MOTOR-OFF DELAY.** The fuel valve is closed and the burner motor is kept on for the selected motor-off delay time before the control returns the burner to standby.



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#### Control System Features

Feature	Interrupted ignition	Limited reset, Limited recycle	Diagnostic LED, cad cell indicator	Valve-on delay	Burner motor off delay	Alarm Contacts
R7184A	YES	YES	YES	—	—	—
R7184B	YES	YES	YES	YES	—	—
R7184P	YES	YES	YES	YES	YES	Optional

## Wire burner

### NOTICE

**Some Thermostats Are Polarity Sensitive. Reversed polarity could cause erratic cycling of the burner control.**

- Connect the wire from the R<sub>H</sub> or R terminal on the thermostat to the TR terminal on the control.
- Connect the wire from the W terminal on the thermostat to the TW terminal on the control.
- Make connections to the control's terminals as shown in **Figures 11a** and **11b**. Refer to the label on the underside of the control for wiring details.
- Note: Motor-off delay on a 7505P will be disabled if the safety and operating limits as shown in Figures 11a and 11b interrupt power to the control terminal L1.
- Connect thermostat leads to the TR and TW terminals on the control or jumper the TR and TW terminals on the control, as directed by the appliance wiring diagram.
  - Thermostat anticipator Current: 0.1 amp
  - Thermostat voltage: 24 volts AC

**Note that** if the thermostat short cycles or operates improperly, it may require an isolation relay for proper operation. The Beckett A/C Ready Kit (part no. 51950U) provides this function. Wiring instructions are included with the A/C Ready Kit.

## Start up burner/set combustion



### WARNING

#### Hot Gas Puff-Back and Heavy Smoke Hazard

**Failure to prime the pump properly could result in unstable combustion, hot gas puff-back and heavy smoke.**

- Do not allow oil to spray into a hot combustion chamber while bleeding air from the pump.
  - Install a gauge in the nozzle discharge port tubing or fully open the pump bleed valve to prevent oil spray from accumulating in the combustion chamber during the air bleed procedure.
  - Ensure that all bubbles and froth are purged from the oil supply system before tightening the pump bleed valve.
  - Ensure that the appliance is free of oil and oil vapor before starting or resetting the burner.
1. Open the shutoff valves in the oil supply line to the burner.
  2. Close air band and partially open air shutter. This is an initial air setting for the pump bleeding procedure only. Additional adjustments must be made with instruments.

3. Set the thermostat substantially above room temperature.
4. Close the line voltage switch to start the burner. If the burner does not start immediately you may have to reset the burner primary control.
5. Initiate a call for heat.
6. After the burner starts, press and hold the reset button for 15 seconds until the yellow light turns on. This indicates that the button has been held long enough.
7. Release the reset button. The yellow light will turn off and the burner will start up again.
8. At burner start up, click the reset button while the igniter is still on. This will transition the control to a dedicated Pump Prime mode, during which the motor, igniter, and valve are powered for four minutes. The yellow light will be on.
9. Bleed the pump until all froth and bubbles are purged. If desired, terminate the call for heat or hold the reset button for at least one second to exit Pump Prime mode and return to Standby.
10. At the end of 4 minutes, the yellow light will turn off and the control will automatically return to standby mode.
11. If prime is not established during the four minute pump prime mode, return to step 8 to re-enter Pump Prime mode. Repeat steps 8 through 10 until the pump is fully primed and the oil is free of bubbles.
12. Terminate the call for heat, and the control will resume normal operation.

#### ▪ Cad Cell Resistance Indicator

- During the burner Run state, click the reset button (less than 1 second) to check the cad cell resistance range. The yellow light will flash 1 to 4 times, depending on the amount of light detected by the cad cell. See chart below:

Yellow Light Flashes	Flame Detection Range
1	Normal (0 - 400 ohms)
2	Normal (400 - 800 ohms)
3	Normal (800 - 1600 ohms)
4	Limited (1600 ohms - Lockout)

#### ▪ Resetting From Restricted Lockout

- If the control locks out three times without a satisfied call for heat, or fails the motor relay check, the Lockout becomes *restricted* in order to limit accumulation of unburned oil in the combustion chamber.
- To reset, hold the button down for 15 seconds until the red light turns off and the yellow light turns on.
- Always verify the control functions according to all specifications before leaving the installation site.
- Replace the control if it does not operate as specified.

## Startup / Checkout

### **WARNING** Explosion and Fire Hazard



**Failure to follow these instructions could lead to equipment malfunction and result in heavy smoke emission, soot-up, hot gas puff-back, fire and asphyxiation hazards.**

- Do not attempt to start the burner when excess oil has accumulated in the appliance, the appliance is full of vapor, or when the combustion chamber is very hot.
- Do not attempt to re-establish flame with the burner running if the flame becomes extinguished during start-up, venting, or adjustment.
- **Vapor-Filled Appliance:** Allow the unit to cool off and all vapors to dissipate before attempting another start.
- **Oil-Flooded Appliance:** Shut off the electrical power and the oil supply to the burner and then clear all accumulated oil before continuing.
- If the condition still appears unsafe, contact the Fire Department. Carefully follow their directions.
- Keep a fire extinguisher nearby and ready for use.

If the burner or control fails any of the following tests, recheck control wiring. If the burner or control still fails any tests, replace the control.

#### ▪ Check Safety Features

- Safe Start Check
  1. Place a jumper across the cad cell terminals.
  2. Refer to the steps for “Start up burner/set combustion” and have the system call for heat.
  3. Burner must not start. Verify that the green light is on continuously and that the control remains in Standby mode.
  4. End the call for heat and remove the cad cell jumper.
- Simulate Flame Failure and Ignition Failure
  1. Refer to the steps for “Start up burner/set combustion” and have the system call for heat.
  2. After flame is established and the burner igniter turns off, close the hand valve in the oil supply line.
  3. At flame loss, the control will enter Recycle mode. Verify that the green light is flashing. The control will remain in Recycle for 60 seconds.

4. After the 60 second recycle period, the control will try to restart the system.
  5. After the 15 second lockout time, the control will lock out the burner and the reset button will flash. Verify that the burner motor and igniter are off and that the burner oil solenoid valve (if used) is not energized.
  6. Open the hand valve in the oil line.
  7. Click the reset button and verify that the red light in the reset button shuts off and that the burner lights.
  8. End the call for heat.
- Before leaving the installation, verify that all thermostat and boiler/furnace control wiring is correct. Consult heating appliance manual for directions.

## Set combustion with instruments

### **CAUTION** OIL-BURNING EQUIPMENT SHALL BE CONNECTED TO FLUES HAVING SUFFICIENT DRAFT AT ALL TIMES TO ENSURE SAFE AND PROPER OPERATION OF THE BURNER.

1. Allow the burner to run for approximately 5 to 10 minutes.
2. Set the stack or over-fire draft to the level specified by the appliance manufacturer.
  - **Natural Draft Applications;** typically over-fire draft is  $-0.01''$  or  $-0.02''$  w.c.
  - **Direct Venting;** typically may not require draft adjustment.
  - **High Efficiency/Positive Pressure Appliances;** also vary from traditional appliances (see manufacturer’s recommendations).
3. Follow these four steps to properly adjust the burner:
  - Step 1:** Adjust the air shutter/band until a trace of smoke is achieved.
  - Step 2:** At the trace of smoke level, measure the  $\text{CO}_2$  (or  $\text{O}_2$ ) . This is the vital reference point for further adjustments. Example: 13.5%  $\text{CO}_2$  (2.6%  $\text{O}_2$ )
  - Step 3:** Increase the air to reduce the  $\text{CO}_2$  by 1.5 to 2 percentage points. ( $\text{O}_2$  will be increased by approximately 2.0 to 2.7 percentage points.) Example: Reduce  $\text{CO}_2$  from 13.5% to 11.5% (2.6% to 5.3%  $\text{O}_2$ ).

## Perform regular maintenance

- Step 4:** Recheck smoke level. It should be Zero.
- This procedure provides a margin of reserve air to accommodate variable conditions.
  - If the draft level has changed, recheck the smoke and CO<sub>2</sub> levels and readjust the burner if necessary
4. Once combustion is set, tighten all fasteners on air band, air shutter and head adjusting plate or es-cutcheon plate.
  5. Burner equipped with cover - Reinstall the cover and repeat Steps 2 and 4. If CO<sub>2</sub> increases (O<sub>2</sub> decreases), remove the cover and adjust the air setting so the CO<sub>2</sub> (O<sub>2</sub>) with cover on meets requirements of Step 3.
  6. Start and stop the burner several times to ensure satisfactory operation. Test the primary control and all other appliance safety controls to verify that they function according to the manufacturer's specifications.

- Verify the nozzle is the one originally specified by the appliance manufacturer and replace the nozzle with one having the exact specifications from the same manufacturer.
- Clean and inspect the electrodes for damage, replacing any that are cracked or chipped.
- Check electrode tip settings. Replace electrodes if tips are rounded.
- Inspect the igniter spring contacts. Clean or replace if corroded.
- Clean the cad cell grid surface, if necessary.
- Make sure Low Firing Rate Baffle is in place if required for the burner application. Omitting the baffle can result in unacceptable burner combustion.
- Inspect all gaskets. Replace any that are damaged or would fail to seal adequately.
- Inspect the combustion head and air tube. Remove any carbon or foreign matter. Replace all damaged units with exact parts.
- Clean the blower wheel, air inlet, air guide, burner housing and static plate of any lint or foreign material.
- If motor is not permanently lubricated, oil motor with a few drops of SAE 20 nondetergent oil at each oil hole. DO NOT over oil motor. Excessive oiling can cause motor failure.
- Check motor current. The amp draw should not exceed the nameplate rating.
- Check all wiring for secure connections or insulation breaks.
- Check the pump pressure and cutoff function.
- Check primary control safety lockout timing.
- Check ignition system for proper operation.
- Inspect the vent system and chimney for soot accumulation or other restriction.
- Clean all flue passages and flue pipe. Replace corroded or damaged pipes.
- Clean the appliance thoroughly according to the manufacturer's recommendations.
- Check the burner performance. Refer to the section "Set combustion with test instruments".
- It is good practice to make a record of the service performed and the combustion test results.

## Perform regular maintenance

### **WARNING Annual Professional Service Required**



***Tampering with or making incorrect adjustments could lead to equipment malfunction and result in asphyxiation, explosion or fire.***

- DO NOT TAMPER WITH THE UNIT OR CONTROLS - CALL YOUR QUALIFIED SERVICE TECHNICIAN OR SERVICEMAN.
- To ensure continued reliable operation, a qualified service technician must service this burner annually.
- More frequent service intervals may be required in dusty or adverse environments.
- Operation and adjustment of the burner requires technical training and skillful use of combustion test instruments and other test equipment.

- Replace the oil supply line filter. The line filter cartridge must be replaced to avoid contamination of the fuel unit and nozzle.
- Inspect the oil supply system. All fittings should be leak-tight. The supply lines should be free of water, sludge and other restrictions.
- Remove and clean the pump strainer if applicable.

## Shutting the Burner Off

 **CAUTION IF THE BURNER IS SHUT DOWN FOR AN EXTENDED PERIOD OF TIME, ALWAYS KEEP THE VALVE SHUT OFF.**

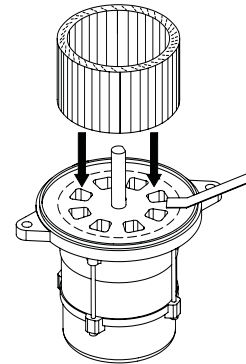
Turn off all electric power to the burner.

**Note:** There could be more than one disconnect switch.

**Replace the blower wheel:**

1. Turn off all power to the burner before servicing.
2. Disconnect the burner motor wires.
3. Remove the bolts securing the motor to the burner housing.
4. Remove the motor and blower wheel.
5. Remove the existing blower wheel.
6. Referring to the figure below, slide the new blower wheel onto the shaft.
  - Use a feeler gauge to set the wheel-to-motor gap, as shown below. (AF =  $0.125 \pm 1/64$  inch, AFG =  $0.030 \pm 1/64$  inch)
  - Slide blower wheel toward motor until it contacts feeler gauge.
  - Rotate the blower wheel until the setscrew is centered on the flat of the motor shaft. Tighten the setscrew to secure the wheel.
7. DO NOT use a motor that has endshield openings outside the blower wheel circumference (represented by the dashed line).
8. Install the motor on the burner housing. Tighten screws. Reconnect wires.
9. Restore power, start the burner and perform combustion tests. Refer to the section "Set combustion with test instruments".

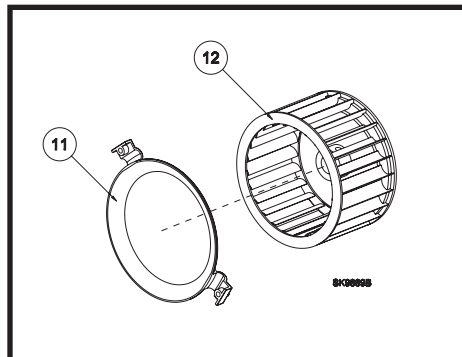
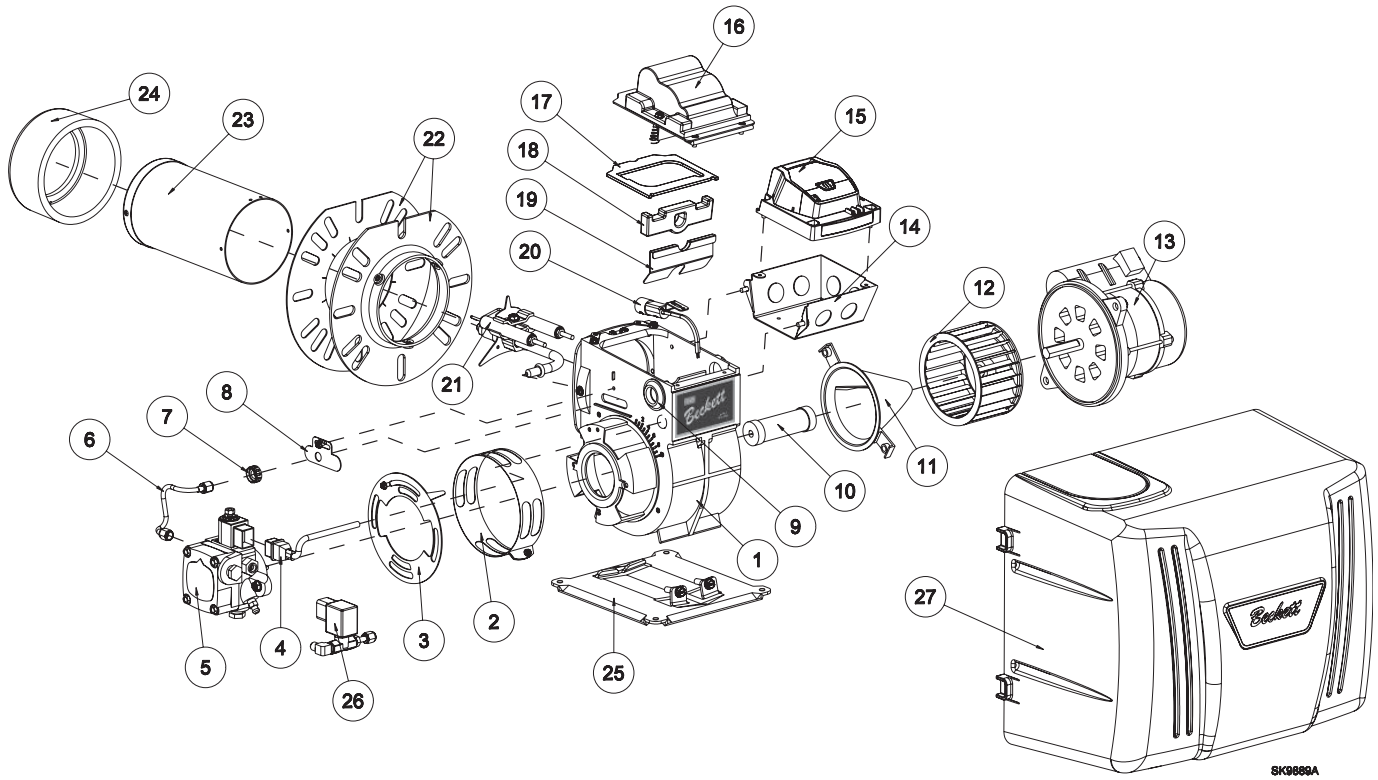
**Figure 12. Blower wheel assembly**



Use a Feeler Gauge to set the gap to;  
AF =  $0.125 \pm 1/64$  inch  
AFG =  $0.030 \pm 1/64$  inch

SK9190

For best performance specify genuine *Beckett* replacement parts



These parts are unique to AF burners.  
Replace parts numbered 11 and 12 with  
the exact parts designated in the parts list.

For best performance specify genuine *Beckett* replacement parts

#	Part No.	Description
1		Burner Housing Assembly
2	Specify*	Air Band - Specify # of slots
3	Specify*	Air Shutter - Specify # of slots
4	21807U	Valve Cordset
Not Shown	21887U	PD Timer Delay Cordset
5	2184404U	CleanCut Pump
6	5394	Copper Oil Line - 8"
7	3666	Splined Nut
8	3493	Escutcheon (F & L1/L2 heads)
	5941	Head Adjusting Plate (V1 head)
9	2139	Hole Plug
10	2454	Coupling
11	31231U (AFG) 31841U (AF)	Air Guide (AFG) Air Inlet Bell (AF)
12	2999U (AFG) 2459U (AF)	Blower Wheel (AFG) Blower Wheel (AF)
13	21805U 4189	PSC Motor Mounting Screws
14	5770	Electrical Box
15	7505A	Replaces R7184A - Interrupted Ignition
	7505B	Replaces R7184B - Pre-purge
	7505P	Replaces R7184P - Pre and Post-purge**

#	Part No.	Description
16	51771U	Igniter & Base Plate
17 & 18	51304	Igniter Gasket Kit
19	5880	Low Firing Rate Baffle
20	7006U	Cad Cell Detector
21	5780	Electrode Kit - F Head up to 9"
	5782	Electrode Kit - F Head over 9"
	5940	Electrode Kit - M Head up to 9"
22	5432 3616	Universal Flange w/ Gasket Gasket Only
23	Specify *	Air Tube Combination
24	Specify *	Heat Shield, Ceramic or Fiber
25	5685	Pedestal Kit
26	2182602U	Solenoid Valve Kit (delay)
27	52064xxU*	Cover

\* Contact your Beckett Representative for part number and pricing.

\*\* Contact your Beckett Representative for available pre and post purge settings.



**Limited**  
**WARRANTY**

**For Residential, Commercial and Specialty Burners**

The R. W. BECKETT CORPORATION ("Beckett") warrants to persons who purchase its Beckett burners from Beckett for resale or for incorporation into a product for resale ("Customers") that its equipment is free from defects in material and workmanship under normal use and service for 60 months from the date of manufacture for Residential Burners and 18 months from the date of manufacture for Commercial and Specialty Burners. *Residential burner models include:* AF, AFG, AFIL, NX, SF, SR and SMG. *Commercial burner models include:* CF375, CF500, CF800, CF1400, CF2300A, CF2500, CF3500A, CG10, CG15, CG25 and CG50. *Specialty burner models include:* ADC, ADCP, ARV, SDC and SM. The provisions of this warranty are extended to individual major burner components as follows:

- a) 60 months from date of manufacture for all Beckett-branded major components, except for 12 Vdc components.
- b) 18 months from date of manufacture for all non-Beckett-branded major components and Beckett branded 12 Vdc components.

Note: Normal service items found to be defective upon receipt by the customer are covered by this warranty.

**THIS WARRANTY DOES NOT EXTEND TO EQUIPMENT SUBJECTED TO MISUSE, NEGLIGENCE, OR ACCIDENT; NOR DOES THIS WARRANTY APPLY UNLESS THE PRODUCT COVERED BY IT IS PROPERLY INSTALLED BY A QUALIFIED, COMPETENT TECHNICIAN, WHO IS LICENSED WHERE STATE AND LOCAL CODES REQUIRE, AND WHO IS EXPERIENCED IN MAKING SUCH INSTALLATIONS, IN ACCORDANCE WITH THE LATEST EDITION OF NFPA NO. 31 OF THE NATIONAL FIRE PROTECTION ASSOCIATION, THE LATEST EDITION OF THE NATIONAL FUEL GAS CODE (NFPA NO. 54) AND IN ACCORDANCE WITH ALL APPLICABLE LOCAL, STATE AND NATIONAL CODES HAVING JURISDICTIONAL AUTHORITY.**

Equipment, which is defective in material or workmanship and within the warranty period, may be returned for credit as follows:

Beckett Burners, Beckett-branded major components and non-Beckett-branded major components that came as original equipment on a Beckett burner or were sold as a replacement part by Beckett should be returned, freight prepaid, to Beckett's home office. Credit will be issued to the customer unless the returned equipment is determined by Beckett to be out of warranty or damaged by user, in which case the equipment will be scrapped.

**Note: Beckett is not responsible for any labor cost for removal and replacement of equipment.**

THIS WARRANTY IS LIMITED TO THE PRECISE TERMS SET FORTH ABOVE, AND PROVIDES EXCLUSIVE REMEDIES EXPRESSLY IN LIEU OF ALL OTHER REMEDIES, AND IN PARTICULAR THERE SHALL BE EXCLUDED THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT WILL BECKETT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGE OF ANY NATURE. Beckett neither assumes nor authorizes any person to assume for Beckett any other liability or obligation in connection with the sale of this equipment, Beckett's liability and Customer's exclusive remedy being limited to credit as set forth above.

**R.W. BECKETT CORPORATION**

P.O. Box 1289 Elyria, Ohio 44036

Form No. 61545 R72905

The Oilheat Manufacturers' Association supports the use of low sulfur fuels as defined by ASTM D396, Grades No. 1 Low Sulfur and No. 2 Low Sulfur, as the preferred heating fuel for the following reasons:

- Low sulfur fuels reduce deposits on heat exchanger surfaces, extending the service interval between cleanings.
- The reduced deposits increase the efficiency of the appliance.
- Low sulfur fuels reduce particulate emissions.
- Low sulfur fuels reduce oxides of nitrogen emissions.

**R.W. BECKETT CORPORATION**

U.S.A.: P.O. Box 1289 · Elyria, Ohio 44036

[www.beckettcorp.com](http://www.beckettcorp.com)

Canada: R.W. Beckett Canada, Ltd. · Unit #3, 430 Laird Road · Guelph, Ontario N1G 3X7

# H. Fault Diagnosis & Troubleshooting

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## 3. DGH Network

### Typical RS485 Network Problems----

- ❖ A complete Network stops responding
- ❖ A complete Network responds intermittently
- ❖ Individual Sensors not Communicating
- ❖ Individual Sensors read non-sensical values
- ❖ Slow response times to commands
  - ◆ e.g. Heater On
  - ◆ e.g. Change Motor RPM

### Diagnosing RS485 Problems---

- ❖ Problem variables in the User Interface
  - ◆ erratic values displayed
  - ◆ constant communication problems (yellow background)
- ❖ Check Communications→Health Tab
  - ◆ No Problems: %Good > 95%
    - Some dropped messages is normal
  - ◆ One Device Out: %Good Between 90% and 100%
  - ◆ Multiple Devices Out: %Good Between 20% and 95%
  - ◆ No Devices Communicating: %Good 0%
  - ◆ Check individual building tabs (e.g. Communications->HPP) to identify failing sensors.

## Communications – Recovery

- ❖ If all devices on serial network work intermittently its probably a network wiring problem
- ❖ Easy things to do:
  - ◆ Make sure the cable is solidly connected at the drill computer and at the electrical panel.
  - ◆ Check the connectors for bent or broken pins
  - ◆ Use Ohm meter to check Data lines not shorted to ground. Check for 24vdc at power supply & DGH's
- ❖ More difficult things to do:
  - ◆ Check the termination of the network
    - In the drill computer, no termination on the 485 card
  - ◆ Check that the wires are not broken

## Communications Network - Recovery

- ❖ If all devices on serial network stop responding then its likely the serial card has stopped responding.
  - ◆ Restart control server and User interface software and see if the network starts responding. If it does not then...
    - Reboot the Drill Computer and see if the network starts responding.
      - If the network does not come backup after rebooting the drill computer it is likely the serial card has failed. Call a software driller to replace the card.
  - ◆ If the network does come back up, make a note of the occurrence in the log and notify a software specialist driller.

## Diagnosing DGH Problems

- ❖ When a device on a network stops responding, ask the following questions:
  - ◆ Has the sensor ever worked?
  - ◆ Has the value in the UI stopped updating?
  - ◆ Is the UI displaying values that make no sense?
  - ◆ Does the value in the UI have a Yellow background?
  
- ❖ If the sensor never read a valid value, then the DGH may be mis-addressed:
  - ◆ Locate the DGH for that sensor and unplug it.
  - ◆ If the background of the sensors value in the User Interface does not turn YELLOW, then the DGH has been misaddressed.
  - ◆ Verify the address being used:
    - Go to the System->Communications buildings tab and find the address for the variable
    - Check that address with the documented DGH address for the sensor.
    - If the address is incorrect, seek help to re-address the DGH.
  
- ❖ If the sensor previously read a valid value but is now reading an invalid value, the sensor or the DGH may be faulty.
  - ◆ Measure the sensor value directly and compare that to the “raw” value displayed on a System->Communications building tab.

Measuring the “raw” value depends on the type of sensor

- ❖ Some sensors generate pulses:
  - ◆ DGH counts the numbers of pulses per second (HZ)
  - ◆ Example: Flow meters into individual heaters
  - ◆ Measure using a DVM set to the 'Hz' setting.

- ❖ Some sensors are current sources
  - ◆ DGH measures the current between 4 and 20 mA
  - ◆ Example: Pressure sensors that are lowered to the bottom of the water tanks to measure the water level.
  - ◆ Use a DVM set to the "amp's" setting.
    - Note: When measuring current the meter must be in series with the current flow, not in parallel.
  
- ❖ Some sensors are simple switches, closing a circuit if they are turned on.
  - ◆ DGH reports a voltage of 0.
  - ◆ Example: CO or Smoke alarm module
  - ◆ Use a DVM in voltage mode or diode measurement to easily see when the switch is closed.
  
- ❖ Some DGH's are set up as outputs controlled by the computer
  - ◆ Open-collector transistor (current limited to 30ma by resistors) driving relays
  - ◆ Example: Turning burners on and off
  - ◆ If the DGH loses power the outputs are turned off
  - ◆ Use a DVM in voltage mode to monitor chg of state

RS-485 Network biasing

# of nodes	Impedance	I=V/R amps	5 volts/I = ohms	Biasing resistor Value Ohms/2
1	12000	1.66667E-05	300000	150000
2	6000	3.33333E-05	150000	75000
3	4000	0.00005	100000	50000
4	3000	6.66667E-05	75000	37500
5	2400	8.33333E-05	60000	30000
6	2000	0.0001	50000	25000
7	1714	0.000116686	42850	21425
8	1500	0.000133333	37500	18750
9	1333	0.000150038	33325	16662.5
10	1200	0.000166667	30000	15000
11	1091	0.000183318	27275	13637.5
12	1000	0.0002	25000	12500
13	923	0.000216685	23075	11537.5
14	857	0.000233372	21425	10712.5
15	800	0.00025	20000	10000
16	750	0.000266667	18750	9375
17	706	0.000283286	17650	8825
18	667	0.00029985	16675	8337.5
19	632	0.000316456	15800	7900
20	600	0.000333333	15000	7500
21	571	0.000350263	14275	7137.5
22	545	0.000366972	13625	6812.5
23	522	0.000383142	13050	6525
24	500	0.0004	12500	6250
25	480	0.000416667	12000	6000
26	461	0.000433839	11525	5762.5
27	444	0.00045045	11100	5550
28	428	0.00046729	10700	5350
29	414	0.000483092	10350	5175
30	400	0.0005	10000	5000
31	387	0.000516796	9675	4837.5
32	375	0.000533333	9375	4687.5

## EHWD RS-485 System Termination and Bias Resistors

This document will serve as a starting point to properly terminate and bias the existing RS-485 multi-drop communication system that is part of the EHWD.

Three devices are considered:

1. The *Industio* CP-114 RS-485 Industrial Serial Board for PCI bus installed in the Drill Control computers
2. The DGH 1000 series Interface modules
3. The UNICO 1100 and 1105 series drives

Advantages of the RS-485 multi-drop system according to DGH users manual---

1. Balanced line gives excellent noise immunity
2. Can communicate with D1000 modules at 38400 baud
3. Communication distances up to 4,000 feet
4. True multi-drop; modules are connected in parallel
5. Can disconnect modules without losing communications
6. Up to 32 modules on one line;
7. No communications delay due to multiple modules
8. Simplified wiring using standard telephone cable

Looking at all the documentation two groups of facts become evident----

1. Termination matches the impedance of a node (Unico drive or DGH) to the impedance of the cable (approx. 100 ohms) May not have any benefit when used at low data rates (<115KB) or on short runs. Affects biasing. Is termination necessary—**No**. See example
2. The value of bias resistors depends on termination and the number of nodes (12K impedance/node) attached to the line. The bias resistors can be placed anywhere in the network or split among multiple nodes if their values are recalculated to adjust for multiple resistors in parallel.

Present System:

1. The RS-485 board in the computer has 120 ohm termination resistors (jumper selectable) installed on each port. I believe most if not all boards have the termination resistor in the circuit (Jumpers installed)
2. The MDS's containing a mix of UNICO drives and DGH modules have multiple termination resistors (unknown value) and multiple bias resistors (unknown value) installed in the UNICO drives at the J4 connection
3. The MDS's containing only DGH modules have a termination resistor installed at the last node and no bias resistors installed.

Proposed System:

1. In the Drill control computer make sure that the active RS-485 ports have the jumpers removed to ensure that the 120 ohm termination resistors are out of the circuit. Note: Save the jumpers in case conditions change and the resistors are required.

2. In the MDS's with a mix of UNICO drives and DGH modules remove all resistors at the J4 connection in the drives. Remove the termination resistor at the last node in each network either DGH or UNICO. The proper biasing resistor values will be calculated (Example given below) and install the two bias resistors at one place along the network (preferably in the network distribution panel)
3. In the MDS's containing only DGH modules check that termination resistor installed at the last node is removed and calculate and install the proper biasing resistor values (preferably in the network distribution panel)
4. Reset the computer, drives and modules to communicate at 38400 baud

Termination and Biasing Calculation Examples (Thanks to B&B electronics):

### Termination?

Is termination needed? The UART (Universal Asynchronous Receiver-Transmitter) will sample the data in the middle of the bit. A rule of thumb is; if the propagation delay of a cable is much less than one bit width, you do not need termination.

Determine the propagation delay of the cable going the longest distance (MHP3 = 275' = 84 meters), and a data rate of 38400 bps

We make the follow two assumptions:

- The propagation velocity of a typical cable is 0.66 times the speed of light (c) and
- Reflections due to impedance mismatch typically damp down in 3 round trips of a cable

Speed of light  $c = 3000000000$  m/s

Length of cable = 84 meters

A round trip distance will be twice the cable length which is 168 meters

Round trip time =  $168 / 0.66c = .848$  microsec

As the reflections will damp down in 3 round trips, this means that the signal will stabilize

$3 * .848$  microsec = 2.544 microsec after the leading edge of a bit

- As we will be running at 38400 bps, a bit will be  $1/38400 = 26.04$  microsec wide
- The receiving UART will sample the data in the middle of the bit

Since the reflections are damped out after only 2.544 microsec into the bit (which is significantly before the center of the bit), termination is not necessary.



**Biasing (With and without termination resistors)**

Determine the bias resistors required to maintain at least 200mV between the data lines in the following system

- **10** RS-485 nodes (assume 12K ohm impedance per node)
- **2** x 120 ohm termination resistors
- +5 v supply

Ten RS-485 nodes of 12K Impedance per node in parallel gives an effective impedance of 1.2K. Two termination resistors in parallel gives an effective impedance of 60 ohms.

$$\text{Total Load} = 1.2\text{K} * 60 / (1.2\text{K} + 60) = 57 \text{ ohm}$$

It can be seen that the termination resistors contribute to the majority of the loading. When added, they drag the effective impedance at the receiver inputs down thus adding to driver loading. To have at least 200 mv between the A and B lines we need:

$$I = V/R = 200\text{mv} / 57 \text{ ohms} = 3.5 \text{ mA to flow through the load.}$$

To get 3.5 mA bias from a 5v supply requires a total series resistance of

$$R = V/I = 5 / 3.5 \text{ mA} = 1428 \text{ ohms}$$

We already have 57 ohms as part of the load so we subtract this:

$$1428 - 57 = 1371 \text{ ohms}$$

This is the total series resistance needed for the two bias resistors (pullup and pulldown). We divide this between them.

$$1371 / 2 = 685.5 \text{ ohms for each biasing resistor.}$$

The nearest equivalent is a pair of **680 ohm** resistors.

Re-doing the above calculation assuming **no** termination resistors provides the following bias resistor values:

$$\text{Total load} = 1.2\text{K}$$

$$I = V/R = 200\text{mv} / 1.2\text{K} = .16666 \text{ mA}$$

$$5\text{v} / .16666 \text{ mA} = 30\text{K ohms} \quad \text{or} \quad \mathbf{15\text{K ohms}}$$

### Purpose

Describe the criteria to be followed for inspecting the EHWD Supply Hose and determining the suitability for use.

### Materials / Equipment / Tools Needed

- Good Light
- Naked Eye

### Preparation / Setup

- The hoses have numbers stamped onto the ends of the fittings. These numbers are also recorded on the proof test reports. Should a problem arise, it would be useful to cross-reference the failed hose number to the test report.
- Record the hose numbers per the position of the section on the reel in order to establish the position of a particular hose.



### Responsibilities

The Drilling Manager at each facility will insure that the following inspection procedures are communicated to the Drill Team. Any inspection failures require that the hose section in question be either removed immediately or from the hose system when convenient, segregated from the "good" hose and be tagged appropriately. The Shift Leads will assign inspection duties.

### Scope

This document applies to all EHWD Hot Water Hoses both at PSL and at the South Pole.

### Terms and Definitions

**Immediately:** as soon as possible and convenient during the drilling process before commencing with the drilling of the next hole.

### Requirements / Additional Information

Each of the following criteria will be depicted verbally and will contain a pertinent picture where possible. All rejected hoses must be documented through the use of the Non-Conforming Materials Form. Please note the number of any failed hose on the NCM form.

## Hose Inspection Criteria

### Contamination

#### Petroleum Damage/Sticky Surface

- When the hose has been contaminated with petroleum/JP8, it is difficult to determine the severity of the damage.
- If the contamination lies in the middle part of the hose, then there is no real problem. Use the hose as is.
- If the contamination lies near a fitting and there is no apparent damage, then the hose should be evaluated prior to drilling the next hole. The strain relief should be removed and the hose checked. If any apparent damage exists, then replace the section immediately.

### Physical Defects

**Surface Defects** - Over time the surface of the hose becomes marred or otherwise damaged from routine wear and tear on the hose.

- If the surface is damaged but there is no visible textile strength member, then the hose section need not be replaced.
- If the textile strength member is visible, and there is no apparent damage, then the hose section must be replaced before drilling the next hole.
- If the textile strength member is visible, and there is apparent damage to the textile, then the hose must be replaced immediately.



#### Necked Hose

A "necked hose" is demonstrated by an elongation of the hose at the fitting and at the strain relief. Acceptable "necking" is defined as when the minimum diameter is above 3.5 inches.

- Minor Necking is represented by a minimum diameter between 3.25 inches and 3.5 inches. If a hose exhibits minor necking, then the hose must be replaced before drilling the next hole.
- Major Necking is represented by the smallest diameter being less than 3.25 inches. If a hose exhibits major necking, then the hose must be replaced immediately.



#### Kinking (surface hose)

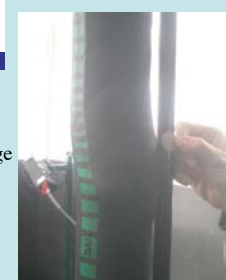
- Kinked surface *supply* hose (hot) should be immediately removed from surface and replaced with new red-striped hose.
- Kinked surface *return* hose (cold) should be promptly straightened and observed for visible damage before service. Mark the region with spray paint. Replace any sections showing visible signs of damage.

### Reference Documents

Document #	Title of document
9000-0039	EHWD Hose Inspection Criteria

#### Crooked Hose-

A crooked or "not straight" hose, even though there may be no visible outer damage to the hose, represents damage to the textile strength member. The hose section must be replaced immediately.

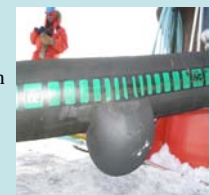


#### Leaking Hose -

- Any leaking section of hose must be replaced immediately.

#### Bulging Hose -

- Any hose section with a visible bulge or bulges must be replaced immediately.



**Fitting Slip Criteria** - Fittings can slip during the routine use of the hose. This slippage can create a potentially dangerous situation.

- A circular paint mark needs to be drawn at the end of the strain relief on the hose. This mark is placed so that, if it is viewed from the side, the end of the strain relief lines up with the paint mark. If the hose adjacent to the fitting stretches or slips within the fitting, a gap would develop between the paint line and the end of the strain relief.
- A gap of less than 10mm is considered as acceptable and could be explained as the "stretching" or settling of the hose.
- A gap of more than 10mm would indicate slipping in the fitting, necessitating replacement of the hose immediately.

### Hose Retirement

- For any hose to be retired, record its serial number, date of failure, failure mode, and position on reel. Also record the serial number of its replacement hose.
- Never** reuse any removed drill hose as surface *supply* line hose.
- Retired drill hose exhibiting only superficial surface damage (strain relief cutting, gouges, all without visible damage to strength member), may be reused as surface *return* hose only.
- Hose exhibiting fitting slip or "pull-out" should be destroyed immediately upon removal. Cut off fittings (see below).
- All failed hose sections should have both end fittings cut off and any damaged sections cut out and collected for return to Madison for observation. Samples should be grouped by hose piece and labeled for easy identification.

**Purpose**

The purpose of this poster is to serve as a reminder to Plug-in all Heated hoses and associated Heat tapes on the EHWD when preparing the SES and TOS for drill operations. Heated Hoses have replaced selected surface hoses in order to provide freeze protection when there is no water flow in them.

**Materials/ Equipment**

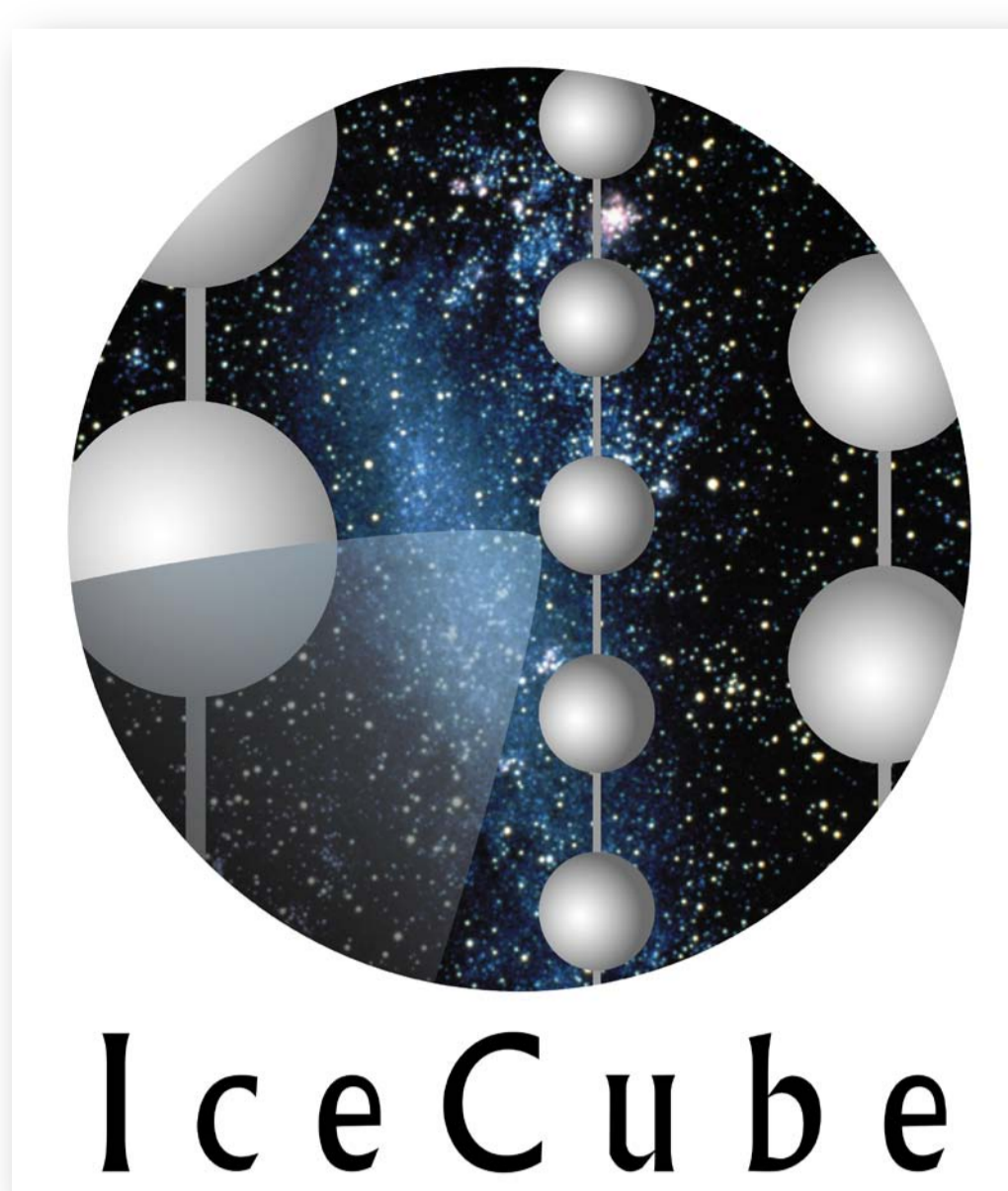
Orange jacketed Heated Hose, Yellow jacketed Heated Hose/ 240vac Test Kits in DCC

**Tools Needed**

None

**Preparation/ Setup**

None



**Responsibilities**

The Drill Manager/ Shift leads will insure the following reminders are communicated to the Drill Team. Leads will assign Heat Hose/ Tape duties.

**Scope**

This document applies to all EHWD "Heated" Hoses and associated Heat Tapes with the EHWD at the South Pole.

**Requirements/ Additional Information**

Each of the following criteria will be depicted verbally, as part of a checklist/ spreadsheet and will contain a picture where possible.

# Heated Hose Specification

**•Lists of Heated Hose to be identified and plugged in**

SES PRIMARY HEATED WATER HOSE ID CHART							
HOSE ID	NAME	SERVICE	TYPE	TEMP	ID	LENGTH	NOTES
H100	RWS SUPPLY	WT1 --> RWS	Heated "Orangejacket"	Cold	1.5"	35'	Suspended across utility aisle (new for 07-08)
H101	RWS COLD RETURN	RWS --> WT1	Heated "Orangejacket"	Cold	1.5"	35'	Suspended across utility aisle (new for 07-08)
H102	RWS HOT RETURN	RWS --> WT1	Heated "Orangejacket"	Hot	1.5"	35'	Suspended across utility aisle (new for 07-08)
H103	WT TRANSFER LINE	WT1 --> WT2	Heated "Yellowjacket"	Cold	4"	45'	Suspended between tanks, Qty: 2
H104	PHS SUPPLY	WT2 --> PHS	Heated "Yellowjacket"	Warm	4"	15'	Suspended
H105	PHS RETURN	PHS --> WT2	Heated "Yellowjacket"	Warm/Hot	1.5"	15'	Suspended, Qty: 2
H106	PHS RETURN	PHS --> WT1	Heated "Yellowjacket"	Warm/Hot	1.5"	15'	Suspended
H106	HPP SUPPLY	WT2 --> HPP	Heated "Yellowjacket"	Warm	4"	35'	Lays on ground, Qty: 4
H106	+ 4 more		Heated "Orangejacket"		2"		
H117	RETURN WATER WT1 BYPASS	RETURN WATER @ WT1 --> RWS	Heated "Yellowjacket"	Cold	1.5"	50'	Suspended (existing spare)
H122	GEN WATER WT1 BYPASS	GEN WATER @ WT1 --> WT2	Heated "Yellowjacket"	Warm/Hot	1.5"	50'	Suspended between tanks
H123	OVERPRESSURE BYPASS	HPP --> WT2	Heated "Yellowjacket"	Warm	1.5"	40'	Suspended across utility aisle, " 2 x 20' hoses in series (existing spares, RWS return during 06-07)
H124	CONDENSATE SUM	MHP1 JUNCTION --> PHS	Heated "Yellowjacket"	Warm	1.5"	33.5'	Suspended across utility aisle (existing spare, Idle Line during 06-07)

SES Heated Hose are plugged into either the 240v outlets at the corners of most containers or into the Power Sled

EHWD SES HEAT TRACE ID CHART							
TRACE ID	NAME	SERVICE	TYPE	TEMP	ID	LENGTH	NOTES
	Heat Trace in HPP	Over Pressure Lines	Heat Trace w/ Ind. Light		N/A	N/A	Plug into closest outlet in HPP
	Heat Trace	@ End of Heated HPP --> WT2	Heat Trace w/ Ind. Light		N/A	N/A	Plug into the end of Heated HPP --> WT2 Hose
	Heat Trace	Over Pressure line					
	Heat Trace	WT2 change pumps, Qty = 2	Change pump stand pipes/hoses		N/A	N/A	Plugs into the end of HPP supply lines

EHWD TOS HEATED WATER HOSE ID CHART							
HOSE ID	NAME	SERVICE	TYPE	TEMP	ID	LENGTH	NOTES
	Bypass Hose		Heated "Yellowjacket"		1.5"	50'	

**Important!!! The TOS Bypass hose acts as an extension cord for the heat trace at the end of the Main Hose Reel**

**Note: Test Kits are available in DCC w/ Indicator lights to test the heated hoses and outlets.**

**•Identify Heated Hoses**



Yellow Heated Hose



Orange Heated Hose

- Connect physically as directed by the shift lead
- Connect the GFCI modules and the Hoses Electrically---Via 240vac receptacles on containers or the Power Sled located in the Utility Aisle between the containers. The GFCI modules have a standard 240vac 3 prong plug on one end and a Hubbell Twist-Lock connector on the other end.
- Make sure the Twist-Locks are "Locked". See closed padlock symbol on plastic connector
- Make sure that 240vac power is present at the receptacle. Check for "Green" light on the GFCI module. There are also power test kits available in the DCC.
- Do "Not" get wrapped up in your work.



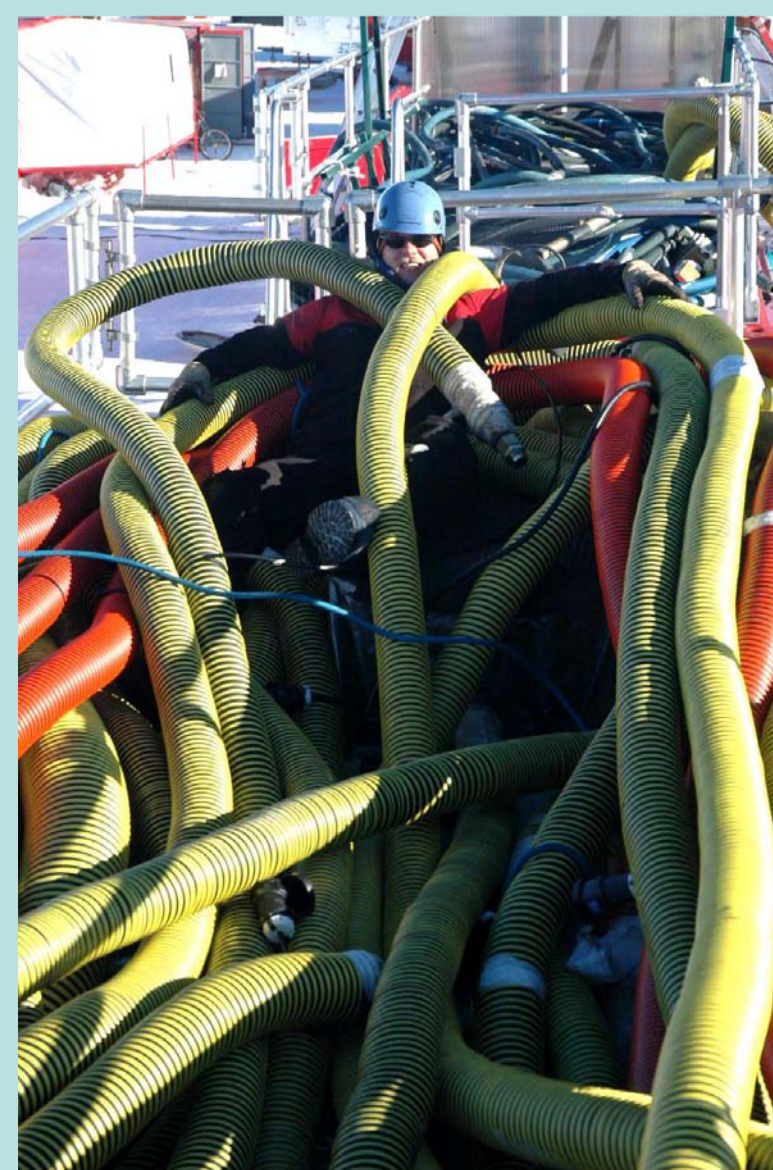
Connection to container



Twist-Lock Connection



Close-up of GFCI module



**Reference Documents**

Document #	Title of document
8510-0377	EHWD Heated Hose Specification

# EHWD DNF List

-----Graceland----- Summer DNF Storage

Date: 1/25/2007

Last Edited by: TDM

**All contents should be moved to DCC, TOS1 or TOS2  
Winter Storage Areas**

Remember to Mark and Inventory entire contents of  
Graceland prior to decommissioning building-----

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## Seasonal Electrical Workshop - SEW

Hose crimping machine motor starting capacitors	2
Hose crimping machine control panel	1
Smoke detectors	1
Emergency Lights	1
Cordless tool batteries and chargers	All
Flashlights	All
Magnalube and any other grease/epoxy	All
Handifoam and any other liquids	All

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## **Offsite Mechanical Lab----(OML) Now called --- (SHOP)**

Hose crimping machine motor starting capacitors	2
Hose crimping machine control panel	1
Smoke detectors	1
Emergency Lights	1
Cordless tool batteries and chargers	All
Flashlights	All
Magnalube and any other grease/epoxy	All
Handifoam and any other liquids	All

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## **Drill Control Center - DCC      Winter DNF Storage Facility**

Computer CPU's	4
Monitor/ Keyboard/ Mouse	4
UPS Ferrups/ FE	2
HP Network switch	1
IP phone	1
E-Stop electronics (rack mt'd)	1
Smoke detectors	1
Emergency Lights	1
Radios & chargers	
NiMH battery charger & batteries	1
Defibrillator	1

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## **Tower Operations Structure #1 (TOS1)      Winter DNF Storage facility**

TOS1-V1,V3,V6  
TOS1-V4,V7  
TOS1-V2,V5  
External Capacitor TOS1-C1      1  
KLCUL80A2 (Line Filter)      1      For V3  
KRF80APT (RFI Line Filter)      1      For V3  
KRF16CTB (RFI Line Filter)      4      For V2,V4,V5,V7  
KRF45CTB (RFI Line Filter)      2      For V1,V6  
KRF16ATB (RFI Line Filter)      1      For Autobander/Hose Heater

### **Computers/Electronics**

Computer CPU's      2  
Monitor/ Keyboard/ Mouse      2  
UPS Ferrups/ FE      1  
HP Network switch      1  
IP phone      1  
E-Stop controller (rack mt'd)      1  
Smoke detectors      1  
Emergency Lights      1  
  
Drill electronics      1  
Micro DAC LT controllers for  
TOS1 I/O boxes      5  
Load cell interface      1  
  
1 million CP light & charger      1  
Flashlights      All  
  
Chairs w/ Lifts      2  
  
Chromalox Heater Control  
Control      1  
High Limit      1



# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## Tower Operations Structure #2 (TOS2) Winter DNF Storage Facility

TOS2-V1,V3,V6		
TOS2-V4,V7		
TOS2-V2,V5		
External Capacitor TOS2-C1	1	
KLCUL80A2 (Line Filter)	1	For V3
KRF80APT (RFI Line Filter)	1	For V3
KRF16CTB (RFI Line Filter)	4	For V2,V4,V5,V7
KRF45CTB (RFI Line Filter)	2	For V1,V6
KRF16ATB (RFI Line Filter)	1	For Autobander/Hose Heater

## Computers/Electronics

Computer CPU's	2	
Monitor/ Keyboard/ Mouse	2	
UPS Ferrups/ FE	1	
HP Network switch	1	
IP phone	1	
E-Stop controller (rack mt'd)	1	
Smoke detectors	1	
Emergency Lights	1	
Drill electronics	1	
Micro DAC LT controllers for		
TOS2 I/O boxes	5	
Load cell interface	1	
Chair w/ Lifts	2	
Chromalox Heater Control		
Control	1	
High Limit	1	

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

**Storage and Work area for DOM testing------(TOW)**

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## High Pressure Pump (HPP)

HPP-V5,V6,V7,V8  
HPP-V1,V2,V3,V4

Setra Pressure & Flow sensors	ALL
CO/Smoke Detector	1
Emergency light	1

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## **Pre-Heater System (PHS)**

PHS-V1,V2  
PHS-V3,V4

Setra Pressure & Flow sensors	ALL
CO/Smoke Detector	1
Emergency light	1

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## Rodriquez Well System (RWS)

RWS-V1,V2,V4

RWS-V3

KLCUL16A1 (Line Filter)	1	For V4
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Setra Pressure & Flow sensors	ALL
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CO/Smoke Detector	1
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Emergency light	1
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# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## **Main Heating Plants - MHP1/ MHP2/ MHP3/ MHP4**

Setra Pressure & Flow sensors	ALL
CO/Smoke Detector	1
Emergency light	1
Fire Extinguisher	1
MHP2 - PDA router	1

# EHWD DNF List

Date: 1/25/2007  
Last Edited by: TDM

## **Mobile Equipment Conversation Center----(MECC)**

Bacharach Portable Combustion Analyzer 2

## EHWD FY05/06 DNF List

Date: 01/23/06  
Last edited by: TDM

Parameter	Weight	Height	Width	Length	Volume	Volume	Quantity	
Device/Component	Units	lbs	in	in	in	in <sup>3</sup>	ft <sup>3</sup>	
Hose crimping machine motor starting capacitors		0.5	2	2	6	24.00	0.01	2
Hose crimping machine control panel		5	2	10	6	120.00	0.07	1
Banding machine electrical enclosure		416	42	48	12	24192.00	14.00	1
Pressure Sensors		0.75	2.75	2.75	2.5	18.91	0.01	48
<b>Generator</b>								
Generator Batteries		60	9.25	10.75	6.5	646.34	0.37	12
PDM Batteries		60	9.25	10.75	6.5	646.34	0.37	2
PDM Battery cabinet		40	20.5	24	15	7380.00	4.27	1
ECMP II+ controller		85.4	12	28	13	4368.00	2.53	3
Genset Interface cabinet		67	24	24	8	4608.00	2.67	3
<b>Motor drives</b>								
<b>High Pressure Pump (HPP)</b>								
HPP-V5,V6,V7,V8		66	21.2	10.84	13	2987.50	1.73	4
HPP-V1,V2,V3,V4		17	12.31	9.5	7.75	906.32	0.52	4
<b>Pre-Heater System (PHS)</b>								
PHS-V1,V2		24	15.16	9.5	8.75	1260.18	0.73	2
PHS-V3,V4		17	12.31	9.5	7.75	906.32	0.52	2
<b>Rodriquez Well System (RWS)</b>								
RWS-V1,V2,V4		24	15.16	9.5	8.75	1260.18	0.73	3
RWS-V3		17	12.31	9.5	7.75	906.32	0.52	1
<b>Tower Operations Structure #1 (TOS1)</b>								
TOS1-V1,V3,V6		66	21.2	10.84	13	2987.50	1.73	3
TOS1-V4,V7		24	15.16	9.5	8.75	1260.18	0.73	2
TOS1-V2,V5		17	12.31	9.5	7.75	906.32	0.52	2
Motor Drive Dunnage		40	6	48	48	13824.00	8.00	2
External Capacitor TOS1-C1		30	12	12	6	864.00	0.50	1
<b>Tower Operations Structure #2 (TOS2)</b>								
TOS2-V1,V3,V6		66	21.2	10.84	13	2987.50	1.73	3
TOS2-V4,V7		24	15.16	9.5	8.75	1260.18	0.73	2
TOS2-V2,V5		17	12.31	9.5	7.75	906.32	0.52	2
Motor Drive Dunnage		40	6	48	48	13824.00	8.00	2
External Capacitor TOS2-C1		30	12	12	6	864.00	0.50	1
<b>Spare UNICO Drives</b>								
1100-50hp, 1105-30hp		66	21.2	10.84	13	2987.50	1.73	2
1105-10hp		24	15.16	9.5	8.75	1260.18	0.73	1
1105-3hp		17	12.31	9.5	7.75	906.32	0.52	1
<b>Filters</b>								
KLCUL80A2		64	19.13	15.5	15.5	4595.98	2.66	2
KLCUL16A1		23	12.25	12.5	6.75	1033.59	0.60	1
KRF80APT		20	12	24	8	2304.00	1.33	2
KRF16CTB		7	6	14.25	4.25	363.38	0.21	8

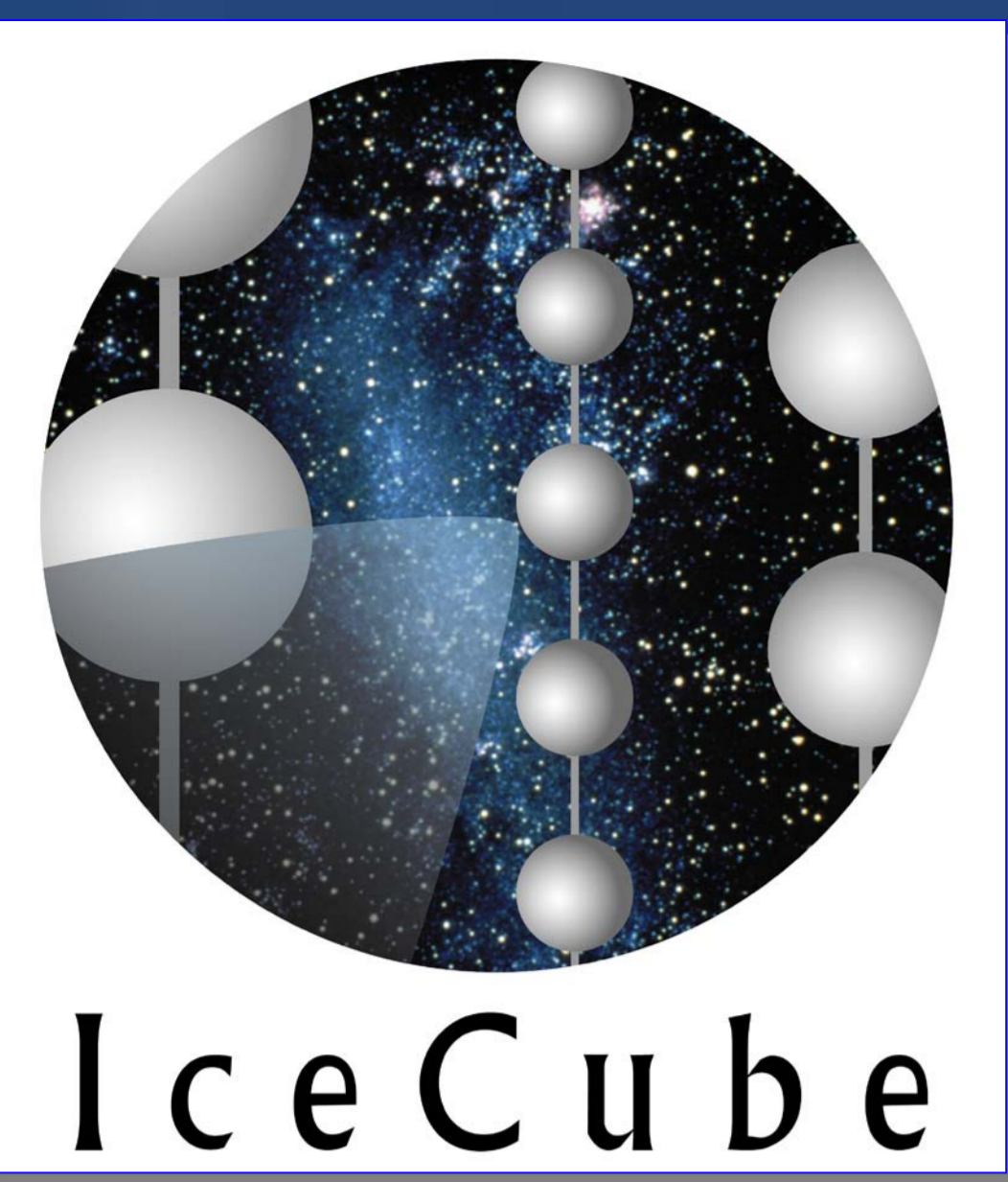


KRF45CTB	10	8	16	4.25	544.00	0.31	4
<b>Computers</b>							
CPU	85.4	19	22.5	25.5	10901.25	6.31	5
Monitor	21.5	13.25	21	22	6121.50	3.54	5
Keyboard	4	2	19	8.75	332.50	0.19	5
Peripherals	0.75	2	19	8.75	332.50	0.19	5
UPS Model 9104	125	16	6.8	24	2611.20	1.51	1
UPS Battery Module/ 9104	125	16	6.8	24	2611.20	1.51	1
UPS Ferrups/ FE	248	21.2	15.25	22	7112.60	4.12	4
Network switches	5	7	23	12	1932.00	1.12	3
IP phones	2	10	7	2	140.00	0.08	5
Analog phones	2	10	7	5	350.00	0.20	15
E-Stop electronics (rack mt'd)	10	4	17	15	1020.00	0.59	2
Smoke detectors	0.5	6	6	2	72.00	0.04	20
Medications in first aid kits	0.5	3	3	2	18.00	0.01	16
Oscilloscope	5	12	15	5	900.00	0.52	1
Multimeters	1	9	6	3	162.00	0.09	3

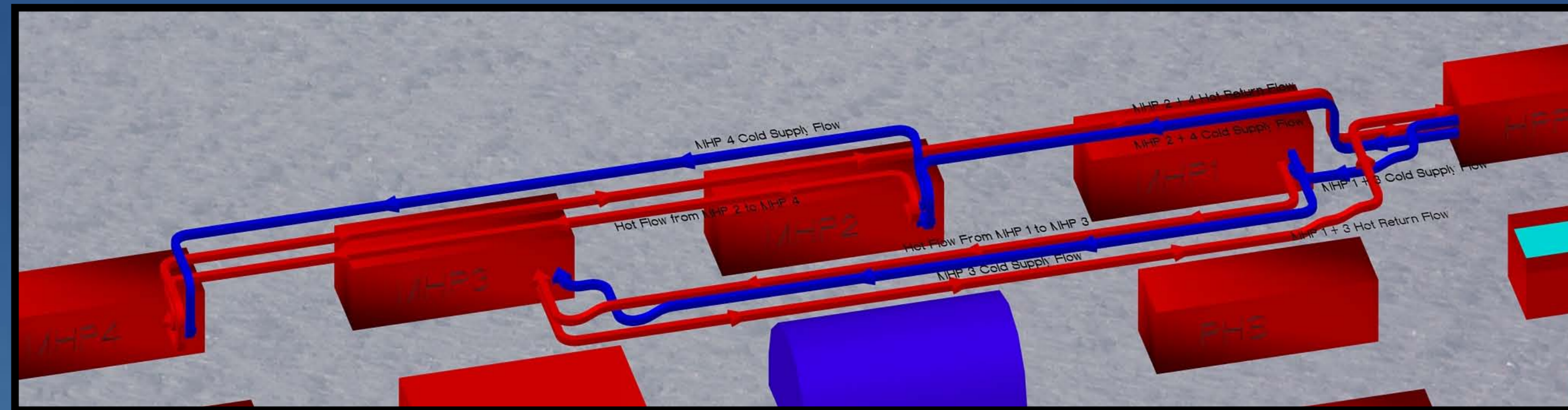
Totals
--------

Weight lbs	Volume in <sup>3</sup>	Volume ft <sup>3</sup>	Shipping Column
1.00	48	0.03	C
5.00	120	0.07	C
416.00	24192	14.00	A/B
36.00	908	0.53	
720.00	7756	4.49	A/B
120.00	1293	0.75	A/B
40.00	7380		
256.20	13104	7.58	A/B
201.00	13824	8.00	A/B
264.00	11950	6.92	A/B
68.00	3625	2.10	A/B
48.00	2520	1.46	C
34.00	1813	1.05	C
72.00	3781	2.19	C
17.00	906	0.52	C
198.00	8963	5.19	C
48.00	2520	1.46	A'
34.00	1813	1.05	A'
80.00	27648	16.00	A'
30.00	864	0.50	
198.00	8963	5.19	C
48.00	2520	1.46	A'
34.00	1813	1.05	A'
80.00	27648	16.00	A'
30.00	864	0.50	
132.00	5975	3.46	C
24.00	1260	0.73	A'
17.00	906	0.52	A'
128.00	9192	5.32	
23.00	1034	0.60	
40.00	4608	2.67	
56.00	2907	1.68	

40.00	2176	1.26	
427.00	54506	31.54	C
107.50	30608	17.71	C
20.00	1663	0.96	C
3.75	1663	0.96	C
125.00	2611	1.51	A/B
125.00	2611	1.51	A/B
992.00	28450	16.46	
15.00	5796	3.35	C
10.00	700	0.41	C
30.00	5250	3.04	
20.00	2040	1.18	C
10.00	1440	0.83	C
8.00	288	0.17	C
5.00	900	0.52	A'
3.00	486	0.28	A'
5439.45	343904.10	194.75	

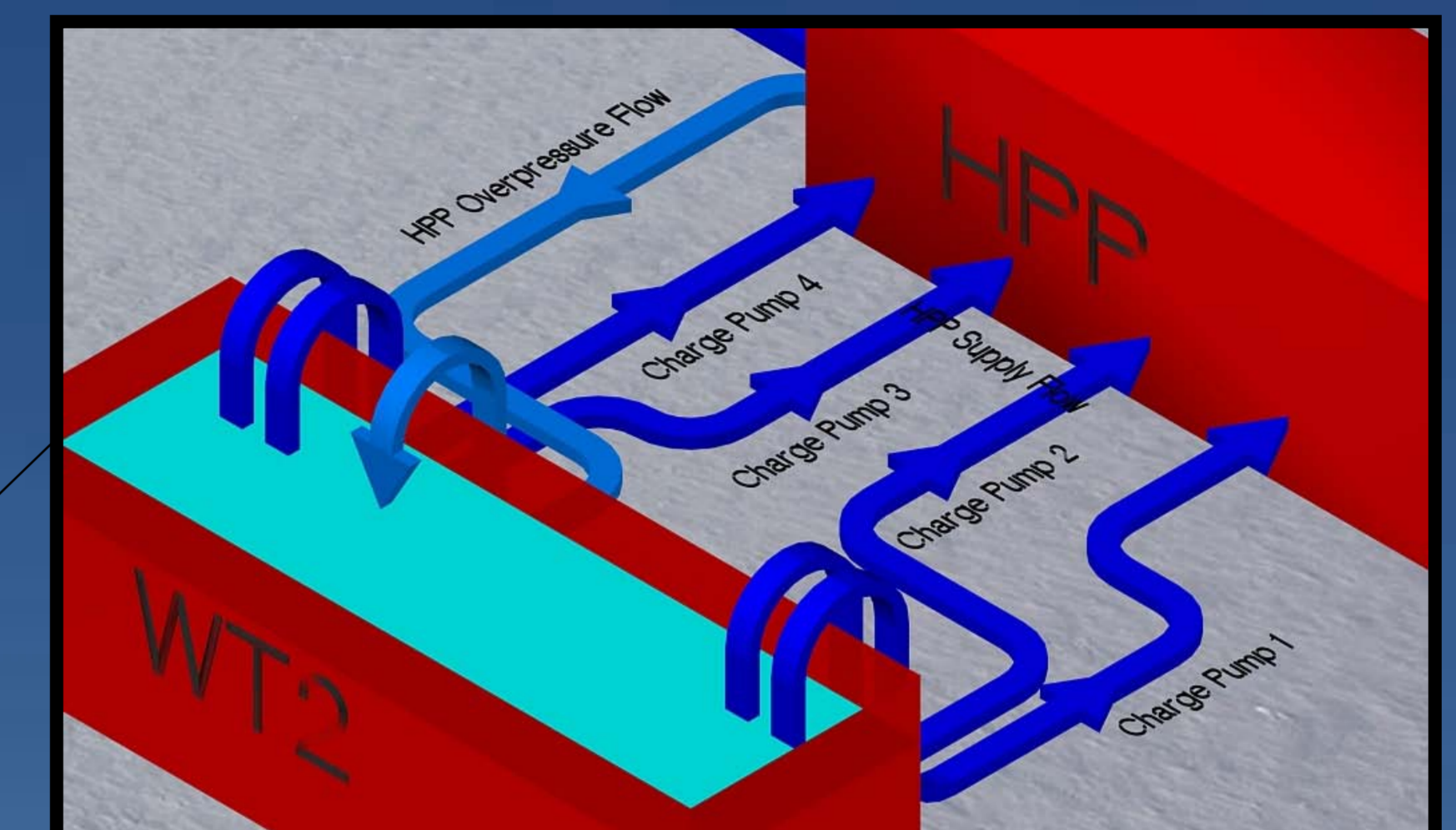
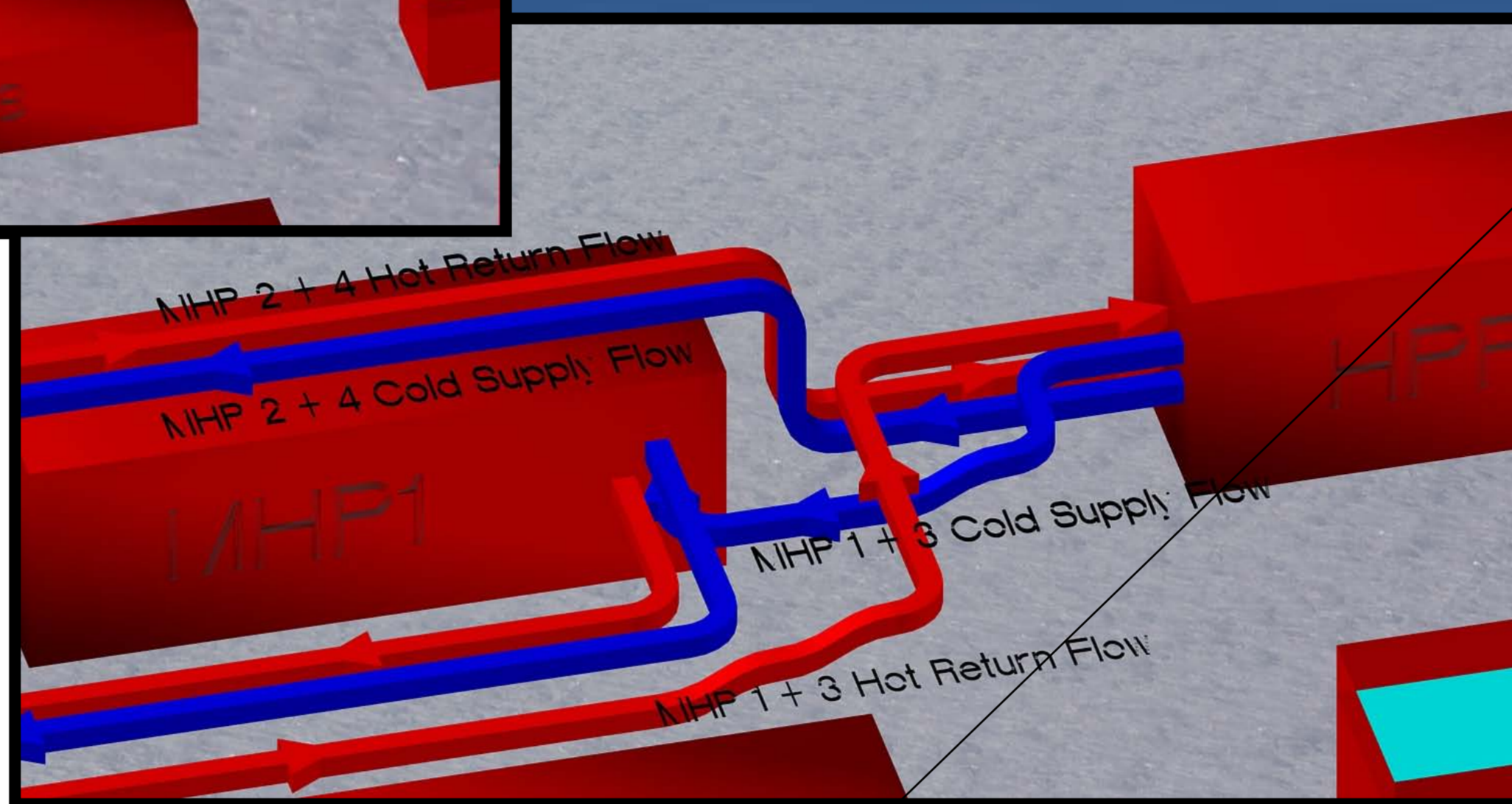


# SES Water Flows



## MHP Flows

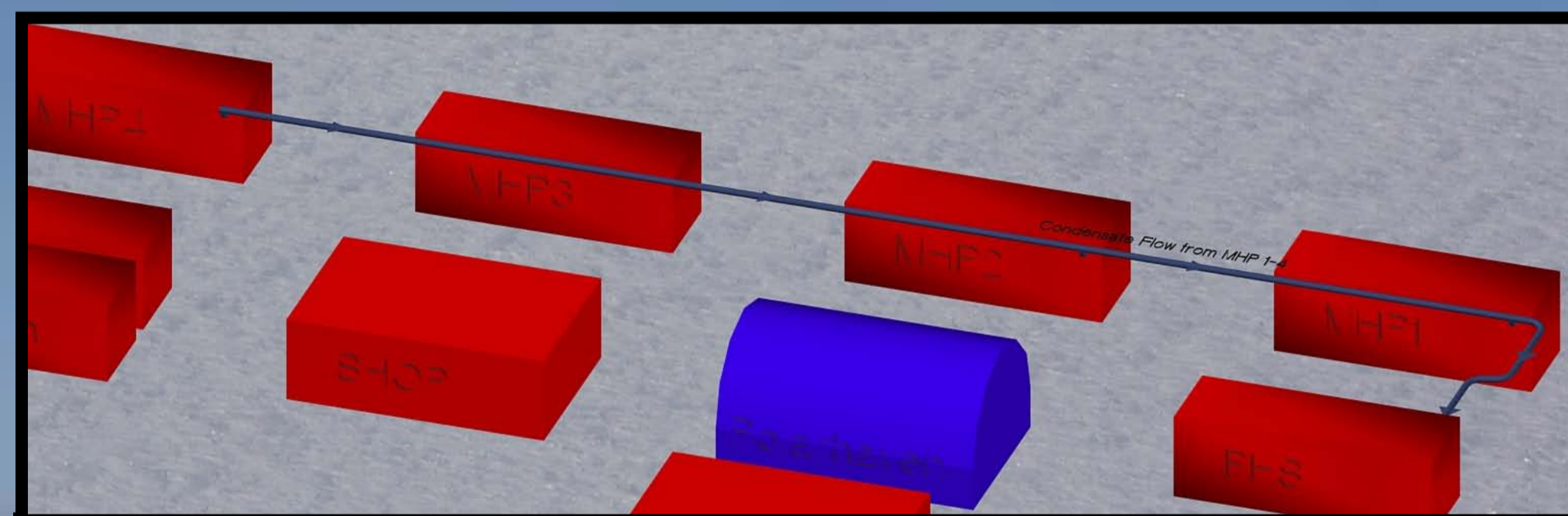
The Main Heating Plants (MHP) contains 35 high capacity heaters, each nominally receiving 7 gpm. There are two flow supply loops to MHP from HPP. The flow from the High Pressure Pumps is divided in HPP, one loop supplying MHP 1 & 3 with flow, the other one supplying MHP 2 & 4 with flow. For the MHP 1 & 3 loop, the following applies: Cold Supply Flow comes from HPP to MHP 1. Some flow passes through MHP 1 to be heated, the rest is forwarded to MHP 3 to be heated. The hot output from MHP 1 is forwarded to MHP 3, where it is mixed with the hot output from MHP 3. Together they make up the Hot Return Flow from MHP 1 & 3 to HPP. The corresponding flow pattern applies to MHP 2 & 4. The flows from MHP 1 & 3 and MHP 2 & 4 merge in HPP and are forwarded to the TOS through the Supply Surface Hose.



## HPP Flows

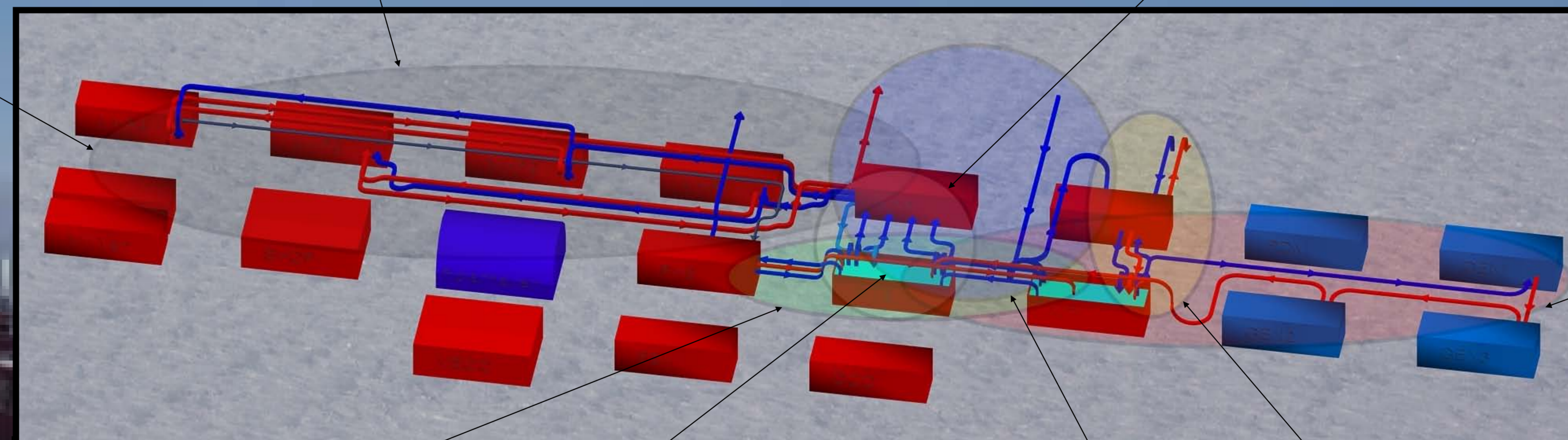
HPP controls the pumps:  
 • Charge Pump 1-4  
 • High Pressure Pump 1-4

Submersible Charge Pumps (CP) supply low pressure flow to positive displacement High Pressure Pumps (HP). The High pressure Pumps increase the flow pressure and forward the flow to MHP1-4. Each HP has one CP supplying it with flow. In case the pressure from the HP's get to high, there are four safety mechanisms in place. 1. HP Unico torque limit (reduction of rpm), 2. HPP Overpressure Valve (with output in WT2 as seen in picture), 3. Overpressure valve in MHP (pressure dropped inside MHP), 4. Overpressure valve at MSHR (pressure dumped out into the air).



## Condensate Flows

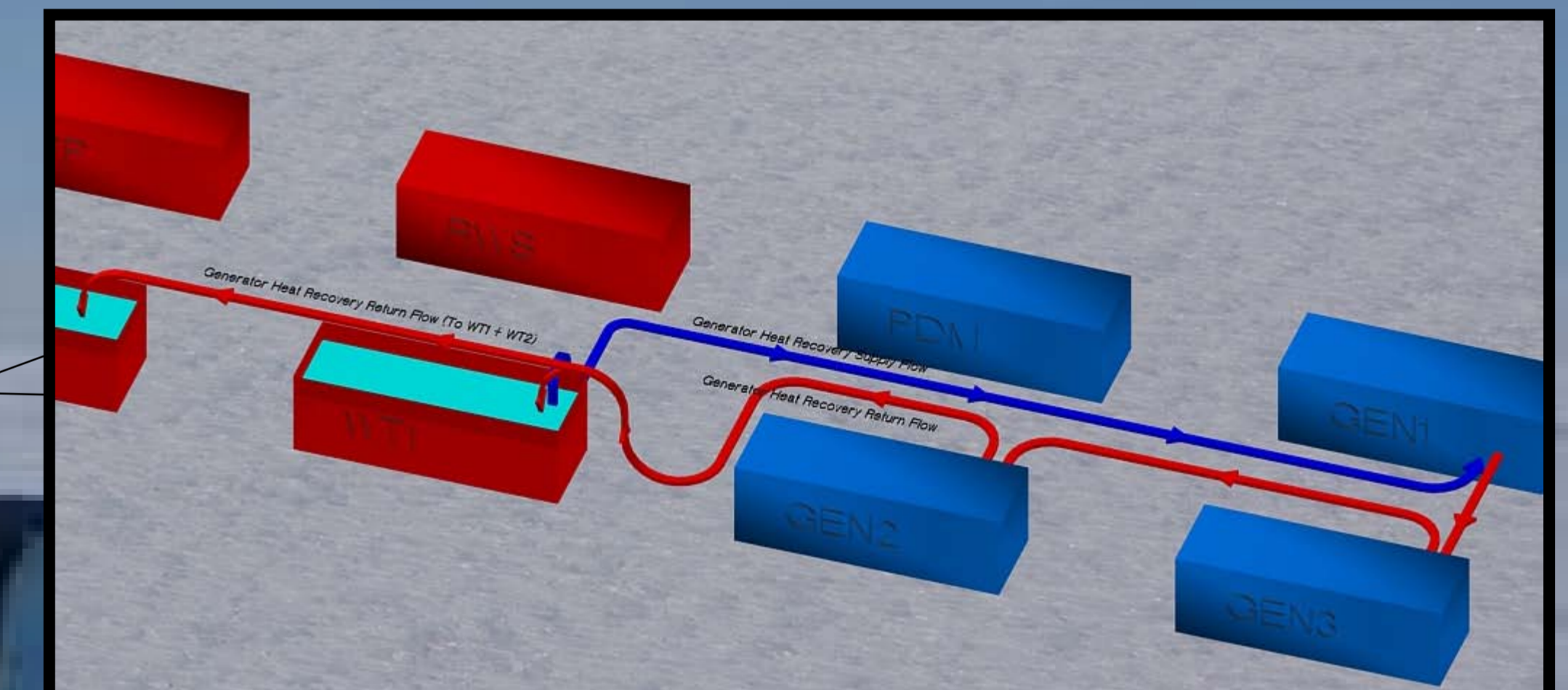
The Condensate System recovers water from burnt fuel. The water is deposited in condensate tanks inside each MHP. Automated pumps forwards the water to a tank inside PHS. Another automated pump in the PHS tank forwards the flow through a filtration system in PHS to WT2.



## SES

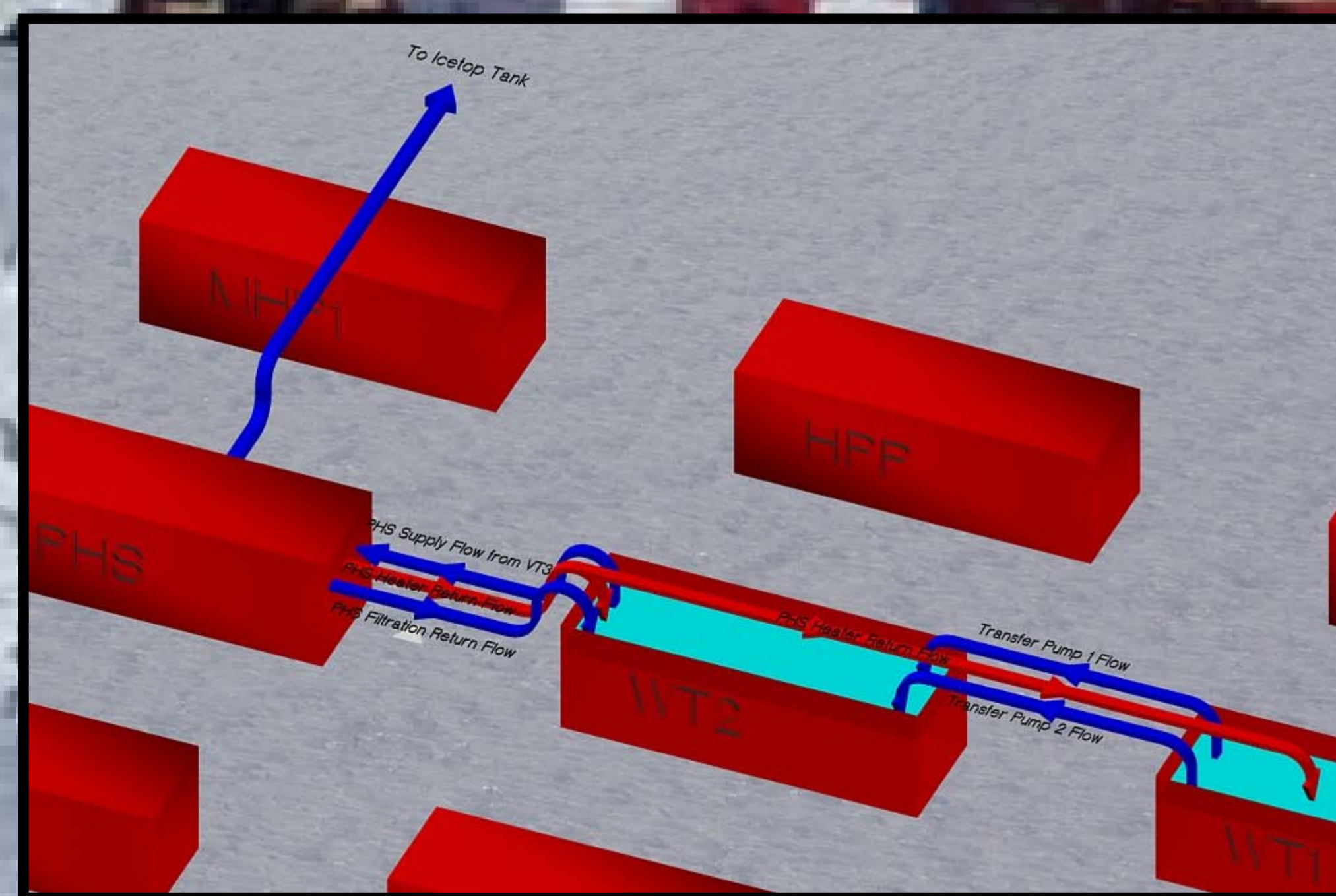
The purpose of SES (Seasonal Equipment Site) is to in a safe manner supply TOS with clean water of a high, steady temperature at a high, steady flow at required pressure. To accomplish this, water flows between different MDS plants.

Note: The charts describe the flow patterns within SES. The MDS input/output and hose locations may differ from actual setup.



## Generator Heat Recovery Flow

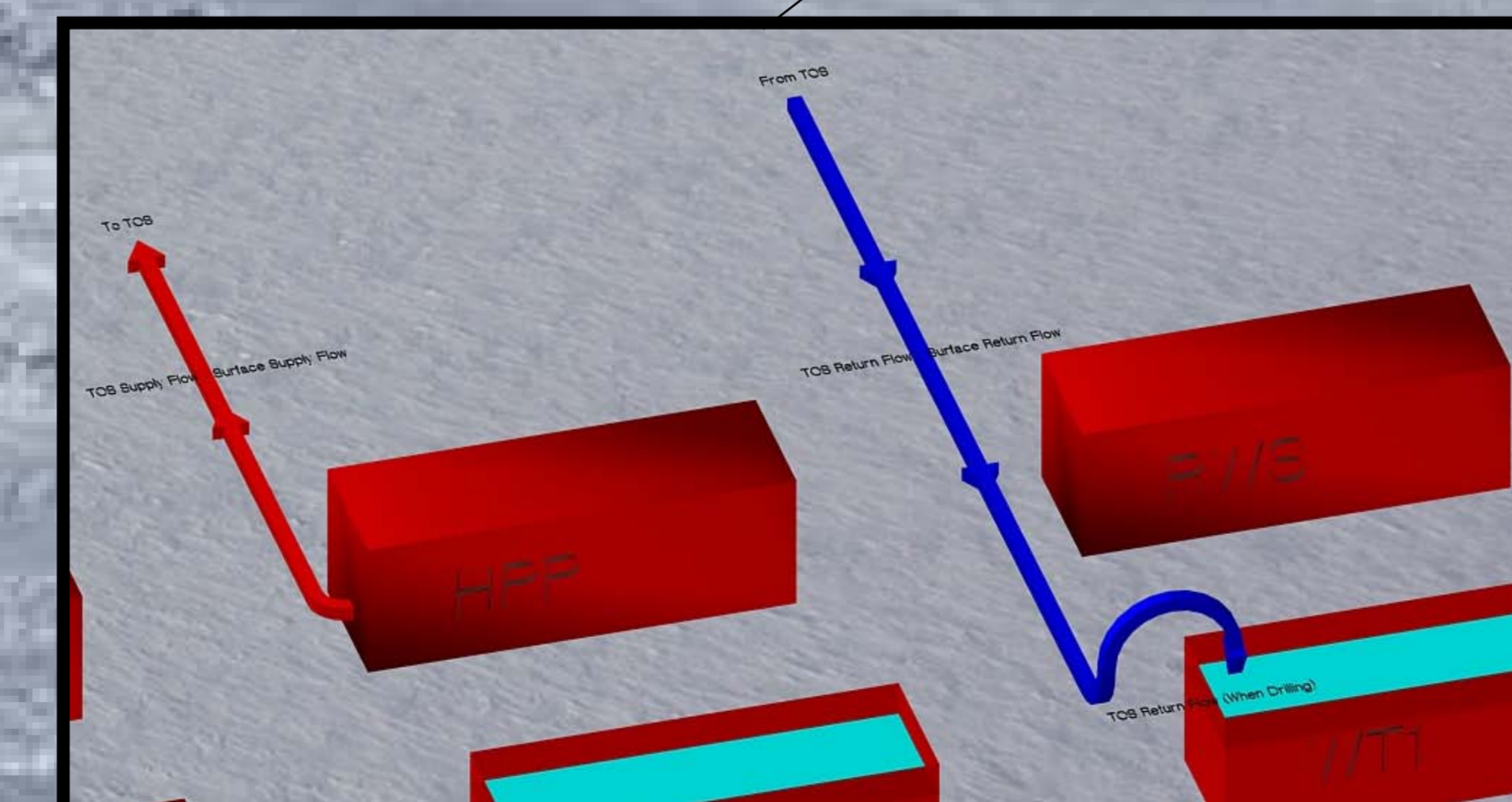
Vertical Turbine Pump 1 & 2 (VTP1 & 2) supplies the Generator Heat Recovery Loop with flow. The heat recovery is used to recover cooling heat from the generators that otherwise would get lost, and using that to heat WT1 and WT2. The flow passes Gen 1, 2 and 3 and the water is returned to WT1 & WT2. The ratio of flow going to WT1 & WT2 is controlled by a manual valve in the WT1 dog house.



## PHS Flows

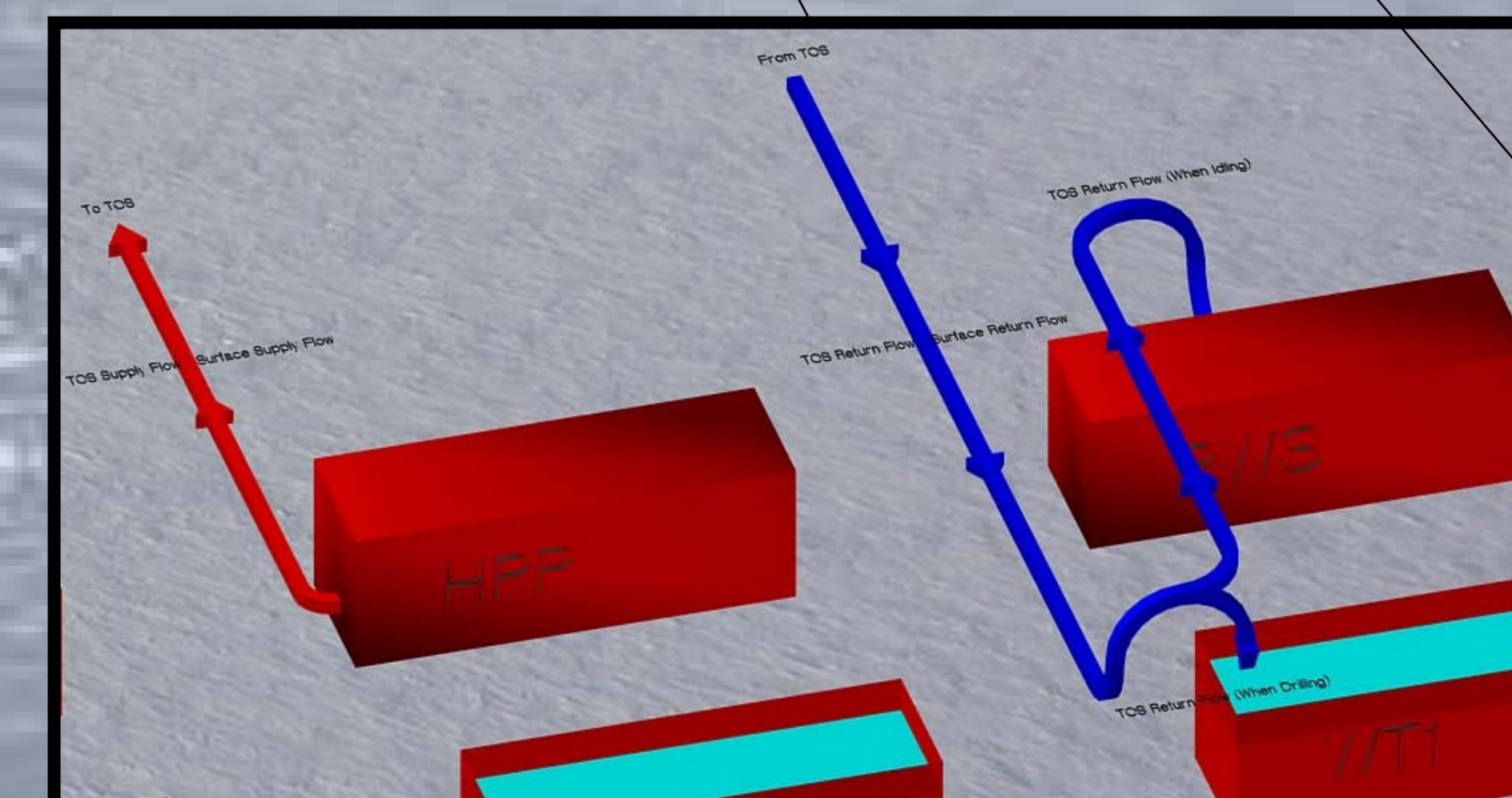
PHS Controls the Pumps:  
 • Vertical Turbine Pump 3 (VTP3)  
 • Booster Pump  
 • Transfer Pumps (TP1 & TP2)

Pre Heat System (PHS) is responsible for the Water Tank 2 (WT2) environment. I.e. to keep WT2 water filled, the water clean and the temperature stable. A Vertical Turbine Pump (VTP3) inside the WT2 dog house supply PHS with flow. Some of that flow passes through a filtration system inside PHS and is returned to WT2. VTP3 also supply flow to the four model 75 heaters in PHS, as well as to the Ictetop osmosis filter. An optional Booster Pump is located inside PHS, that is used to increase the pressure of the supplied flow. The flow going through the heaters is returned to WT2 and WT1. The distribution of the returned flow to the two tanks is controlled by manual valves in the WT2 dog house. The flow going through the osmosis filter is delivered to a movable Ictetop storage tank for further distribution to Ictetop stations on the ice. The Ictetop flow is controlled by manual valves in PHS as well as by VTP3 (and if required the Booster Pump). To make up for the water delivered to HPP and Ictetop, two submersible Transfer Pumps transfer water from WT1 to WT2. The Transfer Pumps are located in WT1.



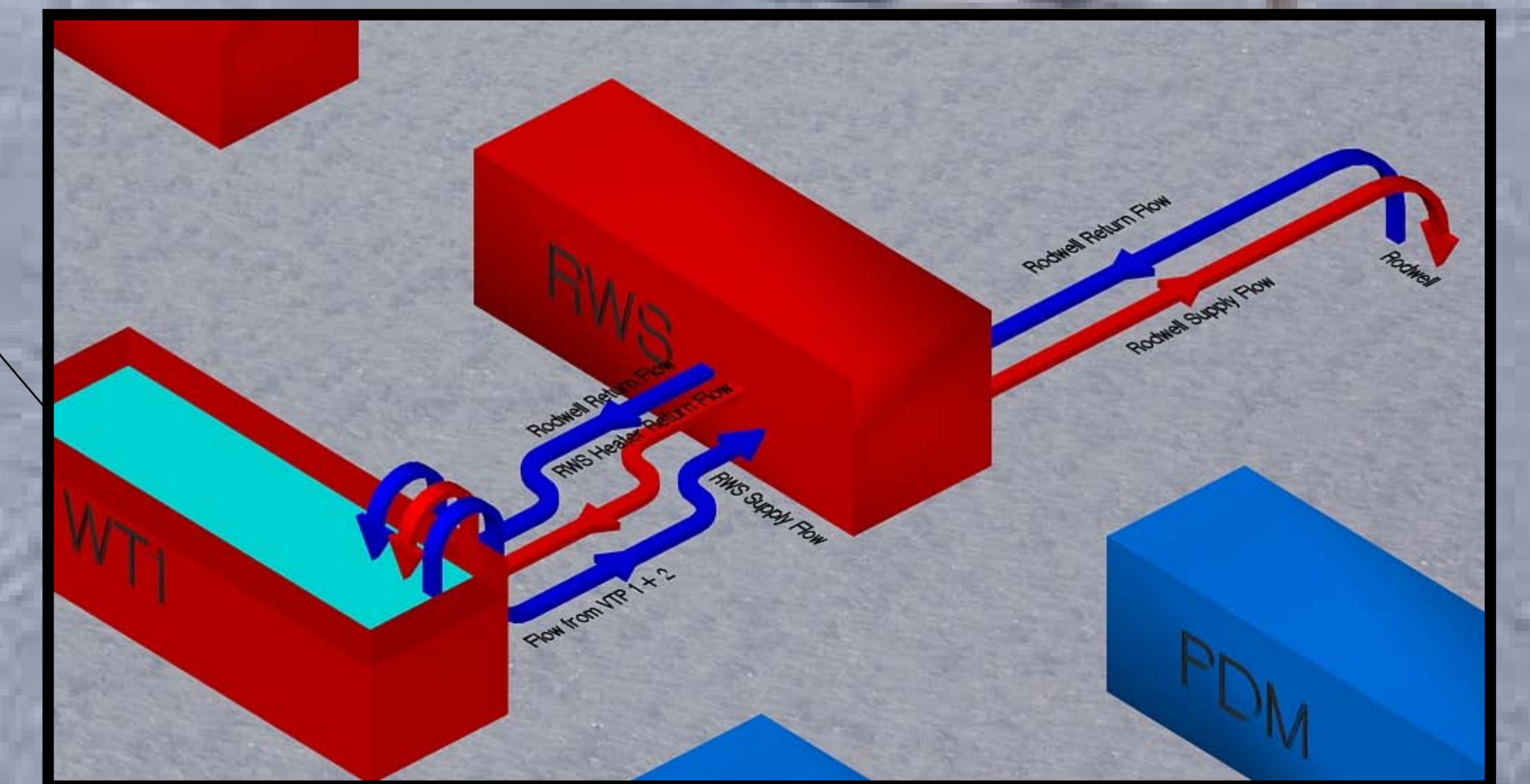
## Drilling Flow (surface flow when drilling)

At Drilling Flow, full surface flow of 200 gpm is going out from SES to TOS. After the flow has passed MHP and HPP for pressurization and heating the flow passes through the Supply Surface Hose down to the MSHR (Main Supply Hose Reel) and further on to the Drill Head. A submersible Return Water Pump in the drill hole will pump back cold water from the drill hole through the Return Surface Hose to WT1. This recovers 90% of the water deposited in the drill hole. To make up for the water loss, the remaining 10% is drawn from the Rodwell.



## Idle Flow (surface flow when not drilling)

When only maintenance flow is sustained, the flow is called Idle Flow. Whenever Drilling Flow is not provided, Idle Flow has to be upheld to prevent equipment and hoses from freezing. Idle flow uses much the same path as Drilling Flow, but the flow is not used for drilling and a flow of only roughly 25-40 gpm is maintained. Some flow is passed through HPP and MHP, given low pressure and heated. The flow passes through the Supply Surface Hose to MSHR, through RWHR (Return Water Hose Reel) and back to SES through the Return Surface Hose. At SES the return water, because it still is warm, is deposited into the Rodwell. A marginal drizzle is typically allowed into WT1 to keep the WT1 Return Water Manifold from freezing. The conversion from Drill Flow to Idle Flow and vice versa is manually done in RWS, at the WT1 Return Water Manifold and at the TOS.



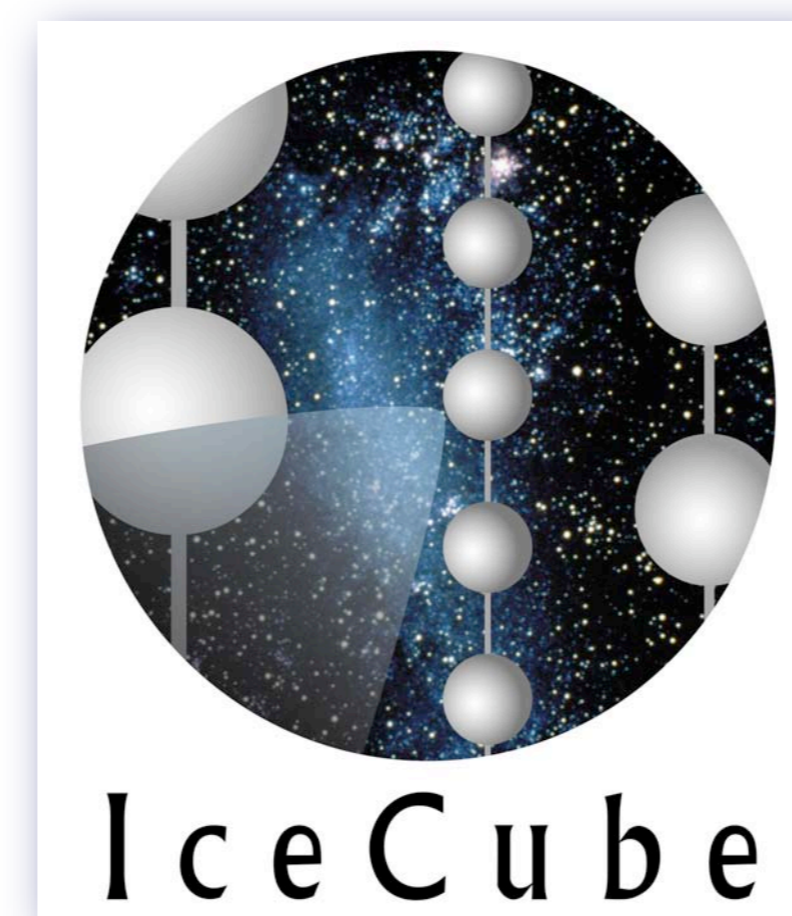
## RWS Flows

RWS controls the pumps:  
 • Vertical Turbine Pump 1 & 2  
 • Rodwell Pump

Rodwell System (RWS) controls Water Tank 1 (WT1), i.e. tank temperature and resupplying WT1 with water. Vertical Turbine Pump 1 & 2 (VTP 1 & 2) supplies RWS with flow. The flow passes through RWS Stinger heaters. Some of the flow is returned to WT1, while some flow is forwarded to the rodwell to melt ice and make water. DCC controlled valves decide where the flow should go. A submersible pump in the Rodwell brings water from the Rodwell into WT1.

# Hose Reel Move

ALL available personnel required



## Tools

- 4' Pipe Wrench
- 6 mm Allen Wrench for everyone
- Extra clamshell bolts
- Extra O-rings for IVG hose
- BIG wrenches
- 2 buckets for parts
- 2 hammers
- Flathead screwdrivers
- Medium crescent wrench for operating ball valve on main hose
- 2 heat guns
- Extension cords for reaching reels
- Straps for pulling
- 2 snowmobiles
- 953 and 287
- Hose handling/moving equipment

- Coordinate with everyone including Raytheon
- Stabilize water temp through hoses
- Move as many items to next location as possible
- Plan hose move
- Ensure the path is clear of obstacles

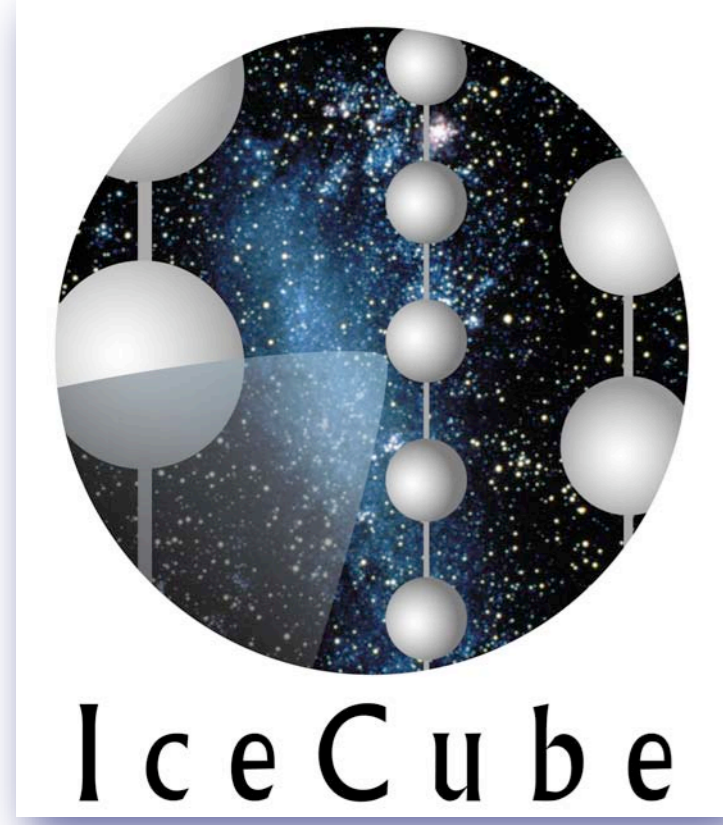
- Request DCC to shut down heaters
- Hook up dozer to DSHR, hook up 953 to RWHR
- Request DCC to stop flow
- Disconnect supply from DSHR, Disconnect return from RWHR, Disconnect Bypass
- Transport reels, bypass to new hole location

- Place DSHR and RWHR in correct locations
- Deliver bypass hose
- Reconnect surface supply to DSHR
- Reconnect surface return to RWHR
- Reconnect Bypass
- Open all necessary valves

- Request flow from DCC
- DCC monitors MIHP return line pressure and HPP outlet pressure
- DCC/SES confirms flow back to WT1
- Organize hoses
- Clean up/ insulate surface supply hose and return hose

## Reference Documents

Document #	Title of document
9000-0039	Hose Reel Move



# Hose Section Change Procedure Checklist

6 people required minimum

## Gather

## DCC

## TOS

## Change out

## Re-establish

## End

Supplies/Tools —> Prep for Bypass —> Prep for Bypass —> Hose Section —> drill operation —> of Procedure

- Continue drilling to position bad hose to come off (drill 20 meters below, and come back up)
- Retrieve and position new hose section (correctly orient hose ends, install strain reliefs)

- Shut heaters for min flow
- Reduce flow

- Switch to Manual Control
- Tie off down hole hose section
- Release tension on hose reel
- Establish bypass through both reels

- Break hose connection
- Drag bad section off reel
- Disconnect bad section
- Connect new section
- Reel new section onto reel
- Connect to down hole hose

- Start flow (take bypass out)
- Add tension to hose (700 lbs.)
- Release tie off
- Establish computer control
- Drill baby drill!

- Clean up
- Prep hose for next time
- Mark and put away bad hose section

## Tools

- Heat guns
- 6 mm T handle Wrenches
- BIG wrenches for bypass hose bales
- Yale grip and tie off straps
- Shackle
- Rocking horse (strain relief tools)
- Anti- seize
- O-rings main hose
- Rollers and pipe (guide for hose)
- Plywood for dragging hose over cables
- 287

- Stop flow in and out of hose

- Install strain relief if not already done
- Use ground rollers and plywood to drag hose around building

## Reference Documents

Document #	Title of document
9000-0039	Hose Section Change Procedure Checklist



# IceCube Lock-Out/Tag-Out (LOTO) Policy

10/28/2009

**I.** An Individual (Authorized person) performing repair or maintenance upon a piece of equipment will “lock-out” and “tag-out” the equipment to prevent its accidental use.

- The person will lock it out and keep the key in his possession.
- The person will complete the tag and affix it to the unit.
- The person will notify all affected users of the situation.

**II.** When the work is completed, the Authorized person will remove his own tag and lock.

## **NO ONE MAY REMOVE SOMEONE ELSE’S LOCK/TAG UNDER ANY CIRCUMSTANCES**

- The Authorized person will notify all affected users that the work is done and that the equipment is available.

**III.** Should an Affected user need to use the equipment or have inquiries about its use, the Authorized person must be contacted.

**IV.** There are ample Lock-Out/Tag-Out supplies in the SEW and in the MECC.

### Reference Documents

Document #	Title of document
8510-0498	LOTO Poster

# TOS Pre-drill Checklist



# DCC Pre-drill Checklist

- Safety
- Reels
- Computer
- Drill head



- E-stop set

- Main hose, cable, and drill head is not anchored in any way
  - Computer control established
  - Brakes disengaged
  - Flow routed full open to drill head
- Trickle of flow in bypass back to camp
- Drill head communicating and zeroed
- Taper standing by

\*\*\*This checklist is designed as a final check for the TOS operator to use just prior to calling for full flow from the DCC. It does not address specifics to main hose to drill connection, flow/bypass configuration, mechanical tie-down around the drill site and countless other checks and tasks that must be done before this point.

## Drill Baby, Drill!

- Safety
- Fluids
- Pumps
- MHPs
- Electricity



- E-stop set in a global loop
- Water tanks and rodwell full and at temperature
- HPP and Charge pumps showing “Ready”
- Personnel standing by to bring up heaters
  - Two generators warm and online
- Return water plumed to Tank 1
- HPP bypass set

\*\*\*This checklist is to help the DCC operator prepare for ramping up to full flow. Other considerations include the ramp up plan for the MHPs and the HPPs or the time frame that the return water pump will be available in Communication is the key to the DCC.

## Drill Baby, Drill!

### Reference Documents

Document #	Title of document
8510-0482	EHWD TOS Pre-Drill Checklist Procedure





# Tower and TOS Relocation

6 people required minimum



- Continue drilling to position bad hose to come off (drill 20 meters below, and come back up)
- Retrieve and position new hose section (correctly orient hose ends)

- Shut heaters for min flow
- Reduce flow

- Switch to Manual Control
- Tie off down hole hose section
- Release tension on hose reel
- Establish bypass through both reels

- Break hose connection
- Drag bad section off reel
- Disconnect bad section
- Connect new section
- Reel new section onto reel
- Connect to down hole hose

- Start flow (take bypass out)
- Add tension to hose (700 lbs.)
- Release tie off
- Establish computer control
- Drill baby drill!

- Clean up
- Prep hose for next time
- Mark and put away bad hose section

## Tools

- Heat gun
- 6 mm T handle wrenches
- Big wrenches for bypass hose bales
- Yale grip and tie off straps
- Shackle
- Rocking horse (strain relief tools)
- Anti- seize
- O-rings main hose
- Rollers and pipe (guide for hose)
- Plywood for dragging hose over cables
- 287

- Stop flow in and out of hose

- Install strain relief if not already done
- Use ground rollers and plywood to drag hose around building

## Reference Documents

Document #	Title of document
8510-0483	EHWD TOS & Tower Move Checklist Procedure



# Weight Stack Assembly



- Proper tools and hardware
- Three Drillers
- Tower hoist is active
- Proper hole cover

- 1-12' Strap
- 2-5" elevators
- 2-4" elevators
- 2- orange clamps
- 1- large shackle
- 1- locking carabeener
- 3/16' allen keys
- 3/16' allen on drill
- Anti-seeze
- Step ladder or stool
- Extra collar screws

- Safety Strap to over head anchor
- Hard hats

- Place section on Ground attach hoist (Elevator lock "up")
- Lower section into hole, and attach with collar (anti-seeze screws)
- Weight stack is always secured to either the safety or the hoist

- When mating sections ensure smooth insertion
- Slack hoist slightly before installation of collar
- Attach and lock "Orange Clamp," and safety strap before removing hoist elevator

- Drill Head will be hanging on the chain hoist. Be conscious of the end orientation of the straps and rigging when total weight is transferred to the tower hoist.

- Move safety strap to drill head before removing "Orange clamp"

- Attach adapter to top of the drill head
- Attach drill cable to adapter
- Attach water connection

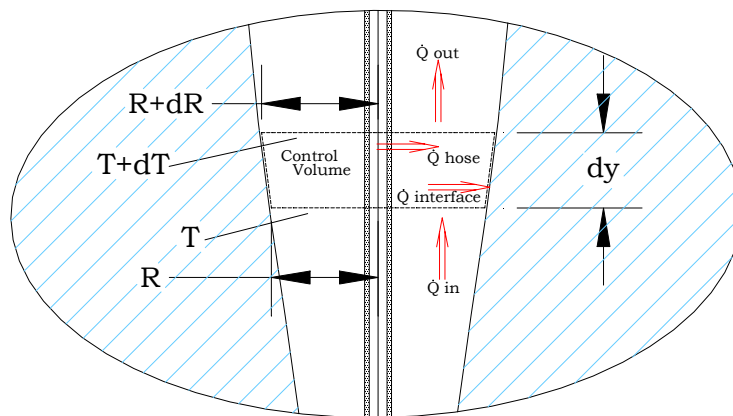
- Inspect all pins and cotter keys
- Tape whole apparatus to prevent chafing
- SS to SS connection of braided hose needs anti-seeze, and care when attaching
- Inspect o-rings on drill power cable before mating

- Cable reel active and holding drill head
- Crystal palace clean and clear

**Reference Documents**

Document #	Title of document
8510-0484	EHWD Weight Stack Assembly Checklist Procedure

A First Principles Method  
of  
Analyzing  
Drill Speed, Hole Profile  
and Energy Consumption  
in the  
Hot Water Drill  
of the  
South Pole  
Ice Cube Project



by  
Lee Greenler, PhD  
of the  
UW Physical Sciences Lab



## **I. Introduction**

The Ice Cube Project is undertaking the construction of a “neutrino telescope” at the South Pole. It will gather information from neutrinos that have originated in space above the earth’s Northern Hemisphere and traveled through the earth on their way to the ice cap of the South Pole. This detector consists of long strings of optical modules oriented vertically in the ice cap. These strings are approximately 2400 meters long so their deployment requires the drilling of 80 to 100 holes 2400 meter deep. The holes will be drilled with a hot water drill consisting of an intelligent nozzle on the end of 2400 meters of hose. It is lowered and melts its way through the ice as 90°C water is pumped through the nozzle. The cooled water, at 1-2 °C, is pumped out of the top of the hole and recycled through the heaters. After a hole is formed a string of optical modules is deployed into the hole. Over the following couple days the hole freezes closed around the modules.

The drilling process consists of a drill phase (the drill melts its way down through the ice) and a ream phase (the drill is raised with the hot water continuing to flow). The ream enlarges the hole and also keeps warm water in contact with the hole for more time to give more heat an opportunity to conduct into the ice. The more heat contained in the ice surrounding the hole the longer it will take for the hole to close. This is important as there must be adequate time, after producing the hole, to place the optical module string before the hole gets too small.

The calculations in this model are based on fundamental principles. Very little reliance is placed on rules of thumb, or extrapolations from other drilling operations. The best understanding will come from doing both empirical studies and theoretical studies and working with them until their disagreements are understood. The approach taken here puts this work in the theoretical category.

The focus of this paper is not the presentation of specific results; that will be done in separate papers as the results are produced. Instead the intention is to produce a document that will show how these calculations are done so that interested parties can understand the methods and assumptions built in to the results. A couple of the more complex derivations in this paper are relegated to the appendices.

### A. Two Main Sections of this Paper

Sections II and III are the two main parts of this paper. In section II hole shape and temperature profile equations are derived ignoring heat conduction losses into the ice. These equations are useful for certain types of calculations. In section III heat conduction losses into the ice are included. The complexity that this adds changes the solution from a set of closed form equations to a finite difference computer model.

### B. Applicability

The investigation leading to this paper has focused on the “Enhanced Hot Water Drill” of the Ice Cube Project. The calculations done are meant to give meaningful insight into that project. However the equations and methods used are quite general and are applicable to other ice holes drilled in this manner.

### C. Parameters and Variables

It is assumed that the physical properties of ice do not vary significantly over the range of temperatures and pressures involved here. The same is assumed for the physical properties of water except for the viscosity and Prandtl number, which are strongly temperature dependent. (The Prandtl number is a dimensionless number that relates the relative rates of momentum and heat diffusion in a flowing fluid. It is important in calculating heat transfer from the water to the ice)

The parameters used in this report (and assumed values) are:

$\rho_i$	density of ice (897 kg/m <sup>3</sup> )
$\rho_w$	density of water (982 kg/m <sup>3</sup> )
$c_i$	specific heat of ice (1950 J/kg·C)
$c_w$	specific heat of water (4170 J/kg·C)
$c_f$	heat of fusion of ice (335,000 J/kg)
$\dot{V}$	volume flow rate of water through drill (1.262e-2 m <sup>3</sup> /sec)
$T_i$	temperature of water exiting drill tip (function of depth)
$T_\infty$	far field temperature of ice (function of depth, °C)
$\mu$	viscosity of water (function of temp., kg·m/s)
$r_{core}$	the outer radius of the central weights or hose (0.048m)
$k_{ice}$	thermal conductivity of ice (2.2 W/m·°C)
$k_{hose}$	average thermal conductivity of tube matl. (0.26 W/m·°C)

Variables used are:

$r$	radial position of a point in the ice(m)
$t$	time (sec)
$R$	radius of hole(m)
$Y$	distance above drill tip(m)
$v$	drill speed (m/sec)
$h$	convective heat transfer coefficient (W/m <sup>2</sup> ·°C)
$T_w$	water temperature in hole(°C)
$T$	ice temperature – a function of position (°C)
$\dot{Q}$	heat rate(W or W/meter of depth)
$\dot{Q}_{hose}$	rate of heat leakage through hose(W/meter of hose)
$Re$	Reynolds number (dimensionless)
$Pr$	Prandtl number (dimensionless)

## II. Vertical Hole Temperature Profile, Hole Shape and Drilling Rate Heat Conduction into the Ice Neglected.

Ignoring heat conduction losses into the ice simplifies the problem considerably. Doing so is more than an interesting academic exercise. Near the bottom of the hole during drilling, the hole is growing very quickly and there has not been enough time for significant amounts of heat to be conducted into the ice. In this region it is quite reasonable to ignore heat conduction losses into the ice. Ignoring heat conduction losses doesn't even require assuming that no heat conducts into the ice. In fact it must in order to heat subzero ice up to the melting point. One is just assuming that, due to the rapidly expanding hole wall and the short time scale, the ice region around the hole that is warmer than the far field temperature is negligibly small.

Another use for these equations is as a check on the answers from a more complete analysis. The water temperature predicted by these equations is an upper bound (at some given hole radius and for some given hot water input). Any calculation that includes heat losses to the ice under the same conditions should predict a lower water temperature due to this lost energy. If it doesn't it is suspect.

An important unknown that this analysis can help find is the temperature of the water at the drill head since the drill head is fairly close to the bottom of the hole. The drill body has a water and pressure proof cavity that encloses the drill electronics. It is very important that this cavity remain at a temperature that will not harm the electronics during drilling. This cavity consists of a pocket in the aluminum drill body that is covered with a stainless steel shell. The hot water line to the drill tip passes through the drill body but the hot water is insulated from the cavity by a fiberglass tube. The temperature of the cavity, therefore, is primarily determined by the temperature of the water surrounding the drill body.

### A. Overview of Approach

#### *1. Temperature as a function of hole radius*

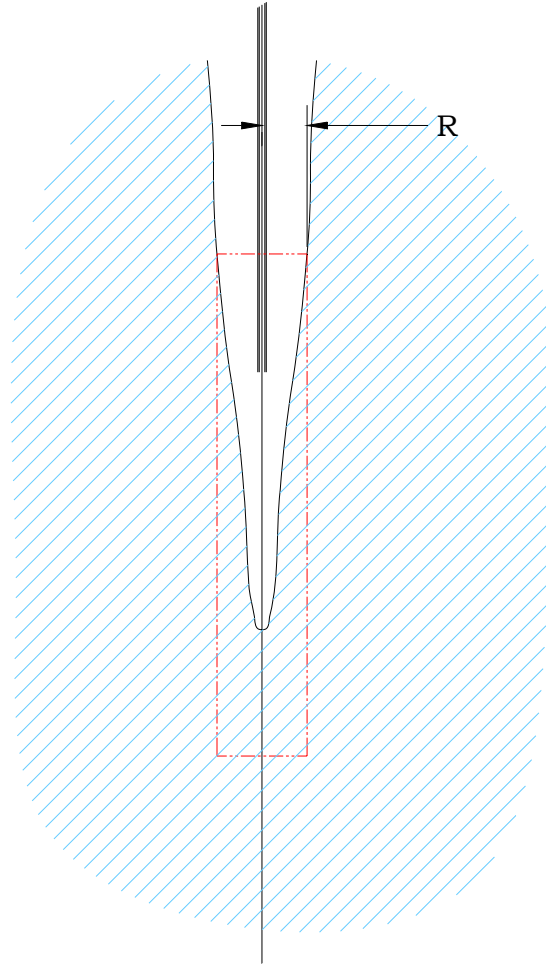
An energy balance on a control volume attached to the drill will show that the temperature of the water in the hole at some height above the tip (some value of  $Y$ ) is a function of the radius of the hole at that height. This temperature is designated  $T_w(R)$ . It is important to point out that this does not refer to temperature variation as a function of distance from the center of the hole but, rather, to temperature variation vertically in the hole as a function of the radius of the hole at that point. Other quantities turn out to be functions of  $R$  in this same way.

#### *2. Hole shape*

Two equations can be written for the rate of heat going into melting ice. One relates the taper of the hole wall ( $dR/dY$ ) to the velocity of drilling. The other is based on heat transfer into the ice, based on the temperature of the water and the thermal boundary layer along the ice wall. Setting these two equal to each other gives an expression in  $dR/dY$  and  $R$ . This can be integrated (numerically) to give  $Y$  as a function of  $R$ .  $R$  as a function of  $Y$  would be preferable but the inversion is difficult and  $Y(R)$  is satisfactory.

## B. Derivation of Equations - Ignoring Heat Conduction into the Ice

### *1. Temperature as a function of hole radius*



**Fig. 2.1**

Consider a control volume that moves with the drill (Fig. 2.1). The upper surface of the control volume is a horizontal circular area that matches the hole radius at some arbitrary height where the hole has radius  $R$ . The side of the volume is a vertical cylinder of radius  $R$  extending downward from the horizontal disk. The bottom is another disk, again of radius  $R$  that closes the volume far enough below the drill that it is in ice at the far field temperature. After the drill has been drilling for awhile it will reach a “steady state” where the temperature and flow of the water and the shape of the hole, in this moving control volume, will not vary with time. The bottom of the hole will stay in a fixed position relative to the drill and the location of the point above, where the radius of

the hole is “R”, will do likewise. In this steady state condition the energy in the control volume remains constant so that the sum of the energy entering and leaving is zero. The terms in this sum (in J/s) are:

- $\dot{V}\rho_w c_w T_i$  Heat input rate from water entering through hose – relative to 0°C
- $-(\dot{V} + \pi R^2 v)\rho_w c_w T_w$  Heat exit rate from water leaving the volume through the top surface at radius R. If the drill were not advancing this flow rate would simply be  $\dot{V}$  (ignoring volume change of melting ice) but the volume swept by the circle of radius R must be included since the control volume is moving.
- $-\pi R^2 v \rho_{ice} (c_f - c_i T_\infty)$  Rate of heat absorption by warming and melting ice. As the control volume advances downward, ice crosses the bottom of the volume at the far-field temperature at a volume rate of  $\pi R^2 v$ . Since we are using 0°C water as our reference temperature for heat content, this ice is actually considered to be entering with negative heat content and, by the time it has been melted at 0°C, has zero heat content. This term accounts for the heat that both warms the ice from the far-field temperature to 0°C and melts it to 0°C water. Perhaps surprisingly, the heat to warm up ice from -50°C to 0°C is not negligible and accounts for 23% of the total heat included in this term when the far-field temperature is -50°C.

Summing these three, setting that sum equal to zero and solving for  $T$  gives:

$$T_w = \frac{1}{\dot{V} + \pi R^2 v} \left[ T_i \dot{V} - \pi R^2 v \left( \frac{\rho_{ice} (c_f - c_i T_\infty)}{\rho_w c_w} \right) \right] \quad (2.1)$$

Eqn. 2.1 gives the temperature of the water at some height,  $Y$ , as a function of the radius of the hole at that point. This shows that (for a given drilling speed, water flow rate and nozzle temperature) the temperature of the water in the hole is determined by the hole radius.

Solving this for R gives:

$$R = \left[ \frac{\dot{V} (T_i - T_w)}{\pi v \left( T_w + \left( \frac{\rho_{ice} (c_f - c_i T_\infty)}{\rho_w c_w} \right) \right)} \right]^{1/2} \quad (2.2)$$

The hole will reach its maximum radius at the point up the hole where the temperature of the water reaches 0°C. Setting  $T_w=0$  in eqn. 2.2 and simplifying gives:



$$R_{\max} = \left[ \frac{\dot{V} T_i \rho_w c_w}{\pi v \rho_{ice} (c_f - c_i T_\infty)} \right]^{1/2} \quad (2.3)$$

All the values in the brackets have been assigned earlier except for  $v$ . If a desired final hole radius ( $R_{\max}$ ) is chosen eqn. 2.3 can be solved for  $v$ , the drilling speed. For a hole radius of 0.3 m the drilling speed turns out to be 0.038 m/sec or 2.25 m/min. Again, this is assuming no conduction heat loss to the ice. It can take up to a few hundred meters for the hole to reach its maximum diameter for a large hole – after this time and distance the assumption of no heat conduction into the ice is inaccurate. The maximum hole diameter that would result, with the heat loss, would be smaller.

Note: The assumption that the water temperature has a single value at any particular height in the hole is a better assumption if the flow is turbulent rather than laminar. The degree of turbulence is characterized by the Reynolds number ( $=VD_h\rho/\mu$  where  $V$  is the avg. water speed,  $D_h$  is the hydraulic diameter of the hole,  $\rho$  is the water density and  $\mu$  is the dynamic viscosity of the water). At a hole diameter of 0.15 m  $Re$  is about 163,000 and at 0.6 m it is about 25,000. This is well into the turbulent range; turbulent flow in pipes is considered to be anything above about 2000 to 4000.

## 2. Hole shape

As mentioned above there are two equations that can be derived for the rate at which heat goes into melting ice. The first is purely geometrical and is based on the assumption that the hole shape is constant in the coordinate system fixed to the drill tip (ignoring the distant top of the hole).

Consider a  $dY$  of the hole with some outward slope so  $dR/dY > 0$  (see Fig. 2.2). As the ice moves past the drill (in our frame of reference) at a speed of  $v$  the volume rate of ice melting per  $dY$  of hole length is  $(2\pi RvdR)/dY$ . This can be stated as:

$$\frac{d\dot{Q}_{ice}}{dY} = 2\pi Rv\rho_{ice} (c_f - c_i T_\infty) \frac{dR}{dY} \quad (2.4)$$

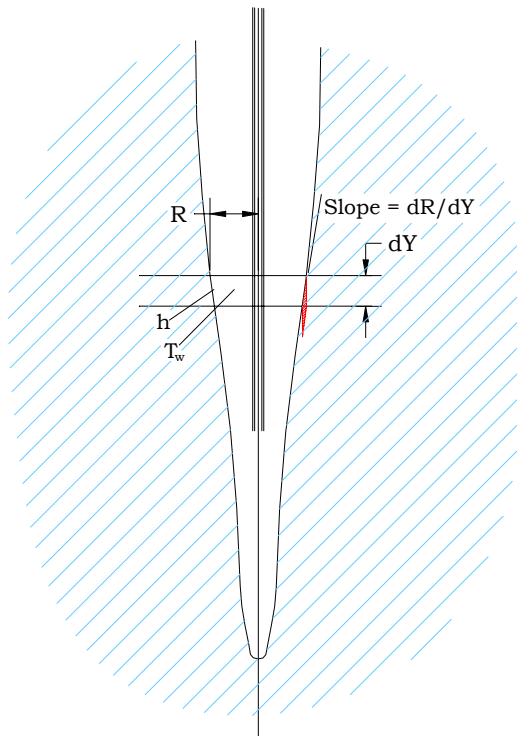
This is the rate at which heat goes into melting ice per  $dY$  of the hole at that point.

The second equation is based on heat transfer at the wall. The rate of heat transfer between a fluid flowing over a surface is equal to the area times the temperature difference (between the surface temperature and the average fluid temperature) times the convective heat transfer coefficient,  $h$ , or:

$$d\dot{Q}_{ice} = (2\pi R dY) T_w h \quad (2.5)$$

or

$$\frac{d\dot{Q}_{ice}}{dY} = 2\pi R T_w h \quad (2.6)$$



**Fig. 2.2**

The temperature difference between the wall and the fluid is just  $T_w$  since the melting wall will be at a temperature of  $0^\circ\text{C}$ . We know  $T_w$  as a function of  $R$  (eqn. 2.1). “ $h$ ” can be found for these flow conditions from an empirical equation (see ref. 1, J.P. Holman):

$$h = \frac{k}{D_h} 0.023 \text{Re}^{0.8} \text{Pr}^{0.3} \quad (2.7)$$

where  $D_h$  is the hydraulic diameter,  $k$  is the thermal conductivity of the fluid,  $\text{Re}$  is the Reynolds number and  $\text{Pr}$  is the Prandtl number.  $\text{Pr}$  is a dimensionless number that relates the relative rates of momentum diffusion and heat diffusion in the boundary layer of a flowing fluid. For a particular fluid  $\text{Pr}$  is a function of temperature only. “ $k$ ” is  $\sim$  constant (at about  $0.655 \text{ W}/(\text{m}\cdot^\circ\text{C})$ ) over the range of temperatures considered.  $D_h$  turns out to be  $2(R-R_{\text{core}})$ . The viscosity,  $\mu$ , part of the Reynolds number, and  $\text{Pr}$  are temperature dependent, but over the range of temperatures of greatest interest ( $\sim 10^\circ\text{C}$  to  $\sim 90^\circ\text{C}$ ) can be linearly approximated by:

$$\mu = (9.2 \times 10^{-4}) - (7.2 \times 10^{-6})T_w \quad (\text{kg}\cdot\text{m}/\text{sec}) \quad (2.8)$$

and 
$$\text{Pr} = 7.0 - 0.06T_w \quad (\text{dimensionless}). \quad (2.9)$$

Both of these are functions of  $T_w$  but we know  $T_w$  as a function of  $R$  so they can be written as functions of  $R$ . This means that we know everything in eqn. 7 in terms of  $R$  and that  $h$  itself is, therefore, just a function of  $R$ . After simplifying and combining terms

it is:

$$h = (7.53e - 3) \frac{\text{Re}^{0.8} \text{Pr}^{0.3}}{(R - R_{core})} \quad (2.10)$$

Now, setting the right sides of eqns. 2.4 and 2.6 equal to each other gives:

$$2\pi r T_w(R) h(R) = 2\pi \rho_{ice} c_{fplus} R v \frac{dR}{dY} \quad (2.11)$$

or

$$\frac{dR}{dY} = \frac{T_w(R) h(R)}{\rho_{ice} c_{fplus} v} = F(R) \quad (2.12)$$

(with notation added to remind that  $T_w$  and  $h$  are functions of  $R$  and to define  $F(R)$  as a shorthand for the whole function). This is an equation in  $R$  and  $dR/dY$  which can be integrated. The function to be integrated is quite complex in  $R$  but it can be integrated numerically (using a package such as Mathcad<sup>®</sup>). The result is  $Y$  as a function of  $R$ . Although  $R$  as a function of  $Y$  would be nicer this will give the necessary information.

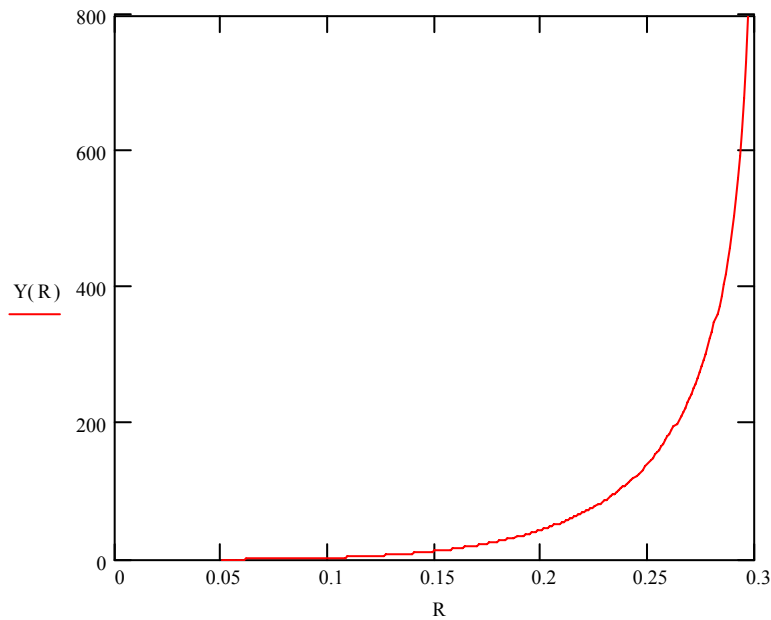


Figure 2.3. Height above tip as function of hole radius

Some representative values are:

$Y(0.06) = 0.0$	$Y(0.25) = 142.4$
$Y(0.075) = 0.4$	$Y(0.26) = 184.3$
$Y(0.1) = 2.0$	$Y(0.27) = 243.6$
$Y(0.15) = 12.0$	$Y(0.28) = 335.0$
$Y(0.1578) = 15.0$	$Y(0.29) = 503.7$
$Y(0.2) = 43.4$	$Y(0.30) = 1.3 \cdot 10^3$

Table 2.1. Height above drill tip as a function of hole radius

where  $Y(R)$  and  $R$  are in meters. The height at a radius of 0.1578 is 15 meters which is the approximate location of the drill. If this radius is substituted into eqn. 2.1 we find the water temperature there should be about 47

The values close to the final hole radius should be regarded with some suspicion since they are in the region where the temperature difference between water and ice has gotten small so that the hole diameter is growing very slowly. Small changes in parameters can make large differences in the  $Y$  values. Also, in this part of the hole, heat losses into the ice start to become significant.

The core diameter (the diameter of weights) near the tip is not exactly correct since the bottom one-meter long weight tapers down to the tip. This analysis also ignores the area ahead of the drill tip where the hot water jet is starting the hole into the ice. These are second order effects since their result is to alter the start radius of the hole at the height where the core radius becomes constant - at the top of the tapered section ( $y$  equals  $\sim 1$  m). An error here has the effect of just shifting the whole curve up or down and, due to the rapid rate of change of the hole radius here, the shift is small.

If some of the above  $r$  values are substituted into eqn. 2.1 some representative temperatures can be found:

$T_w(0.05) = 76.0$
$T_w(0.1) = 65.1$
$T_w(0.15) = 49.6$
$T_w(0.1578) = 47.0$
$T_w(0.2) = 32.5$
$T_w(0.25) = 15.6$
$T_w(0.3) = 0.2$

Table 2.2. Water temperature as a function of hole radius

At a height above the tip of 15 m (the approximate height of the drill body using all weights) the radius can be seen to be  $\sim 0.1578$ m. The temperature at this height is predicted to be  $\sim 47$  °C.

### III. Hole Shape and Drilling Rate with Heat Conduction into the Ice Included.

When an attempt is made to include heat conduction losses into the ice in these calculations the difficult part is the ice. Closed form calculations are possible for temperature and heat movement in the water filled hole - given some reasonable approximations and simplifications. The situation is different, however, in the ice surrounding the hole. Heat conduction into the ice is governed by a partial differential equation. The combination of cylindrical geometry, an infinite solid surrounding the hole (so no steady state solution), and a moving inner boundary (as ice melts or refreezes) makes this a very difficult problem to solve in a closed form manner.

The method used in this investigation is to employ explicit equations in the water and a finite difference approach in the surrounding ice. These can be joined nicely at the constant temperature wall of the hole (constant at 0 °C).

#### A. Assumptions

- 1) The goal in drilling is to produce a hole specified as a certain diameter at a certain number of hours after drilling. A smaller hole runs the risk of closing too much before optical module deployment is completed. A larger hole wastes expensive energy. As of this writing the nominal goal is a 45 cm diameter hole 30 hrs after drilling is finished. The trade off between hole size, hole lifetime and energy cost can be explored running models using other targets.
- 2) The temperature distribution with depth, in the region, was measured on the AMANDA project. These temperatures (at some selected depths) are shown in Table 3.1.

Depth (m)	Temperature (°C)
250	-50
750	-48
1250	-44
1750	-36
2250	-25

Table 3.1. Ice temperature with depth at South Pole

- 3) The pump/heater/drill system is designed to deliver  $1.262e-2 \text{ m}^3/\text{sec}$  (200 gallons per minute) of water. The temperature of this water, at the top of the hole, will be approximately 90 °C. The temperature of the water drops as it travels down through the hose due to heat loss through the hose into the surrounding water. With the hose that is proposed (2.5"ID, 3.75"OD, avg. k of 0.26 W/m-°C) the water temperature will drop to about 74°C by 2500 m.

#### B. Working With the Steady State Analysis

The heart of this approach is the "steady state" model, presented in section II, that is extended to the varying-condition problem at hand. In general the temperature

distribution in the ice resulting from drilling is a function of three independent variables: depth, radius and time. The steady state model allows the elimination of one of these.

Consider drilling a deep hole in constant temperature ice. Once the drill is away from the surface, where drilling started, a “steady state” will be reached where all temperatures and all mass and heat flow rates will be constant if viewed in a reference frame attached to the drill. Calculations in this reference frame gives the temperature of the water, temperature distribution in the ice and heat flow between the ice and water as a function of distance above the tip. The model is steady state so none of these variables are functions of time.

However, since it is assumed that the drilling is done at a constant speed, the conditions at some distance,  $Y_o$ , above the tip are the same as would be observed at a fixed point in the ice at a time  $Y_o/(\text{drill speed})$  after the passing of the drill tip. So the change in conditions with distance above the tip (from the steady state model) can be freely converted to change in condition with time at a fixed point in the ice. The link is the drill speed.

This is important because it allows the finite difference calculations of ice temperature to be done in two independent variables,  $T = T(r, \text{time})$ , instead of three,  $T = T(r, \text{depth}, \text{time})$ , vastly decreasing the size of the problem.

Since the temperature of the ice isn't actually constant with depth the total depth of 2500 meters is divided into five 500 meter sections (with constant, average properties assumed throughout the section) and each section is treated in the manner described above.

### C. The Water

Consider some height above the tip where the radius of the hole is  $R$  and the temperature of the water is  $T_w$ . The velocity of the water up the hole is the volume flow rate,  $\dot{V}$ , divided by the area between the hole wall and the hose. With this the Reynolds number of the flow can be calculated and then the convective heat transfer coefficient,  $h$ , from:

$$h = \frac{k}{D_h} 0.023 \text{Re}^{0.8} \text{Pr}^{0.3} \quad (\text{ref. 1}) \quad (3.1)$$

The interface, the actual wall of the hole, is assumed to stay at 0 °C. So the heat rate into this interface (per meter of hole depth) is:

$$\dot{Q} = 2\pi R h T_w \quad (3.2)$$

This heat into the interface can be thought of as being split into two destinations; some of it is conducted into the ice at a rate determined by the thermal conductivity of the ice and the temperature gradient in its surface. The rest melts ice and enlarges the hole. This heat rate going into melting determines how fast the radius of the hole is increasing and is given by:

$$\frac{dR}{dt} = \frac{\dot{Q}_{melting}}{2\pi R \rho_i c_f} \quad (3.3)$$

where  $\dot{Q}_{melting}$  is the rate at which heat goes into melting ice in W/meter of hole depth. Note that at some stages of the drilling process the heat drawn off by the temperature gradient in the ice is bigger than what is being transmitted into the interface from the water. Then  $\dot{Q}_{melting}$  is negative and, instead of melting, we get refreezing of the hole.

If an energy balance is written for a small  $\Delta Y$  of the hole and then rearranged we get an expression for  $dT_w/dt$  – the change of water temperature with time (at a fixed depth in the hole). This is:

$$\frac{dT_w}{dt} = \frac{\dot{Q}_{hose} - 2\pi R h T_w - 2\pi R \rho_w c_w T_w (dR/dt)}{[\dot{V} + v\pi(R^2 - R_{hose}^2)](\rho_w c_w / v)} \quad (3.4)$$

See the appendix for a detailed derivation of this equation.

An initial hole radius,  $R_0$ , is assumed and the corresponding water temperature,  $T_{w0}$ , is calculated with eqn. 2.1. Note that  $T_{w0}$  will be less than  $T_i$  as heat has already been expended to open the hole to  $R_0$ . The rate of change of the hole size and hole water temperature are calculated from eqns. 3.3 and 3.4, respectively, and then the new radius and temperature found for a small  $\Delta t$  later. This process is iterated to predict the development of the hole.

The accuracy of the value that is assumed for the initial hole radius (at tip level) is not very important. Since the water temperature depends on the radius of the hole an error here only shifts the vertical position of the entire hole up or down relative to the drill. The hole radius is changing very fast in this region so the shift will be small – probably less than a meter or two.

#### D. The Ice

As mentioned above the heat going into melting ice at the hole wall is the difference between the heat going into that interface (eqn. 3.2) and the heat being conducted off into the ice. The heat conducted off into the ice depends on the  $k$  of the ice and the temperature gradient in the ice immediately adjacent to the wall. In order to get this temperature gradient the temperature profile in the ice is calculated and stepped forward along with the water temperature and the hole radius. The initial temperature profile, corresponding to  $R_i$  and  $T_i$  is assumed to be 0 °C at the hole surface ( $R_i$ ) and  $T_\infty$  everywhere else.

The governing equation for the change of temperature in the ice is:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} = \frac{1}{\alpha} \frac{\partial T}{\partial t} \quad (3.5)$$

Solving this equation in an infinite solid, in cylindrical coordinates, and with a moving



inner boundary is a very difficult problem so a solution was found using a finite difference integration with respect to time. The “grid” consists of a row of points, spaced an appropriate distance apart in radius ( $\Delta r$ ), extending out from the hole wall. The temperature at each of these points is given an initial value ( $0^\circ\text{C}$  at the hole surface and  $T_\infty$  from there on out). This temperature profile is integrated forward each  $\Delta t$  using a modified Euler method of integration that is second order accurate (the standard Euler method is first order accurate). Details of how this integration is performed are given in the appendix.

At each time step the change in radius is calculated from the amount of heat that goes into melting. After this new hole radius is found the grid is shifted so that the innermost point of the grid stays at the hole wall. The temperature of the point at the wall is set to zero and the temperatures of the rest of the points are interpolated from the temperatures of the unshifted grid.

If the temperature profile is known then so is the temperature gradient ( $dT/dr$ ) in the ice at the hole wall. As mentioned above this is needed to get the rate of heat conduction into the ice. If the wall of the hole were at a fixed radius this would be an easy integration with a fairly large grid and fairly large time steps. However, upon considering the physical situation, one sees that, as the hole wall melts, the  $0^\circ\text{C}$  hole wall moves out into the colder ice creating very steep temperature gradients. (Physically these steep temperature gradients are necessary to get the heat into the  $< 0^\circ\text{C}$  ice to warm it to  $0^\circ\text{C}$  prior to melting. The faster the melting boundary is advancing, in cold ice, the steeper these gradients need to be to get enough heat into the ice.) Steep temperature gradients such as these are very sensitive to small numerical error and, so, require a fine mesh for accurate values right at the advancing wall. Since this numerical value of the gradient at the wall is the main number we care about it is imperative that an adequately fine grid and fine time step be used. Adequately fine, in this case, was determined by refining the grid and time step until the results showed little change with further refinement.

When the hole size is changing slowly or when the hole is refreezing this situation does not exist and a coarser time step can be used.

### E. Reaming

The method discussed up to this point should work well for the downward drilling phase of the hole production. However a modified approach was taken when modeling the ream phase of the operation. It is difficult to predict the water path as it leaves the drill, which makes it difficult to predict heat transfer rates to the ice. On the other hand we are not particularly concerned with the evolution of the hole shape during the ream process, we just want to know the increase in radius after the tip passes.

A more appropriate method relies on the fact that if you know the rate at which the nozzle is delivering heat (in the form of heated water, with respect to  $0^\circ\text{C}$ ) and the total elapsed time of the ream then you know the total heat that ends up being delivered to the hole (in Joules) during the ream. If you know the depth of the hole you can calculate this heat delivered in J/meter of hole. This still doesn't tell you the rate at which heat is delivered to some point on the wall. If you assume that some location's allotment of heat is delivered mostly when the drill is within, say, 10 m of that point then you would find a very high heat rate for a short amount of time. If, instead, you assume that heat is

delivered evenly to the entire hole for the entire time of the reaming operation (an absurd exaggeration in the opposite direction) you would find a very low heat rate delivered over a long time. In either case the total heat delivered to the section could be the same. Fortunately, the effect of assuming that the heat is spread over a few meters or assuming that it is spread over a few hundred meters is small. In both of these cases most of the ream heat would go to melting ice and enlarging the hole rather than being conducted into the ice. Only in absurd cases, approaching the one where it was assumed that the heat was evenly distributed over the entire hole for the entire ream time, would we find that a significant portion of the ream heat was being conducted into the ice.

Therefore, the approach that was taken in this model for the ream phase was to bypass calculation of boundary layer coefficients and heat transfer rates from the water. Instead the heat rate was calculated as above (by assuming a reasonable distance above the tip over which the ream heat is spread) and injected directly into the interface from where some is conducted into the ice (based on  $dT/dr$ ) and the rest melts ice. Taking this approach means you may not get realistic information on how the hole radius increases during the ream but you do get realistic information about the total increase during the ream.

There is one place where the assumed distribution of the heat above and below the tip during the ream cycle has an effect on the final hole radius. This is at the bottom of the hole. If it is assumed that the ream heat is delivered to the ice over a short span above and below the tip then points quite close to the bottom of the hole will get their full ream heat. If the distribution is assumed to be spread out over a couple hundred meters then points less than a couple hundred meters from the bottom don't get their full ream heat - making the hole there smaller. Unfortunately this is a real physical effect rather than just a shortcoming of the model. It is not clear what the most realistic assumption would be. If the ream melting does take place over a few hundred meters the bottom few hundred meters of the hole could end up undersized and cold so that they would close up quickly. It would be wise to study this part of the hole more closely.

## IV. Results

As a number of runs with slightly varying conditions will be made during the course of this investigation specific results are not included in this paper – just a description of the method. Results of individual runs will be written up separately.

### A. Drill Speed and Elapsed Time

Since the drill equations were derived assuming constant properties the hole was divided into a number of depth sections (~5) over which the depth-varying properties (ice temperature and drill tip water temperature) were taken to be constant. The values used for these properties were calculated at the depth of the middle of the section. The described method was then used to analyze the development of the hole in the middle of one of these sections using these properties. In order to know the time required from this starting point to the bottom of the hole and back one must know the drilling and reaming speeds used in the sections below this point. In order to do this it was found most convenient to start the analysis with the lowest section and find the drill and ream speeds for that section that gives a hole of the desired diameter at the desired time after drilling (taken to be 45 cm 30 hrs. after drilling). Now the second lowest section can be analyzed since the time taken to travel through the lowest section is known. This process is repeated, each time with the next higher section, until the top is reached. In each section the drill and ream times are adjusted (by educated trial and error) until a combination is found which gives the target diameter at the target time. There is a trade off between drilling and reaming; more drilling means less reaming and vice versa. Some other knowledge of the process must be used to decide how to trade these off. One may choose a constant ream speed and then vary drill speed, or choose a constant drill speed and vary ream speed or one may choose some other criteria.

Once this process is finished and the drill and ream speed is known for each section then the total elapsed time for the drilling and reaming process is found by summing the times for each section.

### B. Energy Consumption

The heat rate flowing down the hose comes from the volume flow rate of water down through the hose times density and specific heat then multiplied by the temperature of the water above the return temperature. This heat rate times the total elapsed drilling and reaming time gives the total heat pumped down the hole. If it can be estimated how much fuel is required to produce this much heat one can calculate the fuel consumption for a hole.

## V. Comments

### A. The Bottom of the Hole

Humphery and Echelmeyer (ref.2) assume that the hole develops to full size within a few tens of meters of the passing of the drill tip. For the smaller holes that they were considering this is probably a reasonable assumption. For the large holes of the Ice Cube project this assumption may not be accurate. This, as well as the distribution of ream heat question mentioned in section III.E, means that following a drilling scheme that gives good results over most of the hole might not produce a good hole as the bottom is approached. If the hole tapers towards the bottom and/or if there is relatively little heat stored in the ice the hole could fall far short of the diameter/time target. One simple solution is to drill past the required depth enough to ensure a full sized hole but unless one understands the bottom well enough to know “how much past?” one will end up drilling a wastefully deep hole just to be sure.

### B. Conduction Heat Losses to the Ice

A question that is related to part A has to do with the conductive heat losses to the ice. Humphery and Echelmeyer assume the hole opens to full size within a few tens of meters of the passing of drill tip and they assume no heat is conducted into the ice surrounding the full size hole during this stage. They start their hole lifetime calculations with all the ice outside the hole wall at the far-field temperature. These are reasonable assumptions when the full size hole is formed quickly and, again, the hole may reach full size fairly quickly for the smaller holes that they considered. The larger holes in this analysis open up over a longer time span and by the time they are at full size there is a non-negligible amount of heat in the ice. If the heat in the ice at this point is ignored then that heat has essentially been removed from the simulation and has to be replaced at some other point to achieve the target hole size.

## VI. Appendices

### A. Development of $dT/dt$ equation

The equation that gives the time rate of change of temperature in the water at some point is derived from the steady state model. The equation is written using a steady state control volume (Figure 6.1) but the derivative with respect to position above the tip is converted into a derivative with respect to time (at some fixed position above the tip) as described earlier.

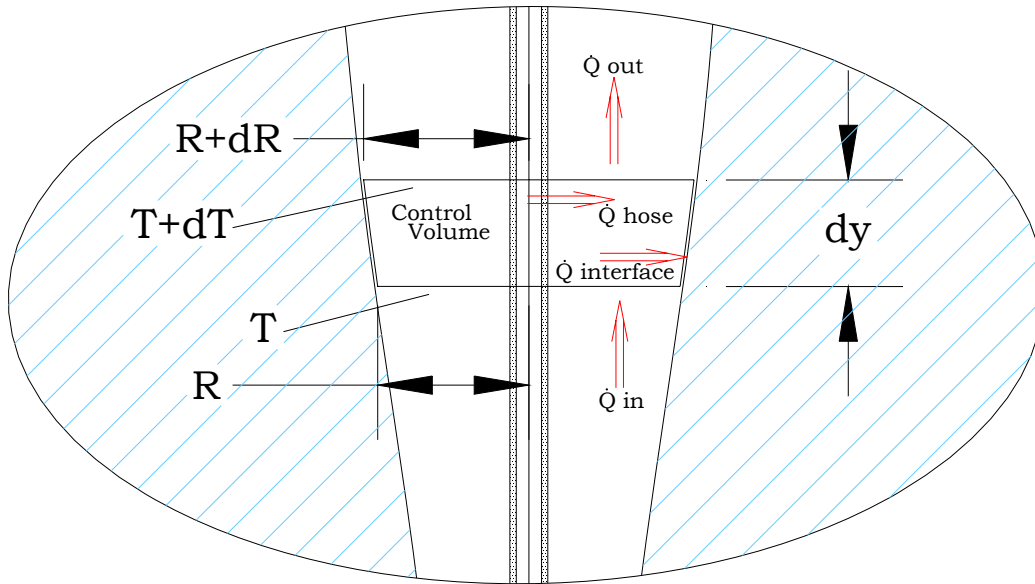


Figure 6.1. The control volume used to derive the  $dT/dt$  equation

Consider a control volume, as shown in fig. 6.1, that is bounded above and below by horizontal planes, bounded inside by the hose and bounded outside by an area minutely inside the wall of the hole. The control volume is fixed with respect to the drill head so that, away from the top of the hole and assuming constant temperature, the control volume reaches a steady state where it stops changing. The energy change within the c.v. is then zero. Assume the arbitrary zero energy point is taken to be zero degree water. The energy balance becomes:

$$\dot{Q}_{in} - \dot{Q}_{out} + \dot{Q}_{from\_hose} - \dot{Q}_{interface} = 0 \quad (6.1)$$

where

$$\dot{Q}_{in} = [\dot{V} + v\pi(R^2 - R_{hose}^2)]\rho_w c_w T_w \quad (6.2)$$

The heat flow in is the volume flow rate of water into the c.v. times the density, the specific heat and the temperature. The volume flow rate past a fixed point in the ice is approx.  $\dot{V}$  (ignoring here the contraction of ice on

melting) but since the c.v. is moving the second term must be added to give the correct volume flow rate into the c.v.

$$\dot{Q}_{out} = [\dot{V} + v\pi((R + dR)^2 - R_{hose}^2)]\rho_w c_w (T_w + dT_w) \quad (6.3)$$

$$\dot{Q}_{from\_hose} = \dot{Q}_{hose} dy \quad (6.4)$$

and

$$\dot{Q}_{interface} = 2\pi R h T_w dy \quad (6.5)$$

Although water from melted ice is entering the c.v. through the area next to the wall the water is at 0 °C, our zero energy reference, so that this flow makes no contribution. If a different zero energy reference were used this term would have to be included but a equal and opposite term would appear in  $\dot{Q}_{in} - \dot{Q}_{out}$  that would cancel it so the derived equation would be unchanged (as must happen since the arbitrary choice of zero energy reference should not change the equation)

Substituting Eqns. 6.2-6.5 into eqn. 6.1, simplifying and neglecting powers and products of differentials gives:

$$[\dot{V} + v\pi(R^2 - R_{hose}^2)]\rho_w c_w dT_w + 2v\pi R \rho_w c_w T_w dR + 2\pi R h T_w dy - \dot{Q}_{hose} dy = 0 \quad (6.6)$$

At this point the substitution  $dy = v dt$  can be made (as described earlier) changing the equation so that it gives the change with respect to time of a fixed point in the ice. Making this substitution, dividing through by  $dt$ , and rearranging gives:

$$\frac{dT_w}{dt} = \frac{\dot{Q}_{hose} - 2\pi R h T_w - 2\pi R \rho_w c_w T_w (dR/dt)}{[\dot{V} + v\pi(R^2 - R_{hose}^2)]\left(\frac{\rho_w c_w}{v}\right)} \quad (6.7)$$

This value is calculated at each time step and used to find the new water temperature a  $\Delta t$  later.

In section II the convective heat transfer coefficient,  $h$ , was calculated from linear approximations of the viscosity and Prandtl Number (see eqns. 2.8 and 2.9). In the computer model it is easy to use a more accurate approximation to calculate a value of  $h$  at each time step. The approximations used were:

Prandtl:

$$\begin{array}{ll} \text{for } 0 < T < 5.8 \text{ }^\circ\text{C} & \text{Pr} = 13.25 \\ \text{for } 5.8 < T < 90 \text{ }^\circ\text{C} & \text{Pr} = 38T^{-0.6} \end{array}$$

viscosity:

$$\begin{array}{ll} \text{for } 0 < T < 7.5 \text{ }^\circ\text{C} & \mu = 1.79e-3 \\ \text{for } 7.5 < T < 90 \text{ }^\circ\text{C} & \mu = 0.006T^{-0.615} \end{array}$$

B. Modified Euler Integration of Ice Temperature P.D.E.

Using the ordinary Euler method of integration one would solve for  $(dT/dt)_i$  (change in temperature with respect to time) at some  $t_i$ . (Note that in this section  $T_i$  is being used to indicate the temperature at an arbitrary “ith” location in the ice – not as it was used in the main body of this paper) Then  $T_{i+1}$  (at  $t_{i+1}$ ) would be found by:  $T_{i+1}=T_i +(\Delta t)(dT/dt)_i$ .  $(dT/dt)_{i+1}$  is calculated and the process is repeated. In the modified Euler method one solves for  $(dT/dt)_{i+1}$  but then averages it with  $(dT/dt)_i$  and applies this average to find  $T_{i+1}$  so  $T_{i+1}=T_i +(\Delta t)(dT/dt)_{avg}$ . This method is second-order accurate allowing a bigger step size and better stability.

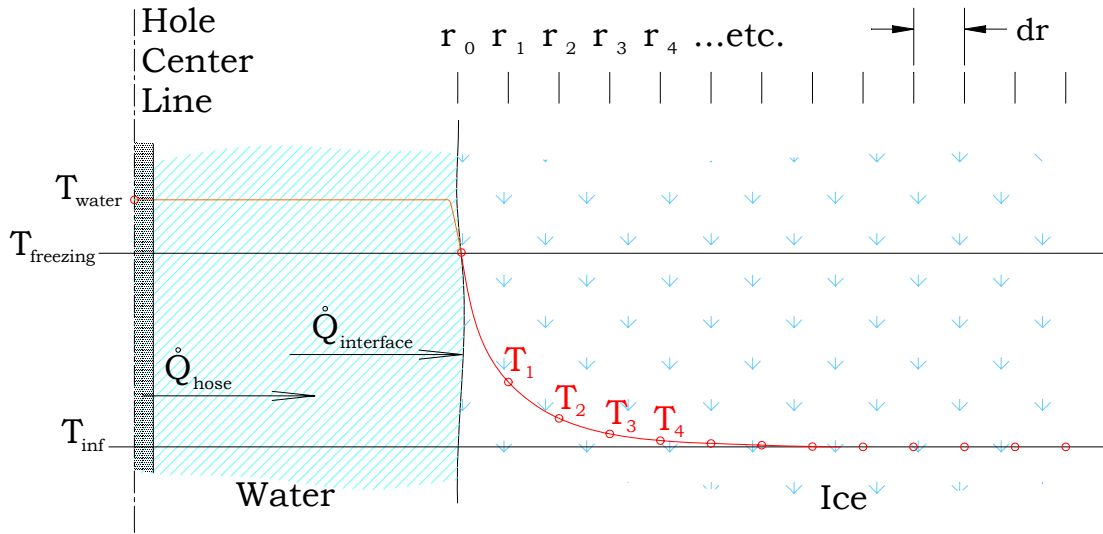


Figure 6.2. Schematic of the grid used in the integration of the heat equation in the ice adjacent to the hole.

The partial differential equation that governs the heat flow in the ice in cylindrical coordinates is:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} = \frac{1}{\alpha} \frac{\partial T}{\partial t} \tag{6.8}$$

where  $\alpha = k\rho/c$ . From this equation it can be seen that  $\partial T/\partial t$  can be solved for from the first and second derivatives of  $T$  with respect to  $r$  at a point in the ice. Numerical approximations to these two derivatives are found from the temperature distribution.

Figure 6.2 shows the grid that is used. The variable  $r_0$  is the radius at the hole wall. Then  $r_1, r_2$  etc. are calculated out from there from the chosen  $dr$ . Initially,  $T_0$  is set to  $0^\circ\text{C}$  and all the rest of the points are set to the local far-field temperature. Over time the temperature distribution takes a shape similar to that shown in figure 6.2.

In practice the following arrays were set up:

- r) This array holds the 100 or so radii,  $r_0, r_1, r_2$  etc.

T) Holds the corresponding temperatures at these radii.  
 $\partial T/\partial r$ ) Holds the first spatial derivatives calculated at each point  
 $\partial^2 T/\partial r^2$ ) The second spatial derivatives  
 $\partial T/\partial t$ ) The time derivative calculated from 3.5.  
T at dt) The temperatures predicted for each radius after dt. These temperatures have been arrived at with the ordinary Euler method. The following steps continue on to get the temperatures using the Improved Euler method.  
 $\partial T/\partial r$  at dt) The first spatial derivatives calculated with these new T's.  
 $\partial^2 T/\partial r^2$  at dt) The second spatial derivatives with these new T's.  
 $\partial T/\partial t$  at dt) The time derivative at dt.  
T at dt – Improved Euler) The first  $\partial T/\partial t$  and the second ( $\partial T/\partial t$  at dt) are averaged, the result multiplied by dt and added to the original T. These are the new temperatures predicted at dt. The first set of “T at dt”, calculated by the ordinary Euler method, are abandoned in favor of these.

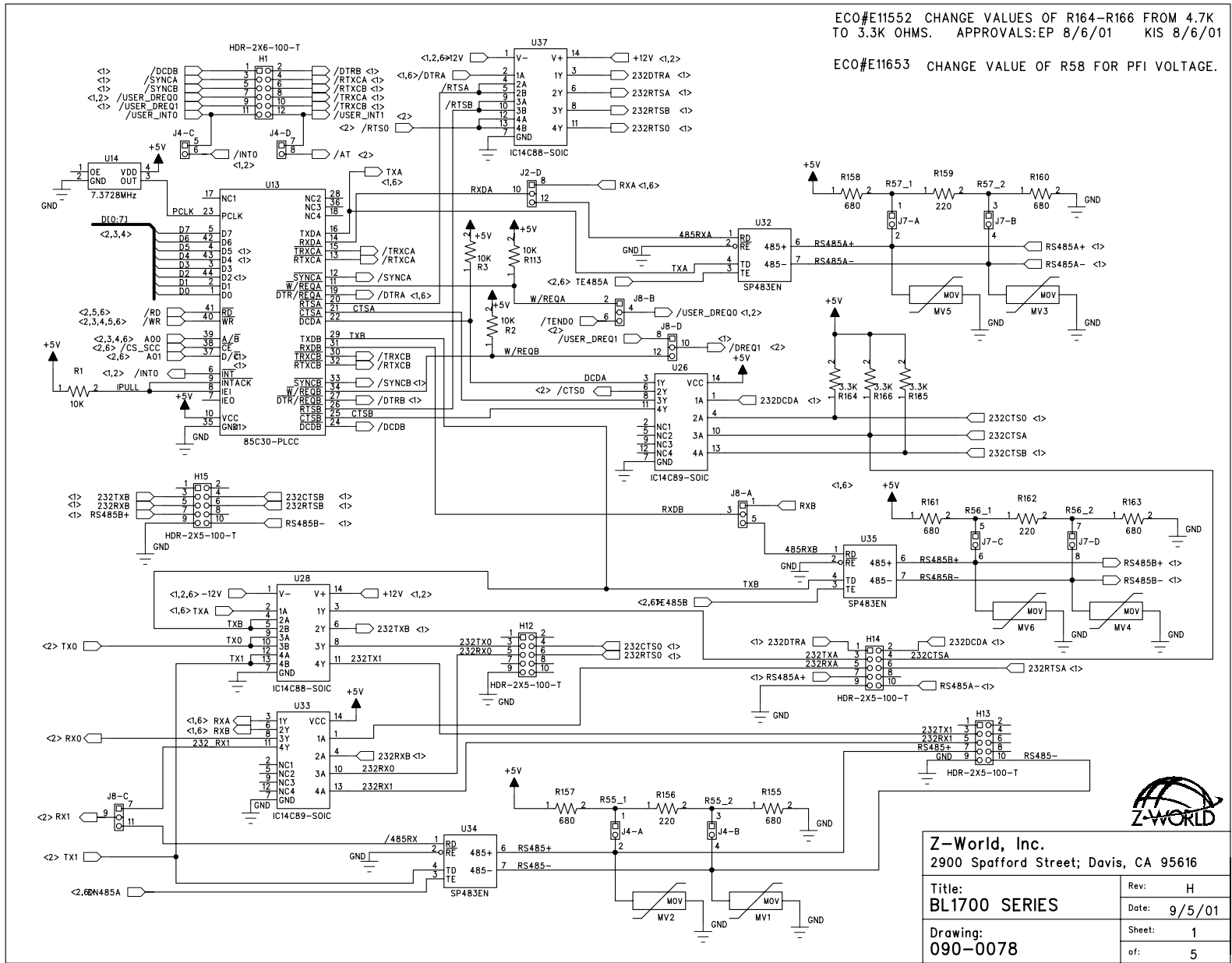
After each time step the increase (or decrease) in the hole radius due to melting (or refreezing) is calculated and the radial grid is repositioned so that  $r_0$  is at the hole wall. The temperatures corresponding to these new radii are linearly interpolated from the temperatures before repositioning. This new set of r and T are used to repeat the process.

This entire process is used to integrate forward one time step (typically 1 sec. when the hole is changing fast and 5 sec. when it is changing slowly). A typical run, to follow the hole out to 30 hrs after the end of drilling requires between 40,000 and 60,000 steps. (Surprisingly, on a desktop computer, programmed in BASIC, an entire run takes only about 10 minutes!)

## VII. References

1. Text: Heat Transfer 4<sup>th</sup> ed. by J.P. Holman, pub by McGraw Hill, © 1976
2. Paper: Neil Humphery and Keith Echelmeyer, Hot-Water Drilling and Bore Hole Closure in Cold Ice, 1990



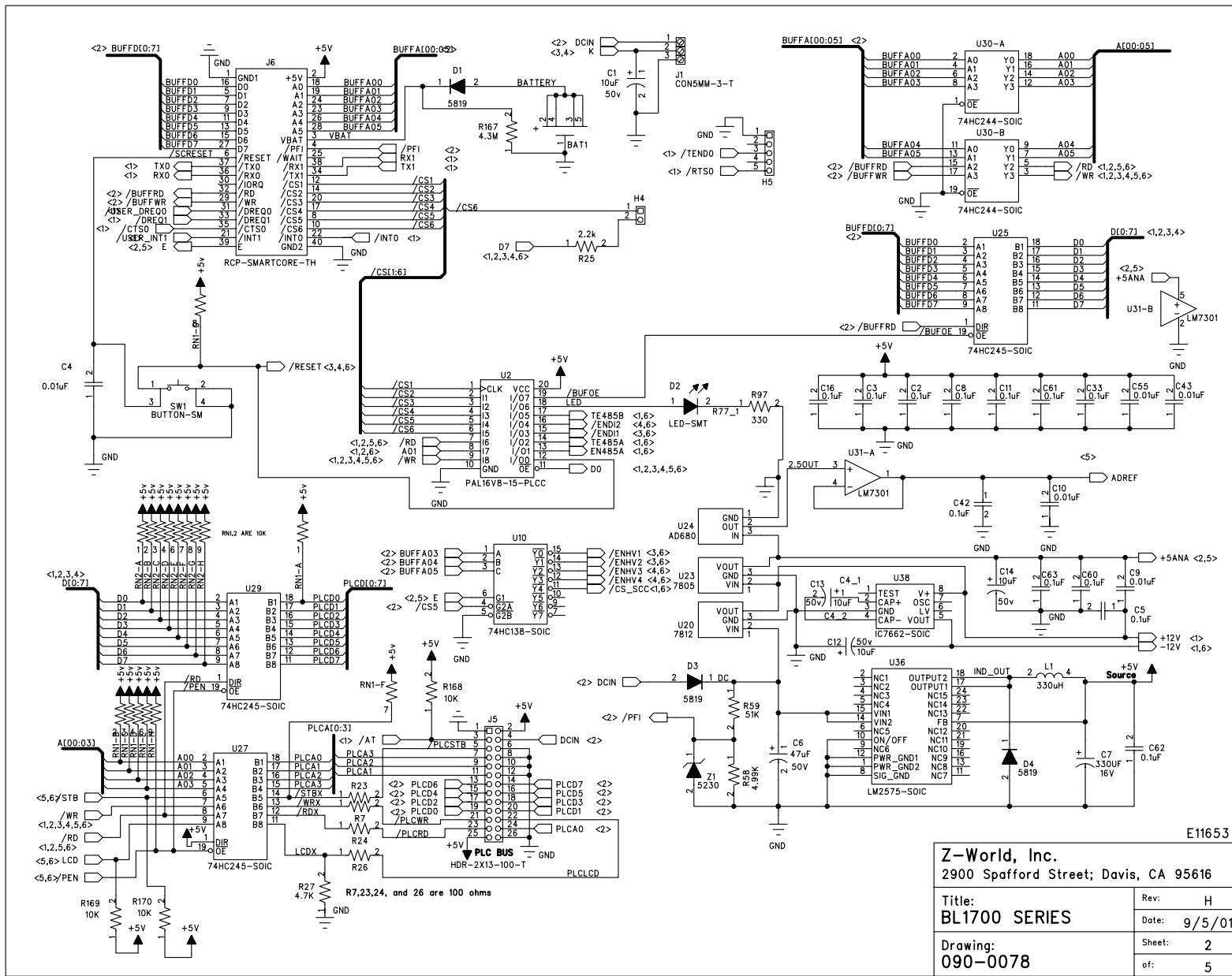


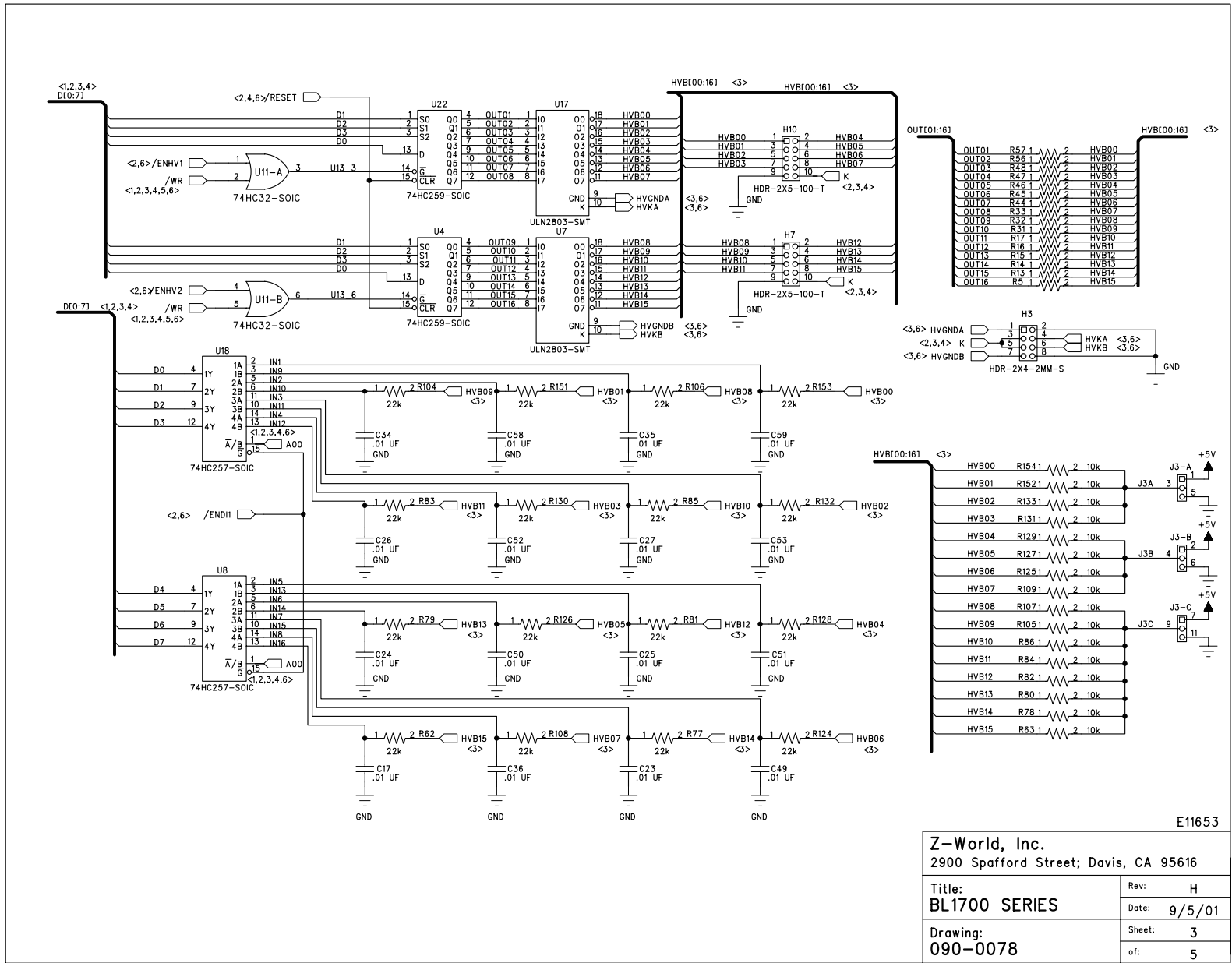
ECO#E11552 CHANGE VALUES OF R164-R166 FROM 4.7K TO 3.3K OHMS. APPROVALS:EP 8/6/01 KIS 8/6/01

ECO#E11653 CHANGE VALUE OF R58 FOR PFI VOLTAGE.



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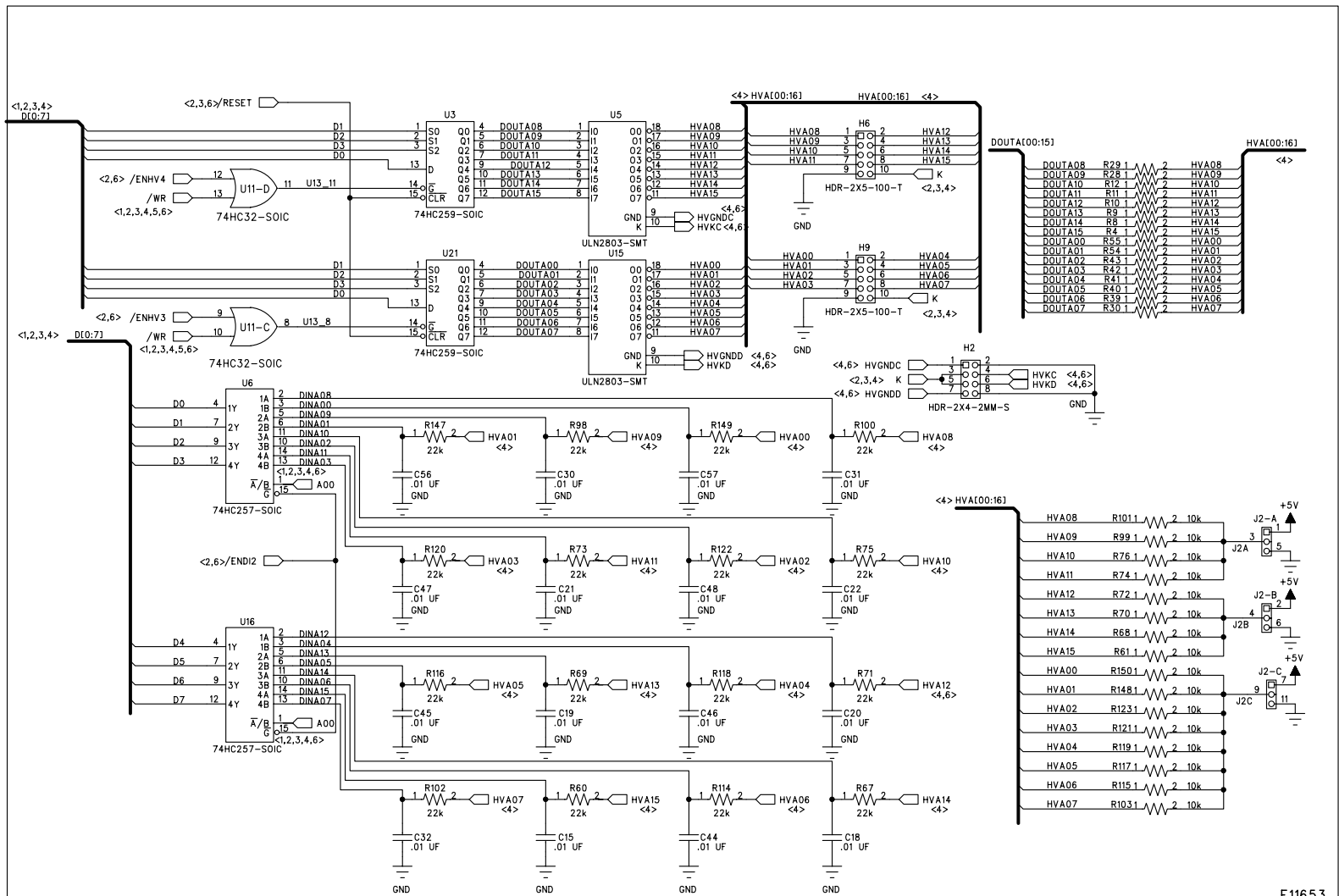




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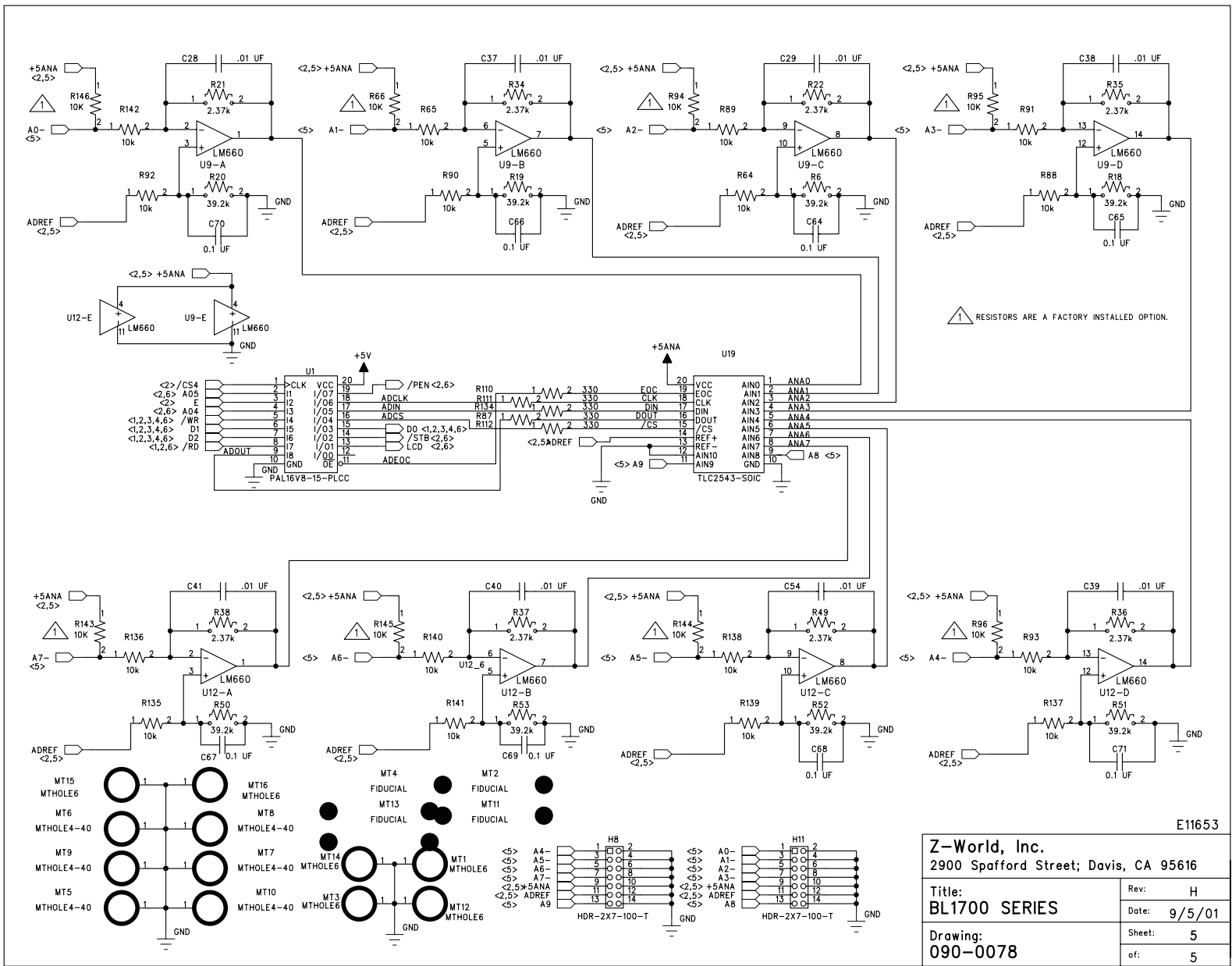
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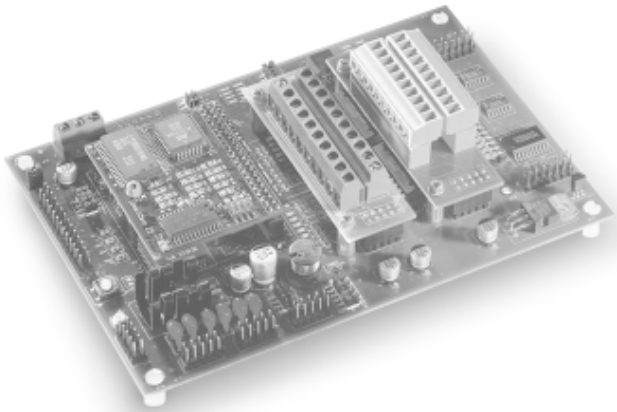
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	Sheet: 5
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# **BL1700**

**C-Programmable Controller**

## **User's Manual**

019-0048 • 020415-G



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# BL1700 User's Manual

Part Number 019-0048 • 020415-G • Printed in U.S.A.

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No complex software or hardware system is perfect. Bugs are always present in a system of any size. In order to prevent danger to life or property, it is the responsibility of the system designer to incorporate redundant protective mechanisms appropriate to the risk involved.

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**Schematics**

# ABOUT THIS MANUAL

---

This manual provides instructions for installing, testing, configuring, and interconnecting the Z-World BL1700 controller. Instructions are also provided for using Dynamic C functions.

## Assumptions

Assumptions are made regarding the user's knowledge and experience in the following areas:

- Ability to design and engineer the target system that a BL1700 will control.
- Understanding of the basics of operating a software program and editing files under Windows on a PC.
- Knowledge of the basics of C programming.



For a full treatment of C, refer to the following texts.

*The C Programming Language* by Kernighan and Ritchie  
*C: A Reference Manual* by Harbison and Steel

- Knowledge of basic Z80 assembly language and architecture.



For documentation from Zilog, refer to the following texts.

*Z180 MPU User's Manual*  
*Z180 Serial Communication Controllers*  
*Z80 Microprocessor Family User's Manual*

# Acronyms

Table 1 lists and defines the acronyms that may be used in this manual.







**Table 1. Acronyms**

Acronym	Meaning
EPROM	Erasable Programmable Read-Only Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
NMI	Nonmaskable Interrupt
PIO	Parallel Input/Output Circuit (Individually Programmable Input/Output)
PRT	Programmable Reload Timer
RAM	Random Access Memory
RTC	Real-Time Clock
SIB	Serial Interface Board
SRAM	Static Random Access Memory
UART	Universal Asynchronous Receiver Transmitter

# Icons

Table 2 displays and defines icons that may be used in this manual.

**Table 2. Icons**

Icon	Meaning	Icon	Meaning
	Refer to or see		Note
	Please contact	<b>Tip</b>	Tip
	Caution		High Voltage
	Factory Default		

# Conventions

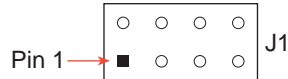
Table 3 lists and defines the typographic conventions that may be used in this manual.

**Table 3. Typographic Conventions**

Example	Description
<b>while</b>	Courier font (bold) indicates a program, a fragment of a program, or a Dynamic C keyword or phrase.
// IN-01...	Program comments are written in Courier font, plain face.
<i>Italics</i>	Indicates that something should be typed instead of the italicized words (e.g., in place of <i>filename</i> , type a file's name).
<b>Edit</b>	Sans serif font (bold) signifies a menu or menu selection.
...	An ellipsis indicates that (1) irrelevant program text is omitted for brevity or that (2) preceding program text may be repeated indefinitely.
[ ]	Brackets in a C function's definition or program segment indicate that the enclosed directive is optional.
< >	Angle brackets occasionally enclose classes of terms.
a   b   c	A vertical bar indicates that a choice should be made from among the items listed.

## Pin Number 1

A black square indicates pin 1 of all headers.



## Measurements

All diagram and graphic measurements are in inches followed by millimeters enclosed in parenthesis.





## *CHAPTER 1: OVERVIEW*

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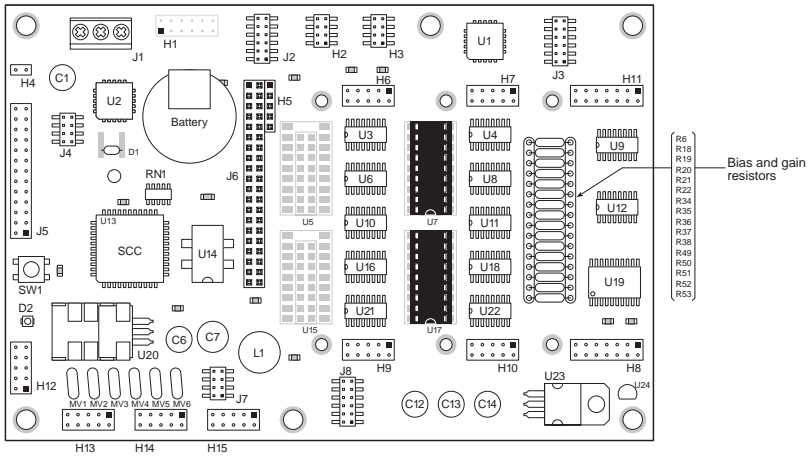
Chapter 1 provides an overview and a brief description of the BL1700 features.



# Overview

The BL1700 is a feature-rich controller with modular digital and analog I/O that allows easy custom modification. The BL1700 is programmed using Dynamic C, Z-World's version of the C programming language designed for embedded control.

Figure 1-1 illustrates the BL1700 board layout.



**Figure 1-1. BL1700 Board Layout**

## Features

The BL1700 includes the following features.

### • **Core Module**

The BL1700 uses a core module (Z-World part number 129-0099) designed for easy, in-system programming. The core module includes the CPU, RAM, flash EPROM, real-time clock, and microprocessor watchdog circuitry.

### • **I/O**

Serial channels—Four full-duplex serial channels interface directly with serial I/O devices. RS-232 and RS-485 signal levels are supported.

Digital inputs—Up to 32 protected digital inputs capable of detecting logic level or high-voltage signals.

Digital outputs—Up to 32 high-voltage, high-current outputs capable of driving resistive and inductive loads.

Pulse-width modulated outputs—Up to 7 digital outputs can provide pulse-width modulation.

Analog inputs—Eight conditioned analog inputs, each with user-configurable bias and gain, interface directly with many sensors. Two unconditioned analog inputs which allow for custom signal conditioning circuitry or direct interfacing.

Expansion bus—I/O expansion via built-in PLCBus. The PLCBus uses inexpensive off-the-shelf Z-World expansion boards.

### • **Additional Features**

Field Wiring Terminals—Removable field wiring terminals in several configurations are available for the digital and analog I/O ports.

Compact form factor—Compatible with standard 100 mm wide DIN mounting products.

LED—A general-purpose, user-programmable LED is included.

DIN Rails—The BL1700 may be mounted in 110 mm DIN rail trays.



Appendix B provides detailed specifications for the BL1700.



See Appendix C, “Field Wiring Terminals (FWT) and DIN Rails,” for more information on FWTs and DIN rail mounting.

## Flexibility and Customization

The BL1700 was designed with customization in mind. The design was optimized for cost effective, quick-turn, custom manufacturing. Surface mount technology was used extensively in order to reduce both size and cost while providing the flexibility to meet individual design needs. For quantity orders, the BL1700 can be customized to better meet the needs of your application.

### Standard Models

The BL1700 Series of controllers currently has four versions. Table 1-1 lists the standard features for these versions.

**Table 1-1. BL1700 Series Features**

Model	Features
BL1700	18.432 MHz clock, 16 protected digital inputs, 16 high-voltage sinking outputs, 4 full-duplex serial channels, 10 A/D channels, PLCBus expansion port.
BL1710	BL1700 without A/D channels.
BL1720	BL1700 with two serial channels instead of four.
BL1730	BL1700 with two serial channels instead of four and 9.216 MHz clock.

### Customization Options

The BL1700 can be customized for individual applications. The options include the following configurations.

- Core module configuration—CM7100 and CM7200 core modules can be used on the BL1700. Customization options include RAM size, flash EPROM size, EPROM size, clock speed, and real-time clock option.



CM7100 and CM7200 core modules must have a 5-pin header installed at H1, and the BIOS must be customized for these core modules to be used on the BL1700.

- Digital I/O configuration—optional TTL level I/O.
- Analog input configuration—gain and offset configuration.
- Serial channel configuration—two or four serial ports.



For ordering information, or for more details about the various options and prices, call your Z-World Sales Representative at (530) 757-3737.

## Development and Evaluation Tools

The BL1700 is supported by a Development Kit that includes everything you need to start development with the BL1700.

### ***Development Kit***

The Development Kit includes these items.

- Manual with schematics.
- Programming cables and adapter.
- 24 V DC wall-mount power supply.
- Field wiring terminals.
- Sourcing high-voltage driver ICs.

An optional Serial Interface Board (SIB) allows full access to all serial ports during development.

### ***Software***

The BL1700 is programmed using Z-World's Dynamic C, an integrated development environment that includes an editor, a C compiler, and a debugger. Library functions provide an easy and robust interface to the BL1700.



Z-World's Dynamic C reference manuals provide complete software descriptions and programming instructions.

## CE Compliance

The BL1700 has been tested by an approved competent body, and was found to be in conformity with applicable EN and equivalent standards. Note the following requirements for incorporating the BL1700 in your application to comply with CE requirements.



- The power supply provided with the Development Kit is for development purposes only. It is the customer's responsibility to provide a clean DC supply to the controller for all applications in end-products.
- Fast transients/burst tests were not performed on the BL1700. Signal and process lines that are longer than 3 m should be routed in a separate shielded conduit.
- The BL1700 has been tested to Light Industrial Immunity standards. Additional shielding or filtering may be required for an industrial environment.
- The BL1700 has been tested to EN55022 Class A emission standards. Additional shielding or filtering may be required to meet Class B emission standards.



Visit the "Technical Reference" pages of the Z-World Web site at <http://www.zworld.com> for more information on shielding and filtering.



## CHAPTER 2: **GETTING STARTED**

---

Chapter 2 provides instructions for connecting the BL1700 to a host PC and running a sample program. The following sections are included.

- Development Kit Packing List
- Connecting the BL1700 to Your PC
- Establishing Communication with the BL1700
- Running a Sample Program

## Development Kit Packing List

The BL1700 Development Kit includes the following items.

- Two serial cables with DB-9 and 10-pin header connectors.
- DB-25 to DB-9 serial adapter.
- 24 V DC wall-mount power transformer.
- Two FWT-50 field wiring terminals.
- One FWT-A/D field wiring terminal.
- Two 2985 high-voltage driver ICs.
- BL1700 User's Manual (this document).

## Connecting the BL1700 to a Host PC

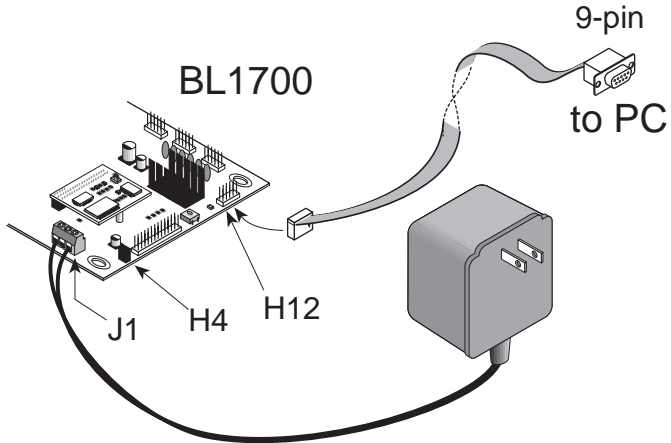
The BL1700 can be programmed using a PC through an RS-232 port with the programming cable provided in the Developer's Kit. You can also use Z-World's SIB2 to program the BL1700. Using the SIB2 frees all of the serial channels for the application during development. The SIB2 is not part of the standard Developer's Kit, and must be purchased separately. Both programming methods are described below.



For ordering information, call your Z-World Sales Representative at (530) 757-3737.

**Connecting the BL1700 to a PC using the serial port.**

1. Make sure that Dynamic C is installed on your system as described in the Dynamic C *Technical Reference* manual.
2. Connect the 10-pin programming cable from H12 on the BL1700 to the appropriate COM port of your computer as shown in Figure 2-1. Make sure that pin 1 on the ribbon cable connector (indicated by a small triangle on the connector) matches up with pin 1 on H12 (indicated by a small white circle near the corner of the connector).



**Figure 2-1. BL1700 Programming Connections**



Use only the transformer and programming cable supplied by Z-World.

3. Make sure that the Run/Program jumper on header H4 is installed.
4. Connect the 24 V DC transformer as follows.
  - Connect the lead with the red sleeve to the screw terminal (J1) labeled DCIN on the BL1700.
  - Connect the other lead to the screw terminal (J1) labeled GND.
5. Plug the transformer into a wall socket.



## Connecting the BL1700 to your PC using the SIB2.

1. Make sure that Dynamic C is installed on your system as described in the *Dynamic C Technical Reference* manual.
2. Disconnect power from the BL1700. Connect an RJ-12 cable between the RJ-12/DB-9 adapter attached to the PC and the SIB2.
3. Plug the SIB2's 8-pin connector onto header JP1 located on the CM7200 core module (mounted on the BL1700), as shown in Figure 2-2. Make sure that pin 1 on the ribbon cable connector (on the striped side) matches up with pin 1 on JP1 (indicated by a small white circle next to the header).

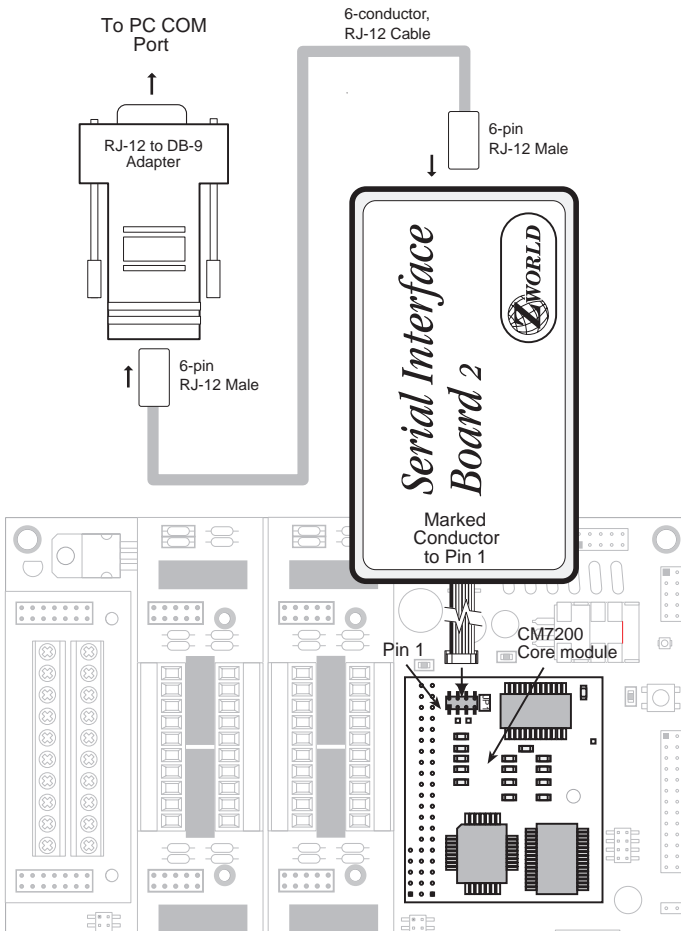


Figure 2-2. SIB2 Connection (BL1700 Top View)



Use only the transformer and programming cable supplied by Z-World.



Observe the polarity of the cable and the 8-pin connector. Attach the connector to JP1 exactly as shown in Figure 2-2.

4. Make sure that the Run/Program jumper on header H4 is installed.
5. Connect the 24 V DC transformer as follows.
  - Connect the lead with the red sleeve to the screw terminal (J1) labeled DCIN on the BL1700.
  - Connect the other lead to the screw terminal (J1) labeled GND.
6. Plug the power supply into a wall socket.

## Establishing Communication with the BL1700

1. Double-click the Dynamic C icon to start the software. Note that communication with the BL1700 is attempted each time you start Dynamic C.
2. If the communication attempt is successful, no error messages are displayed.



See Appendix A, “Troubleshooting,” if an error message such as **Target Not Responding** or **Communication Error** appears.



Once the necessary changes have been made to establish communication between the host PC and the BL1700, use the Dynamic C shortcut **<Ctrl Y>** to reset the controller and initiate communication.

## Running a Sample Program

1. Open the sample program **BL17FLSH.C** located in the Dynamic C **SAMPLES\BL17XX** directory. This program flashes the onboard LED.
2. Compile the program by pressing **F3** or by choosing **Compile** from the **Compile** menu. Dynamic C compiles and downloads the program into the BL1700's flash memory.

During compilation, Dynamic C rapidly displays several messages in the compiling window. This condition is normal.



See Appendix A, “Troubleshooting,” if an error message such as **Target Not Responding** or **Communication Error** appears.

3. Run the program by pressing **F9** or by choosing **Run** from the **Run** Menu.
4. To halt the program, press **<Ctrl Z>**. This action halts program execution.
5. To restart program execution, when required, press **F9**.



## *CHAPTER 3: **BL1700 HARDWARE***

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Chapter 3 describes the BL1700 hardware subsystems. The following sections are included.

- Operating Modes
- BL1700 Subsystems Overview
- Microprocessor Core Module
- Serial Communications Channels
- High-Voltage Digital Outputs
- Protected Digital Inputs
- Analog Inputs
- PLCBus Expansion Port

# Operating Modes

The BL1700 has two mutually exclusive operating modes, run mode and program mode. Each mode is explained in detail below.

- **Program Mode**

In program mode, the BL1700 controller runs under the control of your PC that is running Dynamic C. The BL1700 must be in this mode to compile a program to the BL1700 or debug a program.



- In program mode, the BL1700 matches the baud rate of the PC COM port up to 57,600 bps.
- USER LED is “ON” in program mode.

- **Run Mode**

In run mode, the BL1700 controller runs standalone. At power-up, the BL1700 checks to see if its onboard memory contains a program. If a program exists, the BL1700 controller executes the program immediately after power-up.



- In run mode, the BL1700 does not respond to Dynamic C running on the PC. A program cannot be compiled or debugged when the BL1700 is in run mode.
- USER LED D2 is under the control of the application on the BL1700 when the BL1700 is in run mode.

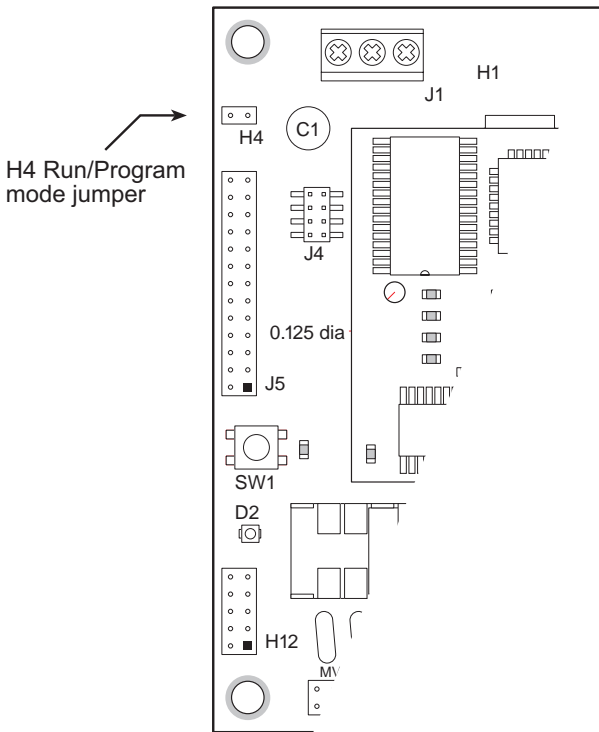
Table 3-1 shows the jumper settings for the program and run modes.

**Table 3-1. BL1700 Jumper Settings for Run/Program Modes**

Operating Mode	Header H4	Permissible Activities
Program Mode		<ul style="list-style-type: none"> <li>• Compile a program.</li> <li>• Run a program under debugger control.</li> <li>• Run a program without “polling.” See your Dynamic C manuals for a description of program polling.</li> </ul>
Run Mode		Run application.

## Changing the Operating Mode

1. Locate the **Run/Program** jumper on header H4. Figure 3-1 shows the location of header H4.



**Figure 3-1. H4 Run/Program Jumper Location**

2. Select the desired operating mode.
  - Install jumper on header H4 to select program mode.
  - Remove jumper on header H4 to select run mode.
3. Press the reset switch SW1 to switch the BL1700 to the selected mode.



Be sure careful when installing or removing the H4 jumper if power is connected to the BL1700.

## Run Mode

1. Place the BL1700 in program mode (with the H4 jumper installed) and cycle the unit's power.
2. Open a program if one is not already open.
3. Select the **Compile** command from the **Compile** menu, or press **F3** on your keyboard.
4. If no errors are detected, Dynamic C compiles the program and automatically downloads it into the BL1700's onboard flash memory.
5. Remove the **Run/Program** jumper.
6. Press the reset switch SW1 on the BL1700. This action resets the BL1700 and places it into run mode. The downloaded program begins to run immediately.



The downloaded program begins to run as soon as the reset switch is pressed or power is applied. Pay close attention to any electronic or mechanical devices connected to the BL1700 that could cause injury.

The program is now loaded in the BL1700's onboard flash EPROM. This program runs automatically every time the BL1700 powers up in run mode until you load another program.

Follow these steps to return to the program mode.

1. Re-install the **Run/Program** jumper on header **H4**. Refer to Figure 3-1 for the jumper location.
2. Press the reset switch on the BL1700.



Refer to the previous section, "Changing the Operating Mode," for more detailed information.

# BL1700 Subsystems Overview

The BL1700 is comprised of several subsystems including a microprocessor core module, serial communications channels, digital I/O, analog inputs, and PLCBus expansion port. Figure 3-2 illustrates the BL1700 subsystems.

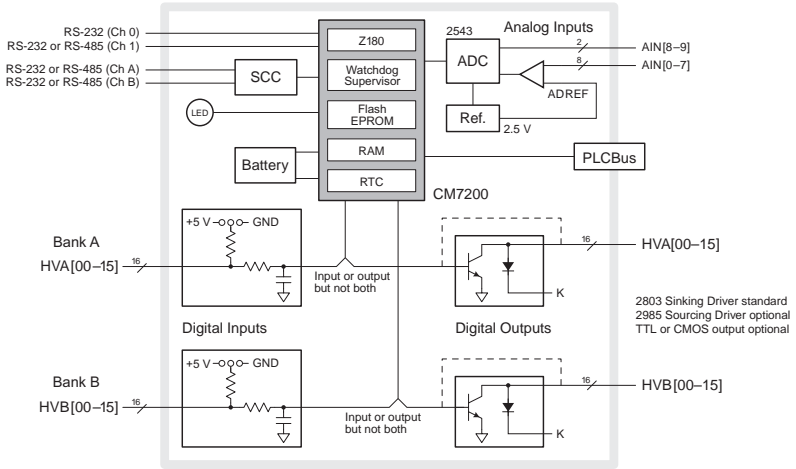


Figure 3-2. BL1700 Block Diagram

## Microprocessor Core Module

The BL1700 is built around a Z-World CM7200 Series microprocessor core module. The core module is comprised of a Zilog Z180 microprocessor, 32K of battery-backed static RAM, 128K of flash EPROM, a real-time clock, and a watchdog timer/microprocessor supervisor.

The Z180 CPU runs at 18.432 MHz. Internal to the Z180 are two asynchronous serial ports, two DMA channels, two programmable-reload timers (PRTs), and three interrupt lines.

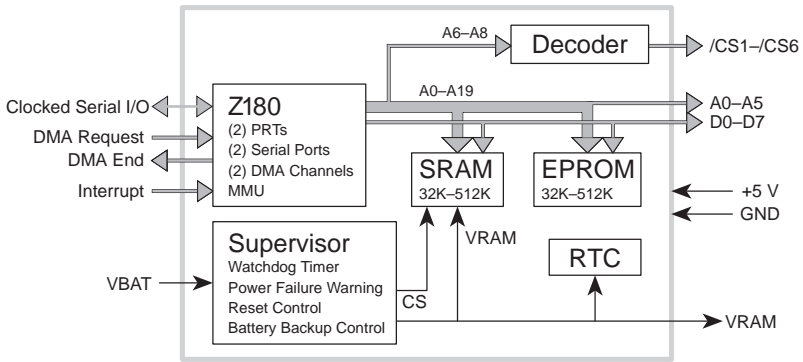
Six chip-select lines (/CS1-/CS6) enable one of six groups of 64 I/O addresses. These lines are used to access peripherals on the BL1700 board.

The power-supervisor IC performs several functions. It provides a watchdog timer function, performs power-failure detection, RAM protection, and battery backup when the CM7200 is unpowered.

Your program can obtain the time and the date from the real-time clock.



Figure 3-3 shows a block diagram of the CM7200 microprocessor core module.



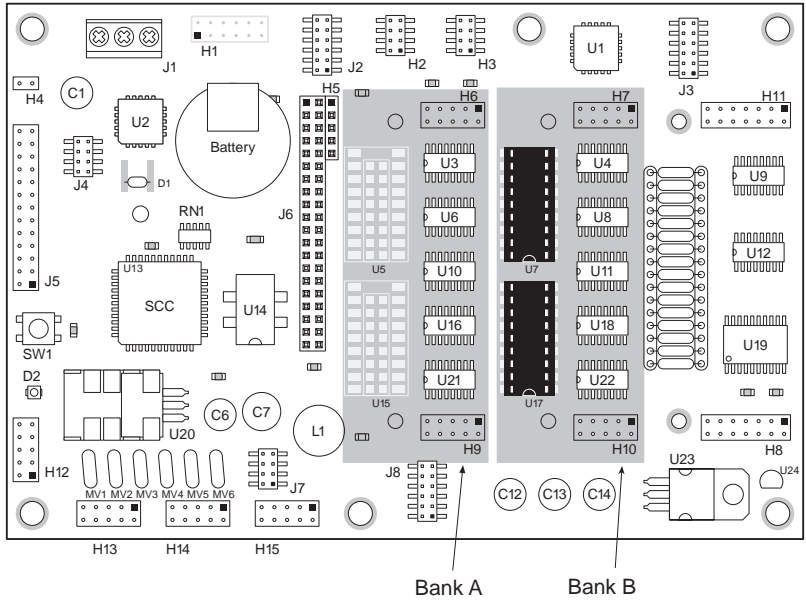
**Figure 3-3. CM7200 Block Diagram**

### Core Module External Connections

The core module also provides connections to the Clock Serial I/O (CSIO) port on the Z180. This port can be used to program the BL1700 using Z-World's Serial Interface Board 2 (SIB2). This allows programming and debugging of the BL1700 while providing access to all the onboard serial channels.

# Digital Inputs and Outputs

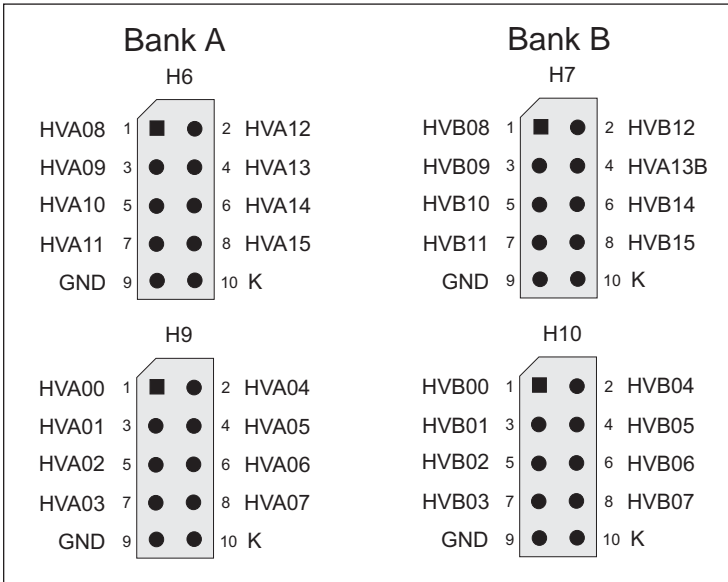
The digital inputs and outputs are divided into two banks, A and B, as shown in Figure 3-2 and Figure 3-4. The 16 factory-default digital inputs on the BL1700, BL1710, BL1720, and BL1730 occupy Bank A, and 16 digital outputs are located on Bank B. Future and/or custom versions of the BL1700 may have both or no banks configured as digital inputs. In order for a bank to be configured as an input, the appropriate interface ICs must be installed. In order for a bank to be configured as an output, the appropriate high-voltage driver ICs must be installed. These modifications should only be performed at Z-World's manufacturing facility.



**Figure 3-4. BL1700 Banks A and B**

## External Connections

Connections to Bank A are made on headers H6 and H9. Connections to Bank B are made on headers H7 and H10. The pinouts for headers H6, H7, H9 and H10 are shown in Figure 3-5.



**Figure 3-5. Pinouts for BL1700 Digital Input External Connections**

Connections to the digital inputs/outputs can be made with a ribbon cable, Z-World's FWT field wiring terminals, or a custom interface board. Z-World offers FWT modules for the digital inputs in three configurations.

- Screw terminals (Z-World part number 101-0184).
- Removable screw terminals (Z-World part number 101-0185)
- Optically isolated removable screw terminals (Z-World part number 101-0186)



Input lines connected to optically isolated devices must be configured as pull-up. Otherwise, damage to the circuit may occur.

Each FWT module mates with one of the BL1700's header pairs (H6–H9 and H7–H10). Different types of field wiring terminals can be mixed on the same BL1700.



See Appendix C, "Specifications," for FWT mechanical dimensions and pinouts.

## Digital Inputs

The BL1700 can provide up to 32 protected digital inputs designed as logical data inputs, returning a 1 or 0. Their normal operating range is -20 V DC to +24 V DC, and they are protected from voltages between -48 V DC and +48 V DC. The inputs can detect logic-level signals and have a nominal logic threshold of 2.5 V DC. This means an input returns a 0 if the input voltage is below 2.5 V DC and a 1 if the input voltage is above 2.5 V DC. The inputs can be pulled up to +5 V or down to ground.

A low-pass filter on each input channel has a time constant of

$$T_{RC} = 220 \mu\text{s} \text{ (4.5 kHz).}$$

They may be configured as pull-up or pull-down in groups of fours and eights. The configuration of each input should be determined by normal operating conditions, power-down mode and possible failure modes including open or shorted conditions. These factors will influence your decision about configuring the inputs as pull-up or pull-down.

## Operating Modes and Configuration

Inputs may be pulled up to +5 V or pulled down to ground by configuring the jumpers on BL1700 headers J2 and J3.

J2 jumpers select pull-up/pull-down resistors for Bank A. Jumpers on J3 select pull-up/pull-down resistors for inputs for Bank B. To change an input from the factory default of pull-up, simply place a jumper across the appropriate two pins of J2 and/or J3.

Table 3-2 and Table 3-3 illustrate the jumper settings for pull-up and pull-down configurations for the BL1700's Bank A and Bank B inputs.



The factory default is for the digital inputs to be pulled up to +5 V.

**Table 3-2. BL1700 Bank A Digital Input Jumper Configurations**

Channel	Jumper Settings	
	Inputs Pulled Up	Inputs Pulled Down
HVA 8–11 Bank A Channels 8–11 (Physical Channels 24–27)	<p>J2</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p> <p>FD</p>	<p>J2</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p> <p>FD</p>
HVA 12–15 Bank A Channels 12–15 (Physical Channels 28–31)	<p>J2</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p> <p>FD</p>	<p>J2</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p> <p>FD</p>
HVA 0–7 Bank A Channels 0–7 (Physical Channels 16–23)	<p>J2</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p> <p>FD</p>	<p>J2</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p> <p>FD</p>

**Table 3-3. BL1700 Bank B Digital Input Jumper Configurations**

Channel	Jumper Settings	
	Inputs Pulled Up	Inputs Pulled Down
HVB 0–3 Bank B Channels 0–3 (Physical Channels 0–3)	<p style="text-align: center;">J3</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p>	<p style="text-align: center;">J3</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p>
HVB 4–7 Bank B Channels 4–7 (Physical Channels 4–7)	<p style="text-align: center;">J3</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p>	<p style="text-align: center;">J3</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p>
HVB 8–15 Bank B Channels 8–15 (Physical Channels 8–15)	<p style="text-align: center;">J3</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p>	<p style="text-align: center;">J3</p> <p>1 2 3 4 5 6 7 8 9 10 11 12</p>



The high-voltage driver chips must be removed from Bank B and interface chips must be installed before the Bank B inputs can be used as digital inputs.

## **Digital Outputs**

Up to 32 high-voltage, high-current digital outputs are possible on the BL1700. The digital outputs can be configured in groups of eight for either sinking or sourcing operation by setting jumpers and installing the appropriate driver ICs. Sinking drivers can sink up to 500 mA at voltages up to 48 V DC. Sourcing drivers can source up to 250 mA at voltages up to 30 V DC. All outputs are diode protected against inductive spikes.

TTL/CMOS level outputs are also possible by bypassing the driver ICs. This option is for quantity orders only, and should be performed at Z-World's manufacturing facility.

High-voltage outputs are diode protected against inductive spikes. All outputs are individually addressable.

## **Operating Modes and Configuration**

The digital inputs and outputs are divided into two banks, Bank A and Bank B. In the factory default, digital outputs occupy Bank B and digital inputs are located on Bank A. In order for a bank to be configured as an output, the appropriate interface ICs must be installed. Z-World recommends that this be done only at Z-World's manufacturing facility.

## **High-Voltage Drivers**

Outputs may be configured for either sinking or sourcing current. The configuration is determined by the type of driver ICs installed and the jumper settings.

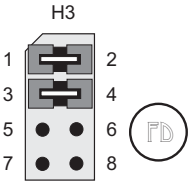
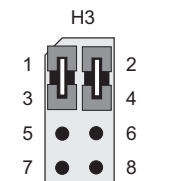
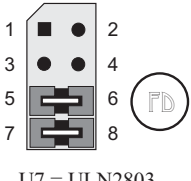
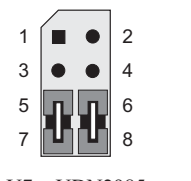
For Bank A, U5 drives outputs 8-15 and U15 drives outputs 0-7. For Bank B, U7 drives outputs 8-15 and U17 drives outputs 0-7. The jumpers placed on H3 configure sourcing/sinking modes for the outputs on Bank B. Jumpers on H2 configure sourcing/sinking modes for the outputs on Bank A (if it is configured for output). Table 3-4 and Table 3-5 show the jumper settings for sinking and sourcing configurations.

The sinking driver chips used on the BL1700 are ULN2803 or equivalent. The sourcing driver chips are UDN2985 or equivalent.

To configure drivers for sinking outputs (default for Bank B), install the ULN2803 driver chips in the appropriate socket locations. For sourcing outputs, install UDN2985 driver chips.

When installing high-voltage driver chips, make sure that pin 1 on the IC matches up with pin 1 on the socket. The chip has a small semicircular notch on one end that matches up with a similar notch on the IC socket. The chips can be removed by gently prying them out with a small screwdriver or IC extractor.

**Table 3-4. BL1700 Bank B Digital Output Jumper Configurations**

Bank B	Jumper Settings	
	Sinking Outputs	Sourcing Outputs
HVB 0-7 Channels 0-7	 <p>U17 = ULN2803</p>	 <p>U17 = UDN2985</p>
HVB 8-15 Channels 8-15	 <p>U7 = ULN2803</p>	 <p>U7 = UDN2985</p>

Also make sure that the jumpers on H3 and/or H2 are properly configured. If the jumpers are not properly set for the drivers installed, damage to both the drivers and the circuit board is possible.

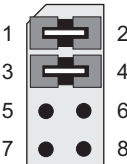
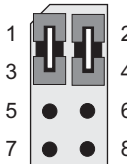
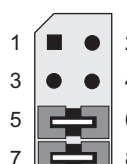
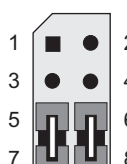
Connections to Bank A are made on headers H6 and H9. Connections to Bank B are made on headers H7 and H10. The pinouts for headers H6, H7, H9 and H10 are shown in Figure 3-5 on page 30.



See Appendix B, “Specifications,” for detailed specifications on the high-voltage drivers.



**Table 3-5. BL1700 Bank A Digital Output Jumper Configurations**

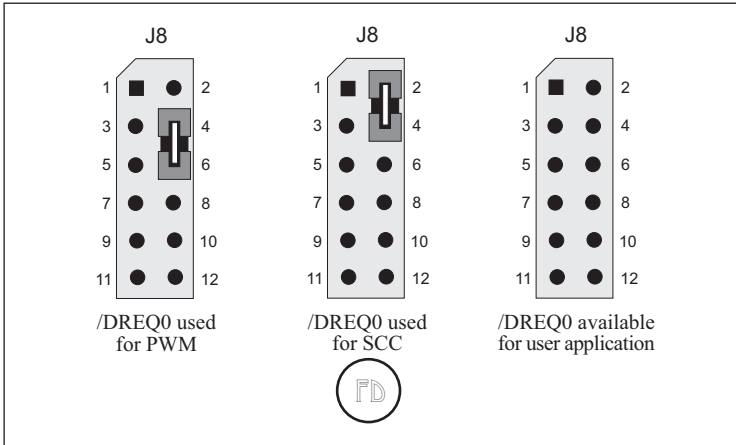
Bank A	Jumper Settings	
	Sinking Outputs	Sourcing Outputs
HVA 8–15 Channels 8–15	<p style="text-align: center;">H2</p>  <p style="text-align: center;">U5 = ULN2803</p>	<p style="text-align: center;">H2</p>  <p style="text-align: center;">U5 = UDN2985</p>
HVA 0–7 Channels 0–7	<p style="text-align: center;">H2</p>  <p style="text-align: center;">U15 = ULN2803</p>	<p style="text-align: center;">H2</p>  <p style="text-align: center;">U15 = UDN2985</p>



The digital interface chips must be removed from Bank A and high-voltage driver chips must be installed before the Bank A inputs can be used as outputs.

## Pulse-Width Modulation (PWM) Configuration

In order to use the PWM feature of the digital outputs, J8 must be jumpered from pin 4 to pin 6. See Figure 3-6.



**Figure 3-6. /DREQ0 Jumper Settings**

## Analog Inputs

The BL1700, BL1720, and BL1730 provide 10 single-ended analog-to-digital conversion channels with 12-bit resolution. Eight channels are conditioned and two are unconditioned. The eight conditioned inputs can measure bipolar or unipolar signals. User-installable resistors determine the signal conditioning for your application. Two inputs are connected directly to the A/D converter.



The BL1710 does not have analog inputs.

## Operating Modes and Configuration

User-selected gain and bias resistors determine voltage ranges for the conditioned input signals.



Standard BL1700, BL1720, and BL1730 controllers come with 2370  $\Omega$  gain resistors and 39.2 k $\Omega$  bias resistors. These resistors provide a gain of 0.25 for a unipolar input signal range of 0 V to 10 V.

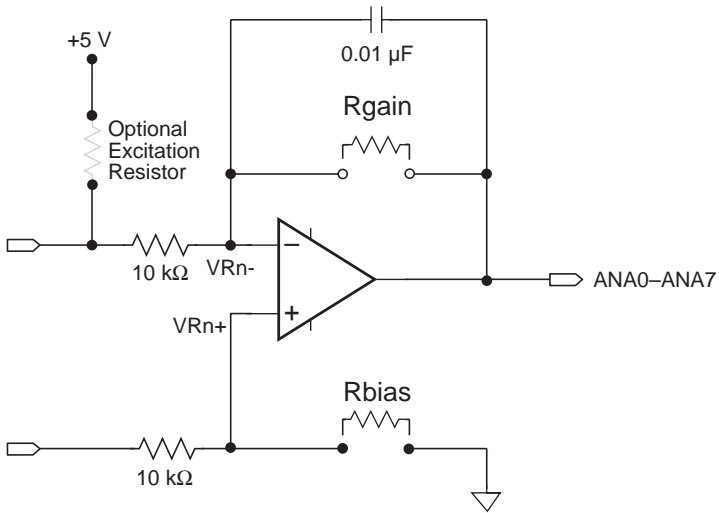
The BL1700 comes with gain and bias resistors installed for an input range of 0 V to 10 V. Table 3-6 lists the gain and bias resistors for other selected input-voltage ranges. A step-by-step procedure follows to explain how to calculate the values for the gain and bias resistors for a particular input-voltage range.

**Table 3-6. Representative Analog Input Setups**

Input Voltage Range (V)	Gain	R <sub>gain</sub> ( $\Omega$ )	R <sub>bias</sub> ( $\Omega$ )
-10.0 to +10.0	0.125	1180	8060
-5.0 to +5.0	0.250	2370	6650
-2.5 to +2.5	0.500	4750	4990
-2.0 to +2.0	0.625	5900	4530
-1.0 to +1.0	1.250	11,800	2870
-0.5 to +0.5	2.500	23,700	1690
-0.25 to +0.25	5.000	47,500	931
-0.10 to +0.10	12.500	118,000	392
0 to +10.0	0.250	2370	39,200
0 to +5.0	0.500	4750	20,000
0 to +2.5	1.000	9530	10,000
0 to +1.0	2.500	23,200	4020

## 1. Set up the analog inputs.

The first eight analog input signals are routed to the inverting input of one of the eight op-amps in U9 and U12. The op-amps in U9 and U12 operate in an inverting configuration. User-selectable resistors set the gain and bias voltages of the amplifiers. The 10 k $\Omega$  input resistors are fixed. Feedback capacitors roll off the high-frequency response of the amplifiers to attenuate noise. Figure 3-7 shows a schematic diagram of the conditioned input amplifier circuit.



**Figure 3-7. Analog Conditioning Circuit**

Table 3-7 lists the gain and bias resistors for each of the eight conditioned analog input channels.

**Table 3-7. Gain and Bias Resistors**

Channel	R <sub>bias</sub>	R <sub>gain</sub>
ANA0	R20	R21
ANA1	R19	R34
ANA2	R6	R22
ANA3	R18	R35
ANA4	R51	R36
ANA5	R52	R49
ANA6	R53	R37
ANA7	R50	R38

Strip sockets spaced 0.400 inches (10.2 mm) apart accommodate the gain and bias resistors.



Z-World can install surface-mounted excitation, gain and bias resistors for your exact configuration in production quantities. For more information, call your Z-World Sales Representative at (530) 757-3737.

## 2. Select gain resistor.

The gain and bias resistors determine the input signal's voltage relative to ground as well as its range. For example, assume your circuit must handle an input signal voltage range of 10 V spanning -5 V to +5 V. You should first select the gain (feedback) resistor to suit an input signal voltage range of 10 V.

The gain of the amplifier is the ratio of its maximum output-voltage swing to your application's maximum input-voltage swing. The 2.5 V input-voltage range of the A/D chip limits the op-amp's output swing to 2.5 V. Therefore, Equation (3-1) expresses an amplifier's gain in terms of its input-voltage range.

$$g = \frac{2.5 \text{ V}}{V_{\text{IN}_{\text{max}}} - V_{\text{IN}_{\text{min}}}} \quad (3-1)$$

where  $g$  is the gain,  $V_{\text{IN}_{\text{max}}}$  is the maximum input voltage and  $V_{\text{IN}_{\text{min}}}$  is the minimum input voltage.

The ratio of the user-specified gain resistor  $R_{\text{gain}}$  to its associated fixed input resistor determines an amplifier's gain. For the amplifier in Figure 3-7 with its input resistor fixed at 10 k $\Omega$ , the gain is

$$g = \frac{R_{\text{gain}}}{10,000 \Omega} \quad (3-2)$$

Given an input voltage range of 10 V, this gain equation fixes the amplifier's gain at 0.25. This gain scales the input signal's range properly down to the op-amp's 2.5 V maximum output range.  $R_{\text{gain}}$  must therefore be 2500  $\Omega$ .

## 3. Determine bias resistor.

If the op-amp is to servo its output properly around the desired center voltage, you must establish the appropriate bias voltage at the op-amp's noninverting input. You must select the bias, or offset, resistor,  $R_{\text{bias}}$ , to position the input-voltage range correctly with respect to ground. For this example, let us use -5 V to +5 V.

Because the value for  $R_{\text{gain}}$  has already been selected, the maximum input voltage,  $V_{\text{INmax}}$ , determines the maximum voltage seen at the amplifier's summing junction (inverting input)—circuit nodes VR0– through VR7–. Compute VR0– through VR7– using Equation (3-3).

$$\text{VR0} = V_{\text{INmax}} \times \left( \frac{g}{1+g} \right) \quad (3-3)$$

For each op-amp, the bias voltage,  $V_{\text{bias}}$ , must equal its corresponding VRn–. A voltage divider, comprising a bias resistor and a fixed 10 k $\Omega$  resistor, derive the bias voltage from VREF+. Note that VREF+ is not necessarily the same as REF+. REF+ is the positive reference voltage the A/D chip uses.

VREF+ is 2.5 V and  $R_{\text{bias}}$  is

$$R_{\text{bias}} = \frac{V_{\text{bias}} \times 10,000 \Omega}{2.5 \text{ V} - V_{\text{bias}}} \quad (3-4)$$

Continuing the example for an input-voltage range that necessitates a gain of 0.25, and for which  $V_{\text{MAX}}$  is +5 V,  $V_{\text{bias}}$  is then 1.0 V. Therefore,  $R_{\text{bias}}$  is 6667  $\Omega$  in absolute mode.

Now suppose that the input range is 0 V to +10 V instead of –5 V to +5 V.  $V_{\text{max}}$  is now +10 V and  $V_{\text{bias}}$  becomes 2.0 V.  $R_{\text{bias}}$  is then 40 k $\Omega$ .

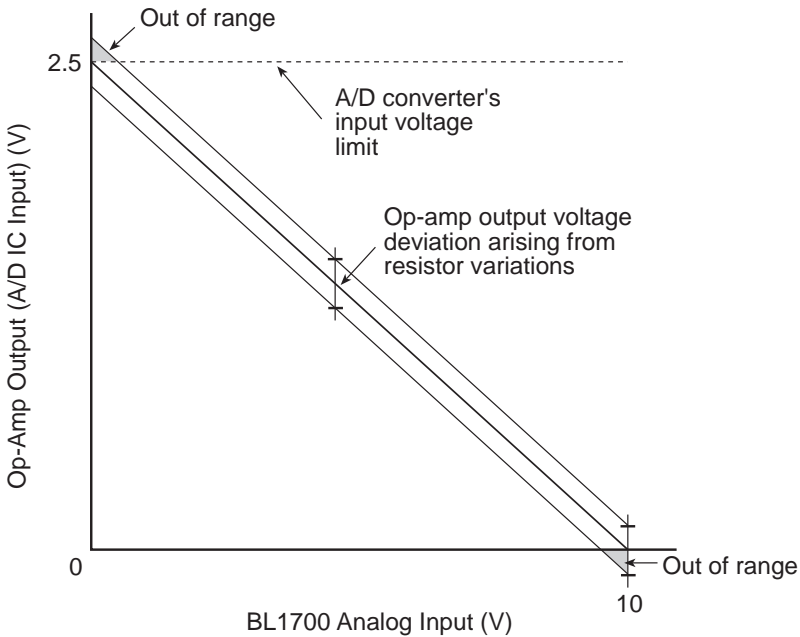
#### 4. Choose resistor values.

The calculated values, of course, will not always be available as standard resistor values. In these cases, use the nearest standard resistor value. For example, rather than 6667  $\Omega$ , use 6650  $\Omega$  if you are using 1% resistors, or use 6800  $\Omega$  if you are using 5% resistors.

#### 5. Bracket input range.

To be sure of accurately measuring signals at the extremes of an input range, you must be aware of the interaction between the 10 k $\Omega$  fixed resistors and the resistors you install. In the ideal case, if you were to measure a signal at the minimum input level, the A/D converter's input would be at the maximum expected value of 2.5 V.

However, in the real world, resistor values vary within their rated tolerance bands. Thus, if the fixed input resistor is lower than its nominal value, and the installed resistor is slightly higher than its nominal value, the actual input to the A/D converter would be greater than 2.5 V. A loss of accuracy then results because the A/D converter input would reach its maximum input value before the true signal input reaches the minimum expected input level, as shown in Figure 3-8.



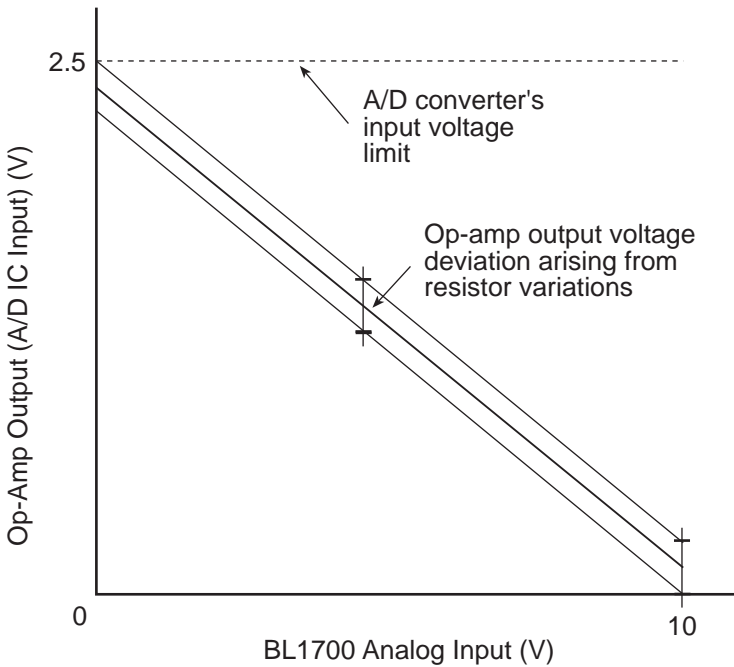
**Figure 3-8. Input Out of Range**

A deviation from nominal values in the bias network could skew the A/D converter's input voltage away from the theoretically computed value. For example, a small positive or negative deviation of the bias voltage arising from variances in the resistive divider would offset the A/D converter's input voltage. This offset would be positive or negative, tracking the deviation's sign, and would be equal to the bias deviation multiplied by the amplifier's gain plus one. Both of these effects could occur in the same circuit.

## 6. Pick proper tolerance.

Use care when compensating for any discrepancies discovered. For example, if you use standard 5% resistors, the values are spaced approximately 10% apart. If your gain is too high by just a small amount, then going to the next smallest standard 5% value could result in a drop in gain, and an A/D converter excursion approaching 10%. The same caveat applies to the bias network. Using 1% resistors allows a more precise choice of values.

Figure 3-9 illustrates the result of adjusting the resistor values so that the input signal to the A/D converter stays within its specified 2.5 V range.



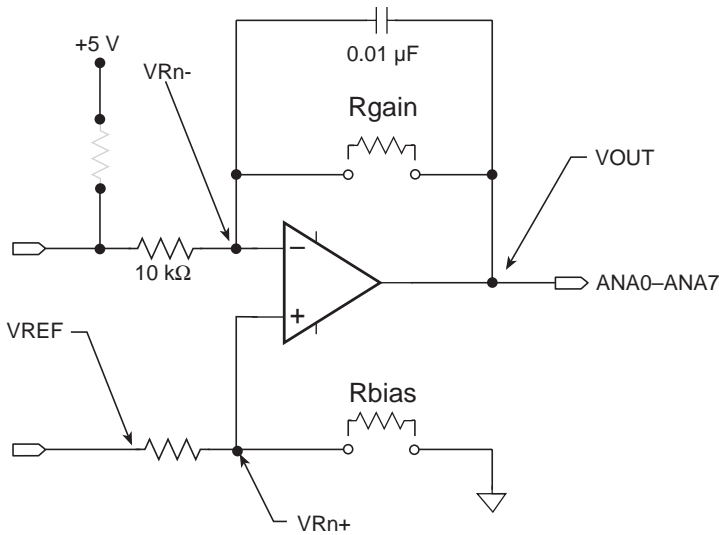
**Figure 3-9. Proper Input Range**

## 7. Confirm performance.

If your measurements are critical, check setups after installing resistors by measuring test signals at and near the input-voltage limits. See if the voltages fall within the A/D converter's input range or if accuracy is lost due to over-excursions at the A/D converter's input. Another method is to measure the resistance of the factory-installed fixed resistors before selecting your own resistors.

You can indirectly measure the fixed resistors after installation by measuring the voltages at the amplifiers' inputs and outputs. See Figure 3-10.





**Figure 3-10. Signal Conditioning Test Points**

Using Channel 0 as an example, ground the input A0 at pin 1 of H11. Then measure the voltages at VR0- and the amplifier's output. Because the currents through the input resistor and the feedback resistor are essentially identical, the ratio of the voltages across the resistors is equivalent to the ratio of the resistors. Therefore, the gain is

$$\text{gain} = \frac{V_{\text{OUT}} - V_{\text{R0-}}}{V_{\text{R0-}}} \quad (3-5)$$

Again using Channel 0 as an example, measure the voltage of VREF and the voltage at VR0+. Because the current into the op-amp input is negligible, the resistance ratio of the two resistors in the voltage divider alone determines VR0+. You can then compute the value of the fixed resistor in the divider once you know both the value of the resistor you installed and the value of VR0+.

## 8. Calibrate the BL1700 A/D converter.

Mathematically derived values provide good baseline gain values. Calibration is necessary because the inherent component-to-component variations of resistors can completely swamp the 0.25% resolution of the A/D converter. To achieve the highest accuracy possible, calibrate the BL1700.

Dynamic C provides a routine to compute calibration coefficients and store the coefficients in nonvolatile memory. The routine uses two reference points to compute the coefficients. Each reference point comprises a pair of values: the actual applied test voltage and raw converted A/D value (a 12-bit integer). The supplied Z-World A/D software will automatically use these calibration coefficients to correct all subsequent A/D readings.

The factory installed fixed resistors have a 1% tolerance.

Calibration constants for the factory installed resistors are stored in simulated EEPROM during testing.

## 9. Recalibrate the BL1700.

To recalibrate a BL1700, apply two known test voltages to each channel you plan to use. Get the converted reading for each test voltage and pass them, along with the test voltages, to the function `eiOBrdACalib` to calculate the conversion coefficients for that channel. `eiOBrdACalib` will automatically store the coefficients in the flash EPROM.

Sample program `BL17AIN.C` in the Dynamic C `SAMPLES` directory shows how to calibrate the conditioned analog input channels of a BL1700 manually, assuming test voltages of 1.00 V and 9.00 V.

### Drift

The AD680JT voltage reference displays a voltage drift of 10 ppm/°C (typ) to 30 ppm/°C (max). This drift corresponds to 25 mV/°C to 75 mV/°C, or 1.75 mV to 5.25 mV over the temperature range of 0°C to 70°C.

The LMC660C operational amplifier exhibits an offset-voltage drift of 1.3  $\mu\text{V}/^\circ\text{C}$  (typ), or 91 mV over the operating temperature range.

### Low-Pass Filter

The 0.01 mF feedback capacitors in the amplifier's feedback path transform the amplifiers into low-pass filters. These filters attenuate any high-frequency noise that may be present in your signal. These filters' characteristics depend on the resistors you select.

The 3 dB corner frequency of a filter is

$$f_{3\text{db}} = \frac{1}{2\pi \times R_g \times 0.01 \mu\text{F}} \quad (3-6)$$

For the case above with a gain of 0.25 using a 1% feedback resistor of 2490  $\Omega$ , the 3 dB corner frequency is 6392 Hz.

## Excitation Resistors

Some transducers require an excitation voltage. For example, a thermistor, serving as one leg of a voltage divider (having a fixed resistor in the other leg), measures temperature. The voltage at the divider's junction will vary with temperature. There is provision for excitation resistors to be installed on the inputs of the eight conditioned analog channels. The excitation resistors are tied to the +5 V analog supply.

## Using the Unconditioned Converter Channels

The eight conditioned channels use the first eight channels, AIN0–AIN7, of the A/D converter chip. Two additional channels are also available. You can access these channels with software by inserting your desired channel number in the library functions that control the BL1700. These signals are available on headers H8 and H11.

For optimum results, drive these channels with low output impedance voltage sources—less than 50  $\Omega$ . Op-amps are ideal for this purpose. High output impedance sources, on the other hand, are susceptible to coupled noise. In addition, only a low-impedance source can quickly charge the sampling capacitors within the A/D converter. When designing the signal sources to drive the extra channels, be sure to consider whether the amplifiers you choose can handle the capacitance of the cable that connects to the analog input connectors.

## Internal Test Voltages

In addition to the external input channels of the A/D converter chip, three additional internal channels exist to measure reference points within the A/D converter chip. Unfortunately, the A/D converter compares its internal nodes to REF+ and REF- so the conversions yield either all 1s or all 0s. You may access these channels using ordinary library routines by specifying the appropriate channel address when calling the functions.

**Table 3-8. Internal Test Voltages**

Channel	Internal Voltage Read
Channel 11	$(V_{REF+} - V_{REF-}) \div 2$
Channel 12	$V_{REF-}$
Channel 13	$V_{REF+}$

## Power-Down Mode

If you select Channel 14, the A/D converter chip enters a power-down mode in which all circuitry within the chip goes into a low-current, standby mode. Upon power-up and before the first conversion, the chip also goes into the power-down mode. The chip remains in the power-down mode until you select a channel other than 14. The normal operating current of the A/D converter chip is 1 mA to 2.5 mA. In power-down mode this consumption is reduced to 4  $\mu$ A to 25  $\mu$ A.

## External Connections

Connections to the analog inputs can be made with a ribbon cable, Z-World's FWT field wiring terminals, or a custom interface board. Z-World offers FWT modules for the digital inputs in three configurations.

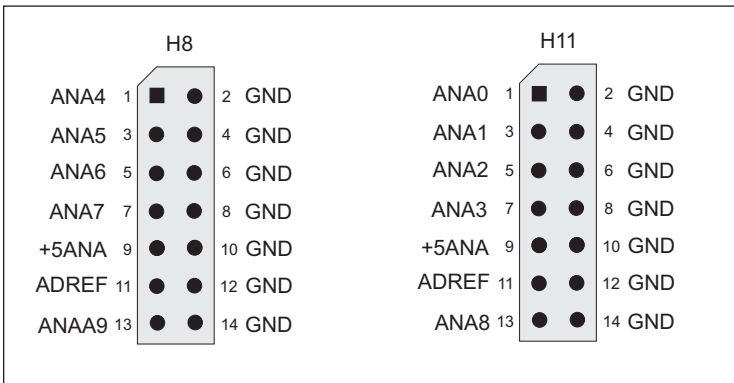
- Screw terminals (Z-World part number 101-0184).
- Removable screw terminals (Z-World part number 101-0185)

The FWT module mates with the BL1700's header pairs H8–H11.

Connections to the analog inputs are made on headers H8 and H11. The pinouts for headers H8 and H11 are shown in Figure 3-11.



See Appendix C, “Field Wiring Terminals and DIN Rails,” for FWT mechanical dimensions and pinouts.



**Figure 3-11. Pinouts for BL1700 Analog Input Headers H8 and H11**

## Serial Channels

Four serial channels are available on the BL1700. One channel, Channel 0, is a dedicated RS-232 communication channel. The other three are available in either RS-232 or RS-485 configurations. Channel 0 and Channel 1 are connected to the Z180's Serial Channel 0 and Serial Channel 1, respectively. Channel A and Channel B are controlled by the Serial Communications Controller (SCC) chip on the BL1700; these two ports also have hardware support for synchronous communication. Serial channel signals are routed to either RS-232 or RS-485 converters via configuration jumpers. Baud rates up to 57,600 bps are supported.

The BL1720 and BL1730 versions have two serial ports. The serial ports on the BL1720–BL1730 versions do not support synchronous communication.

Table 3-9 summarizes the operating modes for the four channels.

**Table 3-9. Serial Channel Configuration Options**

Channel	Configurations
Channel 0	Three-wire or five-wire RS-232 only
Channel 1	Two-wire RS-485 or three-wire RS-232
Channel A	Two-wire RS-485 or five-wire RS-232, plus DCD and DTR
Channel B	Two-wire RS-485 or five-wire RS-232

### Channel 0

Channel 0 is the BL1700's RS-232 programming port and is configured as three-wire or five-wire RS-232. Channel 0 cannot be reconfigured.

### Channel 1

Channel 1 is a general-purpose serial channel that can be configured as two-wire RS-485 or three-wire RS-232.

### Channel A

Channel A is a general-purpose serial channel controlled by a Zilog Serial Communication Controller (SCC) chip on the BL1700. Channel A can be configured as two-wire RS-485 or five-wire RS-232. When configured as RS-232, Channel A also provides DCD and DTR signals. Synchronous communication is possible on this channel, but is not supported by Dynamic C drivers at this time. Channel A is not available on the BL1720 or BL1730.

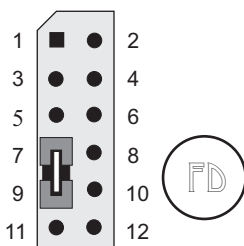
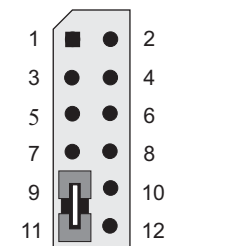
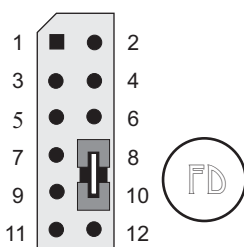
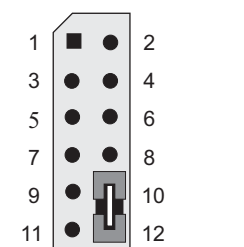
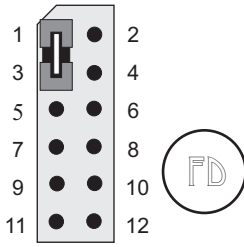
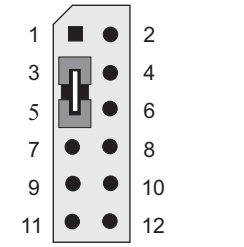
### Channel B

Channel B is a general-purpose serial channel. Along with Channel A, it is controlled by the Serial Communication Controller chip. Channel B can be configured as two-wire RS-485 or five-wire RS-232. Synchronous communication is possible on this channel, but is not supported by Dynamic C drivers at this time. Channel B is not available on the BL1720 or BL1730.

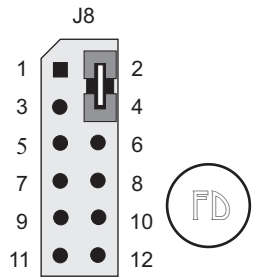
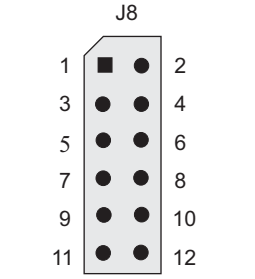
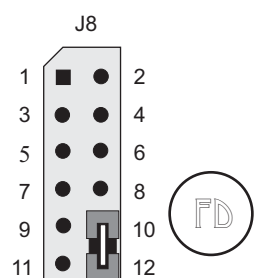
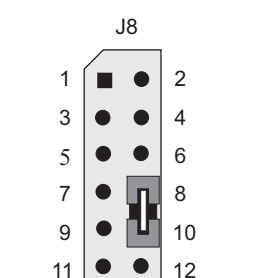
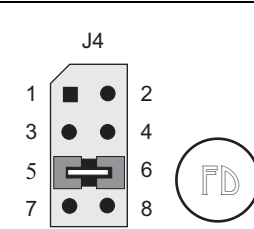
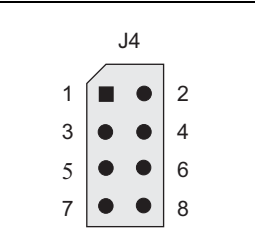
## Operating Modes and Configuration

Table 3-10 and Table 3-11 show the operating modes and jumper configurations for the serial channels on the BL1700.

**Table 3-10. Serial Channel Configuration Jumper Settings**

Channel	Jumper Settings	
	RS-232 Communication	RS-485 Communication
Channel 0	No jumper settings	
Channel 1	<p style="text-align: center;">J8</p>  <p style="text-align: center;">3-wire RS-232</p>	<p style="text-align: center;">J8</p>  <p style="text-align: center;">2-wire RS-485</p>
Channel A	<p style="text-align: center;">J2</p>  <p style="text-align: center;">5-wire RS-232 +DCD +DTR</p>	<p style="text-align: center;">J2</p>  <p style="text-align: center;">2-wire RS-485</p>
Channel B	<p style="text-align: center;">J8</p>  <p style="text-align: center;">5-wire RS-232</p>	<p style="text-align: center;">J8</p>  <p style="text-align: center;">2-wire RS-485</p>

**Table 3-11. Serial Channel Configuration Jumper Settings**

Channel	Jumper Settings	
	SCC Option	User Application Option
Channel A	 <p>/DREQ0 used for SCC Channel A</p>	 <p>/DREQ0 available for user application</p>
Channel B	 <p>/DREQ1 used for SCC Channel B</p>	 <p>/DREQ1 available for user application</p>
Channel A and Channel B	 <p>/INT0 used for serial communication on Channel A and Channel B</p>	 <p>/INT0 available for user application</p>

## **Configuring a Multidrop Network**

- Configure the serial channels that you wish to use for RS-485 communication.
- On all networked controllers, connect RS-485+ to RS-485+ and RS-485- to RS-485- using single twisted pair wires (nonstranded, tinned).



Refer to the Dynamic C manuals for more details on master-slave networking.

### **RS-485 Termination**

Termination and bias resistors are required in a multidrop network to minimize reflections (echoing), and to keep the network line active in an idle state. Typically, termination resistors are installed at the master node and the physical end node of an RS-485 network. Termination resistors are provided for Channel 1, Channel A, and Channel B configured as RS-485.

If you wish to configure a multidrop network, be sure to enable the 120  $\Omega$  termination resistors on both the master network controller and the “end” slave controller.

Figure 3-12 illustrates a multidrop network, and Table 3-12 provides the jumper settings to enable/disable the termination resistors.

### **External Connections**

Each serial channel has its own individual header for external connections. Both RS-232 and RS-485 signal lines for Channel 1, Channel A, and Channel B are brought out to a serial channel’s 10-pin header. Only one set of signals, RS-232 or RS-485, is active.

The three-wire RS-232 interface provides the following signals.

- RX
- TX
- GND

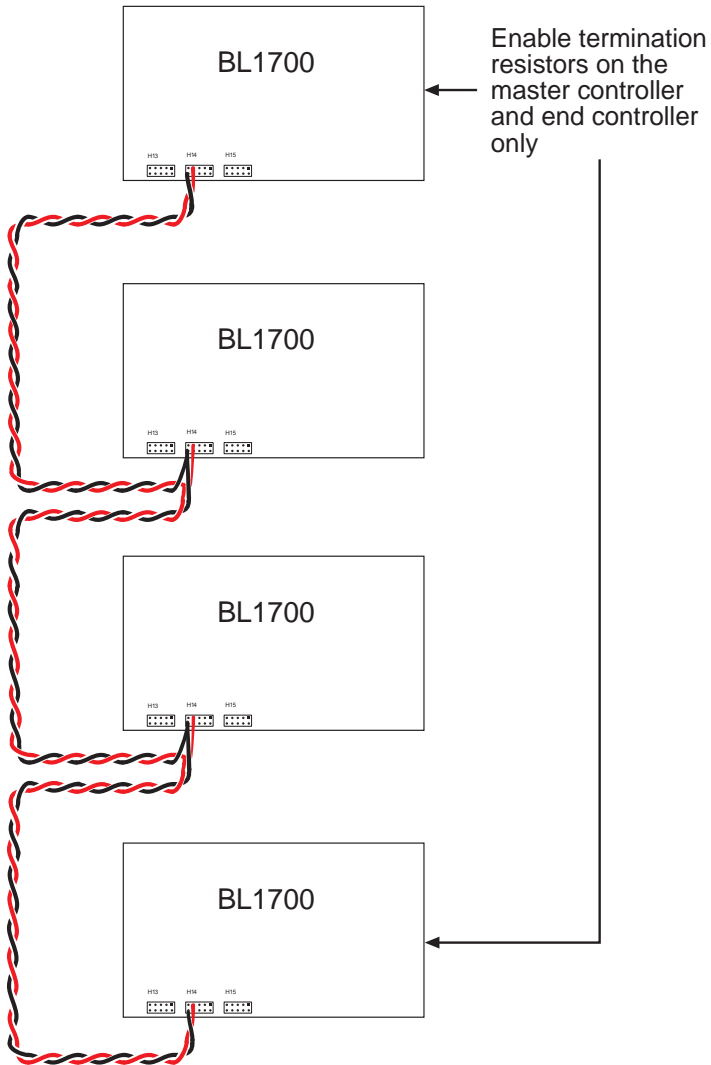
The five-wire RS-232 interface provides the following signals.

- RX
- TX
- RTS
- CTS
- GND

The two-wire RS-485 interface provides the following signals.

- RS-485+
- RS-485-





**Figure 3-12. Multidrop Network**

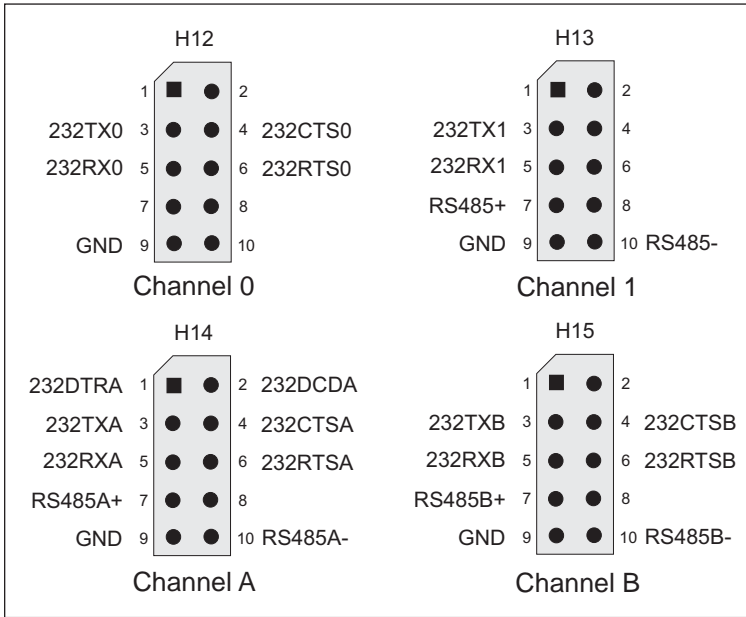


The RS-485 drivers supplied with the BL1700 support up to 32 nodes. The transmission bandwidth may be reduced as additional nodes over the benchmark quantity of 32 are added to the network. Contact Z-World Technical Support for assistance with large-scale network design.

**Table 3-12. Termination Resistor Jumper Settings**

Channel	Jumper Settings	
	Termination Resistors Enabled	Termination Resistors Disabled
Channel 0	No RS-485 available	
Channel 1	<p>J4</p> <p>1 2 3 4 5 6 7 8</p> <p>FD</p>	<p>J4</p> <p>1 2 3 4 5 6 7 8</p>
Channel A	<p>J7</p> <p>1 2 3 4 5 6 7 8</p> <p>FD</p>	<p>J7</p> <p>1 2 3 4 5 6 7 8</p>
Channel B	<p>J7</p> <p>1 2 3 4 5 6 7 8</p> <p>FD</p>	<p>J7</p> <p>1 2 3 4 5 6 7 8</p>

Connections to the serial channels are made via the 10-pin headers shown in Figure 3-13. The headers are standard vertical 0.025" square (0.635 mm square) posts on 0.100" (2.54 mm) centers.



**Figure 3-13. Pinouts of BL1700 Serial Communication Headers H12 through H15**

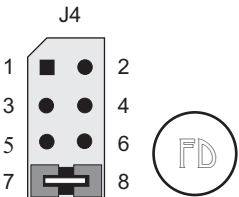
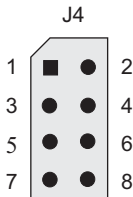
# PLCBus

The PLCBus provides easy I/O expansion for the BL1700. PLCBus expansion boards provide additional I/O capacity, A/D converters, D/A converters, serial channels, relay outputs, stepper motor controllers, and more. Expansion boards are connected to the BL1700 via a 26-conductor ribbon cable. Several PLCBus expansion boards may be daisy-chained to increase the I/O capacity further. Dynamic C provides easy to use software for all Z-World expansion boards.

## Operating Modes and Configuration

Some PLCBus expansion boards use the /AT line on the PLCBus. Jumpers on header J4 on the BL1700 determine whether the /INT1 signal is connected to the PLCBus /AT line, as shown in Table 3-13. If you intend to use a PLCBus expansion board that uses the /AT signal, make sure that a jumper is installed in the JP4:7-8 position. If you want to use the /INT1 signal for another external signal, and it is not needed for the PLCBus, then remove the jumper from the J4:7-8 position.

**Table 3-13. BL1700 PLCBus Jumper Settings**

/INT1 used as /AT on PLCBus	/INT1 external use only
 <p>The diagram shows an 8-pin header labeled J4. The pins are numbered 1 through 8. Pin 1 has a square symbol, and pin 2 has a circle symbol. Pins 3, 4, 5, and 6 each have a circle symbol. Pins 7 and 8 are connected by a jumper. To the right of the header is a circle containing the letters 'FD'.</p>	 <p>The diagram shows an 8-pin header labeled J4. The pins are numbered 1 through 8. Pin 1 has a square symbol, and pin 2 has a circle symbol. Pins 3, 4, 5, and 6 each have a circle symbol. Pins 7 and 8 are not connected by a jumper.</p>

## External Connections

J5 is the PLCBus connector on the BL1700. PLCBus devices are connected with ribbon cables on 26-pin connectors.



Refer to Appendix E, “PLCBus,” for more detailed information on the PLCBus and Z-World’s expansion boards.





## *CHAPTER 4: SOFTWARE DEVELOPMENT*

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Chapter 4 describes how to use the features of the BL1700 Series controller. The following major sections are included.

- Supplied Software
- Digital Inputs
- Digital Outputs
- PWM Outputs
- Analog Inputs
- Serial Channels
- LED
- Additional Software

# Supplied Software

Software drivers for controlling the BL1700's inputs/outputs are provided with Dynamic C. The library **EZIOBL17.LIB** provides drivers specific to the BL1700. In order to use **EZIOBL17.LIB** and other libraries, it is necessary to include the appropriate Dynamic C libraries. These libraries are listed in Table 4-1.

**Table 4-1. BL1700 Software Libraries**

Library	Application
<b>AASC.LIB</b>	All BL1700 serial communication applications
<b>AASCURT2.LIB</b>	XP8700 applications only
<b>EZIOBL17.LIB</b>	All BL1700 applications
<b>EZIOBBDV.LIB</b>	All expansion board applications
<b>EZIOPLC2.LIB</b>	All expansion board applications
<b>STEP2.LIB</b>	XP8800 applications only

Your application program can use these libraries by including them in your program. To include these libraries, use the **#use** directive as shown below.

```
#use eziobl17.lib
```



See the *Dynamic C Technical Reference* manual for more information on **#use** and other directives as well as other libraries.

## Digital Inputs

The BL1700 is equipped with protected digital inputs designed as logical data inputs that return a 1 when the input is high or 0 when the input is low.

A low-pass filter on each input channel has a time constant of:

$$T_{RC} = 220 \mu\text{s} (4.5 \text{ kHz}).$$

If the signals present on the digital inputs change states faster than this, the readings on the inputs may not be accurate.

### *How to Read the Input*

This section provides information on using the Dynamic C software drivers for the BL1700's protected digital inputs.

The following software drivers read the status of the protected digital inputs.

- **unsigned BankA( unsigned eioAddr )**
- **unsigned BankB( unsigned eioAddr )**

**BankA** converts **eioAddr** to a value of 16–31 for addressing the correct input or output assignments. **BankB** converts **eioAddr** to a value of 0–15.

PARAMETER: **eioAddr** specifies channel number from 0–15.

RETURN VALUE: the formatted I/O assignment, or –1 if the parameter **eioAddr** is out of range.

- **int eioBrdDI( unsigned eioAddr )**

Reads the state from one of the 32 physical digital inputs. Sets **eioErrorCode** if **eioAddr** is out of range.

PARAMETER: **eioAddr** specifies the input to be read. Valid numbers are from 0 to 31. 0–15 represents Bank B. 16–31 represents Bank A.

RETURN VALUE: 0 if input reads low, 1 if input reads high.



- **unsigned inport( unsigned port )**

Reads a value from an I/O port.

PARAMETER 1: **port** is the BL1700 port address to read. When used to read the digital inputs, **port** is one of four groups of eight inputs. There are two groups of eight inputs for each bank.

RETURN VALUE: The value read from the port.

Table 4-2 lists the addresses and corresponding headers of the digital input ports on the BL1700.

**Table 4-2. Digital Input Addresses**

Bank	Bank B		Bank A	
Header	H10	H7	H6	H9
Channels	HVB00–HVB07	HVB08–HVB15	HVA08–HVA15	HVA00–HVA07
Physical Channels	0–7	8–15	24–31	16–23
Address	0x4040	0x4041	0x4042	0x4043



The factory default is for Bank A to be configured for digital inputs.

The lower eight bits of the value read back by the inport function represent the status of the inputs. Bit 0 represents inputs 0, 8, 16, or 24, depending on which address is read. Bit 1 represents inputs 1, 9, 17, or 25, and so forth.

### **Sample Program**

The sample program **BL17DIO.C** shows how to use the digital I/O. It can be found in the Dynamic C **SAMPLES\BL17XX** subdirectory.

## Digital Outputs

The BL1700 provides up to 32 high-voltage, high-current driver outputs. Some outputs can also function as pulse width modulated (PWM) outputs. This section provides information on the Dynamic C software drivers for the BL1700's high-voltage driver outputs.

The following software function turns a specified high-voltage driver ON or OFF.

- **unsigned BankA( unsigned eioAddr )**
- **unsigned BankB( unsigned eioAddr )**

**BankA** converts **eioAddr** to a value of 16–31 for addressing the correct input or output assignments. **BankB** converts **eioAddr** to a value of 0–15.

PARAMETER: **eioAddr** specifies channel number from 0–15.

RETURN VALUE: the formatted I/O assignment, or -1 if the parameter **eioAddr** is out of range.

- **int eioBrdDO( unsigned eioAddr, char state )**

Sets the state of a digital output. Sets **eioErrorCode** if parameter **eioAddr** is out of range.

PARAMETERS: **eioAddr** specifies the output to be set. Valid numbers are from 0 to 31. 0–15 represents Bank B. 16–31 represents Bank A.

**state** is the desired output state for the specified output. A non-zero value turns the output on. A zero turns the output off.

RETURN VALUE: Returns 0 if successful, -1 if **eioAddr** is out of range.

- **void output( unsigned port, unsigned value )**

Writes data to an I/O port.

PARAMETERS: **port** is the BL1700 port address to be written. When used to write to the digital outputs, **port** is one of four groups of eight outputs. There are two groups of eight outputs for each bank.

**value** is the data to be written to the port. When used to write to the digital outputs, data bits D3, D2, and D1 determine which output in a group is selected. Data bit D0 determines the state of the output. Data bits D7 through D4 are unused.

Table 4-3 shows the address and data values used with the **output** function for writing to the digital outputs.

**Table 4-3. Digital Output Addresses**

Bank B HVB00–HVB15		Address	OFF data	ON data	Bank A HVA00–HVA15		Address	OFF data	ON data
H10	0	0x4100	0	1	H9	16	0x4110	0	1
	1	0x4100	2	3		17	0x4110	2	3
	2	0x4100	4	5		18	0x4110	4	5
	3	0x4100	6	7		19	0x4110	6	7
	4	0x4100	8	9		20	0x4110	8	9
	5	0x4100	10	11		21	0x4110	10	11
	6	0x4100	12	13		22	0x4110	12	13
	7	0x4100	14	15		23	0x4110	14	15
H7	8	0x4108	0	1	H6	24	0x4118	0	1
	9	0x4108	2	3		25	0x4118	2	3
	10	0x4108	4	5		26	0x4118	4	5
	11	0x4108	6	7		27	0x4118	6	7
	12	0x4108	8	9		28	0x4118	8	9
	13	0x4108	10	11		29	0x4118	10	11
	14	0x4108	12	13		30	0x4118	12	13
	15	0x4108	14	15		31	0x4118	14	15



The factory default is for Bank B to be configured for digital outputs.

### Sample Program

The sample program **BL17DIO.C** shows how to use the digital I/O. It can be found in the Dynamic C **SAMPLES\BL17XX** subdirectory.

## Pulse-Width Modulated (PWM) Outputs

Digital outputs 0–6 on Bank B can produce fixed-frequency, pulse-width modulated (PWM) signals. When these outputs are being used for PWM operation, Channel 7 is used by software to support PWM and cannot be used for your application.

The periods of the PWM signals are fixed at 13.3 ms (75 Hz), with a resolution of 256 divisions per period (8-bit resolution). Using the supplied software, generating PWM signals consumes about 8% of controller's processing power.

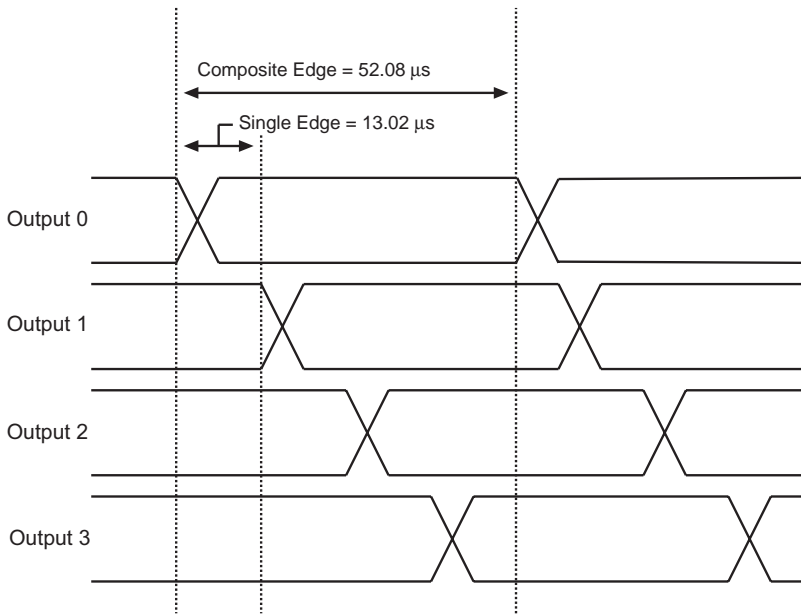


When PWM functions are used, serial communication baud rates may be affected because of an overloading of the microprocessor's resources. In addition, serial data rates become limited and fixed at 4800 bps for Serial Port 1. Be sure to reset the Dynamic C baud rates to 4800 bps.

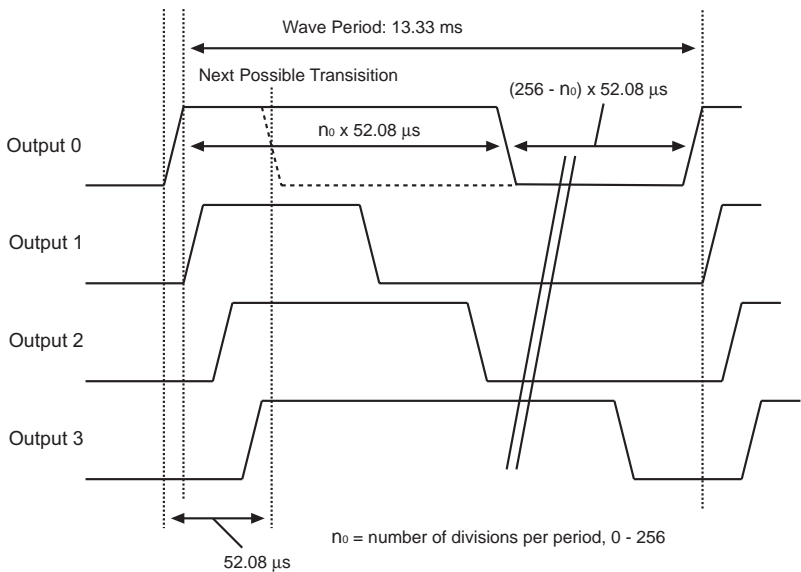
Contact Z-World Technical Support at (530)757-3737 for further assistance with PWM functions.

### ***How to Use the PWM Feature***

The BL1700 can produce fixed-frequency, fixed-phase, variable-duty-cycle square waves from up to seven of its outputs. Figure 4-1 and Figure 4-2 show PWM transition and DMA timing.



**Figure 4-1. Transition Timing**



**Figure 4-2. DMA Timing**

Notice that each square wave's period is exactly 1024 "divisions." One division equals 120 clock cycles ( $120/9.216 \text{ MHz} = 13.02 \mu\text{s}$ ) for the PWM function. Consequently, the period of each square wave is  $1024 \times 13.02 \mu\text{s} = 13.33 \text{ ms}$ .

Notice also that the square waves are displaced slightly from each other in phase. That is, output 1s output starts and ends one division after output 0s, output 2s one division after output 1s, and output 3s one division after output 2s. As a result, although the period of each wave is 1024 divisions, a change to one particular channel is possibly only every 4 divisions. Therefore, the resolution of the transition edge in the wave is  $1/256$ .

### **PWM Software**

The supplied software provides two levels of support. The first level provides easy-to-use fixed PWM functions for only four of the outputs (outputs 0–3). The periods of the PWM signals are fixed at 13.3 ms (75 Hz), with a resolution of 256 division per period (8-bit resolution). Using the supplied software, generating PWM signals consumes about 8% of the controller's processing power. The second PWM support level allows you to create custom PWM functions for seven of the outputs (outputs 0–6).

The following three functions are the first level functions. They are designed for ease of use. These functions are located in **EZIODPWM.LIB** that is automatically included when **EZIOBL17.LIB** is included.

- **int eioBrdAO( unsigned eioAddr, unsigned state )**

Specifies the duty cycle for a particular output channel. Set **eioErrorCode** if **eioAddr** is out of range.

PARAMETERS: **eioAddr** is a number ranging from 0 to 3.

**state** is a placeholder for a number ranging from 0 (to turn off the channel) to 256 (to turn-on the channel, 100% duty cycle). The duty cycle is  $\text{state}/256$  (e.g., 128 for 50% duty cycle, 64 for 25% duty cycle).

RETURN VALUE: 0 if successful, -1 if not.



The PWM functions use the Z180's built-in DMA hardware. The use of DMA-driven PWM limits the communication speed of the Z180's Serial Port 1 to 4800 bps. In addition, the Z180 effectively runs at least 8% more slowly.

Be sure your application calls `_eioBrdAORf` at least every 25 ms to refresh the drivers' period.

Contact Z-World Technical Support at (530)757-3737 for further assistance with PWM functions.

- **void \_eioSetupA01st ()**

Initializes the PWM hardware.

`_eioSetupA01st` must be called before using `eioBrdAO`.

- **int \_eioBrdAORf ()**

Refreshes the DMA counter and address pointer.

Your program must call it every 25 ms (or more frequently) after `_eioSetupA01st` is called.

RETURN VALUE: The function returns -1 if the DMA count is zero (PWM has stopped), and returns 0 otherwise. If the function returns -1, the driver is either not initialized (by calling `_eioSetupA01st`), or `_eioBrdAORf` is not called at least every 25 ms.

## **Sample Program**

**BL17PWM4.C** is a sample program that shows how to use the pulse width modulation feature using the functions listed above. It can be found in the Dynamic C directory under **SAMPLES\BL17XX**.

## Analog Inputs

The BL1700's analog inputs provide an easy-to-use interface to a wide variety of sensors and transducers. The BL1700 provides 10 single-ended A/D conversion channels with 12-bit resolution.

### Using the Analog Inputs

The factory calibrates each BL1700, storing each unit's individual zero offset and actual gain for its eight primary channels in simulated EEPROM. Your application can use library functions to access the simulated EEPROM's calibration constants to correct measurements for offset and gain error.

- **void eioBrdInit( int flags )**

Initializes the analog-to-digital converter to the default output mode. The default mode is unipolar input, 12-bit data length, most significant bit first.

PARAMETER: **flags** is not used at this level and should be set to 0.



Call **eioBrdInit** before calling **eioBrdAI**.

- **int eioBrdAI( unsigned eioAddr )**

Reads one of the 10 voltage inputs and performs analog-to-digital conversion. Sets **eioErrorCode** if **eioAddr** is out of range.

PARAMETER: **eioAddr** specifies an input number of 0 to 9 or 16 to 25 to be read. **eioAddr** values 0 through 9 represent analog inputs 0 through 9, and will cause the function to return the voltage read on an input. **eioAddr** values 16 through 25 also represent analog inputs 0 through 9, but cause the function to return a 12-bit raw data value for the analog input.

RETURN VALUE: The function returns the voltage read as a real number in a floating-point representation for **eioAddr** values 0–9 if the read is successful. For **eioAddr** values 16–25, if the read is successful, the function returns a floating-point representation of an unsigned integer value (0–4095) for the 12-bit raw data value read from the A/D converter.



- `int eioBrdAdcMode( int datalen, int dataformat, int polarformat )`

Sets the analog-to-digital conversion data length, data format, and polarity format other than default. Call this function after `eioBrdInit` and before `eioBrdAI`.

RETURN VALUE: returns 1 if successful, -1 if an invalid parameter is passed to the function.



Call `eioBrdAdcMode` after calling `eioBrdInit` and before calling `eioBrdAI`.

Table 4-4 shows the parameters `datalen`, `dataformat`, and `polarformat`.

**Table 4-4. Analog-to-Digital Converter Modes**

Parameter	Value
<code>datalen</code>	0 – 12-bit data length 1 – 8-bit data length 2 – 12-bit data length 3 – 16-bit data length
<code>dataformat</code>	0 – most significant bit first 1 – least significant bit first
<code>polarformat</code>	0 – unipolar 1 – bipolar

- `int eioBrdACalib( int eioAddr, unsigned d1, unsigned d2, float v1, float v2 )`

Calculates the calibration constants for an analog input channel using two known voltages and two corresponding raw data readings. Stores the calibration constants in EEPROM.

PARAMETERS: **eioAddr** is the analog input channel.

**d1** is the raw data corresponding to **v1**.

**d2** is the raw data corresponding to **v2**.

**v1** is the known voltage used to obtain **d1**.

**v2** is the known voltage used to obtain **d2**.

RETURN VALUE: 0 if successful, -1 if **eioAddr** is out of range.



Since the BL1700 is calibrated at the factory, it is only necessary to use this function to recalibrate the BL1700.

### **Sample Program**

**BL17AIN.C** is a sample program that shows how to use the analog inputs. It can be found in the Dynamic C directory under **SAMPLES\BL17XX**.

## Serial Channels

The BL1700 and BL1710 provide four serial communication channels. Three of the ports can be configured as RS-232 or RS-485. This section provides information on RS-232 and RS-485 communications.

The BL1720 and BL1730 have only two serial communication channels. One of these channels is a dedicated RS-232 channel, the other is configurable as either RS-232 or RS-485.



Chapter 3, “BL1700 Hardware,” provides information on configuring the serial channels.

### **RS-232 Communication**

The RS-232 channels and the supplied Dynamic C software allows the BL1700 to communicate with other computers or controllers. By adding a modem, remote communications can be achieved (including remote downloading) using the X-modem protocol. Examples of RS-232 software drivers can be found in the Dynamic C `\SAMPLES\AASC` directory.



Refer to your Dynamic C manuals for additional information on remote downloading.

Use the optional Z-World SIB2 if you need to make all of the serial channels available to your application during software development.



See Chapter 2, “Getting Started,” and Appendix D, “Serial Interface Board 2,” for more information.

### **RS-485 Communication**

The BL1700 can be configured to provide up to three channels of RS-485 communications. RS-485 is an asynchronous multi-drop half-duplex standard that provides multi-drop networking with maximum cable lengths up to 4000 feet.

Dynamic C provides library functions for master-slave two-wire half-duplex RS-485 9th-bit binary communications.

This RS-485 hardware standard supports up to 32 controllers on one network. The supplied software supports 1 master unit, plus up to 255 slave units (which may consist of any combination of Z-World controllers that support the RS-485 protocol).

## Software

Serial channels 0 and 1 are available on all versions of the BL1700. These serial channels are supported by Dynamic C library functions.

Serial channels A and B are driven by U13 (a Zilog Serial Communication Controller). The BL1720 and BL1730 do not have this chip installed, therefore, channels A and B are not supported on the BL1720 or BL1730. Serial channels A and B have additional capabilities beyond those supported by the Dynamic C libraries. If you would like to use these additional capabilities, refer to the Zilog *Serial Communication Controllers Manual*.



Comprehensive information on the serial channel software and programming can be found in the *Dynamic C Function Reference* manual and the *Dynamic C Application Frameworks* manual.

The following functions are used with the RS-485 serial channels on the BL1700.

- **int sccSw485( unsigned channel, unsigned state )**

Enables or disables the RS-485 drivers for Channel A or Channel B on the SCC.

PARAMETERS: **channel** is **SCC\_A** or **SCC\_B**.

**state** is 1 to enable the driver, 0 to disable it.

RETURN VALUE: 0 if **channel** is valid, -1 if not.

- **int z1Sw485( unsigned state )**

Enables or disables the RS-485 driver for Channel 1.

PARAMETER: **state** is 1 to enable the driver, 0 to disable it.

RETURN VALUE: 0 if **channel** is valid.

## Sample Program

**BL17SCC.C** is a serial communication sample program found in the Dynamic C **SAMPLES\BL17XX** directory.

## LED

LED D2 is a general-purpose device that can be turned on and off under software control by using this function.

- **int switchLED( unsigned state )**

Turns LED D2 on or off.

PARAMETER: **state** is 1 to turn the LED on, 0 to turn it off.

RETURN VALUE: 0 if **state** is valid, -1 otherwise.

## Additional Software

- For real-time clock information, refer to descriptions of functions **tm\_rd** and **tm\_wr** in your Dynamic C manuals.
- For watchdog information, refer to descriptions of the function **hitwd** in your Dynamic C manuals.
- For simulated EEPROM information, refer to descriptions of the functions **ee\_rd** and **ee\_wr** in Appendix G.
- For power failure flag information, refer to the descriptions of the function **\_sysIsPwrFail** and **sysIsPwrFail** in your Dynamic C manuals.
- For resetting the board information, refer to descriptions of the functions **sysForceSupRst**, **sysIsSuperReset**, **\_sysIsSuperReset**, **sysForceReset**, **\_sysIsWDTO**, and **sysIsWDTO** in your Dynamic C manuals.



## *APPENDIX A: TROUBLESHOOTING*

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Appendix A provides procedures for troubleshooting system hardware and software. The following sections are included.

- Out of the Box
- Dynamic C Will Not Start
- Finding the Correct COM Port and Baud Rate
- BL1700 Resets Repeatedly
- Troubleshooting Software

## Out of the Box

Check the items listed below before starting development. Rechecking may help to solve problems found during development.

- Do not connect any boards with PLCBus, RS-485 or any other I/O devices until you verify that the BL1700 runs standalone.
- Verify that your entire system has a good, low-impedance ground. The BL1700 is often connected between the PC and some other device. Any differences in ground potential from unit to unit can cause serious, hard-to-diagnose problems.
- Double-check the connecting cables.
- Verify that your PC's COM port actually works. Try connecting a known-good serial device to your COM port. Remember that on a PC COM1/COM3 and COM2/COM4 share interrupts. User shells and mouse software, particularly, often interfere with proper COM-port operation. For example, a mouse running on COM1 can preclude your running Dynamic C on COM3, unless the interrupt is changed.
- Use the supplied Z-World power supply. If you must use your own power supply, verify that it has enough capacity to support the BL1700 and is adequately filtered.
- Use the supplied Z-World cables. The most common fault of home-made cables is their failure to properly assert CTS at the RS-232 port of the BL1700. Without CTS's being asserted, the BL1700's RS-232 port will not transmit. You can assert CTS by either connecting the RTS signal of the PC's COM port or looping back the BL1700's RTS.
- Experiment with each peripheral device you connect to your BL1700 to determine how it appears to the BL1700 when it is powered up, powered down, when its connecting wiring is open, and when its connecting wiring is shorted.

## LCD Connected to BL1700 Does Not Work

Under extreme conditions, some LCDs connected to a BL1700 via the PLCBus may fail to function. The main reason for this is that the 18.432 MHz clock speed of the BL1700 is too fast for the LCD connected via the PLCBus port. The easiest software solution is to add a line to the application to slow down the clock speed, but this will impact other functions such as the serial rate and the PRT timer that depend on the clock speed. If a 9.216 MHz clock speed is adequate, then the BL1700 is available with a CM7210 core module, which features a 9.216 MHz clock.



The BL1730 comes with a CM7210 core module, but only has two serial ports.

## Dynamic C Will Not Start

If Dynamic C will not start, an error message on the Dynamic C screen (for example, **Target Not Responding** or **Communication Error**), announces a communication failure.

You could have one or more of the following problems in series:

- You have selected the wrong COM port.
- You need to reset the BL1700 (press reset switch SW1).
- You have not connected the wiring properly.

The first thing to check is the hardware and software setup of your PC's COM port. Areas to check are listed below.

- Ensure that all wiring and cables are connected properly.
- Ensure that you have selected the proper COM port.

Most PCs have at least two COM ports (COM1 and COM2), while some computers have additional COM ports. Sometimes a PC assigns COM1 or COM2 to an internal modem, leaving the other COM port available on the back of the PC.



Some PCs have special programs to reconfigure their port assignments. You may need to run such a program to make a given COM port appear at an external back panel “D” connector.

Repeat the following procedure until you find a COM port that works with Dynamic C and your BL1700.

1. Use the Serial command of Dynamic C's **Options** menu to try a different COM port.
2. Reset the BL1700 by pressing reset switch SW1.
3. Select **Reset Target** from the **Run** menu. Dynamic C tries to establish communication again.



## BL1700 Resets Repeatedly

If the program fails to hit the watchdog timer periodically, the watchdog timer causes a reset every 1.0 second. When you debug a program using the Dynamic C debugger, Dynamic C hits the watchdog timer. If your program does not hit the watchdog timer, then you will have trouble running your program in standalone mode. (To hit the watchdog, make a call to the Dynamic C library function `hitwd`).

- **Dynamic C loses link with application program**

If your program disables interrupts for a more than 50 ms, Dynamic C may lose its link with the BL1700.

## Troubleshooting Software

**Symptom:** The DMA-driven PWM correctly drives the output for a while, then suddenly some channels remain ON, others remain off.

**Cause:** Most likely, the function `_eioBrdAORf ()` is not called frequently enough.

**Resolution:** There are three possible solutions. One is to increase the frequency of calling `_eioBrdAORf ()`, the other is to increase the size of the waveform pattern buffer. The third solution is to slow down the clock **CKA1**.



Refer to the section “PWM Addressing Detail” in Appendix F, “Advanced Programming,” for more details.



## *APPENDIX B: SPECIFICATIONS*

---

Appendix B provides comprehensive BL1700 physical, electronic and environmental specifications.

## Electronic and Mechanical Specifications

Table B-1 lists the electronic, mechanical, and environmental specifications for the BL1700.

**Table B-1. BL1700 General Specifications**

Parameter	Specification
Board Size	4.20" × 6.25" × 0.85" (107 mm × 159 mm × 21.6 mm)
Operating Temperature	-40°C to 70°C
Humidity	5% to 95%, noncondensing
Power	15 V DC to 30 V DC, 140 mA
Digital Inputs	16 standard, up to 32 possible at expense of outputs
Digital Outputs	16 standard, up to 32 possible at expense of inputs
Analog Inputs	Ten 12-bit channels: <ul style="list-style-type: none"> <li>• 8 conditioned, factory configured 0 V to 10 V</li> <li>• 2 unconditioned, 0 V to 2.5 V</li> </ul>
Analog Outputs	Pulse-width modulated, on digital output lines
Resistance Measurement Input	No
Processor	Z180
Clock	18.432 MHz standard
SRAM	32K standard, supports up to 512K
Flash EPROM	128K standard, supports up to 256K, up to 512K EPROM possible
Serial Ports	<ul style="list-style-type: none"> <li>• 1 full-duplex RS-232</li> <li>• 3 configurable as full-duplex RS-232 or as RS-485</li> </ul>
Serial Rate	Up to 57,600 bps
Watchdog	Yes
Time/Date Clock	Yes
Backup Battery	Panasonic BR2325-1HG 3 V DC lithium ion, rated life 190 mA·h

## BL1700 Mechanical Dimensions

Figure B-1 shows the mechanical dimensions for the BL1700.

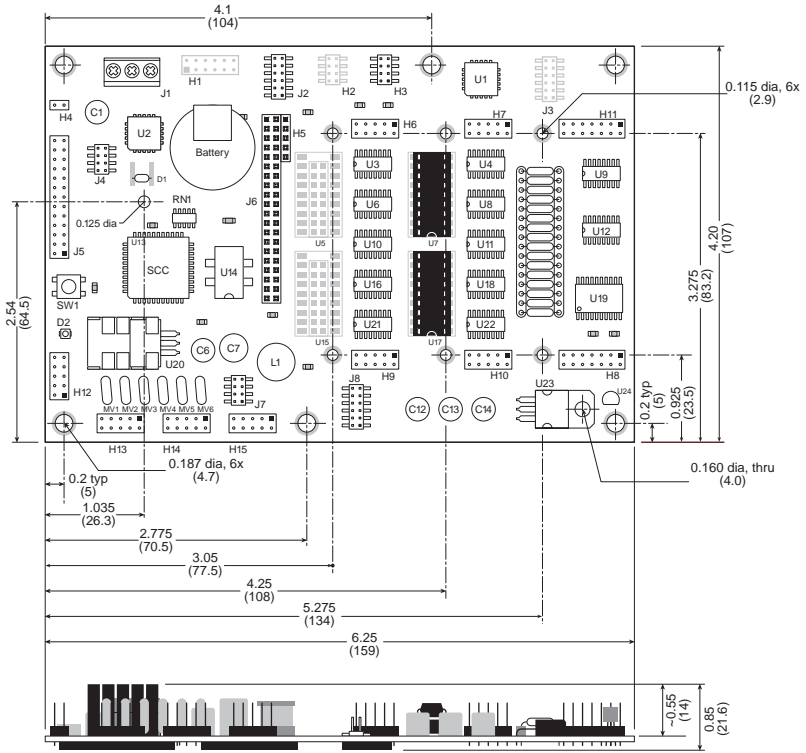


Figure B-1. BL1700 Dimensions



The dimensions shown above include the CM7200 that is part of the BL1700. With the tallest field-wiring terminal (FWT-Opto) attached, the height of the BL1700 assembly becomes 1.35" (34.3 mm).

## Header and Jumper Information

Table B-2 lists the header functions for the input/output and serial communication headers. The header locations are shown in Figure B-2.

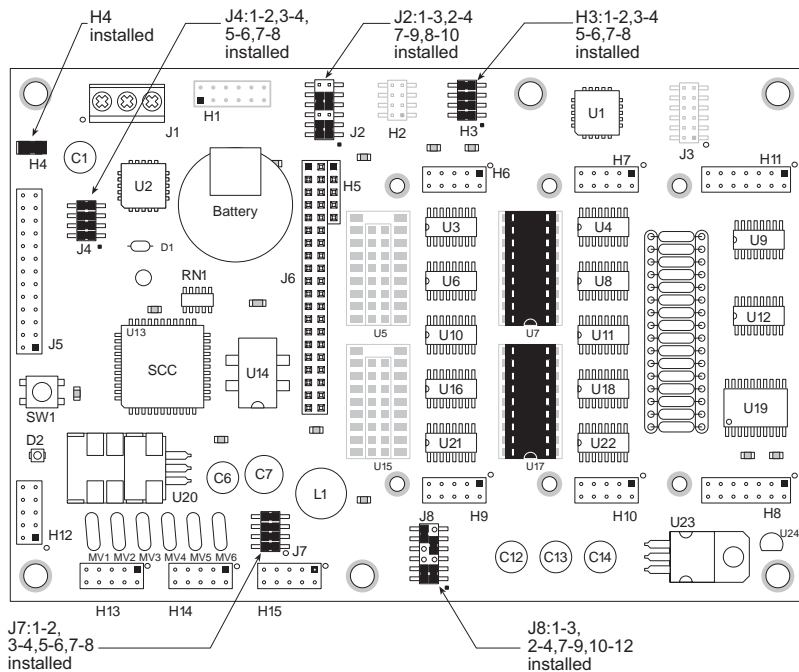
**Table B-2. BL1700 Header Functions**

Header	Function
H1	Serial communication and interrupts (optional)
H6	Digital input/output
H7	Digital input/output
H8	Analog input
H9	Digital input/output
H10	Digital input/output
H11	Analog input
H12	Channel 0 RS-232 serial communication port
H13	Channel 1 RS-232/RS-485 serial communication port
H14	Channel A RS-232/RS-485 serial communication port
H15	Channel B RS-232/RS-485 serial communication port
J1	Power input
J5	PLCBus

Table B-3 provides the relevant pin 1 locations for these headers.

**Table B-3. BL1700 Pin 1 Locations  
(in inches)**

Header	Location
H1	1.5, 3.95
H6	3.7, 3.375
H7	4.9, 3.375
H8	6.1, 3.375
H9	3.7, 0.925
H10	4.9, 0.925
H11	6.1, 0.925
H12	0.2, 0.5
H13	1.0, 0.25
H14	1.7, 0.25
H15	2.4, 0.25
J5	0.2, 2.015



**Figure B-2. BL1700 Headers and Factory Default Jumper Configurations**

Table B-4 lists the jumper configurations for the BL1700 configurable headers.

**Table B-4. Standard BL1700 Jumper Settings**

Header	Pins	Description	Factory Default
H3	1–2 3–4	Connect for HVB00–HVB07 sinking output	Connected
	1–3 4–4	Connect for HVB00–HVB07 sourcing output	
	5–6 7–8	Connect for HVB08–HVB15 sinking output	Connected
	5–7 6–8	Connect for HVB08–HVB15 sourcing output	
H4	1–2	Connected for Program Mode, disconnected for Run Mode	Connected

continued...

**Table B-4. Standard BL1700 Jumper Settings (continued)**

Header	Pins	Description	Factory Default
J2	1-3	Connect for HVA08-HVA11 inputs pulled up	Connected
	3-5	Connect for HVA08-HVA11 inputs pulled down	
	2-4	Connect for HVA12-HVA15 inputs pulled up	Connected
	4-6	Connect for HVA12-HVA15 inputs pulled down	
	7-9	Connect for HVA00-HVA07 inputs pulled up	Connected
	9-11	Connect for HVA00-HVA07 inputs pulled down	
	8-10	Connect for 5-wire RS-232, DCD and DTR	Connected
	10-12	Connect for 2-wire RS-232	
J4	1-2 3-4	Connect to enable RS-485 termination resistors for Channel 1	Connected
	5-6	Connect for /INT0 serial communication on Channel A and Channel B, disconnect to allow /INT0 for user application	Connected
	7-8	Connect to allow /INT1 to be used as /AT on PLCBus, disconnect for /INT1 external use only	Connected
J7	1-2 3-4	Connect to enable RS-485 termination resistors for Channel A	Connected
	5-6 7-8	Connect to enable RS-485 termination resistors for Channel B	Connected

continued...

**Table B-4. Standard BL1700 Jumper Settings (concluded)**

Header	Pins	Description	Factory Default
J8	1-3	Connect to enable 5-wire RS-232 on Channel B	Connected
	3-5	Connect to enable 2-wire RS-485 for Channel B	Connected
	2-4	Connect to allow /DREQ0 to be used for Channel A	Connected
	4-6	Connect to allow /DREQ0 to be used for PWM, disconnect for user application	
	2, 4, 6	Disconnected, /DREQ0 available for user application	
	7-9	Connect for 3-wire RS-232 on Channel 1	Connected
	9-11	Connect for 2-wire RS-485 on Channel 1	
	10-12	Connect to allow /DREQ1 to be used for Channel B	Connected
	8-10	Connect to allow user application for Channel B	



Table B-5 lists the jumper settings for optional BL1700 configurations. These optional configurations involve adding or removing input interface or high-voltage driver ICs, which are surface-mounted. This work is most easily done in the factory in response to customer needs.

**Table B-5. BL1700 Jumper Settings for Optional Inputs/Outputs**

Header	Pins	Description
<b>Bank A Digital Outputs</b>		
H2	1-2 3-4	Connect for HVA00–HVA07 sinking output
	1-3 4-4	Connect for HVA00–HVA07 sourcing output
	5-6 7-8	Connect for HVA08–HVA15 sinking output
	5-7 6-8	Connect for HVA08–HVA15 sourcing output
<b>Bank B Digital Inputs</b>		
J3	1-3	Connect for HVB0–HVB03 inputs pulled up
	3-5	Connect for HVB00–HVB03 inputs pulled down
	2-4	Connect for HVB04–HVB07 inputs pulled up
	4-6	Connect for HVB04–HVB07 inputs pulled down
	7-9	Connect for HVB08–HVB15 inputs pulled up
	9-11	Connect for HVB08–HVB15 inputs pulled down



For ordering information, or for more details about the various options and prices, call your Z-World Sales Representative at (530) 757-3737.

# Protected Digital Inputs

Table B-6 lists the specifications for the protected digital inputs.

**Table B-6. BL1700 Protected Digital Input Specifications**

Protected Digital Inputs	Absolute Maximum Rating
Input Voltage	-20 V DC to +24 V DC, protected against spikes to $\pm 48$ V
Logic Threshold	2.5 V
Input Current	-15 mA to +15 mA
Leakage Current	5 $\mu$ A
Noise/Spike Filter	Low-pass filter, RC time constant 220 $\mu$ s
Frequency Response (worst case)	<ul style="list-style-type: none"><li>• Faster than 656 Hz</li><li>• Not slower than 1.52 ms (input at 5 V DC)</li></ul>

## Frequency Response for the Protected Inputs

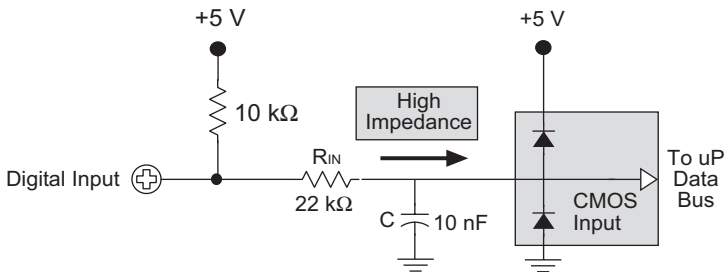
The protection network comprises a low-pass filter with a corner frequency of 724 Hz. For example, if the driving source of a protected input is a step function, that step becomes available 1.38 ms later as a valid +5 V DC CMOS input to the BL1700's data bus.

Equation (B-1) shows how  $R_{IN}$  and  $C$  affect the frequency response of the protected inputs HVA00 through HVA15.

$$f_c = [2\pi R_{IN} C]^{-1} = [(2\pi)(22 \times 10^3)(10^{-8})]^{-1} \quad (\text{B-1}) \\ = 724 \text{ Hz}$$

$$\tau = [f_c]^{-1} = 1.38 \text{ ms (at 0.707 of full input value)}$$

Figure B-3 shows the protected input circuitry for protected inputs HVA00 to HVA15 in the factory default pulled-up configuration.



**Figure B-3. Protected Input Circuitry, HVA00 through HVA15**

If a faster frequency response is needed, it is possible to replace  $R_{IN}$  with a smaller value. For example, if the digital input is being driven by a +5 V DC CMOS compatible driver,  $R_{IN}$  can be replaced with a zero-ohm 0805 resistor.




Replacing  $R_{IN}$  with a zero-ohm resistor will adversely affect the BL1700's noise immunity.

## High-Voltage Drivers

Table B-7 lists the high-voltage driver characteristics when sinking drivers or sourcing drivers are used.

**Table B-7. High-Voltage Driver Characteristics**

Characteristic	Sinking Driver	Sourcing Driver
		
IC	2803	2985
Number of Channels	8	8
Max. Current per Channel (all channels ON)	75 mA @ 60°C 125 mA @ 50°C	75 mA @ 60°C 125 mA @ 50°C
Voltage Source Range	2 V to 48 V DC	3 V to 30 V DC
Package Power Dissipation	2.2 W	2.2 W
Max. Current (all channels ON)	1.38 A	1.38 A
Max. Collector-Emitter Voltage (VCE)	1.6 V	1.6 V
Derating	18 mW/°C (55°C/W)	18 mW/°C (55°C/W)
Output Flyback Diode (K)	Yes	Yes
Max. Diode-Drop Voltage (K)	2 V DC	2 V DC



For additional information on maximum operating conditions for the BL1700 high-voltage drivers, call Z-World Technical Support at (530) 757-3737.

### **Sinking Driver**

The sinking-driver IC can handle a maximum of 1.38 A (500 mA for any channel), or 75 mA per channel on average if all channels are ON, at 60°C. The absolute maximum power that the driver IC can dissipate depends on several factors. The sinking IC's saturation voltage is 1.6 V DC max per channel.

The sinking driver's source voltage must range from 2 V to 48 V DC.

## Sourcing Driver

The sourcing-driver IC can handle a maximum of 1.38 A (250 mA for any channel), or 75 mA per channel on average if all channels are ON, at 60°C. The sourcing IC can dissipate a maximum of 2.2 W. The saturation voltage is 1.6 V DC max per channel.




The sourcing driver's source voltage must range from 3 V to 30 V DC. The minimum output sustaining voltage is 15 V DC. Operating the driver at more than 15 V without providing for energy dissipation may destroy the driver when an inductive load is connected.



For more information on sinking and sourcing high-voltage drivers, refer to the Motorola (DL128) or Allegro (AMS 502Z) linear data books.



See Appendix D, "Sinking and Sourcing Drivers," for more information on installing and using sourcing drivers.



*APPENDIX C: **FIELD WIRING  
TERMINALS (FWT) AND DIN RAILS***

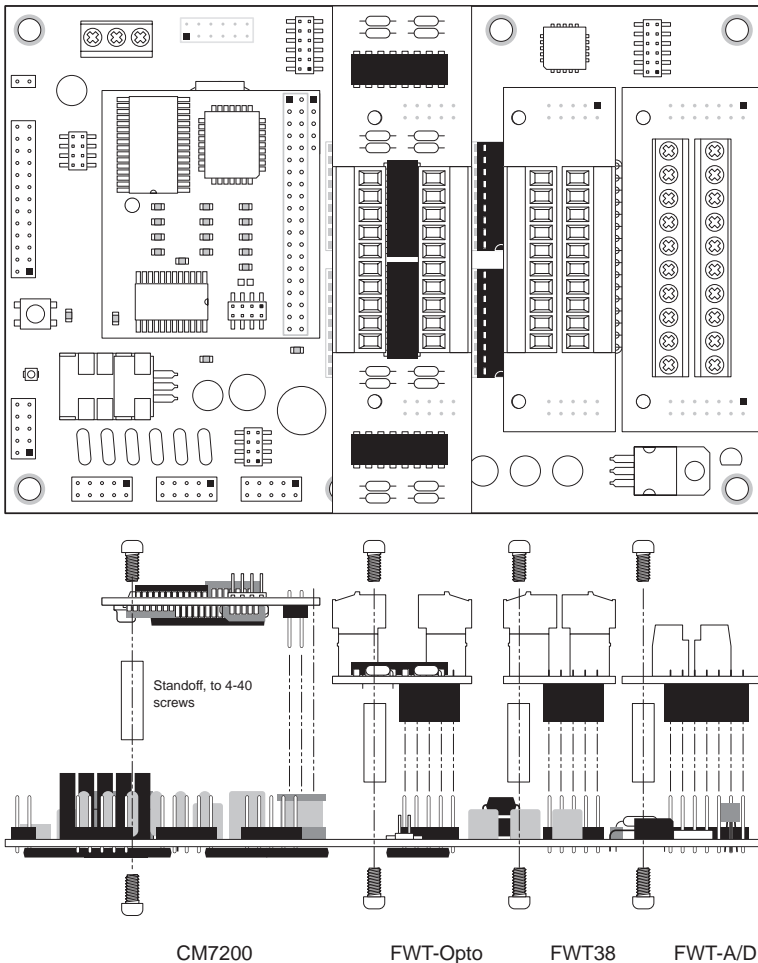
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# Field Wiring Terminals

Discrete input/output lines may be connected to headers on the BL1700 Series of controllers with field wiring terminal (FWT) modules. This eliminates the need for ribbon cables. The optional quick-disconnect modules provide screw terminals for simple wiring.

The FWT38, FWT50, and FWT-Opto modules mate to two of the BL1700 Series board headers (H6–H9 and H7–H10) in any combination. This is equivalent to 20 connections per module. The FWT-A/D module mates with headers H8–H11 only in one position.

Figure C-1 illustrates the mounting configuration for the FWT modules and the CM7200.



**Figure C-1. BL1700 FWT and CM7200 Installation**



These four FWT styles described in this section are available from Z-World. Your application may use a different arrangement than that shown in Figure C-1.

### **FWT38**

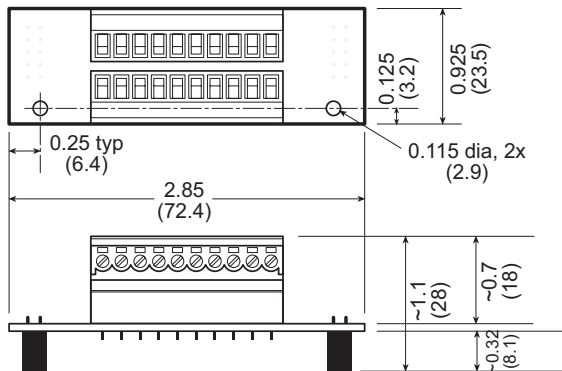
The FWT38 has 20 terminals in two groups with 10 terminals each. Each group of terminals may be removed independently.

Table C-1 summarizes the specifications for the FWT38.

**Table C-1. FWT38 Specifications**

Parameter	Specification
Total I/O Channels	16
Screw Terminal Pitch	3.81 mm
Maximum Wire Gauge	28-16 AWG
Quick-Disconnect Capability	Wiring banks can be unplugged from the board separately (Phoenix Combicon type connection)
Wire Orientation	Top-exiting wires

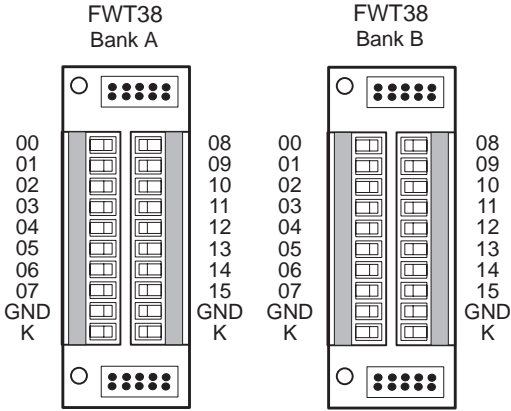
Figure C-2 provides the dimensions for the FWT38.



**Figure C-2. FWT38 Dimensions**



Figure C-3 shows the I/O channel assignments and pinouts for the FWT38.



**Figure C-3. FWT38 Pinouts**

### **FWT50**

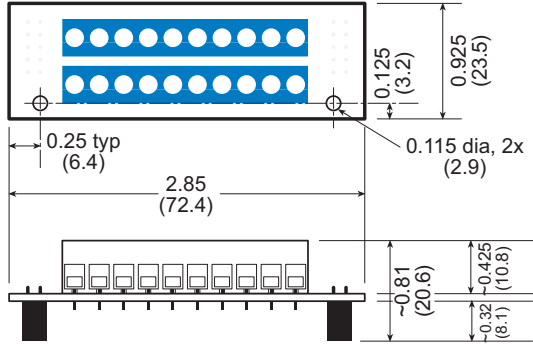
The FWT50 provides 20 screw terminals. The terminal connectors are fixed to the FWT module and cannot be removed.

Table C-2 summarizes the specifications for the FWT50.

**Table C-2. FWT50 Specifications**

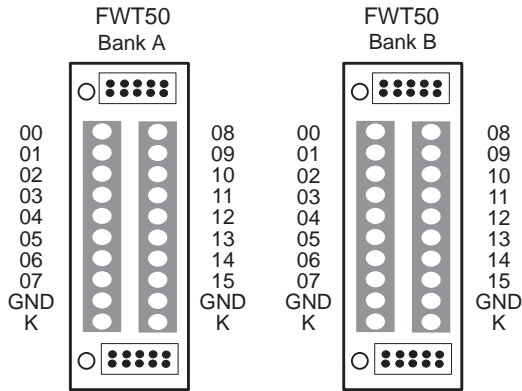
Parameter	Specification
Total I/O Channels	16
Screw Terminal Pitch	5.00 mm
Maximum Wire Gauge	24-12 AWG
Quick-Disconnect Capability	Unplugs from the BL1700 board as a single unit
Wire Orientation	Side-exiting wires

Figure C-4 provides the dimensions for the FWT50.



**Figure C-4. FWT50 Dimensions**

Figure C-5 shows the I/O channel assignments and pinouts for the FWT50.



**Figure C-5. FWT50 Pinouts**

## ***FWT-Opto***

The FWT-Opto provides optical isolation to the input channels. The FWT-Opto is used only for inputs, and is not used if the BL1700 banks are all configured as outputs. All 16 channels must be committed to inputs when an FWT-Opto module is used.



Every four FWT-Opto inputs share a common return. The excitation resistors need to be pulled up to +5 V when the FWT-Opto module is used.

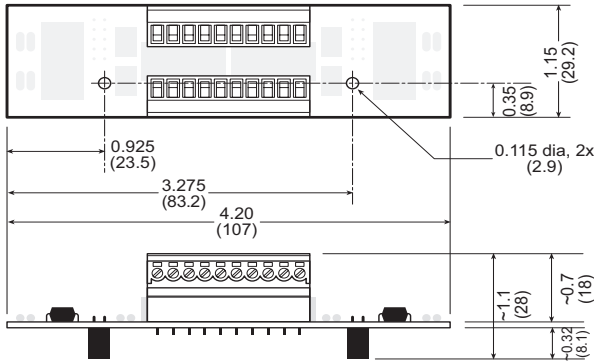
Table C-3 summarizes the specifications for the FWT-Opto.

***Table C-3. FWT-Opto Specifications***

<b>Parameter</b>	<b>Specification</b>
Total Input Channels	16 optically isolated input channels only
Screw Terminal Pitch	3.81 mm
Maximum Wire Gauge	28-16 AWG
Quick-Disconnect Capability	Wiring banks can be unplugged from the board separately (Phoenix Combicon type connection)
Wire Orientation	Top-exiting wires
Input Protection Range	5 kV rms between input and output
Maximum Input Voltage	$\pm 40$ V
Guaranteed Input Switching Threshold	$\pm 9.5$ V

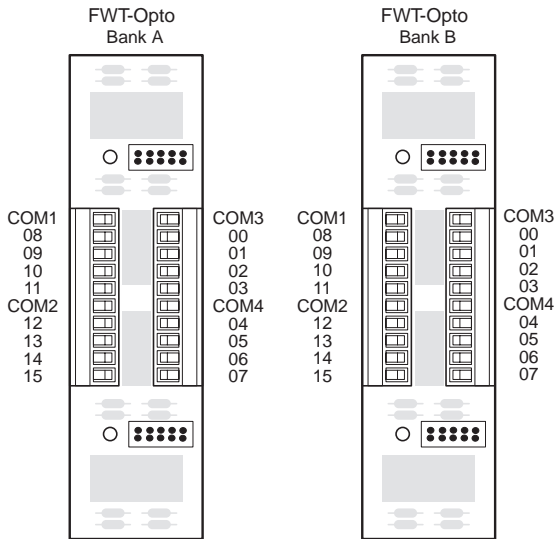
The FWT-Opto module uses 4.7 k $\Omega$  input resistors to accommodate the large range of input voltages. This limits the input switching threshold to  $\pm 9.5$  V. These 4.7 k $\Omega$  input resistors need to be replaced with 1.2 k $\Omega$  input resistors to handle smaller input voltages such as 5 V logic. If 0.125 W resistors are used, this will limit the maximum input voltage to  $\pm 12.2$  V.

Figure C-6 provides the dimensions for the FWT-Opto module.



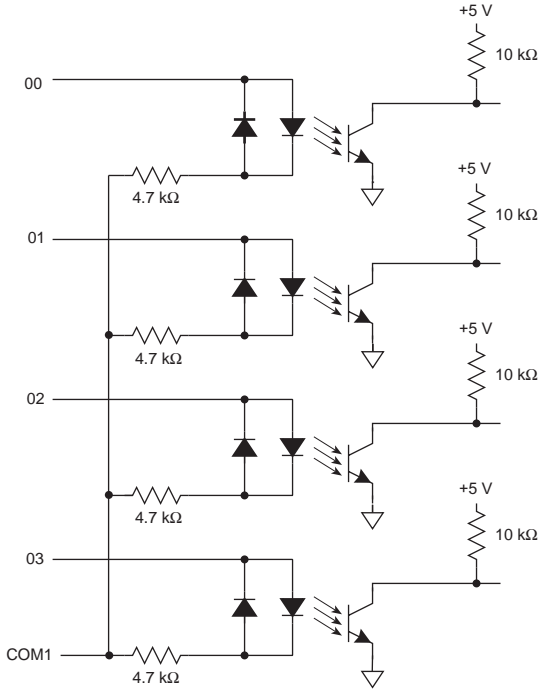
**Figure C-6. FWT-Opto Dimensions**

Figure C-7 shows the input channel assignments and pinouts for the FWT-Opto module.



**Figure C-7. FWT-Opto Pinouts**

Figure C-8 shows an FWT-Opto optical isolation circuit.



**Figure C-8. FWT-Opto Optical Isolation Circuit**



The opto-isolated inputs share a common return in groups of four. The software channel assignments remain the same for Banks A and B.

## FWT-A/D

The FWT-A/D provides 20 screw terminals. The terminal connectors are fixed to the FWT module and cannot be removed.

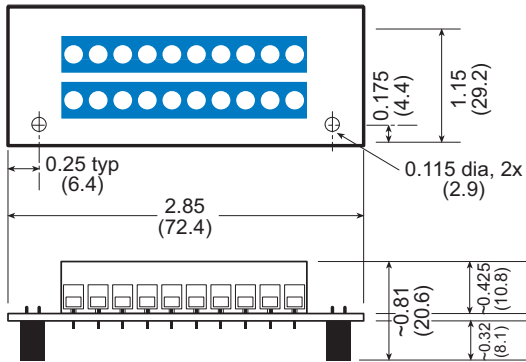
The FWT-A/D is used only to access the analog inputs on the BL1700.

Table C-4 summarizes the specifications for the FWT-A/D.

**Table C-4. FWT-A/D Specifications**

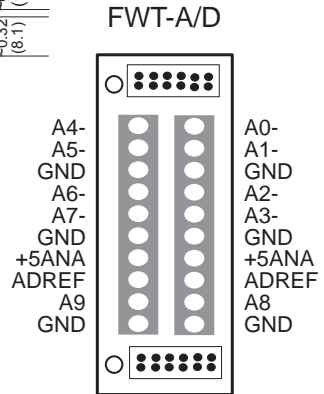
Parameter	Specification
Total Input Channels	10
Screw Terminal Pitch	5.00 mm
Maximum Wire Gauge	24-12 AWG
Quick-Disconnect Capability	Unplugs from the BL1700 board as a single unit
Wire Orientation	Side-exiting wires

Figure C-9 provides the dimensions for the FWT-A/D.



**Figure C-9. FWT-A/D Dimensions**

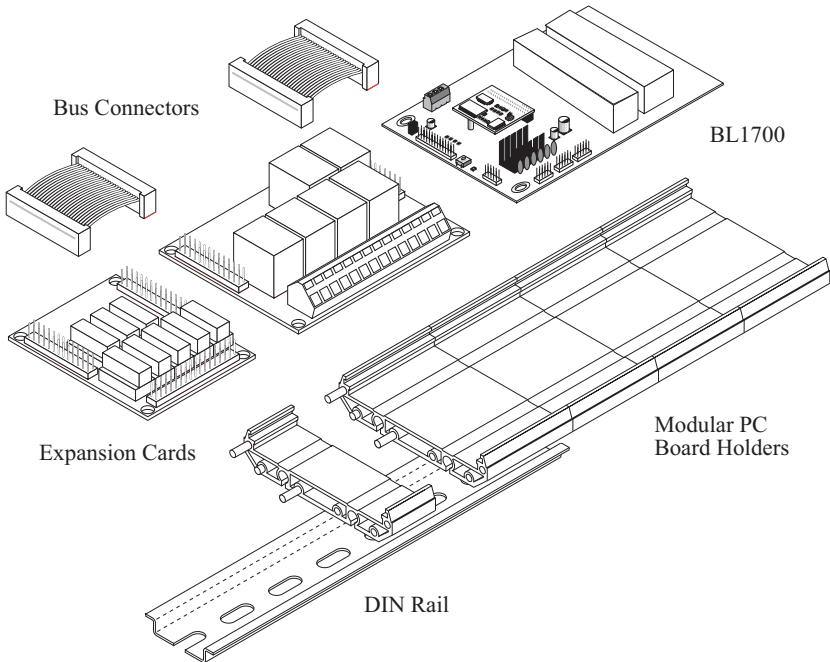
Figure C-10 shows the input channel assignments and pinouts for the FWT-A/D.



**Figure C-10. FWT-A/D Pinouts**

## DIN Rails

The BL1700 and its expansion boards can be mounted using plastic standoffs to any flat surface that accepts screws. BL1700s can also be mounted in modular circuit-board holders and attached to DIN rail, a mounting system widely used for electrical components and controllers, as shown in Figure C-11.



**Figure C-11. Mounting BL1700 on DIN Rail**

A DIN rail is a long metal rail. The BL1700 and other expansion boards slide snugly into modular, plastic printed-circuit board holders, which then snap onto the rail.



The BL1700 uses 110 mm circuit holders, which are available from Phoenix Contact. Z-World sells 75 mm circuit holders in multiples of lengths of 11.25 mm, 22.5 mm, or 45 mm for its expansion boards.



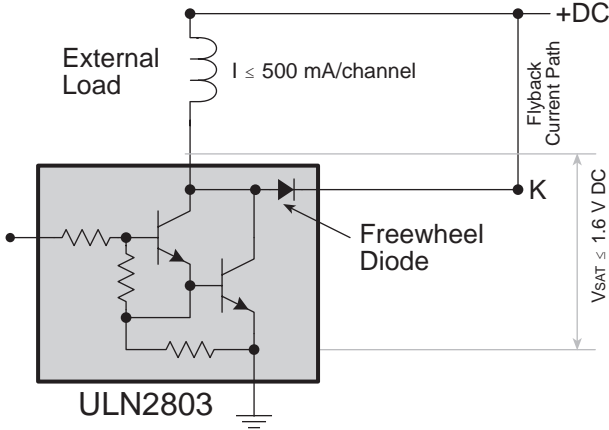
*APPENDIX D: **SINKING AND  
SOURCING DRIVERS***

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## BL1700 Series Sinking and Sourcing Outputs

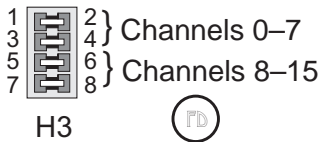
The BL1700 Series controllers are normally supplied with ULN2803 sinking drivers. Figure D-1 shows a typical sinking driver output configuration.



**Figure D-1. Sinking Driver Output**

Figure D-2 shows the jumper configurations for a sinking driver output.

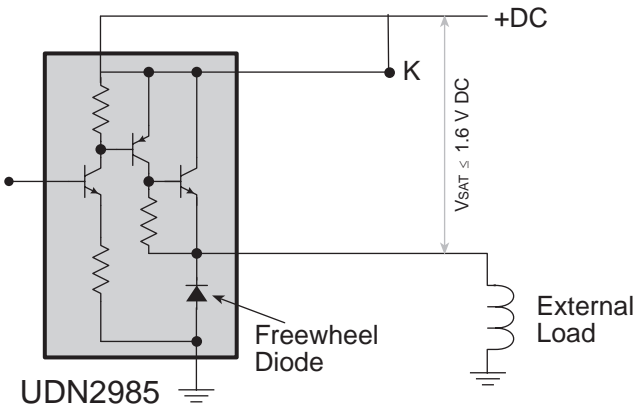
### SINKING DRIVER JUMPER SETTINGS



**Figure D-2. Sinking Driver Jumper Configurations**

Sourcing outputs are possible by replacing the factory-installed sinking driver chips with sourcing output drivers (UDN2985). The UDN2985 sourcing driver chip is capable of sourcing a maximum of 75 mA per output.

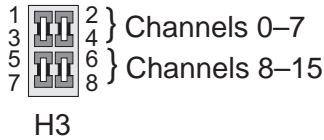
Figure D-3 shows a typical sourcing driver output.




**Figure D-3. Sourcing Driver Output**

Figure D-4 shows the jumper configurations for a sourcing driver output.

**SOURCING DRIVER JUMPER SETTINGS**



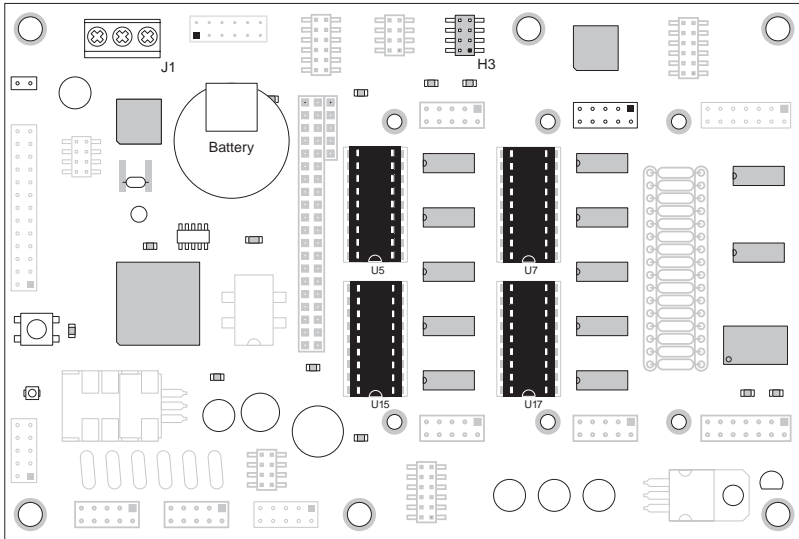
**Figure D-4. Sourcing Driver Jumper Configurations**



Z-World also offers all BL1700 Series controllers for quantity orders with factory-installed sourcing drivers. For ordering information, call your Z-World Sales Representative at (530) 757-3737.

## Installing Sourcing Drivers

Figure D-5 shows the location of the drivers and headers with jumpers to be changed.



**Figure D-5. U5, U7, U15 and U17 Locations of Sinking Drivers**

Pay particular attention to the orientation of the jumpers when changing the driver output from sinking to sourcing. Exercise caution when installing sourcing drivers in the field.

1. Be sure power is removed from the controller.
2. Remove the ULN2803 sinking drivers from the IC sockets. Note that regular BL1700s have two ULN2803 chips (at U7 and U17) and only BL1700s that have been customized for more than 16 outputs will have chips at U5 and U15.
3. Install the jumpers on header H3 for the sourcing configuration, as shown in Figure D-4. Note the location of pin number 1 in Figure D-5.
4. Install UDN2985 sourcing driver chips into the IC sockets.



Be sure the jumper settings conform to what is specified. Failure to install jumpers correctly may damage your controller.

## TTL/CMOS Outputs

Z-World also offers TTL- or CMOS-compatible outputs for the BL1700 Series controllers. Input and output channels may be configured independently in any combination. However, the functionality of each input is not independent; the inputs are still characterized in groups of four or eight.



Z-World offers all BL1700 Series controllers in quantity with factory-installed TTL- or CMOS-compatible outputs. For ordering information, call your Z-World Sales Representative at (530) 757-3737.

## Using Output Drivers

The common supply for all eight channels supplied by a driver chip is called “K,” and is labeled as such on the BL1700’s terminals. “K” must be powered up to allow proper operation.

The “K” connection performs two vital functions to the high-voltage driver circuitry on the BL1700.

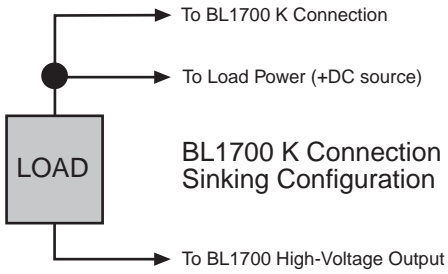
1. “K” supplies power to driver circuitry inside the driver chip.
2. “K” also allows a diode internal to the driver chip to “snub” voltage transients produced during the inductive kick associated with switching inductive loads. (Relays, solenoids, and speakers are examples of inductive loads.)

Long leads may present enough induction to also produce large potentially damaging voltage transients. The anodes of the protection diodes for each channel are common, and so only one voltage supply can be used for all high-voltage driver loads.

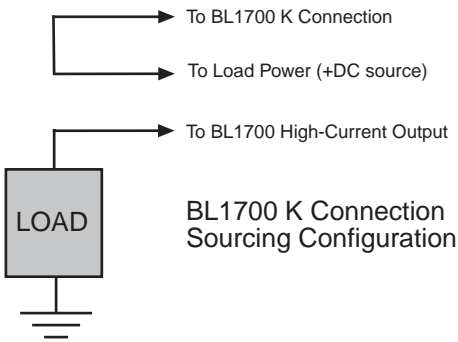
The following points summarize the functions of “K.”

- K provides power to the driver chip circuitry.
- K provides “clamping” for all high-voltage driver loads.
- It is mandatory to connect K regardless of whether sourcing or sinking.
- The load’s supply must have a common ground with all other supplies in your system.
- All loads must use same supply voltage.

Refer to Figure D-6 and Figure D-7 when connecting K.



**Figure D-6. BL1700 K Connections (Sinking Configuration)**



**Figure D-7. BL1700 K Connections (Sourcing Configuration)**



K must be connected to the power supply used for the high-voltage load. See Figure D-6 and Figure D-7.



## *APPENDIX E: **PLCBus***

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Appendix E provides the pin assignments for the PLCBus, describes the registers, and lists the software drivers.

# PLCBus Overview

The PLCBus is a general-purpose expansion bus for Z-World controllers. The PLCBus is available on the BL1200, BL1600, BL1700, PK2100, PK2200, and PK2600 controllers. The BL1000, BL1100, BL1300, BL1400, and BL1500 controllers support the XP8300, XP8400, XP8600, and XP8900 expansion boards using the controller’s parallel input/output port. The BL1400 and BL1500 also support the XP8200 and XP8500 expansion boards. The ZB4100’s PLCBus supports most expansion boards, except for the XP8700 and the XP8800. The SE1100 adds expansion capability to boards with or without a PLCBus interface.

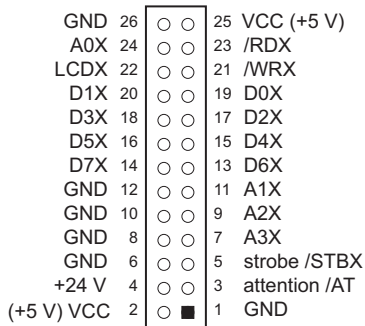
Table E-1 lists Z-World’s expansion devices that are supported on the PLCBus.

**Table E-1. Z-World PLCBus Expansion Devices**

Device	Description
EXP-A/D12	Eight channels of 12-bit A/D converters
SE1100	Four SPDT relays for use with all Z-World controllers
XP8100 Series	32 digital inputs/outputs
XP8200	“Universal Input/Output Board” —16 universal inputs, 6 high-current digital outputs
XP8300	Two high-power SPDT and four high-power SPST relays
XP8400	Eight low-power SPST DIP relays
XP8500	11 channels of 12-bit A/D converters
XP8600	Two channels of 12-bit D/A converters
XP8700	One full-duplex asynchronous RS-232 port
XP8800	One-axis stepper motor control
XP8900	Eight channels of 12-bit D/A converters

Multiple expansion boards may be linked together and connected to a Z-World controller to form an extended system.

Figure E-1 shows the pin layout for the PLCBus connector.



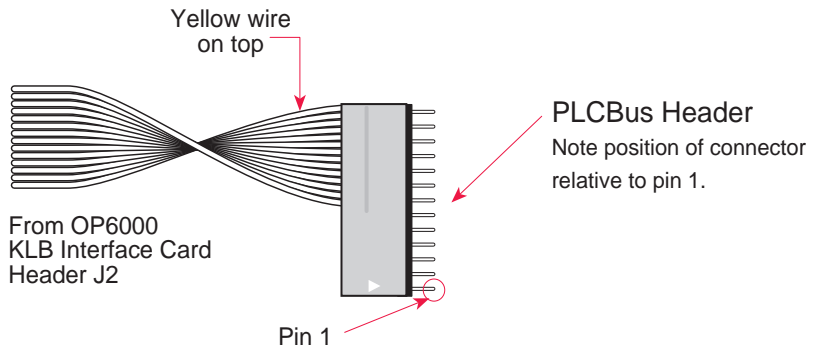
**Figure E-1. PLCBus Pin Diagram**

Two independent buses, the LCD bus and the PLCBus, exist on the single connector.

The LCD bus consists of the following lines.

- LCDX—positive-going strobe.
- /RDX—negative-going strobe for read.
- /WRX—negative-going strobe for write.
- A0X—address line for LCD register selection.
- D0X-D7X—bidirectional data lines (shared with expansion bus).

The LCD bus is used to connect Z-World's OP6000 series interfaces or to drive certain small liquid crystal displays directly. Figure E-2 illustrates the connection of an OP6000 interface to a controller PLCBus.



**Figure E-2. OP6000 Connection to PLCBus Port**

The PLCBus consists of the following lines.

- /STBX—negative-going strobe.
- A1X-A3X—three control lines for selecting bus operation.
- D0X-D3X—four bidirectional data lines used for 4-bit operations.
- D4X-D7X—four additional data lines for 8-bit operations.
- /AT—attention line (open drain) that may be pulled low by any device, causing an interrupt.

The PLCBus may be used as a 4-bit bus (D0X-D3X) or as an 8-bit bus (D0X-D7X). Whether it is used as a 4-bit bus or an 8-bit bus depends on the encoding of the address placed on the bus. Some PLCBus expansion cards require 4-bit addressing and others (such as the XP8700) require 8-bit addressing. These devices may be mixed on a single bus.



There are eight registers corresponding to the modes determined by bus lines A1X, A2X, and A3X. The registers are listed in Table E-2.

**Table E-2. PLCBus Registers**

Register	Address	A3	A2	A1	Meaning
BUSRD0	C0	0	0	0	Read data, one way
BUSRD1	C2	0	0	1	Read data, another way
BUSRD2	C4	0	1	0	Spare, or read data
BUSRESET	C6	0	1	1	Read this register to reset the PLCBus
BUSADR0	C8	1	0	0	First address nibble or byte
BUSADR1	CA	1	0	1	Second address nibble or byte
BUSADR2	CC	1	1	0	Third address nibble or byte
BUSWR	CE	1	1	1	Write data

Writing or reading one of these registers takes care of all the bus details. Functions are available in Z-World's software libraries to read from or write to expansion bus devices.

To communicate with a device on the expansion bus, first select a register associated with the device. Then read or write from/to the register. The register is selected by placing its address on the bus. Each device recognizes its own address and latches itself internally.

A typical device has three internal latches corresponding to the three address bytes. The first is latched when a matching BUSADR0 is detected. The second is latched when the first is latched and a matching BUSADR1 is detected. The third is latched if the first two are latched and a matching BUSADR2 is detected. If 4-bit addressing is used, then there are three 4-bit address nibbles, giving 12-bit addresses. In addition, a special register address is reserved for address expansion. This address, if ever used, would provide an additional four bits of addressing when using the 4-bit convention.

If eight data lines are used, then the addressing possibilities of the bus become much greater—more than 256 million addresses according to the conventions established for the bus.

Place an address on the bus by writing (bytes) to BUSADR0, BUSADR1 and BUSADR2 in succession. Since 4-bit and 8-bit addressing modes must coexist, the lower four bits of the first address byte (written to BUSADR0) identify addressing categories, and distinguish 4-bit and 8-bit modes from each other.

There are 16 address categories, as listed in Table E-3. An “x” indicates that the address bit may be a “1” or a “0.”

**Table E-3. First-Level PLCBus Address Coding**

First Byte	Mode	Addresses	Full Address Encoding
– – – – 0 0 0 0	4 bits × 3	256	0000 xxxx xxxx
– – – – 0 0 0 1		256	0001 xxxx xxxx
– – – – 0 0 1 0		256	0010 xxxx xxxx
– – – – 0 0 1 1		256	0011 xxxx xxxx
– – – x 0 1 0 0	5 bits × 3	2,048	x0100 xxxxxx xxxxxx
– – – x 0 1 0 1		2,048	x0101 xxxxxx xxxxxx
– – – x 0 1 1 0		2,048	x0110 xxxxxx xxxxxx
– – – x 0 1 1 1		2,048	x0111 xxxxxx xxxxxx
– – x x 1 0 0 0	6 bits × 3	16,384	xx1000 xxxxxx xxxxxx
– – x x 1 0 0 1		16,384	xx1001 xxxxxx xxxxxx
– – x x 1 0 1 0	6 bits × 1	4	xx1010
– – – – 1 0 1 1	4 bits × 1	1	1011 (expansion register)
x x x x 1 1 0 0	8 bits × 2	4,096	xxxx1100 xxxxxxxx
x x x x 1 1 0 1	8 bits × 3	1M	xxxx1101 xxxxxxxx xxxxxxxx
x x x x 1 1 1 0	8 bits × 1	16	xxxx1110
x x x x 1 1 1 1	8 bits × 1	16	xxxx1111

This scheme uses less than the full addressing space. The mode notation indicates how many bus address cycles must take place and how many bits are placed on the bus during each cycle. For example, the 5 × 3 mode means three bus cycles with five address bits each time to yield 15-bit addresses, not 24-bit addresses, since the bus uses only the lower five bits of the three address bytes.

Z-World provides software drivers that access the PLCBus. To allow access to bus devices in a multiprocessing environment, the expansion register and the address registers are shadowed with memory locations known as *shadow registers*. The 4-byte shadow registers, which are saved at predefined memory addresses, are as follows.

	SHBUS0	SHBUS0+1	SHBUS1 SHBUS0+2	SHBUS1+1 SHBUS0+3
Bus expansion		BUSADR0	BUSADR1	BUSADR2

Before the new addresses or expansion register values are output to the bus, their values are stored in the shadow registers. All interrupts that use the bus save the four shadow registers on the stack. Then, when exiting the interrupt routine, they restore the shadow registers and output the three address registers and the expansion registers to the bus. This allows an interrupt routine to access the bus without disturbing the activity of a background routine that also accesses the bus.

To work reliably, bus devices must be designed according to the following rules.

1. The device must not rely on critical timing such as a minimum delay between two successive register accesses.
2. The device must be capable of being selected and deselected without adversely affecting the internal operation of the controller.

## Allocation of Devices on the Bus

### 4-Bit Devices

Table E-4 provides the address allocations for the registers of 4-bit devices.

**Table E-4. Allocation of Registers**

A1	A2	A3	Meaning
000j	000j	xxxj	digital output registers, 64 registers 64 × 8 = 512 1-bit registers
000j	001j	xxxj	analog output modules, 64 registers
000j	01xj	xxxj	digital input registers, 128 registers 128 × 4 = 512 input bits
000j	10xj	xxxj	analog input modules, 128 registers
000j	11xj	xxxj	128 spare registers (customer)
001j	xxxj	xxxj	512 spare registers (Z-World)

j controlled by board jumper  
x controlled by PAL

Digital output devices, such as relay drivers, should be addressed with three 4-bit addresses followed by a 4-bit data write to the control register. The control registers are configured as follows

bit 3	bit 2	bit 1	bit 0
A2	A1	A0	D

The three address lines determine which output bit is to be written. The output is set as either 1 or 0, according to D. If the device exists on the bus, reading the register drives bit 0 low. Otherwise bit 0 is a 1.

For digital input, each register (BUSRD0) returns four bits. The read register, BUSRD1, drives bit 0 low if the device exists on the bus.

### 8-Bit Devices

Z-World's XP8700 and XP8800 expansion boards use 8-bit addressing. Refer to the *XP8700 and XP8800* manual.

## Expansion Bus Software

The expansion bus provides a convenient way to interface Z-World's controllers with expansion boards or other specially designed boards. The expansion bus may be accessed by using input functions. Follow the suggested protocol. The software drivers are easier to use, but are less efficient in some cases. Table E-5 lists the libraries.

**Table E-5. Dynamic C PLCBus Libraries**

Library Needed	Controller
<code>DRIVERS.LIB</code>	All controllers
<code>EZIOTGPL.LIB</code>	BL1000
<code>EZIOLGPL.LIB</code>	BL1100
<code>EZIOMGPL.LIB</code>	BL1400, BL1500
<code>EZIOPLC.LIB</code>	BL1200, BL1600, PK2100, PK2200, ZB4100
<code>EZIOPLC2.LIB</code>	BL1700
<code>PBUS_TG.LIB</code>	BL1000
<code>PBUS_LG.LIB</code>	BL1100, BL1300
<code>PLC_EXP.LIB</code>	BL1200, BL1600, PK2100, PK2200

There are 4-bit and 8-bit drivers. The 4-bit drivers employ the following calls.

- **void eioResetPlcBus ()**

Resets all expansion boards on the PLCBus. When using this call, make sure there is sufficient delay between this call and the first access to an expansion board.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void eioPlcAdr12( unsigned addr )**

Specifies the address to be written to the PLCBus using cycles BUSADR0, BUSADR1, and BUSADR2.

PARAMETER: **addr** is broken into three nibbles, and one nibble is written in each BUSADR<sub>x</sub> cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void set16adr( int adr )**

Sets the current address for the PLCBus. All read and write operations access this address until a new address is set.

PARAMETER: **adr** is a 16-bit physical address. The high-order nibble contains the value for the expansion register, and the remaining three 4-bit nibbles form a 12-bit address (the first and last nibbles must be swapped).

LIBRARY: **DRIVERS.LIB.**

- **void set12adr( int adr )**

Sets the current address for the PLCBus. All read and write operations access this address until a new address is set.

PARAMETER: **adr** is a 12-bit physical address (three 4-bit nibbles) with the first and third nibbles swapped.

LIBRARY: **DRIVERS.LIB.**

- **void eioPlcAdr4( unsigned addr )**

Specifies the address to be written to the PLCBus using only cycle BUSADR2.

PARAMETER: **addr** is the nibble corresponding to BUSADR2.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB.**

- **void set4adr( int adr )**

Sets the current address for the PLCBus. All read and write operations access this address until a new address is set.

A 12-bit address may be passed to this function, but only the last four bits will be set. Call this function only if the first eight bits of the address are the same as the address in the previous call to **set12adr**.

PARAMETER: **adr** contains the last four bits (bits 8–11) of the physical address.

LIBRARY: **DRIVERS.LIB**.

- **char \_eioReadD0( )**

Reads the data on the PLCBus in the BUSADR0 cycle.

RETURN VALUE: the byte read on the PLCBus in the BUSADR0 cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB**.

- **char \_eioReadD1( )**

Reads the data on the PLCBus in the BUSADR1 cycle.

RETURN VALUE: the byte read on the PLCBus in the BUSADR1 cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB**.

- **char \_eioReadD2( )**

Reads the data on the PLCBus in the BUSADR2 cycle.

RETURN VALUE: the byte read on the PLCBus in the BUSADR2 cycle.

LIBRARY: **EZIOPLC.LIB, EZIOPLC2.LIB, EZIOMGPL.LIB**.

- **char read12data( int adr )**

Sets the current PLCBus address using the 12-bit **adr**, then reads four bits of data from the PLCBus with BUSADR0 cycle.

RETURN VALUE: PLCBus data in the lower four bits; the upper bits are undefined.

LIBRARY: **DRIVERS.LIB**.

- **char read4data( int adr )**

Sets the last four bits of the current PLCBus address using `adr` bits 8–11, then reads four bits of data from the bus with `BUSADR0` cycle.

PARAMETER: `adr` bits 8–11 specifies the address to read.

RETURN VALUE: PLCBus data in the lower four bits; the upper bits are undefined.

LIBRARY: `DRIVERS.LIB`.

- **void \_eioWriteWR( char ch)**

Writes information to the PLCBus during the `BUSWR` cycle.

PARAMETER: `ch` is the character to be written to the PLCBus.

LIBRARY: `EZIOPLC.LIB`, `EZIOPLC2.LIB`, `EZIOGPL.LIB`.

- **void write12data( int adr, char dat )**

Sets the current PLCBus address, then writes four bits of data to the PLCBus.

PARAMETER: `adr` is the 12-bit address to which the PLCBus is set.

`dat` (bits 0–3) specifies the data to write to the PLCBus.

LIBRARY: `DRIVERS.LIB`.

- **void write4data( int address, char data )**

Sets the last four bits of the current PLCBus address, then writes four bits of data to the PLCBus.

PARAMETER: `adr` contains the last four bits of the physical address (bits 8–11).

`dat` (bits 0–3) specifies the data to write to the PLCBus.

LIBRARY: `DRIVERS.LIB`.

The 8-bit drivers employ the following calls.

- **void set24adr( long address )**

Sets a 24-bit address (three 8-bit nibbles) on the PLCBus. All read and write operations will access this address until a new address is set.

PARAMETER: `address` is a 24-bit physical address (for 8-bit bus) with the first and third bytes swapped (low byte most significant).

LIBRARY: `DRIVERS.LIB`.

- **void set8adr( long address )**

Sets the current address on the PLCBus. All read and write operations will access this address until a new address is set.

PARAMETER: **address** contains the last eight bits of the physical address in bits 16–23. A 24-bit address may be passed to this function, but only the last eight bits will be set. Call this function only if the first 16 bits of the address are the same as the address in the previous call to **set24adr**.

LIBRARY: **DRIVERS.LIB**.

- **int read24data0( long address )**

Sets the current PLCBus address using the 24-bit address, then reads eight bits of data from the PLCBus with a BUSRD0 cycle.

RETURN VALUE: PLCBus data in lower eight bits (upper bits 0).

LIBRARY: **DRIVERS.LIB**.

- **int read8data0( long address )**

Sets the last eight bits of the current PLCBus address using address bits 16–23, then reads eight bits of data from the PLCBus with a BUSRD0 cycle.

PARAMETER: **address** bits 16–23 are read.

RETURN VALUE: PLCBus data in lower eight bits (upper bits 0).

LIBRARY: **DRIVERS.LIB**.

- **void write24data( long address, char data )**

Sets the current PLCBus address using the 24-bit address, then writes eight bits of data to the PLCBus.

PARAMETERS: **address** is 24-bit address to write to.

**data** is data to write to the PLCBus.

LIBRARY: **DRIVERS.LIB**.

- **void write8data( long address, char data )**

Sets the last eight bits of the current PLCBus address using address bits 16–23, then writes eight bits of data to the PLCBus.

PARAMETERS: **address** bits 16–23 are the address of the PLCBus to write.

**data** is data to write to the PLCBus.

LIBRARY: **DRIVERS.LIB**.







*APPENDIX F:*  
**SERIAL INTERFACE BOARD 2**

---

Appendix F provides technical details and baud rate configuration data for Z-World's Serial Interface Board 2 (SIB2).

## Introduction

The SIB2 is an interface adapter used to program the BL1700. The SIB2 is contained in an ABS plastic enclosure, making it rugged and reliable. The SIB2 enables the BL1700 to communicate with Dynamic C via the Z180's clocked serial I/O (CSI/O) port, freeing the BL1700's serial ports for use by the application during programming and debugging.

The SIB2's 8-pin cable plugs into the target BL1700's processor through an aperture in the backplate, and a 6-conductor RJ-12 phone cable connects the SIB2 to the host PC. The SIB2 automatically selects its baud rate to match the communication rates established by the host PC (9600, 19,200, or 57,600 bps). However, the SIB2 determines the host's communication baud rate only on the first communication after reset. To change baud rates, change the COM baud rate, reset the target BL1700 (which also resets the SIB2), then select **Reset Target** from Dynamic C.



Chapter 2 provides detailed information on connecting the SIB2 to the BL1700.

The SIB2 receives power and resets from the target BL1700 via the 8-pin connector J1. Therefore, do not unplug the SIB2 from the target BL1700 while power is applied. To do so could damage both the BL1700 and the SIB2; additionally, the target may reset.

The SIB2 consumes approximately 60 mA from the +5 V supply. The target-system current consumption therefore increases by this amount while the SIB2 is connected to the BL1700.

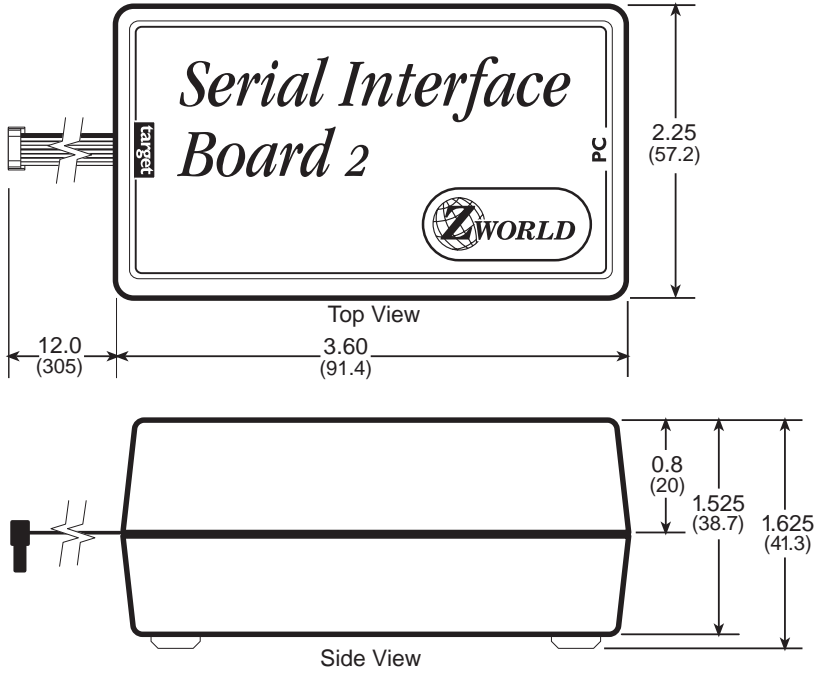
When the BL1700 is powered up or reset with the SIB2 attached, it is automatically in the program mode. To operate the BL1700 in the run mode, remove power, disconnect the SIB2, and re-apply power to the BL1700.



Never connect or disconnect the SIB2 with power applied to the BL1700.

# External Dimensions

Figure F-1 illustrates the external dimensions for the SIB2.



**Figure F-1. SIB2 External Dimensions**





## *APPENDIX G: **ADVANCED TOPICS***

---

Appendix G provides more advanced information to help the user needing to implement special applications. The following topics are included.

- Power Management
- Memory Map
- Interrupts
- Flash EPROM
- Pulse-Width Modulation Software

# Power Management

## Power Failure Detection Circuitry

Figure G-1 shows the power fail detection circuitry of the BL1700.

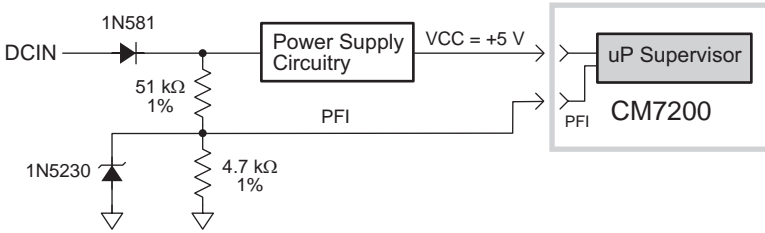


Figure G-1. BL1700 Power-Failure Detection Circuit

## Power Failure Sequence of Events

Figure G-2 shows the events that occur as the input power fails.

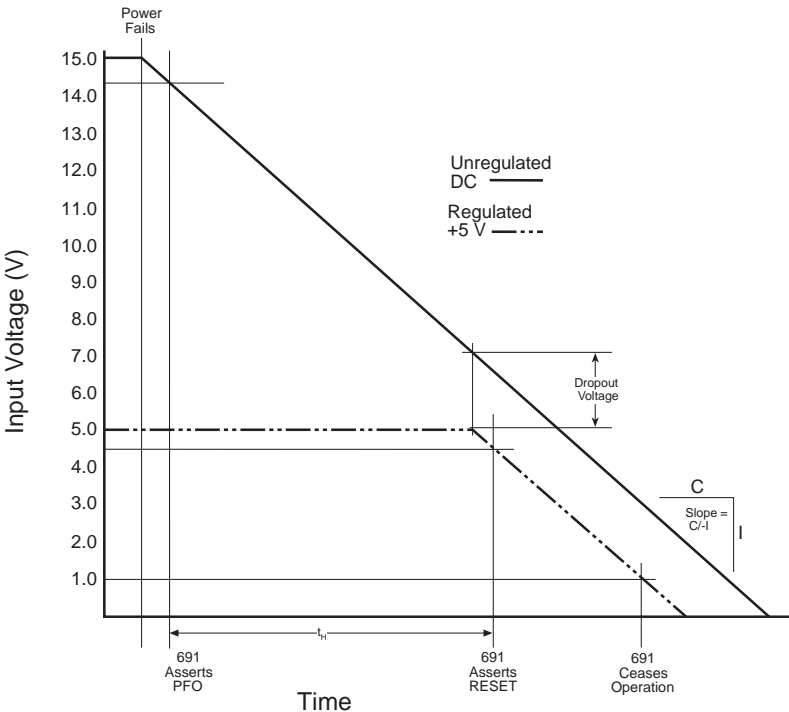


Figure G-2. Power Failure Sequence

1. The power-management IC triggers a power-fail /NMI (nonmaskable interrupt) when the DC input voltage falls within the range of 14.44 V to 14.72 V DC.
2. At some point, the raw input voltage will not be sufficient for the regulator to provide 5 V DC to the BL1700 due to dropout voltage. At that point the regulated output begins to drop. The power-management IC triggers a reset when the regulated 5 V DC output falls within the range of 4.50 V to 4.75 V DC. This causes the power-fail routine to be invoked. The power-fail routine can be used to store important state data.

**Tip** Use a power supply with a large capacitance if you need to increase the holdup time. This will provide additional time for the BL1700 to execute a safe shutdown.

3. The power management IC switches power for the time/date clock and SRAM to the lithium backup battery when the regulated voltage falls below the battery voltage of approximately 3 V DC.
4. The power management IC keeps the system in reset until the regulated voltage drops below 1 V DC. At this point the power-management IC ceases operating. By this time, the portion of the circuitry not battery-backed has already ceased functioning.

The ratio of your power supply's output capacitor's value to your circuit's current draw determines the actual holdup time.

In order to improve the performance of the power-failure NMI circuit, we have added some hysteresis to the power-failure comparator on the core module by adding a resistor, R21, between the comparator input and output pins. R21 can be found on the 175-1093 versions of the core module. The hysteresis prevents the comparator from switching rapidly—and therefore generating multiple interrupts—when the input voltage is falling slowly. Once the comparator switches (DC IN falls to approximately 3.9 V), this feedback holds the input (PFI) low and prevents further interrupts from being generated. At this point, the 3.3 V regulator still has sufficient voltage to keep the processor operating, so that an interrupt service routine can perform shutdown tasks and “tidying up” before the Vcc line fails. The comparator will not turn the output (PFO) high until DC IN has risen to about 5 V. The hysteresis will also help prevent any system oscillation in adverse power supplies/loading situations.

A situation similar to a continuous low input (“brownout”) can occur if the power supply is overloaded. For example, when a high-current device such as a relay turns ON, the raw voltage supplied to the BL1700 may dip below 14.44 V DC. The interrupt routine performs a shutdown. This shutdown turns off the relay, clearing the problem. However, if the cause of the



overload persists, the system oscillates, alternately experiencing an overload and then resetting. Using a power supply with a sufficiently large current capacity will correct this problem.

If you remove the power cable abruptly from the BL1700 side, then only the capacitors on the board provide power, reducing computing time to a few microseconds. These times can vary considerably depending on system configuration and loads on the BL1700 power supplies.

The interval between the power-failure detection and entry to the power-failure interrupt routine is approximately 100  $\mu$ s, or less if Dynamic C/NMI communication is not in use.

# Memory Map

## Input/Output Select Map

The Dynamic C library functions **IBIT**, **ISET** and **IRES** in the **BIOS.LIB** library allow bits in the I/O registers to be tested, set, and cleared. The I/O addresses need to be 16-bit addresses.

### Z180 Internal Input/Output Register Addresses 0x00-0x3F

The internal registers for the I/O devices built into the Z180 processor occupy the first 40 (hex) addresses of the I/O space. These addresses are listed in Table G-1.

**Table G-1. Z180 Internal I/O Registers Addresses 0x00–0x3F**

Address	Name	Description
0x00	CNTLA0	Serial Channel 0, Control Register A
0x01	CNTLA1	Serial Channel 1, Control Register A
0x02	CNTLB0	Serial Channel 0, Control Register B
0x03	CNTLB1	Serial Channel 1, Control Register B
0x04	STAT0	Serial Channel 0, Status Register
0x05	STAT1	Serial Channel 1, Status Register
0x06	TDR0	Serial Channel 0, Transmit Data Register
0x07	TDR1	Serial Channel 1, Transmit Data Register
0x08	RDR0	Serial Channel 0, Receive Data Register
0x09	RDR1	Serial Channel 1, Receive Data Register
0x0A	CNTR	Clocked Serial Control Register
0x0B	TRDR	Clocked Serial Data Register
0x0C	TMDR0L	Timer Data Register Channel 0, low
0x0D	TMDR0H	Timer Data Register Channel 0, high
0x0E	RLDR0L	Timer Reload Register Channel 0, low
0x0F	RLDR0H	Timer Reload Register Channel 0, high
0x10	TCR	Timer Control Register
0x11–0x13	—	Reserved
0x14	TMDR1L	Timer Data Register Channel 1, low
0x15	TMDR1H	Timer Data Register Channel 1, high
0x16	RLDR1L	Timer Reload Register Channel 1, low
0x17	RLDR1H	Timer Reload Register Channel 1, high

continued...

**Table G-1. Z180 Internal I/O Registers Addresses 0x00–0x3F (concluded)**

Address	Name	Description
0x18	FRC	Free-running counter
0x19–0x1F	—	Reserved
0x20	SAR0L	DMA source address Channel 0, low
0x21	SAR0H	DMA source address Channel 0, high
0x22	SAR0B	DMA source address Channel 0, extra bits
0x23	DAR0L	DMA destination address Channel 0, low
0x24	DAR0H	DMA destination address Channel 0, high
0x25	DAR0B	DMA destination address Channel 0, extra bits
0x26	BCR0L	DMA Byte Count Register Channel 0, low
0x27	BCR0H	DMA Byte Count Register Channel 0, high
0x28	MAR1L	DMA Memory Address Register Channel 1, low
0x29	MAR1H	DMA Memory Address Register Channel 1, high
0x2A	MAR1B	DMA Memory Address Register Channel 1, extra bits
0x2B	IAR1L	DMA I/O Address Register Channel 1, low
0x2C	IAR1H	DMA I/O Address Register Channel 1, high
0x2D	—	Reserved
0x2E	BCR1L	DMA Byte Count Register Channel 1, low
0x2F	BCR1H	DMA Byte Count Register Channel 1, high
0x30	DSTAT	DMA Status Register
0x31	DMODE	DMA Mode Register
0x32	DCNTL	DMA/WAIT Control Register
0x33	IL	Interrupt Vector Low Register
0x34	ITC	Interrupt/Trap Control Register
0x35	—	Reserved
0x36	RCR	Refresh Control Register
0x37	—	Reserved
0x38	CBR	MMU Common Base Register
0x39	BBR	MMU Bank Base Register
0x3A	CBAR	MMU Common/ Bank Area Register
0x3B–0x3D	—	Reserved
0x3E	OMCR	Operation Mode Control Register
0x3F	ICR	I/O Control Register

## BL1700 Peripheral Addresses

Table G-2 lists the addresses that control I/O devices external to the Z180 processor.

**Table G-2. BL1700 External I/O Device Registers**

Address	Name	R/W	Function
0x4000	EN485A	W	D0 = RS-485 Channel 1 Enable
0x4040	ENDI1	R	D0-D7 = Digital Input[00-15]
0x4040	TE485B	W	D0 = RS-485 Channel B Transmit Enable
0x4042	ENDI2	R	D0-D7 = Digital Input[16-31]
0x4042	TE485A	W	D0 = RS-485 Channel A Transmit Enable
0x40C0	ADEOC	R	D0 = ADC end of conversion
0x40D0	ADOUT	R	D0 = ADC output
0x40D0	ADIN	W	D2 = ADC instruction
0x40D0	ADCS	W	D1 = ADC chip select
0x40D0	ADCLK	W	D0 = ADC clock
0x40E0	LCD	R/W	PLCBus LCD line
0x40F0	/STB	R/W	PLCBus strobe
0x4100	/ENHV1	W	Digital Output [00-07]
0x4108	/ENHV2	W	Digital Output [08-15]
0x4110	/ENHV3	W	Digital Output [16-23]
0x4118	/ENHV4	W	Digital Output [24-31]
0x4120	SCC	R/W	Serial Channel B, Control
0x4121		R/W	Serial Channel A, Control
0x4122		R/W	Serial Channel B, Data
0x4123		R/W	Serial Channel A, Data
0x4142	LED	W	D0 = LED status
0x417F		R	D7 = Run/Program Mode, D6-D0 = ID



Refer to the Zilog or Hitachi *User's Manual* for more information about the Z80180/Z180 or the 64180 MPU internal I/O register map.

## Epson 72423 Timer Registers 0x4180–0x418F

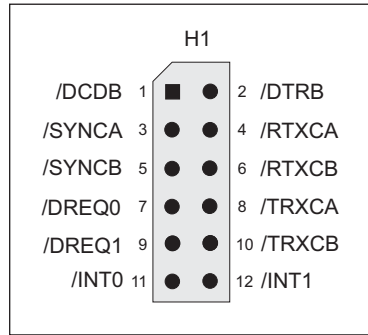
Table G-3 lists the Epson 72423 timer registers.

**Table G-3. Epson 72423 Timer Registers 0x4180–0x418F**

Address	Name	Data Bits	Description
4180	SEC1	D0–D7	seconds, units
4181	SEC10	D0–D7	seconds, tens
4182	MIN1	D0–D7	minutes, units
4183	MIN10	D0–D7	minutes, tens
4184	HOUR1	D0–D7	hours, units
4185	HOUR10	D0–D7	hours, tens
4186	DAY1	D0–D7	days, units
4187	DAY10	D0–D7	days, tens
4188	MONTH1	D0–D7	months, units
4189	MONTH10	D0–D7	months, tens
418A	YEAR1	D0–D7	years, units
418B	YEAR10	D0–D7	years, tens
4180C	WEEK	D0–D7	weeks
418D	TREGD	D0–D7	Register D
418E	TREG E	D0–D7	Register E
418F	TREGF	D0–D7	Register F

# Interrupts

The BL1700 provides user access to two level-sensitive interrupts. The interrupts are shared with onboard peripherals such as the PLCBus port and serial channels. If these peripherals are not used, then external devices may use these interrupts. Header H1 provides connections to the /INT0 and /INT1 interrupt lines of the Z180 processor according to the pinout shown in Figure G-3. Header J4 provides jumper connections to allow external connection to the /INT0 and /INT1 signals.



**Figure G-3. Pinouts for Optional Header H1**



See Chapter 3, “BL1700 Hardware,” for information on jumper settings for header J4.



Z-World can install a header at header location H1 in production quantities. For more information, call your Z-World Sales Representative at (530) 757-3737.

Interrupts can be enabled or disabled by including the following commands in your code.

- Interrupt 0 “ON” (enabled)  
~ `output (ITC, inport (ITC) | 1)`
- Interrupt 1 “ON” (enabled)  
~ `output (ITC, inport (ITC) | 2)`
- Interrupt 0 “OFF” (disabled)  
~ `output (ITC, inport (ITC) & 0xfe)`
- Interrupt 1 “OFF” (disabled)  
~ `output (ITC, inport (ITC) & 0xfd)`

## Interrupt Service Routines

Interrupt service routines are packets of code that the processor jumps to and executes when it receives an interrupt request.



Refer to the Dynamic C manuals for instructions on writing interrupt service routines.

Refer to the Zilog *Z80180/Z180 User’s Manual* (available from Z-World) for complete details on using Z180 interrupts.

## Interrupt Vectors

To “vector” an interrupt to a user function in Dynamic C, a directive such as the following is used.

```
#INT_VEC 0x10 myfunction
```

This example causes the interrupt at offset 10H (Serial Port 1 of the Z180) to invoke the function `myfunction()`. The function must be declared with the `interrupt` keyword.

```
interrupt myfunction() {  
    ...  
}
```

Table G-4 provides the interrupt vectors for various Z180 internal devices.

**Table G-4. Interrupt Vectors for Z180 Internal Devices**

Address	Name	Description
0x00	INT1_VEC	/INT1
0x02	INT2_VEC	/INT2
0x04	PRT0_VEC	PRT timer Channel 0
0x06	PRT1_VEC	PRT timer Channel 1
0x08	DMA0_VEC	DMA Channel 0
0x0A	DMA1_VEC	DMA Channel 1
0x0C	CSIO_VEC	Clocked Serial I/O
0x0E	SER0_VEC	Asynchronous Serial Port Channel 0
0x10	SER1_VEC	Asynchronous Serial Port Channel 1

Table G-5 lists the interrupt priorities.

**Table G-5. Interrupt Priorities**

Interrupt Priorities	
(Highest Priority)	Trap (Illegal Instruction)
	NMI (Nonmaskable Interrupt)
	INT 0 (Maskable Interrupt, Level 0)
	INT 1 (Maskable Interrupt, Level 1)
	INT 2 (Maskable Interrupt, Level 2)
	PRT Timer Channel 0
	PRT Timer Channel 1
	DMA Channel 0
	DMA Channel 1
	Clocked Serial I/O
	Serial Port 0
(Lowest Priority)	Serial Port 1

## **Jump Vectors**

Jump vectors are similar to interrupt vectors, except that instead of loading the address of the interrupt routine from the interrupt vector, these interrupts cause a jump directly to the address of the vector, which contains a jump instruction to the interrupt routine. This is an example of a jump vector.

### **0x66 nonmaskable power-failure interrupt**

Because nonmaskable interrupts can be used for Dynamic C communication, the interrupt vector for power failure is normally stored just in front of the Dynamic C program. Store a vector there by using this compiler directive.

```
#JUMP_VEC NMI_VEC name
```

The Dynamic C communication routines jump to this vector when a power failure causes the NMI rather than a serial interrupt.



# Flash EPROM

## *Simulated EEPROM*

The BL1700 uses a section of the flash EPROM to simulate EEPROM. The size of the simulated EEPROM is 512 bytes (not Kbytes). Locations 0x02 through 0x3D are used to store the analog input calibration constants. The rest of the simulated EEPROM is free for use by the application. These functions are used to read/write from/to the simulated EEPROM.

- **int ee\_rd( int address )**

Reads and returns data from flash EPROM storage location **address**. The function returns -1 if it is unable to read data.

LIBRARY: **BIOS.LIB**

- **int ee\_wr( int address, int data )**

Writes data to flash EPROM storage location **address**. The function returns -1 if it is unable to write data.

LIBRARY: **BIOS.LIB**

## Other Flash EPROM Software

- `int WriteFlash( unsigned long physical_addr, char *buf, int count )`

Writes `count` number of bytes pointed to by `buf` to the flash EPROM absolute data location `physical_addr`. Allocate the data location by declaring the byte arrays as initialized arrays or declare an initialized `xdata` array. If byte array is declared, convert logical memory to physical memory with `phy_addr(array)`. For initialized `xdata`, you can pass the array name directly.

PARAMETERS: `physical_addr` is the absolute data location in the flash EPROM.

`*buf` is a pointer to the bytes to write.

`count` is the number of bytes to write.

RETURN VALUES:

0 if `WriteFlash` is okay.

-1 if the flash EPROM is not in use.

-2 if `physical_addr` is inside the BIOS area.

-3 if `physical_addr` is within the symbol area or the simulated EEPROM area.

-4 if `WriteFlash` times out.

LIBRARY: `DRIVERS.LIB`



Flash EPROM is rated for 10,000 writes. In practice, flash EPROM has performed for up to 100,000 writes. Z-World recommends that any writes to the flash EPROM be made by the programmer rather than automatically by the software to maximize the life of the flash EPROM.

# Pulse-Width Modulation (PWM) Software

## *PWM Addressing Detail*

The driver of the PWM on the BL1700 is fairly complicated. This is because it uses the clock output from communication port 1 (CKA1) to drive the request line DMA Channel 0 in edge detection mode. The simple interface previously described in Chapter 4 provides PWM support for output 0 to output 3. If the application requires more PWM channels or require specific frequencies or precision, the application engineer may need to make trade-offs.

This section describes how PWM channels are driven, as well as how to customize PWM resource allocation to compromise number of modulated channels, frequency, and resolution.

### **1. Determine the number of channels, frequency, and resolution.**

A pulse-width modulated waveform has a frequency and a resolution. The frequency states how many times the pattern repeats itself in a second (Hz). The resolution states how many divisions within one waveform can be resolved (distinguished). As a collection, the PWM driver also needs to know the total number of channels to be pulse-width modulated. The calculations in this section are made with the assumption that all channels have the same frequency and resolution.

The clock output from communication port 1 (CKA1) must have a frequency,

$$f_1 = N_{\text{ch}} \times f_w \times R_w ,$$

where which  $f_1$  is the frequency of CKA1,  $N_{\text{ch}}$  is the number of channels PW modulated,  $f_w$  is the frequency of each channel, and  $R_w$  is the resolution in number of divisions per wave.

For example, the driver interface, `_eioSetupA01st`, makes the following assumptions.

$$N_{\text{ch}} = 4$$

$$f_1 = 76,800 \text{ Hz}$$

$$R_w = 256$$

Consequently,  $f_w = 76,800 \text{ Hz} / (4 \times 256) = 75 \text{ Hz}$ .

### **2. Declare storage for the WPB (waveform pattern buffer).**

Memory must be allocated to store the waveform pattern.

### 3. Set up the waveform.

The PWM functions use the Z180's built-in DMA mechanism to transfer PWM "edges" from memory to the high-current ports at specific time intervals. Each edge is a byte whose least-significant four bits select one of the high-current outputs, output 0 through output 6. The least significant bit is a 1 to turn the specified port on (rising PWM "edge") or a 0 to turn the specified port off (falling PWM "edge"). Edges for the channels being pulse-width modulated are then grouped into composite transitions.

Each composite transition is a series of edges, each representing one possible transition for an individual channel. For example, if output 0 and output 1 are the only pulse-width modulated channels, a composite transition consists of two bytes. The first byte specifies a possible transition for channel output 0. The second byte specifies a possible transition for channel output 1.

Let us assume the first byte in the composite transition corresponds to output 0, and the second byte corresponds to output 1.

The composite PWM waveform is a series of composite transitions (CTs) that specify the duty cycle of the pulse-width modulated channels. For example, if output 0 is to have a 0.375 duty cycle, output 1 is to be at 0.75 duty cycle, and the resolution is 8 divisions per cycle, a simple wave form would be as follows.

CT1: turn on output 0, turn on output 1.

CT2: do nothing.

CT3: do nothing.

CT4: turn off output 0.

CT5: do nothing.

CT6: do nothing.

CT7: turn off output 1.

CT8: do nothing.

Go back to CT1.

Outputting the byte 0x01 turns on output 0, 0x00 turns off output 0, 0x03 turns on output 1, and 0x02 turns off output 1. The byte 0x0E is a “no-op” and it does nothing. The composite transitions (with no-ops) can be translated into the following byte sequence to be sent to the I/O address 0x4100.

CT1: 0x01, 0x03

CT2: 0x0E, 0x0E

CT3: 0x0E, 0x0E

CT4: 0x00, 0x0E

CT5: 0x0E, 0x0E

CT6: 0x0E, 0x0E

CT7: 0x0E, 0x02

CT8: 0x0E, 0x0E

Go back to CT1


The equivalent byte stream (contents in the waveform pattern buffer) is a repeating pattern of the following.

0x01, 0x03, 0x0E, 0x0E, 0x0E, 0x0E, 0x00, 0x0E,  
0x0E, 0x0E, 0x0E, 0x0E, 0x0E, 0x02, 0x0E, 0x0E

The driver library provides a function, **dmapwmSetBuf**, that allows the application engineer to modify the content of the waveform pattern buffer.

#### 4. Set up the clock.

The DMA device transfer from memory to I/O port address 0x4100 is driven by falling edges on signal /DREQ0. Since /DREQ0 is connected to CKA1 (the clock output of communication channel 1), the communication speed of communication channel 1 determines how frequently the DMA device transfer memory to I/O. Each transfer corresponds to one edge in the previous section.

 Refer to the Zilog user’s manual for more information on how to set up the CKA1 frequency for the Z80180/Z180 or to the Hitachi user’s manual for the 64180 MPU.

The driver does include a function, **dmapwmInit**, that sets up the frequency of CKA1. The function is described later in this appendix.

The PWM interface sets up CKA1 to clock at 76,800 Hz in the call **\_eioSetupAO1st()**.

## 5. Refresh the DMA counter and source address.

The DMA device does not automatically reload the counter and source address registers when the specified amount of bytes is transferred. When the DMA device finishes transferring the specified amount of bytes, it stops and optionally causes an interrupt. In other words, the PWM waveform is abruptly ended when the DMA finishes.

To overcome this limitation, the application program must periodically “refresh” the counter and source address registers of the DMA device. The refresh should check whether the counter is less than a critical number. If so, both the counter and the source address registers must be “rebound” to a previous state (a larger counter value and a corresponding lower source address).

Note that the PWM waveforms cannot be disrupted while it is refreshing the registers. In other words, the previous state to which the refresh routine restores must be phase synchronized with the PWM waveforms at the moment.

The driver library provides a refresh routine, `_eioBrdAORf`, to refresh the DMA counter and source address registers. `_eioBrdAORf()` can be called from a preemptive task or from the main program. The refresh routine must be called frequently enough so that the DMA counter never reaches 0. The following inequality states the requirement.

$$f_r \geq f_1 / (l_{\text{wpb}} / 2)$$

in which  $f_r$  is the refresh frequency,  $f_1$  is the frequency of CKA1, and  $l_{\text{wpb}}$  is the total length of the waveform pattern buffer.

For example, `_eioSetupA01st()` sets up  $f_1 = 76,800\text{Hz}$  and  $l_{\text{wpb}} = 4096$ . As a result, the application engineer must ensure  $f_r \geq 37.5\text{ Hz}$ .

## 6. Changing duty cycles.

Once the PWM waveforms are up and running, the application may need to change the duty cycles for the channel(s). This poses two problems. First, the change should only be done to the channel that needs a change of duty cycle, all other channels should remain the same. Second, the change must become effective phase synchronized with the current waveform.

The solution to the first problem depends on how the edges are represented. In particular, it depends on whether the “no-op” edges are used. If the no-op edges are used, changing duty cycle is a matter of moving the edges that are not “no-op”. For example, in our example in the “set up the

waveform” section, if we wish to change the duty cycle of output 0 to 0.25, we change the waveform from

```
0x01, 0x03, 0x0E, 0x0E, 0x0E, 0x0E, 0x00, 0x0E,  
0x0E, 0x0E, 0x0E, 0x0E, 0x0E, 0x02, 0x0E, 0x0E
```

to

```
0x01, 0x03, 0x0E, 0x0E, 0x00, 0x0E, 0x0E, 0x0E,  
0x0E, 0x0E, 0x0E, 0x0E, 0x0E, 0x02, 0x0E, 0x0E
```

The underlined edges are the only ones affected.

Of course, the waveform pattern buffer may have the pattern repeated many times. Each occurrence of the pattern in the buffer must be modified in the same manner.

However, although the use of “no-op” edges seems to be compute-time inexpensive, it does require the application to maintain the location of the non-no-op edges. In other words, besides the waveform pattern buffer, the application program must maintain a duty cycle variable for each channel.

Recall that the second problem of changing the duty cycle is the requirement for the change to be phase synchronized to the current waveform. Many of the involved issues are similar to those of refreshing the DMA counter and pointer. The driver software library provides the function **dmapwmSwBuf** to switch waveform pattern buffers.

## **PWM Software**

The functions shown below are second level functions that allow more PWM outputs. They are also more complex and require a more in-depth understanding of PWM and DMA generation. These functions are located in **EZIODPWM.LIB**.

- **void dmapwmSetBuf ( char \*pBufStart,  
char bufLength256,  
unsigned step, char outChar )**

Formats part of the waveform pattern buffer for DMA-driven PWM.

In other words, **dmapwmSetBuf** does the following: starting at the address pointed to by **pBufStart**, for **bufLength256** many 256-byte pages, change every **step** bytes to **outChar**.

PARAMETERS: **pBufStart** points to the first byte to be formatted. Note that **pBufStart** does not always have to point to a 256-byte aligned address.

**bufLength256** is the length of the buffer, including the overflow area.

**step** is the number of bytes to skip between outputting **outChar**.

**outChar** is the actual bytes to send to the I/O address.

- **void dmapwmSwBuf ( unsigned newBuf256 )**

In order to facilitate all-or-none duty cycle transitions, you should use two buffers. While one buffer is being used by the DMA mechanism to generate the PWM output, modify the other buffer for the new PWM pattern. When the new buffer is ready, this function should be called to switch to use the buffer at the address pointed to by **newBuf256** in 256-byte units.

- **char \*dmapwmBufBeg ( char \*bufPtr )**

The buffer used by the PWM mechanism starts at 256-byte boundaries. Normal data definition declarations such as

```
char buffer[0x2000]
```

start at byte boundaries. **dmapwmBufBeg** returns a character pointer that points to the first 256-byte aligned root address larger than or equal to the parameter **bufPtr**.

- **void dmapwmInit( unsigned phyBuffer256, unsigned bufSize256, unsigned resSize256, unsigned ioAddr, char cka1rate )**

Initializes the DMA PWM mechanism.

When the function returns, CKA1 of communication port 1 generates clock pulses at **cka1rate** \* 19.2 kHz to /DREQ0. DMA Channel 0 would then perform memory to I/O transfer for each clock pulse falling edge.

PARAMETERS: **phyBuffer256** is the 256 byte aligned physical address of the buffer in 256-byte units. In general, if the buffer is defined as an array in root memory (that is, of type **(char \*)**), the following expression should be passed to this parameter

```
(unsigned) ((xaddr (buffer) +255) >>8)
```

in which **buffer** is a pointer of type **(char \*)** to the array.

**bufsize256** is the size of the buffer, in 256 byte units. This size should not include the overflow area.

**resSize256** is the size of the overflow area in 256 byte units.

**ioAddr** is the port to which the DMA should transfer memory content.

**cka1rate** is the clock rate generated by CKA1 in 19.2 kHz units. Allowed numbers are 2, 4, and 8.




## Sample Program

**BL17PWM1.C** and **BL17PWM2.C** are sample programs which show how to use the pulse width modulation feature using the functions listed above. They can be found in the Dynamic C **SAMPLES\BL17XX** directory.



The PWM functions use the Z180's built-in DMA hardware. Using this DMA-driven PWM limits the communication speed of the Z180's Serial Port 1 to 4800 bps, and the Z180 runs effectively at least 8% slower. In addition you must ensure your application calls **\_eioBrdaORf** at least every 25 ms to refresh the drivers' period.

If necessary, call Z-World Technical Support at (530)757-3737 for assistance.



## *APPENDIX H: **BATTERY***

---

Appendix H provides information about the onboard lithium backup battery.

## Battery Life and Storage Conditions

The battery on the BL1700 controller will provide at least 9,000 hours of backup time for the onboard real-time clock and static RAM. However, backup time longevity is affected by many factors, including the amount of time the controller is unpowered and the static RAM size. Most systems are operated on a continuous basis, with the battery supplying power to the real-time clock and the static RAM during power outages and/or during routine maintenance. The time estimate reflects the shelf life of a lithium ion battery with occasional use rather than the ability of the battery to power the circuitry full time.

The battery has a capacity of 190 mA·h. At 25°C, the real-time clock draws 3  $\mu$ A when idle, and the 32K SRAM draws 2  $\mu$ A. If the BL1700 were unpowered 100 percent of the time, the battery would last 38,000 hours (4.3 years).

To maximize the battery life, the BL1700 should be stored at room temperature in the factory packaging until field installation. Take care that the BL1700 is not exposed to extreme temperature, humidity, and/or contaminants such as dust and chemicals.

To ensure maximum battery shelf life, follow proper storage procedures. Replacement batteries should be kept sealed in the factory packaging at room temperature until installation. Protection against environmental extremes will help maximize battery life.

## Replacing Soldered Lithium Battery

Use the following steps to replace the battery.

1. Locate the three pins on the bottom side of the printed circuit board that secure the battery to the board.
2. Carefully de-solder the pins and remove the battery. Use a solder sucker to clean up the holes.
3. Install the new battery and solder it to the board. Use only a Panasonic BR23251HG or its equivalent.

## Battery Cautions

- **Caution (English)**

There is a danger of explosion if the battery is incorrectly replaced. Replace only with the same or equivalent type recommended by the manufacturer. Dispose of used batteries according to the manufacturer's instructions.

- **Warnung (German)**

Explosionsgefahr durch falsches Einsetzen oder Behandein der Batterie. Nur durch gleichen Typ oder vom Hersteller empfohlenen Ersatztyp ersetzen. Entsorgung der gebrauchten Batterien gemäß den Anweisungen des Herstellers.

- **Attention (French)**

Il y a danger d'explosion si la remplacement de la batterie est incorrect. Remplacez uniquement avec une batterie du même type ou d'un type équivalent recommandé par le fabricant. Mettez au rebut les batteries usagées conformément aux instructions du fabricant.

- **Cuidado (Spanish)**

Peligro de explosión si la pila es instalada incorrectamente. Reemplace solamente con una similar o de tipo equivalente a la que el fabricante recomienda. Deshágase de las pilas usadas de acuerdo con las instrucciones del fabricante.

- **Waarschuwing (Dutch)**

Explosiegevaar indien de batterij niet goed wordt vervagen. Vervanging alleen door een zelfde of equivalent type als aanbevolen door de fabrikant. Gebruikte batterijen afvoeren als door de fabrikant wordt aangegeven.

- **Varning (Swedish)**

Explosionsfara vid felaktigt batteritype. Använd samma batterityp eller en likvärdigt typ som rekommenderas av fabrikanten. Kassera använt batteri enligt fabrikantens instruktion.



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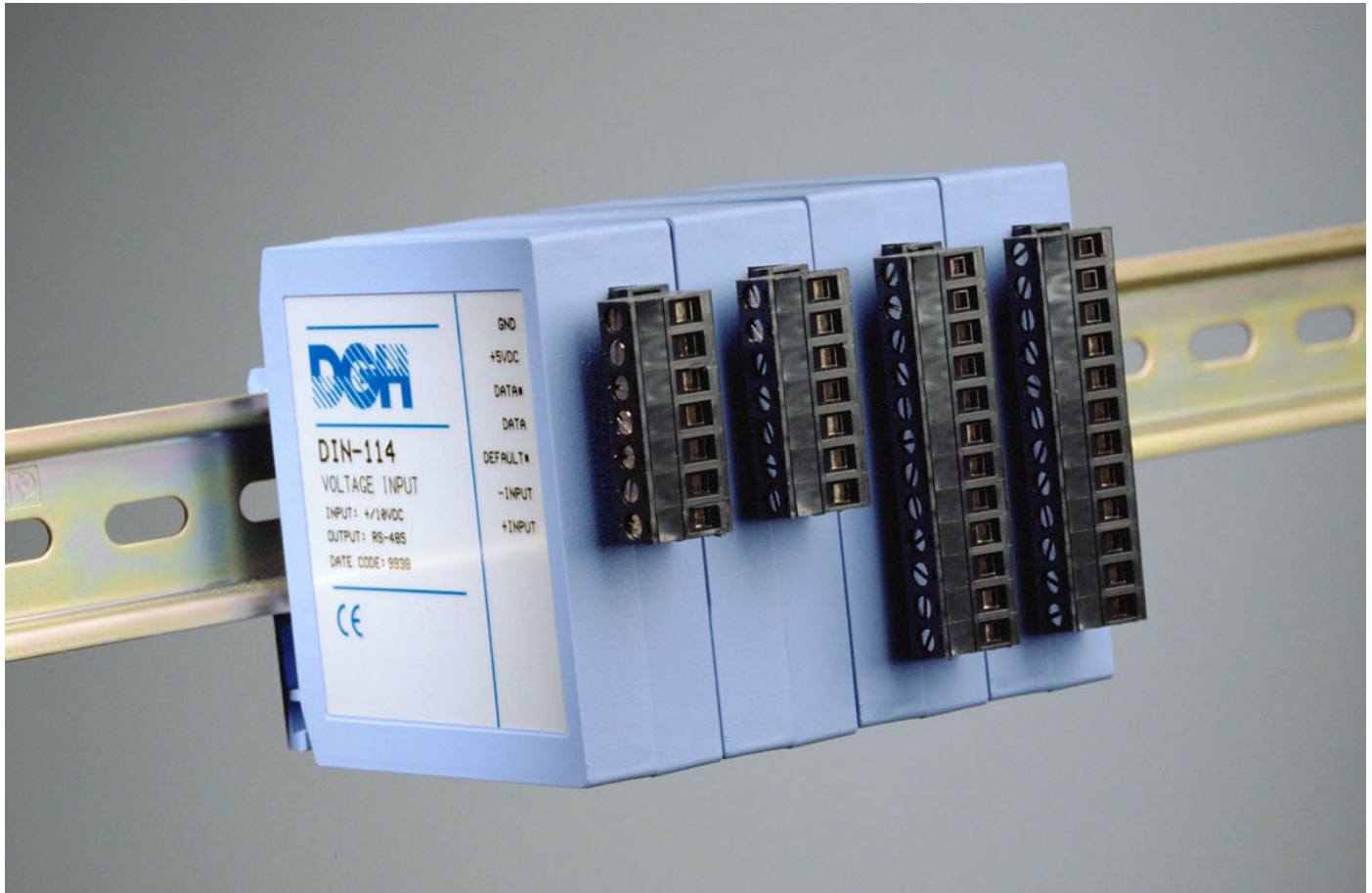
# ***SCHEMATICS***

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## DIN-100 SERIES SENSOR TO COMPUTER INTERFACE MODULES



### DIN-100 FEATURES

- Complete sensor to RS-485 interface.
- 500V rms analog input isolation.
- 15 bit measurement resolution.
- Continuous self-calibration; no adjustments of any kind.
- Programmable digital filter.
- Requires +5VDC supply.
- Transient suppression on RS-485 communications lines.
- Screw terminal plug connectors supplied.

### APPLICATIONS

- Process monitoring and control
- Remote data logging to any host computer
- Product testing
- Interface to PLC

### GENERAL DESCRIPTION

The DIN-100 Sensor to Computer Modules are a family of data acquisition modules that convert analog input signals to digital data and transmit via RS-485 to a controller which may be a computer or other processor-based equipment. The modules can measure temperature, pressure, voltage, current, digital input or digital output signals. The modules provide direct connection to a wide variety of sensors and perform all signal conditioning, scaling, linearization and conversion to either linearized ASCII data values or Modbus RTU data values.

Features such as address, baud rate, parity, echo, etc., are selectable using simple commands over the RS-485 port. The selections are stored in nonvolatile EEPROM which maintains data even after power is removed.



## DIN-100 SPECIFICATIONS (typical at +25°C and nominal power supply unless otherwise noted)

### Analog

- Single channel analog input.
- Maximum CMV, input to output at 60Hz: 500V rms.
- Leakage current, input to output at 115Vrms, 60Hz: <math><2\mu\text{A}</math> rms.
- 15 bit measurement resolution.
- 8 conversions per second.
- Autozero & autocalibration—no adjustment pots.

### Digital

- 8-bit CMOS microcomputer.
- Digital scaling, linearization and calibration .
- Nonvolatile memory eliminates pots and switches.

### Digital filtering

- Small and large signal with user selectable time constants from 0 to 16 seconds.

### Communications

- Communications in MODBUS-RTU via RS-485 ports.
- Selectable baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400.
- NRZ asynchronous data format; 1 start bit, 8 data bits, 1 parity bit and 1 stop bit.
- Parity: odd, even, none.
- User selectable channel address.
- Up to 247 multidrop modules per host serial port.
- Communications distance up to 4,000 feet (RS-485).
- Transient suppression on RS-485 communications lines.
- All communications setups stored in EEPROM.

### Power

Requirements: Regulated +5Vdc ,  
0.75W max (DIN-150, 2.0W max.).  
Protected against power supply reversals.

### Environmental

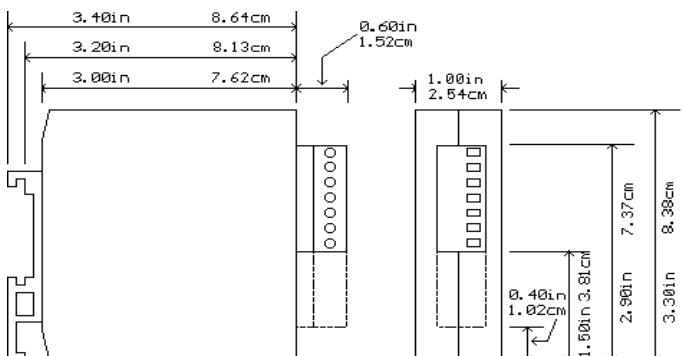
Temperature Range: Operating -25°C to +70°C.  
Storage -25°C to +85°C.  
Relative Humidity: 0 to 95% noncondensing.

### Warranty

12 months on workmanship and material.

### Mechanicals and Dimensions

ABS case with screw terminal barrier plug (supplied).



### DIN-100 Voltage Inputs

- Voltages:  $\pm 10\text{mV}$ ,  $\pm 100\text{mV}$ ,  $\pm 1\text{V}$ ,  $\pm 5\text{V}$ ,  $\pm 10\text{V}$ ,  $\pm 100\text{Vdc}$ .
- Resolution: 0.01% of FS (4 digits).
- Accuracy:  $\pm 0.02\%$  of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max.
- Input burnout protection to 250Vac .
- Input impedance:  $\leq \pm 1\text{V}$  input =  $100\text{M}\Omega$  min.  
 $\geq \pm 5\text{V}$  input =  $1\text{M}\Omega$  min.

### DIN-120 Current Inputs

- Currents: 4-20mAdc.
- Resolution: 0.04% of FS.
- Accuracy: 0.04% of FS.
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max.
- Voltage drop:  $\pm 0.1\text{V}$  max.

### DIN-130 Thermocouple Inputs

- Thermocouple types: J, K, T, E, R, S, B, C (factory set).
- Ranges: J = -200°C to +760°C    B = 0°C to +1820°C  
K = -150°C to +1250°C    S = 0°C to +1750°C  
T = -200°C to +400°C    R = 0°C to +1750°C  
E = -100°C to +1000°C    C = 0°C to +2315°C
- Resolution:  $\pm 1^\circ$ .
- Overall Accuracy (error from all sources) from 0 to +40°C ambient:  $\pm 1.0^\circ\text{C}$  max (J, K, T, E).  
 $\pm 2.5^\circ\text{C}$  max (R, S, B, C)(300°C TO FS).
- Common mode rejection: 100dB at 50/60Hz.
- Input impedance:  $100\text{M}\Omega$  min.
- Lead resistance effect:  $<20\mu\text{V}$  per  $350\Omega$ .
- Open thermocouple indication.
- Input burnout protection to 250Vac.
- Overrange indication.
- Automatic cold junction compensation and linearization.

### DIN-140 RTD Inputs

- RTD types:  $\alpha = .00385$ ,  $.00392$ ,  $100\Omega$  at  $0^\circ\text{C}$ ,  
 $.00388$ ,  $100\Omega$  at  $25^\circ\text{C}$ .
- Ranges:  $.00385 = -200^\circ\text{C}$  to  $+850^\circ\text{C}$ .  
 $.00392 = -200^\circ\text{C}$  to  $+600^\circ\text{C}$ .  
 $.00388 = -100^\circ\text{C}$  to  $+125^\circ\text{C}$ .
- Resolution:  $0.1^\circ$ .
- Accuracy:  $\pm 0.3^\circ\text{C}$ .
- Common mode rejection: 100dB at 50/60Hz.
- Input connections: 2, 3, or 4 wire.
- Excitation current: 0.25mA.
- Lead resistance effect: 3 wire -  $2.5^\circ\text{C}$  per  $\Omega$  of imbalance.  
4 wire - negligible.
- Max lead resistance:  $50\Omega$ .
- Input burnout protection to 120Vac .
- Automatic linearization and lead compensation.

Specifications are subject to change without notice.

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### DIN-145 Thermistor Inputs

- Thermistor types: 2252Ω at 25°C, TD Series
  - Ranges: 2252Ω = -0°C to +100°C.  
TD = -40°C to +150°C.
  - Resolution: 2252Ω = 0.01°C or F.  
TD = 0.1°C or F
  - Accuracy: 2252Ω = ±0.1°C.  
TD = ±0.2°C
  - Common mode rejection: 100dB at 50/60Hz.
  - Input burnout protection to 30Vdc .
- 

### DIN-150 Bridge Inputs

- Voltage Ranges: ±30mV, ±100mV.
  - Resolution: 10μV (mV spans).  
0.02% of FS (V span).
  - Accuracy: ±0.05% of FS max.
  - Common mode rejection: 100dB at 50/60Hz.
  - Input burnout protection to 30Vdc .
  - Offset Control: Full input range.
  - Excitation Voltage: 5V, 10Vdc, 50mA max.
  - Zero drift: ±1μV/°C max.
  - Span tempco: ±50ppm/°C max.
- 

### DIN-160 Frequency Inputs

- Range: 1Hz to 20KHz.
  - Resolution: 0.005% of reading + 0.01Hz.
  - Accuracy: ±0.01% of reading ±0.01Hz.
  - Tempco: ±20ppm/°C.
  - Input impedance: 1MΩ.
  - Switching level: selectable 0V, +2.5V.
  - Hysteresis: Adjustable 10mV-1.0V.
  - Input burnout protection: 250Vac .
- 

### DIN-170 Digital Inputs/Outputs

- 6 digital inputs or 6 digital outputs.
  - Input voltage levels: ±30V without damage.
  - Input switching levels: High, 3.5V min., Low, 1.0V max.
  - Outputs: open collector to 30V, 100mA max. load.
  - Vsat: 1.0V max @ 100mA.
  - Inputs/Outputs are read/set in parallel.
  - Isolated from power supply ground.
- 

### DIN-190 RS-232/485 Converter/Repeater

- Baud Rates: 300-115200 (Dip-switch selectable).
  - Termination and biasing resistors included (selectable via internal jumpers).
  - Isolated to 500Vrms.
- 

**General Description continued:** The key to the DGH product concept is that the modules are easy to use. You do not need engineering experience in complicated data acquisition hardware. With the DGH modules, anyone familiar with a personal computer can construct a data acquisition system. This modular approach to data acquisition is extremely flexible, easy to use and cost effective. Data is acquired on a per channel basis so you only buy as many channels as you need. The modules can be mixed and matched to fit your application. They can be placed remote from the host and from each other. You can string up to 247 modules on a twisted pair of wires by using RS-485 with repeaters.

All modules are supplied with screw terminal plug connectors. The connectors allow system expansion, reconfiguration or repair without disturbing field wiring.

Utility software is available from DGH to make the DIN-100 easier to learn and use. The software is provided at no charge on request with a purchase order and is not copy protected.

### THEORY OF OPERATION

Each DGH module is a complete single-channel data acquisition system. Each unit contains analog signal conditioning circuits optimized for a specific input type. Sensor signals are converted to digital data with a microprocessor-controlled integrating A/D converter. Offset and gain errors in the analog circuitry are continuously monitored and corrected using microprocessor techniques. The DIN-100 converts the digital signal data and stores the resultant data in a memory buffer. The modules continuously convert data at the rate of 8 conversions per second and store the latest result in the buffer.

Host processors may request data by sending a query to the module. The DIN-100 will instantly respond by communicating the memory buffer data back to the host processor. Up to 247 modules may be linked to a single RS-485 port. Each module on a serial line is identified by a unique user-programmable address. This addressing technique allows modules to be interrogated in any order.

### DIGITAL INPUTS/OUTPUTS

DIN-170 digital output modules contain open-collector transistor switches that may be controlled by the host processors. These switches may be used to control solid-state relays which in turn may control heaters, pumps and other power equipment. The digital inputs may be read by the host processor and used to sense the state of remote digital signals. They are ideal for sensing the state of limit or safety switches.

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## DIGITAL FILTER

The DIN-100 analog input modules include two unique programmable single pole digital filters. The filter is used to smooth analog data in noisy environments. Separate time constants may be specified for small and large signal changes. Typically a large time constant is specified for small signal changes to filter out noise and provide stable output readings. A smaller time constant may be chosen for large signal changes to provide fast response to such changes.

## COMMAND SET

The DIN-100 series uses the Modbus RTU or the DGH ASCII protocol for communication.

The Modbus RTU binary protocol uses a master-slave technique, in which only the master device can initiate transactions. The slave devices respond by supplying the requested data to the master or by taking the action requested in the query. The master can address any slave device. The returned messages are considered response messages. The supported master codes are:

### Modbus RTU Functions and Descriptions

- 01 Read Coil Status (Digital Inputs)
- 04 Read Input Register (Analog Inputs)
- 05 Force Single Coil (One Digital Input)
- 06 Preset Single Register (DGH/RTU Protocol)
- 15 Force Multiple Coils (Multiple Digital Output)

The DGH ASCII protocol is a command and response protocol using ASCII characters for easy troubleshooting and interpretation of data values.

## DIN-100 Series ASCII Command Set.

Command and Definition	Typical Command Message (\$ prompt)	Typical Response Message
DI Digital Input	\$1DI	*0003
DO Digital Output	\$1DOFF	*
RD Read Data	\$1RD	*+00072.00
RS Read Setup	\$1RS	*31070142
RSU Read Setup	\$1RSU	*31070142
RZ Read Zero	\$1RZ	*+00000.00
WE Write Enable	\$1WE	*

### Write Protected Commands.

CZ Clear Zero	\$1CZ	*
RR Remote Reset	\$1RR	*
SU Setup Module	\$1SU31070142	*
TS Trim Span	\$1TS+00600.00	*
TZ Trim Zero	\$1TZ+00000.00	*

## SETUP

The DIN-100 series are initiated at the factory using the DGH ASCII protocol. This allows setup and configuration, including the Modbus device address, to be easily performed using the DGH setup software or a dumb terminal. Each DIN-

100 module must be properly configured before installation into a Modbus system.

## UTILITY SOFTWARE

Complimentary Utility Software is included with each purchase order. The software is compatible with Windows 95, 98, NT 4.0+, 2000 operating systems and distributed on CD-ROM. The Utility Software simplifies configuration of all user-selectable options such as device address, baud rate and filtering constants. The latest version of our software is always downloadable from our web site at [www.dghcorp.com](http://www.dghcorp.com).

## PROCESS CONTROL SOFTWARE

Modbus RTU protocol is supported by virtually all commercial process control software programs available today. These programs operate on IBM and compatible personal computers in the Windows 95, 98, NT and IBM OS/2 environments.

## DIN-100 SERIES ORDERING GUIDE

### Voltage Input

- DIN-110 10mV Input/RS-485 Output
- DIN-111 100mV Input/RS-485 Output
- DIN-112 1V Input/RS-485 Output
- DIN-113 5V Input/RS-485 Output
- DIN-114 10V Input/RS-485 Output
- DIN-115 100V Input/RS-485 Output

### Current Inputs

- DIN-125 4-20mA Input/RS-485 Output

### Thermocouple Inputs

- DIN-131 J Thermocouple Input/RS-485 Output
- DIN-132 K Thermocouple Input/RS-485 Output
- DIN-133 T Thermocouple Input/RS-485 Output
- DIN-134 E Thermocouple Input/RS-485 Output
- DIN-135 R Thermocouple Input/RS-485 Output
- DIN-136 S Thermocouple Input/RS-485 Output
- DIN-137 B Thermocouple Input/RS-485 Output
- DIN-138 C Thermocouple Input/RS-485 Output

### RTD/Thermistor Inputs

- DIN-141 .00385 RTD Input/RS-485 Output
- DIN-142 .00392 RTD Input/RS-485 Output
- DIN-143 .00388 RTD Input/RS-485 Output
- DIN-145 2252Ω Thermistor Input/RS-485 Output
- DIN-146 TD Thermistor Input/RS-485 Output

### Bridge Inputs

- DIN-151 30mV Bridge Input, 5V Excitation/RS-485 Output
- DIN-152 30mV Bridge Input, 10V Excitation/RS-485 Output
- DIN-153 100mV Bridge Input, 5V Excitation/RS-485 Output
- DIN-154 100mV Bridge Input, 10V Excitation/RS-485 Output

### Timer and Frequency Inputs

- DIN-161 Frequency Input/RS-485 Output

### Digital Inputs/Outputs

- DIN-171 6 Digital Inputs/RS-485 Output
- DIN-172 6 Digital Outputs/RS-485 Output

### RS-232/485 Converter/Repeater

- DIN-191 RS-232/485 Converter
- DIN-192 RS-485 Repeater

# **DIN-100 SERIES USERS MANUAL**

**REVISED: 06/2000**

**DGH CORPORATION**

**P. O. BOX 5638**

**MANCHESTER, NH 03108**

TELEPHONE: 603-622-0452

FAX: 603-622-0487

URL: <http://www.dghcorp.com>

The information in this publication has been carefully checked and is believed to be accurate; however, no responsibility is assumed for possible inaccuracies or omissions. Applications information in this manual is intended as suggestions for possible use of the products and not as explicit performance in a specific application. Specifications may be subject to change without notice.

DIN-100 modules are not intrinsically safe devices and should not be used in an explosive environment unless enclosed in approved explosion-proof housings.

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<b>CHAPTER 9</b>	<b>Calibration</b>
<b>CHAPTER 10</b>	<b>Extended Addressing</b>
<b>Appendix A</b>	<b>(ASCII TABLE )</b>
<b>Appendix B</b>	<b>DIN-160 Data Sheet</b>
<b>Appendix C</b>	<b>DIN-140 Data Sheet</b>
<b>Appendix D</b>	<b>DIN-150 Data Sheet</b>
<b>Appendix E</b>	<b>DIN-100 Specifications</b>
<b>Appendix F</b>	<b>Modbus Protocol</b>

## **WARRANTY**

DGH warrants each DIN-100 series module to be free from defects in materials and workmanship under normal conditions of use and service and will replace any component found to be defective, on its return to DGH, transportation charges prepaid within one year of its original purchase. DGH assumes no liability, expressed or implied, beyond its obligation to replace any component involved. Such warranty is in lieu of all other warranties expressed or implied.

## **WARNING**

**The circuits and software contained in DIN-100 series modules are proprietary. Purchase of these products does not transfer any rights or grant any license to the circuits or software used in these products. Disassembling or decompiling of the software program is explicitly prohibited. Reproduction of the software program by any means is illegal.**

**As explained in the setup section, all setups are performed entirely from the outside of the DIN-100 module. There is no need to open the module because there are no user-serviceable parts inside. Removing the cover or tampering with, modifying, or repairing by unauthorized personnel will automatically void the warranty. DGH is not responsible for any consequential damages.**

## **RETURNS**

When returning products for any reason, contact the factory and request a Return Authorization Number and shipping instructions. Write the Return Authorization Number on the outside of the shipping box. DGH strongly recommends that you insure the product for value prior to shipping. Items should not be returned collect as they will not be accepted.

### **Shipping Address:**

DGH Corporation  
Hillhaven Industrial Park  
146 Londonderry Turnpike  
Hooksett, NH 03106

# Chapter 1

## Getting Started

### Default Mode

All DIN-100 modules contain an EEPROM (Electrically Erasable Programmable Read Only Memory) to store setup information and calibration constants. The EEPROM replaces the usual array of switches and pots necessary to specify baud rate, address, parity, etc. The memory is nonvolatile which means that the information is retained even if power is removed. No batteries are used so it is never necessary to open the module case.

The EEPROM provides tremendous system flexibility since all of the module's setup parameters may be configured remotely through the communications port without having to physically change switch and pot settings. There is one minor drawback in using EEPROM instead of switches; there is no visual indication of the setup information in the module. It is impossible to tell just by looking at the module what the baud rate, address, parity and other settings are. It is difficult to establish communications with a module whose address and baud rate are unknown. To overcome this, each module has an input pin labeled DEFAULT\*. By connecting this pin to Ground, the module is put in a known communications setup called Default Mode.

**The Default Mode setup is: 300 baud, one start bit, eight data bits, one stop bit, no parity, any address is recognized.**

Grounding the DEFAULT\* pin does not change any of the setups stored in EEPROM. The setup may be read back with the Read Setup (RS) command to determine all of the setups stored in the module. In Default Mode, all commands are available.

A module in Default Mode will respond to any address except the six identified illegal values (NULL, CR, \$, #, {, }). A dummy address must be included in every command for proper responses. The ASCII value of the module address may be read back with the RS command. An easy way to determine the address character is to deliberately generate an error message. The error message outputs the module's address directly after the "?" prompt.

Setup information in a module may be changed at will with the SetUp (SU) command. Baud rate and parity setups may be changed without affecting the Default values of 300 baud and no parity. When the DEFAULT\* pin is released, the module automatically performs a program reset and configures itself to the baud rate and parity stored in the setup information.

The Default Mode is intended to be used with a single module connected to a terminal or computer for the purpose of identifying and modifying setup

values. In most cases, a module in Default Mode may not be used in a string with other modules.

### RS-485 Quick Hook-Up

Software is not required to begin using your DIN-100 module. We recommend that you begin to get familiar with the module by setting it up on the bench. Start by using a dumb terminal or a computer that acts like a dumb terminal. Make the connections shown in the quick hook-up drawings, Figures 1.1 or 1.2. Put the module in the default mode by grounding the Default\* terminal. Initialize the terminal communications package on your computer to put it into the "terminal" mode. Since this step varies from computer to computer, refer to your computer manual for instructions.

Begin by typing \$1RD and pressing the Enter or Return key. The module will respond with an \* followed by the data reading at the input. The data includes sign, seven digits and a decimal point. For example, if you are using a thermocouple module and measuring room temperature your reading might be \*+00025.00. The temperature reading is scaled in °C which has been preset at the factory. Once you have a response from the module you can turn to the Chapter 4 and get familiar with the command set.

All modules are shipped from the factory with a setup that includes a channel address of 1, 300 baud rate, no linefeeds, no parity, alarms off, no echo and two-character delay. Refer to the Chapter 5 to configure the module to your application.

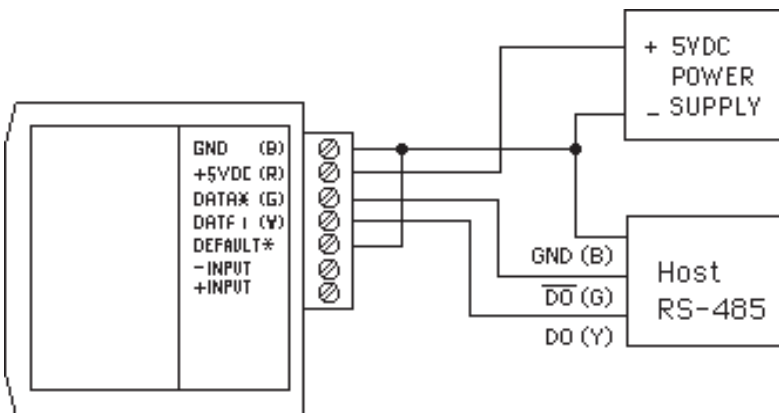


Figure 1.1 RS-485 Quick Hook-Up.

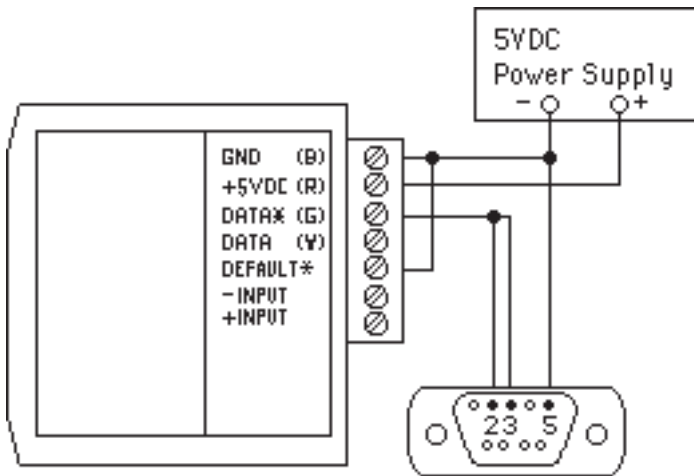


### RS-485 Quick Hook-up to a RS-232 port

An RS-485 module may be easily interfaced to an RS-232C terminal for evaluation purposes. This connection is only suitable for benchtop operation and should never be used for a permanent installation. Figure 1.2 shows the hook-up. This connection will work provided the RS-232C transmit output is current limited to less than 50mA and the RS-232C receive threshold is greater than 0V. All terminals that use 1488 and 1489 style interface IC's will satisfy this requirement. With this connection, characters generated by the terminal will be echoed back. To avoid double characters, the local echo on the terminal should be turned off.

If the current limiting capability of the RS-232C output is uncertain, insert a 100 $\Omega$  to 1k $\Omega$  resistor in series with the RS-232 output.

In some rare cases it may be necessary to connect the module's DATA pin to ground through a 100 $\Omega$  to 1k $\Omega$  resistor.



Note: If using a DB-25 connector ground is tied to pin 7.

Figure 1.2 RS-485 Quick Hook-Up with RS-232C Port.

## Chapter 2

### Functional Description

A functional diagram of a typical module is shown in Figure 2.1. It is a useful reference that shows the data path in the module and to explain the function of many of the module's commands.

The first step is to acquire the sensor signal and convert it to digital data. In Figure 2.1, all the signal conditioning circuitry has been lumped into one block, the analog/digital converter (A/D). Autozero and autocalibration is performed internally and is transparent to the user.

The full-scale output of the A/D converter may be trimmed using the Trim Span (TS) command. The TS command adjusts calibration values stored internally in the EEPROM. The TS command should only be used to trim the accuracy of the unit with a laboratory standard reference applied to the sensor input.

The trimmed data flows into either of two digital filters. The filter selection is performed automatically by the microprocessor after every A/D conversion. The filter selection depends on the difference of the current A/D output data and the previous data stored in the output data register. If the least significant decimal digit from the A/D differs from the old output data by more than 10 counts, the large signal filter is selected. If the change is less than 10 counts, the small signal filter is used.

The two-filter system allows for different degrees of filtering depending on the rate of the input change. For steady-state signals, the small-signal filter averages out noise and small input changes to give a stable steady-state output. The large-signal filter is activated by step changes or very noisy input signals. The time constants for the two filters can be specified independently with the SetUp (SU) command. The filter values are stored in nonvolatile memory. Typically, the small-signal filter is set to a larger time constant than the large-signal filter. This gives very good noise rejection along with fast response to step inputs.

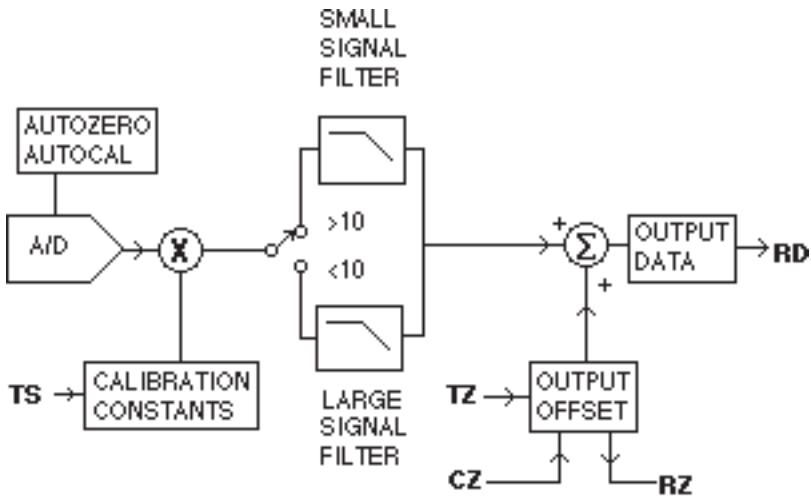
The scaled data is summed with data stored in the Output Offset Register to obtain the final output value. The output offset is controlled by the user and has many purposes. The data in the Output Offset Register may be used to trim any offsets caused by the input sensor. It may be used to null out undesired signal such as a tare weight. The Trim Zero (TZ) command is used to adjust the output to any desired value by loading the appropriate value in the offset register. The offset register data is nonvolatile.

The value stored in the offset register may be read back using the Read Zero (RZ) command. Data loaded in with the SP command will be read back with the sign changed. The output register may be reset to zero with the Clear Zero (CZ) command.

The output data may be read with the Read Data (RD) command. In some cases when a computer is used as a host, the same data value may be read back several times before it is updated with a new A/D conversion.

The DIN-170 general-purpose digital outputs are open-collector transistor switches that may be controlled by the host with the Digital Output (DO) command. They are designed to activate external solid-state relays to control AC or DC power circuits. The output may also be used to interface to other logic-level devices. The number of digital outputs available depends on the module type.

The DIN-170 Digital Input (DI) command is used to sense the logic levels on the digital input pins DI0-DI7. The digital inputs are used to read logic levels generated by other devices. They are also useful to sense the state of electro-mechanical limit switches. The number of digital inputs available varies with the module type.



**NOTE:**  
**BOLDFACE = COMMANDS**

Figure 2.1 Analog Input Block Diagram.

# Chapter 3

## Communications

### Introduction

The DIN-100 modules has been carefully designed to be easy to interface to all popular computers and terminals. All communications to and from the modules are performed with printable ASCII characters. This allows the information to be processed with string functions common to most high-level languages such as BASIC. The ASCII format makes system debugging easy with a dumb terminal.

This system allows multiple modules to be connected to a communications port with a single 4-wire cable. Up to 32 RS-485 modules may be strung together on one cable; 122 with repeaters. The modules communicate with the host on a polling system; that is, each module responds to its own unique address and must be interrogated by the host. A module can never initiate a communications sequence. A simple command/response protocol must be strictly observed to avoid communications collisions and data errors.

Communications to the DIN-100 modules is performed with two-character or three-character ASCII command codes such as RD to Read Data from the analog input. A complete description of all commands is given in the Chapter 4. A typical command/response sequence would look like this:

**Command:**    \$1RD  
**Response:**    \*+00123.00

A command/response sequence is not complete until a valid response is received. The host may not initiate a new command until the response from a previous command is complete. Failure to observe this rule will result in communications collisions. A valid response can be in one of three forms:

- 1) a normal response indicated by a ' \* ' prompt
- 2) an error message indicated by a ' ? ' prompt
- 3) a communications time-out error

When a module receives a valid command, it must interpret the command, perform the desired function, and then communicate the response back to the host. Each command has an associated delay time in which the module is busy calculating the response. If the host does not receive a response in an appropriate amount of time specified in Table 3.1, a communications time-out error has occurred. After the communications time-out it is assumed that no response data is forthcoming. This error usually results when an improper command prompt or address is transmitted. The table below lists the timeout specification for each command:

Mnemonic	Timeout
DI,DO,RD	10 mS
All other commands	100 mS

Table 3.1 Response Timeout Specifications.

The timeout specification is the turn-around time from the receipt of a command to when the module starts to transmit a response.

### Data Format

**All modules communicate in standard NRZ asynchronous data format. This format provides one start bit, seven data bits, one parity bit and one stop bit for each character.**

### Single Module Connection

Figure 1.1 shows the connections necessary to attach one module to a host. Use the Default Mode to enter the desired address, baud rate, and other setups (see Setups).

### RS-485

The RS-485 communications standard satisfies the need for multidropped systems that can communicate at high data rates over long distances. RS-485 is similar to RS-422 in that it uses a balanced differential pair of wires switching from 0 to 5V to communicate data. RS-485 receivers can handle common mode voltages from -7V to +12V without loss of data, making them ideal for transmission over great distances. RS-485 differs from RS-422 by using one balanced pair of wires for both transmitting and receiving. Since an RS-485 system cannot transmit and receive at the same time it is inherently a half-duplex system. RS-485 offers many advantages over RS-232C:

- 1) balanced line gives excellent noise immunity
- 2) can communicate with D1000 modules at 115200 baud
- 3) communications distances up to 4,000 feet.
- 4) true multidrop; modules are connected in parallel
- 5) can disconnect modules without losing communications
- 6) up to 32 modules on one line; 122 with repeaters
- 7) no communications delay due to multiple modules
- 8) simplified wiring using standard telephone cable

RS-485 does have disadvantages. Very few computers or terminals have built-in support for this new standard. Interface boards are available for the IBM PC and compatibles. As RS-485 system usually requires an interface.

The DIN-190 will convert RS-232 signals to RS-485 or repeat RS-485 signals. The DIN-190 connected as an RS-485 repeater can be used to

extend an existing RS-485 network or connect up to 122 modules on one serial communications port.

### RS-485 Multidrop System

Figure 3.1 illustrates the wiring required for multiple-module RS-485 system. Notice that every module has a direct connection to the host system. Any number of modules may be unplugged without affecting the remaining modules. Each module must be setup with a unique address and the addresses can be in any order. All RS-485 modules must be setup for no echo to avoid bus conflicts (see Setup). Also note that the connector pins on each module are labelled with notations (B), (R), (G), and (Y). This designates the colors used on standard 4-wire telephone cable:

Label	Color
(B) GND	Black
(R) V+	Red
(G) DATA* (-)	Green
(Y) DATA (+)	Yellow

This color convention is used to simplify installation. If standard 4-wire telephone cable is used, it is only necessary to match the labeled pins with the wire color to guarantee correct installation.

DATA\* on the label is the complement of DATA (negative true).

To minimize unwanted reflections on the transmission line, the bus should be arranged as a line going from one module to the next. 'Tree' or random structures of the transmission line should be avoided. When using long transmission lines and/or high baud rates, the data lines should be terminated at each end with 200 ohm resistors. Standard values of 180 ohms or 220 ohms are acceptable.

During normal operation, there are periods of time where all RS-485 drivers are off and the communications lines are in an 'idle' high impedance condition. During this condition, the lines are susceptible to noise pickup which may be interpreted as random characters on the communications line. To prevent noise pickup, all RS-485 systems should incorporate 1K ohm bias resistors as shown in Figure 3.1. The resistors will maintain the data lines in a 'mark' condition when all drivers are off.

DIN-191 and DIN-192 modules have the 1K $\Omega$  resistors built-in.

Special care must be taken with very long busses (greater than 1000 feet) to ensure error-free operation. Long busses must be terminated as described above. The use of twisted cable for the DATA and DATA\* lines will greatly enhance signal fidelity. Use parity and checksums along with the '#'

form of all commands to detect transmission errors. In situations where many modules are used on a long line, voltage drops in the power leads becomes an important consideration. The GND wire is used both as a power connection and the common reference for the transmission line receivers in the modules. Voltage drops in the GND leads appear as a common-mode voltage to the receivers. The receivers are rated for a maximum of -7V. of common-mode voltage. For reliable operation, the common mode voltage should be kept below -5V.

To avoid problems with voltage drops, modules may be powered locally rather than transmitting the power from the host. Inexpensive 'calculator' type power supplies are useful in remote locations. When local supplies are used, be sure to provide a ground reference with a third wire to the host or through a good earth ground. With local supplies and an earth ground, only two wires for the data connections are necessary.

### **Communications Delay**

All DIN-100 modules are setup at the factory to provide two units of communications delay after a command has been received (see Chapter 5). This delay is necessary when using host computers that transmit a carriage return as a carriage return-linefeed string. Without the delay, the linefeed character may collide with the first transmitted character from the module, resulting in garbled data. If the host computer transmits a carriage return as a single character, the delay may be set to zero to improve communications response time.

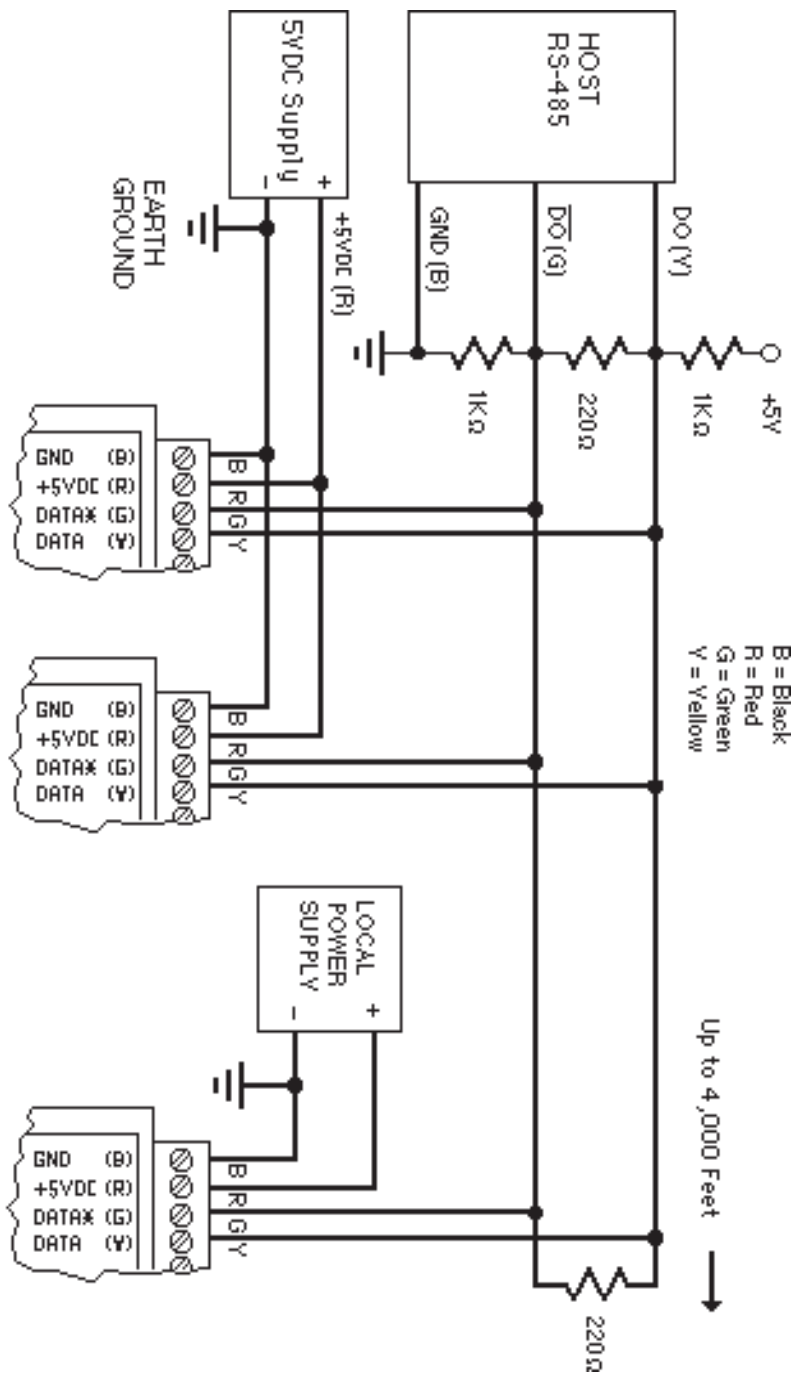


Figure 3.1 RS-485 Network.



# Chapter 4

## ASCII Command Set

The DIN-100 modules operate with a simple command/response protocol to control all module functions. A command must be transmitted to the module by the host computer or terminal before the module will respond with useful data. A module can never initiate a communications sequence. A variety of commands exists to exploit the full functionality of the modules. A list of available commands and a sample format for each command is listed in Table 4.1.

### Command Structure

Each command message from the host must begin with a command prompt character to signal to the modules that a command message is to follow. There are two valid prompt characters; a dollar sign character (\$) is used to generate a short response message from the module. A short response is the minimum amount of data necessary to complete the command. The second prompt character is the pound sign character (#) which generates long responses (will be covered later in this chapter).

The prompt character must be followed by a single address character identifying the module to which the command is directed. Each module attached to a common communications port must be setup with its own unique address so that commands may be directed to the proper unit. Module addresses are assigned by the user with the SetUp (SU) command. Printable ASCII characters such as '1' (ASCII \$31) or 'A' (ASCII \$41) are the best choices for address characters.

The address character is followed by a two-character command that identifies the function to be performed by the module. All of the available commands are listed in Table 4.1 along with a short function definition. All commands are described in Chapter 4. Commands must be transmitted as upper-case characters.

A two-character checksum may be appended to any command message as a user option. See 'Checksum' in Chapter 4 .

All commands must be terminated by a Carriage Return character (ASCII \$0D). (In all command examples in this text the Carriage Return is either implied or denoted by the symbol 'CR'.)

### Data Structure

Many commands require additional data values to complete the command definition as shown in the example commands in Table 4.1. The particular data necessary for these commands is described in full in the complete command descriptions.

The most common type of data used in commands and responses is analog data. Analog data is always represented in the same format for all models in the DIN-100 series. Analog data is represented as a nine-character string consisting of a sign, five digits, decimal point, and two additional digits. The string represents a decimal value in engineering units. Examples:

```
+12345.68  
+00100.00  
-00072.10  
-00000.00
```

When using commands that require analog data as an argument, the full nine-character string must be used, even if some digits are not significant. Failure to do this results in a SYNTAX ERROR.

Analog data responses from the module will always be transmitted in the nine-character format. This greatly simplifies software parsing routines since all analog data is in the same format for all module types.

In many cases, some of the digits in the analog data may not be significant. For instance, the DIN-130 thermocouple input modules feature 1 degree output resolution. A typical analog data value from this type of module could be +00123.00. The two digits to the right of the decimal point have no significance in this particular model. However, the data format is always adhered to in order to maintain compatibility with other module types.

The maximum computational resolution of the module is 16 bits, which is less than the resolution that may be represented by an analog data variable.

The Digital Input, Digital Output, and Setup commands use hexadecimal representations of data. The data structures for these commands are detailed in the command descriptions.

### **Write Protection**

Many of the commands listed in Table 4.1 are under the heading of 'Write Protected Commands'. These commands are used to alter setup data in the module's EEPROM. They are write protected to guard against accidental loss of setup data. All write-protected commands must be preceded by a Write Enable (WE) command before the protected command may be executed.

### **Miscellaneous Protocol Notes**

The address character must be transmitted immediately after the command prompt character. After the address character the module will ignore any character below ASCII \$23 (except CR). This allows the use of spaces (ASCII \$20) within the command message for better readability if desired.

The length of a command message is limited to 20 printable characters. If a properly addressed module receives a command message of more than 20 characters the module will abort the whole command sequence and no response will result.

If a properly addressed module receives a second command prompt before it receives a CR, the command will be aborted and no response will result.

### Response Structure

Response messages from the module begin with either an asterisk '\*' (ASCII \$2A) or a question mark '?' (ASCII \$3F) prompt. The '\*' prompt indicates acknowledgment of a valid command. The '?' prompt precedes an error message. All response messages are terminated with a CR. Many commands simply return a '\*' character to acknowledge that the command has been executed by the module. Other commands send data information following the '\*' prompt. The response format of all commands may be found in the detailed command description.

The maximum response message length is 20 characters.

A command/response sequence is not complete until a valid response is received. The host may not initiate a new command until the response from a previous command is complete. Failure to observe this rule will result in communications collisions. A valid response can be in one of three forms:

- 1) a normal response indicated by a '\*' prompt
- 2) an error message indicated by a '?' prompt
- 3) a communications time-out error

When a module receives a valid command, it must interpret the command, perform the desired function, and the communicate the response back to the host. Each command has an associated delay time in which the module is busy calculating the response. If the host does not receive a response in an appropriate amount of time specified in Table 4.1, a communications time-out error has occurred. After the communications time-out it is assumed that no response data is forthcoming. This error usually results when an improper command prompt or address is transmitted.

### Long Form Responses

When the pound sign '#' command prompt is used, the module responds with a 'long form' response. This type of response will echo the command message, supply the necessary response data and will add a two-character checksum to the end of the message. Long form responses are used when the host wishes to verify the command received by the module. The checksum is included to verify the integrity of the response data. The '#' command prompt may be used with any command. For example:

<b>Command:</b>	<b>\$1RD</b>	<b>(short form)</b>
<b>Response:</b>	<b>*+00072.10</b>	
<b>Command:</b>	<b>#1RD</b>	<b>(long form)</b>
<b>Response:</b>	<b>*1RD+00072.10A4</b>	<b>(A4=checksum)</b>

### Checksum

Checksum is a two character hexadecimal value appended to the end of a message. It verifies that the message received is exactly the same as the message sent. The checksum ensures the integrity of the information communicated.

### Command Checksum

A two-character checksum may be appended to any command to the module as a user option. When a module interprets a command, it looks for the two extra characters and assumes that it is a checksum. If the checksum is not present, the module will perform the command normally. If the two extra characters are present, the module calculates the checksum for the message. If the calculated checksum does not agree with the transmitted checksum, the module responds with a 'BAD CHECKSUM' error message and the command is aborted. If the checksums agree, the command is executed. If the module receives a single extra character, it responds with 'SYNTAX ERROR' and the command is aborted For example:

<b>Command:</b>	<b>\$1RD</b>	<b>(no checksum)</b>
<b>Response:</b>	<b>*+00072.10</b>	
<b>Command:</b>	<b>\$1RDEB</b>	<b>(with checksum)</b>
<b>Response:</b>	<b>*+00072.10</b>	
<b>Command:</b>	<b>\$1RDAB</b>	<b>(incorrect checksum)</b>
<b>Response:</b>	<b>?1 BAD CHECKSUM</b>	
<b>Command:</b>	<b>\$1RDE</b>	<b>(one extra character)</b>
<b>Response:</b>	<b>?1 SYNTAX ERROR</b>	

### Response Checksums

If the long form ' # ' version of a command is transmitted to a module, a checksum will be appended to the end of the response. For example:

<b>Command:</b>	<b>\$1RD</b>	<b>(short form)</b>
<b>Response:</b>	<b>*+00072.10</b>	
<b>Command:</b>	<b>#1RD</b>	<b>(long form)</b>
<b>Response:</b>	<b>*1RD+00072.10A4</b>	<b>(A4=checksum)</b>

### Checksum Calculation

The checksum is calculated by summing the hexadecimal values of all the ASCII characters in the message. The lowest order two hex digits of the sum are used as the checksum. These two digits are then converted to their ASCII character equivalents and appended to the message. This ensures that the checksum is in the form of printable characters.

Example: Append a checksum to the command #1DOFF

Characters:	#	1	D	O	F	F
ASCII hex values:	23	31	44	4F	46	46
Sum (hex addition)	23 + 31 + 44 + 4F + 46 + 46 = 173					

The checksum is 73 (hex). Append the characters 7 and 3 to the end of the message: #1DOFF73

Example: Verify the checksum of a module response \*1RD+00072.10A4

The checksum is the two characters preceding the CR: A4

Add the remaining character values:

*	1	R	D	+	0	0	0	7	2	.	1	0
$2A + 31 + 52 + 44 + 2B + 30 + 30 + 30 + 37 + 32 + 2E + 31 + 30 = A4$												

The two lowest-order hex digits of the sum are A4 which agrees with the transmitted checksum.

The transmitted checksum is the character string equivalent to the calculated hex integer. The variables must be converted to like types in the host software to determine equivalency.

If checksums do not agree, a communications error has occurred.

If a module is setup to provide linefeeds, the linefeed characters are not included in the checksum calculation.

Parity bits are never included in the checksum calculation.

**Table 4.1 DIN-100 Command Set**

Command and Definition	Typical Command Message	Typical Response Message (\$ prompt)
DI Read Alarms/Digital Inputs	\$1DI	*0003
DO Set Digital Outputs	\$1DOFF	*
RD Read Data	\$1RD	*+00072.00
RS Read Setup	\$1RS	*31070142
RZ Read Zero	\$1RZ	*+00000.00
WE Write Enable	\$1WE	*
Write Protected Commands		
MBR Set Modbus Address	\$1MBR01	*
MBD Modbus Disable	\$1MBD	*
RR Remote Reset	\$1RR	*
SU Setup Module	\$1SU31070142	*
TS Trim Span	\$1TS+00600.00	*
TZ Trim Zero	\$1TZ+00000.00	*

**DIN-100 User Commands**

Note that in all command and response examples given below, a carriage return is implied after every character string.

**Clear Zero (CZ)**

The Clear Zero command clears the output offset register value to +00000.00. This command clears any data resulting from a Trim Zero (TZ).

**Command:** \$1CZ

**Response:** \*

**Command:** #1CZ

**Response:** \*1CZF8

**Digital Input (DI)**

The DI command reads the status of the digital inputs on the DIN-171. The response to the DI command is four hex characters representing two bytes of data. The second byte contains the digital input data.

**Command:** \$1DI

**Response:** \*0003

**Command:** #1DI

**Response:** \*1DI0003AB

The second byte displays the hex value of the digital input status. The number of digital inputs varies depending on module type.

Digital Inputs	DI5	DI4	DI3	DI2	DI1	DI0
Data Bits	5	4	3	2	1	0

For example: A typical response from a \$1DI command could be: \*00FE. This response indicates that DI0 = 0 and all other digital inputs are = 1

All digital inputs that are not implemented or left unconnected are read as '1'

Digital input 0 serves a dual function. It is both a digital input and the Event Counter input.

When reading digital inputs with a checksum, be sure not to confuse the checksum with the data.

### Digital Output (DO)

The DO command controls eight bits of digital outputs on the DIN-172 module connector. The number of digital outputs implemented depends on the model used. The digital outputs allow the module to control external circuits under host command. The DO command requires an argument of two hex characters specifying the eight bits of output data.

Digital Outputs	DO7	DO6	DO5	DO4	DO3	DO2	DO1	DO0
Data Bits	7	6	5	4	3	2	1	0

The electrical implementation of the digital output consists of open-collector transistors wired to the module connector. If a digital output is set to '1' the corresponding transistor is turned on and sinks current. Note that when a digital output bit is set to '1' the electrical output is near 0 volts. If a digital output is set to '0' the corresponding transistor is turned off and sinks no current.

Assume a module has two digital outputs, and you wish to turn both outputs on (sinking current). Set data bit 0 and data bit 1 to '1'. Since the module has only two digital outputs, all the other bits are 'don't cares'. For example, this command will turn both outputs 'on':

**Command:** \$1DOFF  
**Response:** \*

To turn both outputs off you could use the command:

**Command:** \$1DO00  
**Response:** \*

Digital output settings are not stored in nonvolatile memory. If a power failure occurs, all digital outputs will be 0 upon power up.

The DO command is the only means of changing digital outputs. There is no software provision to read the state of digital outputs.

### Read Data (RD)

The read data command is the basic command used to read the buffered sensor data. The output buffer (Figure 2.1) allows the data to be read immediately without waiting for an input A/D conversion. For example:

**Command:** \$1RD  
**Response:** \*+00072.00

**Command:** #1RD  
**Response:** \*1RD+00072.10A4

Since the RD command is the most frequently used command in normal operation, a special shortened version of the command is available. If a module is addressed without a two-letter command, the module interprets the string as an RD command.

**Command:** \$1  
**Response:** \*+00072.10

**Command:** #1  
**Response:** \*1RD+00072.10A4

### Remote Reset (RR)

The reset command allows the host to perform a program reset on the module's microprocessor. This may be necessary if the module's internal program is disrupted by static or other electrical disturbances. Once a reset command is received, the module will recalibrate itself. The calibration process takes approximately 3 seconds. For example:

**Command:** \$1RR  
**Response:** \*

**Command:** #1RR  
**Response:** \*1RRFF

In general, the state of the digital outputs and the event counter will not be affected by the RR command. However, if data in the microprocessor's RAM (Random Access Memory) has been lost, the RR command will result in a full power-up reset.

Any commands sent to the module during the self-calibration sequence will result in a NOT READY error.



**Read Setup (RS)**

The read setup command reads back the setup information loaded into the module's nonvolatile memory with the SetUp (SU) command. The response to the RS command is four bytes of information formatted as eight hex characters.

**Command:** \$1RS  
**Response:** \*31070142

**Command:** #1RS  
**Response:** \*1RS3107014292

The response contains the module's channel address, baud rate and other parameters. Refer to the setup command (SU), and Chapter 5 for a list of parameters in the setup information.

When reading the setup with a checksum, be sure not to confuse the checksum with the setup information.

**Read Zero (RZ)**

The Read Zero command reads back the value stored in the Output Offset Register (Figure 2.1).

**Command:** \$1RZ  
**Response:** \*+00000.00

**Command:** #1RZ  
**Response:** \*1RZ+00000.00B0

The data read back from the Output Offset Register may be interpreted in several ways. The commands that affect this value are: Trim Zero (TZ) and Clear Zero (CZ).

**Setup Command (SU)**

Each DIN-100 module contains an EEPROM (Electrically Erasable Programmable Read Only Memory) which is used to store module setup information such as address, baud rate, parity, etc. The EEPROM is a special type of memory that will retain information even if power is removed from the module. The EEPROM is used to replace the usual array of DIP switches normally used to configure electronic equipment.

The SetUp command is used to modify the user-specified parameters contained in the EEPROM to tailor the module to your application. Since the SetUp command is so important to the proper operation of a module, a whole section of this manual has been devoted to its description. See Chapter 5.



With no weight applied, trim the output to read zero. To trim, use the TZ command and specify the desired output reading:

**Command:** \$1TZ+00000.00 (zero output)  
**Response:** \*

The TZ command will load a data value into the Output Offset Register to force the output to read zero. The module will compensate for any previous value loaded into the Output Offset Register. If another output reading is taken, it will show that the offset has been eliminated:

**Command:** \$1RD  
**Response:** \*+00000.00

Although the TZ command is most commonly used to null an output to zero, it may be used to offset the output to any specified value. Assume that with the previously nulled load cell system we performed this command:

**Command:** \$1TZ-00100.00  
**Response:** \*

The new data output with no load applied would be:

**Command:** \$1RD  
**Response:** \*-00100.00

The load cell output is now offset by -100.

The offset value stored by the TZ command is stored in nonvolatile memory and may be read back with the Read Zero (RZ) command and cleared with the Clear Zero (CZ) command.

The SetPoint (SP) command will write over any value loaded by the TZ command.

### Write Enable (WE)

Each module is write protected against accidental changing of alarms, limits, setup, or span and zero trims. To change any of these write protected parameters, the WE command must precede the write-protected command. The response to the WE command is an asterisk indicating that the module is ready to accept a write-protected command. After the write-protected command is successfully completed, the module becomes automatically write disabled. Each write-protected command must be preceded individually with a WE command. For example:

**Command:** \$1WE  
**Response:** \*

**Command:** #1WE  
**Response:** \*1WEF7

If a module is write enabled and the execution of a command results in an error message other than WRITE PROTECTED, the module will remain write enabled until a command is successfully completed resulting in an ‘ \* ‘ prompt. This allows the user to correct the command error without having to execute another WE command.

### Write Extended Address (WEA)

## ERROR MESSAGES

The DIN-100 modules feature extensive error checking on input commands to avoid erroneous operation. Any errors detected will result in an error message and the command will be aborted.

All error messages begin with “?”, followed by the channel address, a space and error description. The error messages have the same format for either the ‘ \$ ‘ or ‘ # ‘ **prompts**. For example:

?1 SYNTAX ERROR

There are eight error messages, and each error message begins with a different character. It is easy for a computer program to identify the error without having **to read the** entire string.

### ADDRESS ERROR

There are six ASCII values that are illegal for use as a module address: NULL (\$00), CR (\$0D), \$ (\$24), # (\$23), { (\$7B) and } (\$7D). The ADDRESS ERROR will occur when an attempt is made to load an illegal address into a module with the SetUp (SU) command. An attempt to load an address greater than **\$7F will** produce an error.

### BAD CHECKSUM

This error is caused by an incorrect checksum included in the command string. The module recognizes any two hex characters appended to a command string as a checksum. Usually a BAD CHECKSUM error is due to noise or interference on the communications line. Often, repeating the command solves the problem. If the error persists, either the checksum is calculated incorrectly or there is a problem with the communications channel. More reliable transmissions might be obtained **by using a lower** baud rate.

## COMMAND ERROR

This error occurs when the two-character command is not recognized by the module. Often this error results when the command is sent with lower-case letters. All **valid commands** are upper-case.

## NOT READY

If a module is reset, it performs a self-calibration routine which takes 2-3 seconds to complete. Any commands sent to the module during the self-calibration period will result in a NOT READY error. When this occurs, simply wait a couple seconds and repeat the command.

The module may be reset in three ways: a power-up reset, a Remote Reset (RR) command, or an internal reset. All modules contain a 'watchdog' timer to ensure proper operation of the microprocessor. The timer may be tripped if the microprocessor is executing its program improperly due to power transients or static discharge.

If the NOT READY error persists for more than 30 seconds, check the power supply to be sure **it is within** specifications.

## PARITY ERROR

A parity error can only occur if the module is setup with parity on (see Setup). Usually a parity error results from a bit error caused by interference on the communications line. Random parity errors are usually overcome by simply repeating the command. If too many errors occur, the communications channel may have to be improved or a slower baud rate may be used.

A consistent parity error will result if the host parity does not match the module parity. In this situation, the easiest solution may be to change the parity in the host to obtain communication. At this point the parity in the module may be changed to the desired value with the SetUp (SU) command.

The parity may be changed or **turned off by using** Default Mode.

## SYNTAX ERROR

A SYNTAX ERROR will result if the structure of the command is not correct. This is caused by having too few or too many characters, signs or decimal points missing or in the wrong place. Table 4.1 lists the correct **syntax** for all the commands.

## VALUE ERROR

This error results when an incorrect character is used as a numerical value. Data values can only contain decimal digits 0-9. Hex values used in the SetUp (SU) and Digital Output (DO) **commands can range** from 0-F.

## WRITE PROTECTED

All commands that write data into nonvolatile memory are write-protected to prevent accidental erasures. These commands must be preceded with a Write Enable (WE) command or else a WRITE PROTECTED error will result.

# Chapter 5

## Setup Information/SetUp Command

The DIN-100 modules feature a wide choice of user configurable options which gives them the flexibility to operate on virtually any computer or terminal based system. The user options include a choice of baud rate, parity, address, and many other parameters. The particular choice of options for a module is referred to as the setup information.

The setup information is loaded into the module using the SetUp (SU) command. The SU command stores 4 bytes (32 bits) of setup information into a nonvolatile memory contained in the module. Once the information is stored, the module can be powered down indefinitely (10 years minimum) without losing the setup data. The nonvolatile memory is implemented with EEPROM so there are no batteries to replace.

The EEPROM has many advantages over DIP switches or jumpers normally used for option selection. The module never has to be opened because all of the options are selected through the communications port. This allows the setup to be changed at any time even though the module may be located thousands of feet away from the host computer or terminal. The setup information stored in a module may be read back at any time using the Read Setup command (RS).

**The following options can be specified by the SetUp command:**

**Channel address (122 values)**

**Linefeeds**

**Parity (odd, even, none)**

**Baud rate (300 to 38,400)**

**Addressing Mode: Extended/Normal**

**CJC disable (DIN-130 series)**

**RTD 3/4 wire (DIN-140 series)**

**Communication delay (0-6 characters)**

**Number of displayed digits**

**Large-signal filter constant**

**Small-signal filter constant**

Each of these options will be described in detail below. For a quick look-up chart on all options, refer to Tables 5.1-4.

### Command Syntax

The general format for the SetUp (SU) command is:

**\$1SU[byte1][byte 2][byte 3][byte 4]**

A typical SetUp command would look like: \$1SU31070182.

Notice that each byte is represented by its two-character ASCII equivalent. In this example, byte 1 is described by the ASCII characters '31' which is the equivalent of binary 0011 0001 (31 hex). The operand of a SU command must contain exactly 8 hex (0-F) characters. Any deviation from this format will result in a SYNTAX ERROR. The Appendix contains a convenient hex-to-binary conversion chart.

For the purposes of describing the SetUp command, 'bit 7' refers to the highest-order bit of a byte of data. 'Bit 0' refers to lowest-order bit:

'bit number':	7	6	5	4	3	2	1	0	
binary data:	0	0	1	1	0	0	0	1	= \$31 (hex)

The SU command is write protected to guard against erroneous changes in the setup data; therefore each SU command must be preceded by a Write Enable (WE) command. To abort an SU command in progress, simply send a non-hex character (an 'X' for example) to generate a SYNTAX ERROR, and try again.

**CAUTION:** Care must be exercised in using the SU command. Improper use may result in changing communications parameters (address, baud rate, parity) which will result in a loss of communications between the host and the module. In some cases the user may have to resort to using Default Mode to restore the proper setups. The recommended procedure is to first use the Read Setup (RS) command to examine the existing setup data before proceeding with the SU command.

### Byte 1

Byte 1 contains the module (channel) address. The address is stored as the ASCII code for the string character used to address the module. In our example command \$1SU31070080, the first byte '31' is the ASCII code for the character '1'. If our sample command is sent to a module, the EEPROM will be loaded with the address '1', which in this particular case remains unchanged. To change the module address to '2', byte 1 of the SetUp command becomes '32', which is the ASCII code for the character '2'. Now the command will look like this: \$1SU32070080. When this command is sent, the module address is changed from '1' to '2' and will no longer respond to address '1'.

When using the SU command to change the address of a module, be sure to record the new address in a place that is easily retrievable. The only way to communicate with a module with an unknown address is with the Default Mode.



are six ASCII codes that are illegal for use as an address. These codes are \$00, \$0D, \$24, \$23, \$7B, \$7D which are ASCII codes for the characters NUL, CR, \$, #, { and }. Using these codes for an address will cause an ADDRESS ERROR and the setup data will remain unchanged. This leaves a total of 122 possible addresses that can be loaded with the SU command. It is highly recommended that only ASCII codes for printable characters be used (\$21 to \$7E) which greatly simplifies system debugging with a dumb terminal. Refer to Appendix A for a list of ASCII codes. Table 5.1 lists the printable ASCII codes that may be used as addresses.

**Table 5.1 Byte 1 ASCII Printable Characters.**

HEX	ASCII	HEX	ASCII	HEX	ASCII	HEX	ASCII
21	!	3A	:	51	Q	68	h
22	"	3B	;	52	R	69	i
25	%	3C	<	53	S	6A	j
26	&	3D	=	54	T	6B	k
27	'	3E	>	55	U	6C	l
28	(	3F	?	56	V	6D	m
29	)	40	@	57	W	6E	n
2A	*	41	A	58	X	6F	o
2B	+	42	B	59	Y	70	p
2C	,	43	C	5A	Z	71	q
2D	-	44	D	5B	[	72	r
2E	.	45	E	5C	\	73	s
2F	/	46	F	5D	]	74	t
30	0	47	G	5E	^	75	u
31	1	48	H	5F	_	76	v
32	2	49	I	60	`	77	w
33	3	4A	J	61	a	78	x
34	4	4B	K	62	b	79	y
35	5	4C	L	63	c	7A	z
36	6	4D	M	64	d	7B	{
37	7	4E	N	65	e	7C	
38	8	4F	O	66	f	7D	}
39	9	50	P	67	g	7E	~

## Byte 2

Byte 2 is used to configure some of the characteristics of the communications channel; linefeeds, parity, and baud rate.

### Linefeeds

The most significant bit of byte 2 (bit 7) controls linefeed generation by the module. This option can be useful when using the module with a dumb terminal. All responses from the DIN-100 are terminated with a carriage return (ASCII \$0D). Most terminals will generate a automatic linefeed when a carriage return is detected. However, for terminals that do not have this capability, the D1000 module can generate the linefeed if desired. By setting bit 7 to '1' the module will send a linefeed (ASCII \$0A) before and after each response. If bit 7 is cleared (0), no linefeeds are transmitted.

When using the '#' command prompt, the linefeed characters are not included in the checksum calculation.

### Parity

Bits 5 and 6 select the parity to be used by the module. Bit 5 turns the parity on and off. If bit 5 is '0', the parity of the command string is ignored and the parity bit of characters transmitted by the module is set to '1'.

If bit 5 is '1', the parity of command strings is checked and the parity of characters output by the module is calculated as specified by bit 6.

If bit 6 is '0', parity is even; if bit 6 is '1', parity is odd.

If a parity error is detected by the module, it will respond with a PARITY ERROR message. This is usually caused by noise on the communications line.

If parity setup values are changed with the SU command, the response to the SU command will be transmitted with the old parity setup. The new parity setup becomes effective immediately after the response message from the SU command.

### Baud Rate

Bits 0-3 specify the communications baud rate. The baud rate can be selected from ten values between 300 and 38400 baud. Refer to Table 5.2 for the desired code.

The baud rate selection is the only setup data that is not implemented directly after an SU command. In order for the baud rate to be actually changed, a module reset must occur. A reset is performed by sending a Remote Reset (RR) command (see Communications) or powering down. This extra level of write protection is necessary to ensure that communications to the module is not accidentally lost. This is very important when

changing the baud rate of an RS-485 string. For more information on changing baud rate, refer to Chapter 3.

Let's run through an example of changing the baud rate. Assume our sample module contains the setup data value of '31070080'. Byte 2 is '07'. By referring to the SU command chart we can determine that the module is set for no linefeeds, no parity, and baud rate 300. If we perform the Read Setup command with this module we would get:

**Command:** \$1RS  
**Response:** \*31070080

Let's say we wish to change the baud rate to 9600 baud. The code for 9600 baud is '0010' (from Table 5.2). This would change byte 2 to '02'. To perform the SU command we must first send a Write Enable command because SU is write protected:

**Command:** \$1WE  
**Response:** \*  
**Command:** \$1SU31020080  
**Response:** \*

This sequence of messages is done in 300 baud because that was the original baud rate of the module. The module remains in 300 baud after this sequence. We can use the Read Setup (RS) command to check the setup data:

**Command:** \$1RS  
**Response:** \*31020080

Notice that although the module is communicating in 300 baud, the setup data indicates a baud rate of 9600 (byte 2 = '02'). To actually change the baud rate to 9600, send a Remote Reset (RR) command (RR is write protected):

**Command:** \$1WE  
**Response:** \*  
**Command:** \$1RR  
**Response:** \*

Up to this point all communications have been sent at 300 baud. The module will not respond to any further communications at 300 baud because it is now running at 9600 baud. At this point the host computer or terminal must be set to 9600 baud to continue operation.

If the module does not respond to the new baud rate, most likely the setup data is incorrect. Try various baud rates from the host until the module responds. The last resort is to set the module to Default Mode where the

baud rate is always 300.

#### Bit 4

Bit 4 is used to enable or disable extended addressing mode.

**Table 5.2 Byte 2: Linefeed, Parity, Addressing and Baud Rate.**

FUNCTION	DATA BIT				3	2	1	0
	7	6	5	4				
LINEFEED	1							
NO LINEFEED	0							
NO PARITY		0	0					
NO PARITY		1	0					
EVEN PARITY		0	1					
ODD PARITY		1	1					
NORMAL ADDRESSING				0				
EXTENDED ADDRESSING				1				
38400 BAUD					0	0	0	0
19200 BAUD					0	0	0	1
9600 BAUD					0	0	1	0
4800 BAUD					0	0	1	1
2400 BAUD					0	1	0	0
1200 BAUD					0	1	0	1
600 BAUD					0	1	1	0
300 BAUD					0	1	1	1

#### Byte 3

This byte contains the setup information for several seldom-used options. The default value for this byte is '01'.

#### Disable CJC

#### RTD 3/4 Wire

#### Trigger Edge Select

The setup information stored in bit 4 has different meanings depending on the DIN-100 model number.

**Disable CJC;** this function pertains only to the DIN-130 series of thermocouple input modules. If the bit is set to '1' the Cold Junction Compensation is disabled. The module calculates the temperature output with a fixed cold junction temperature of 0 degrees Celsius. This setup is useful for calibrating the module or in cases where remote CJC is used. Normally this bit is cleared to '0'.



**Byte 4**

This setup byte specifies the number of displayed digits and the digital filter time constants.

**Number of displayed digits**

For ease of use, the data outputs of all modules are standardized to a common 7-digit output consisting of sign, 5 digits, decimal point, and two more digits. Typical output data looks like: +00100.00. However, best-case resolution of the A/D converter is 1 part in 32,768. In some cases, the resolution of the output format is much greater than the resolution of the measurement system. In such cases, the trailing digits of the response would display meaningless information. Bits 6 and 7 are used to insert trailing zeros into the output data to limit the output resolution and mask off meaningless digits.

<b>Bit 7</b>	<b>Bit 6</b>		
<b>0</b>	<b>0</b>	<b>XXXX0.00</b>	<b>(4 displayed digits)</b>
<b>0</b>	<b>1</b>	<b>XXXXX.00</b>	<b>(5 displayed digits)</b>
<b>1</b>	<b>0</b>	<b>XXXXX.X0</b>	<b>(6 displayed digits)</b>
<b>1</b>	<b>1</b>	<b>XXXXX.XX</b>	<b>(7 displayed digits)</b>

For example, the DIN-141 model for RTD's has 0.1 degree output resolution. The appropriate number of digits for this module is 6, to mask off the 0.01 digit which has no meaningful data. In some cases, the user may want to limit the output resolution to 1 degree. To do this, select bits 6 and 7 to display 5 digits. With this selection, the right-most two digits will always be set to '0'.

The number of displayed digits affects only data received from an RD or ND command.

**Large Signal Filter, Bits 3,4,5****Small Signal Filter, Bits 0,1,2**

The modules contain a versatile single-pole, low-pass digital filter to smooth out unwanted noise caused by interference or small signal variations. The digital filter offers many advantages over traditional analog filters. The filtering action is done completely in firmware and is not affected by component drifts, offsets, and circuit noise typically found in analog filters. The filter time constant is programmable through the SetUp (SU) command and can be changed at any time, even if the module is remote from the host.

The digital filter features separate time constants for large and small signal variations. The Large Signal Filter time constant is controlled by bits 3,4,5. This time constant is used when large signal variations are present on the input. The Small Signal Filter time constant is controlled by bits 0,1,2. This filter time constant is automatically selected when input signal variations are small. The microprocessor in the module automatically selects the correct

filter constant after every A/D conversion. The constant selected depends on the magnitude of the change of the input signal and the setup for the number of digits displayed. The microprocessor always keeps the value of the last calculated output to compare to a new data conversion. If the new data differs from the last output by more than ten counts of the last displayed digit, the large signal time constant is used in the digital filter. If the result of the most recent A/D conversion differs from the last output value by less than ten counts of the last displayed digit, the small signal time constant is used. Let's look at an example:

The DIN-141 RTD module has a standard output resolution of 0.1 degrees. The standard number-of-displayed-digits setup for this module is 6 digits, from byte 4 of the setup data. Therefore, the large signal filter will be selected if a new input conversion differs from the previous value by  $> 1.0$  degree:

<b>Previous data</b>	<b>New data</b>	<b>Filter selected</b>
+00100.00	+00100.50	small
+00100.00	+00101.50	large
+00100.00	+00099.90	small
+00100.00	+00098.90	large
-00050.50	-00050.00	small
-00050.50	-00060.00	small

If the number of displayed digits is changed to reduce output resolution, filter selection is also affected. If the number of displayed digits in the previous example is changed to 5, the output resolution becomes 1.0 degree.

In this case the large signal time constant is used if the new reading differs from the old by more than 10.0 degrees:

<b>Previous data</b>	<b>New data</b>	<b>Filter selected</b>
+00100.00	+00105.00	small
+00100.00	+00111.00	large
+00100.00	+00091.00	small
+00100.00	+00085.00	large
-00050.00	-00045.00	small
-00050.00	-00039.00	large

### **Large Signal Time Constant**

The large signal filter time constant is specified by bits 3,4,5 of byte 4. It may be specified from 0 (no filter) to 16 seconds. The time constant for a first-order filter is the time required for the output to reach 63% of its final value for a step input.

### Small Signal Time Constant

Bits 0,1, 2 specify the filter time constant for small signals. Its values are similar to the ones for the large signal filter. Most sensors can benefit from a small amount of small signal filtering such as  $T = 0.5$  seconds. In most applications, the small signal time constant should be larger than the large signal time constant. This gives stable readings for steady-state inputs while providing fast response to large signal changes.

**Table 5.4 Byte 4 Displayed Digits and Filter Time Constants.**

#### BYTE 4

FUNCTION	DATA BIT							
	7	6	5	4	3	2	1	0
+XXXX0.00 DISPLAYED DIGITS	0	0						
+XXXXX.00 DISPLAYED DIGITS	0	1						
+XXXXX.X0 DISPLAYED DIGITS	1	0						
+XXXXX.XX DISPLAYED DIGITS	1	1						
NO LARGE SIGNAL FILTERING			0	0	0			
0.25 SECOND TIME CONSTANT			0	0	1			
0.5 SECOND TIME CONSTANT			0	1	0			
1.0 SECOND TIME CONSTANT			0	1	1			
2.0 SECOND TIME CONSTANT			1	0	0			
4.0 SECOND TIME CONSTANT			1	0	1			
8.0 SECOND TIME CONSTANT			1	1	0			
16.0 SECOND TIME CONSTANT			1	1	1			
NO SMALL SIGNAL FILTERING						0	0	0
0.25 SECOND TIME CONSTANT						0	0	1
0.5 SECOND TIME CONSTANT						0	1	0
1.0 SECOND TIME CONSTANT						0	1	1
2.0 SECOND TIME CONSTANT						1	0	0
4.0 SECOND TIME CONSTANT						1	0	1
8.0 SECOND TIME CONSTANT						1	1	0
16.0 SECOND TIME CONSTANT						1	1	1

#### Setup Hints

Until you become completely familiar with the SetUp command, the best method of changing setups is to change one parameter at a time and to verify that the change has been made correctly. Attempting to modify all the setups at once can often lead to confusion. If you reach a state of total confusion, the best recourse is to reload the factory setup shown in Table 5.5 and try again, changing one parameter at a time. Use the Read Setup (RS) command to examine the setup information currently in the module as a basis for creating a new setup.



By using the RS command and changing one setup parameter at a time, any problems associated with incorrect setups may be identified immediately. Once a satisfactory setup has been developed, record the setup value and use it to configure similar modules.

If you commit an error in using the SetUp command, it is possible to lose communications with the module. In this case, it may be necessary to use the Default Mode to re-establish communications.

**Table 5.5 Factory Setups by Model.**

(All modules from the factory are set for address '1', 300 baud, no parity)

DIN-100 Series Model Number	Setup Message
111, 115, 125	310701C2
110, 113, 114	31070142
13X	31070142
141, 142, 143 , 112	31070182
145, 15X	310701C2
16X	310701C0
17X	31070100

## Chapter 6

### Digital I/O Functions

The DIN-100 series features the DIN-171 module with six digital inputs and the DIN-172 module with six digital outputs .

#### Digital Outputs

A digital output consists of an open-collector transistor controlled by the host, using the Digital Output (DO) command (See Figure 6.1). The open-collector configuration is used to provide maximum versatility in interfacing to solid state relays (SSR's) or to standard logic levels such as TTL or CMOS. Each digital output can sink up to 100mA and can withstand up to 30V. Power in the transistor must be limited to 300mW. The emitter of each transistor is tied to the GND terminal on the input connector.

A typical connection of a digital output is shown in Figure 6.1. In this case, a solid state relay is controlled by the DIN-172 module. The SSR can then be used to control AC power to alarms, heaters, pumps, etc. A typical connection to a logic input is shown in Figure 6.2. In some cases, the common-mode voltage of the GND terminal may be significantly different from the ground potential of the logic input to be interfaced. This may occur when

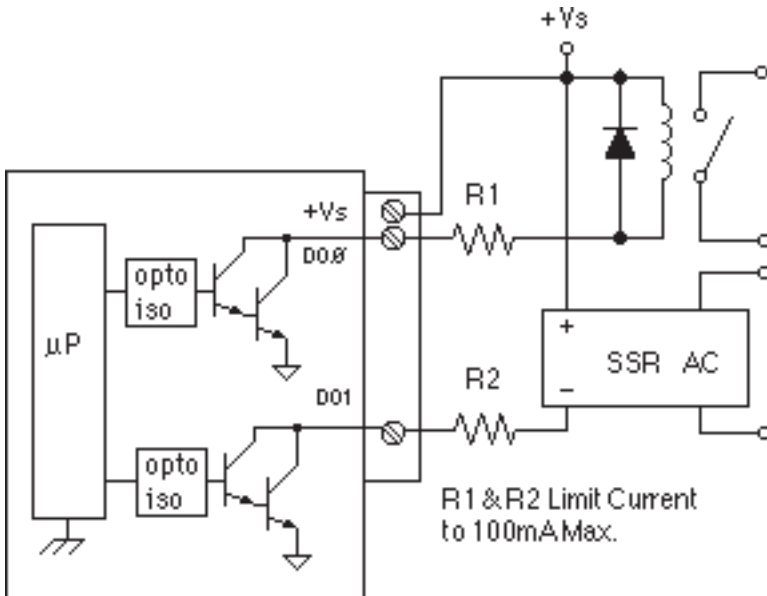


Figure 6.1 Digital Outputs Used With Relays

the module is powered remotely. In this case, an opto-isolator may be used to eliminate the common-mode voltage. See Figure 6.2. In all cases, the current switched by the transistor may not be more than 100mA.

If the module loses power, the digital outputs are turned off. The outputs will remain off until switched by a Digital Output (DO) command.

The digital outputs are not affected by the Remote Reset (RR) command.

### Digital Inputs

Digital inputs are used to sense switch closures and the state of digital signals. The inputs are protected to voltages up to  $\pm 30\text{V}$  and are normally pulled up to the logic "1" condition (see Figure 6.2). Digital inputs can be read by the Digital Input (DI) command. Voltage inputs less than 1V are read back as '0'. Signals greater than 3.5V are read as '1'. No other commands have any affect on the inputs.

Switch closures can be read by the digital input by simply connecting the switch between GND terminal and a digital input with the addition of an external 10K pull-up resistor to +5Vdc. The pull-up supplies only 0.5ma; therefore, self-wiping switches designed for low current operation should be used.

Digital inputs may be used to sense AC voltages by using isolated sensing modules offered by many manufacturers.

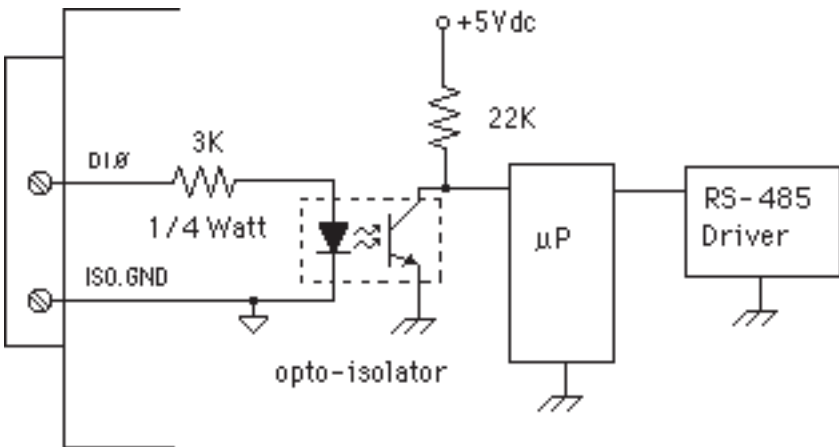


Figure 6.2 Typical Digital Input Circuit.

## **Chapter 7**

### **Power Supply**

DIN-100 modules require a regulated +5Vdc power-supply. The modules contain a low voltage detection circuit that shuts down all circuits in the module at approximately 4.5 Vdc. All power supply specifications are referred to the module connector; the effects of line voltage drops must be considered when the module is powered remotely.

For modules with sensor excitation, consult individual data sheets for power requirements.

The low voltage detection circuit shuts down the module at approximately 4.5Vdc. If the module is interrogated while in a low power supply condition, the module will not respond. Random NOT READY error messages could indicate that the power supply voltage is periodically drooping below the 4.7V minimum.

In some cases, a small number of modules may be operated by “stealing” power from a host computer or terminal.

Small systems may be powered by using wall-mounted calculator-type modular power supplies. These units are inexpensive and may be obtained from many retail electronics outlets.

For best reliability, modules operated on long communications lines (>500 feet) should be powered locally using small calculator-type power units. This eliminates the voltage drops on the Ground lead which may interfere with communications signals. In this case the V+ terminal is connected only to the local power supply. The Ground terminal must be connected back to the host to provide a ground return for the communications loop.

All DIN-100 modules are protected against power supply reversals.

# Chapter 8

## Troubleshooting

### **Symptom:**

**Module is not responding to commands**

**Module responds with ?1 COMMAND ERROR to every command.**

**Characters in each response message appear as graphics characters**

#### **• RS-485 Module is not responding to commands**

1. Using a voltmeter, measure the power supply voltage at the +Vs and GND terminals to verify the power supply voltage is constantly  $5V_{dc} \pm 5\%$ .
2. Verify using an ohmmeter that there are no breaks in the communications data lines.
3. When using a serial communications converter (DIN-191) ensure that the communications Baud Rate switch is set to the proper Baud Rate value.
4. Confirm software communications settings in Host computer match those values being used by the connected module(s).
5. If the Baud Rate value being used in the application is greater than 300 Baud and the module will only communicate 300 Baud then make sure that the DEFAULT\* terminal is not connected to Ground (GND).
6. Ensure that module RS-485 "Data" line (module terminal pin #7) is connected to the Host RS-485 "Data+" line.
7. Ensure that module RS-485 "Data\*" line (module terminal pin #8) is connected to the Host RS-485 "Data-" line.
8. If the problem is not corrected after completing the steps above then connect the module by itself to a Host computer as outlined in Chapter 1.0 under "Quick Hook-up". Start the supplied Utility software and please call the factory for further assistance.

#### **• Module responds with ?1 COMMAND ERROR to every command**

Ensure that characters in the command message are uppercase characters. All commands consist of uppercase characters only.

#### **• Characters in each response message appear as graphics characters**

1. Set the communications software parity setting to "M" for 'MARK' parity type and 7 data bits. Or, utilize any parity type in both the module and software other than "NO" parity.
2. In custom written software routines, mask off the most significant bit of each received character to logic "0". Thus forcing the received character to 7-bit ASCII value.

## Chapter 9 Calibration

The DIN-100 module is initially calibrated at the factory and has a recommended calibration interval of one year. Calibration constants are stored in the EEPROM and may be trimmed using the Trim Span (TS) and Trim Zero (TZ) commands. Calibration procedure is as follows.

**Voltage and current inputs:** clear the output offset register using the Clear Zero (CZ) command. Zero trims are not necessary due to the built-in auto-zero function. Apply a known calibrated voltage or current to the input of the module. The calibrated stimulus should be adjusted to be near 90% of the full scale output of the modules for best results. The accuracy of the calibrated voltage or current must be better than the rated accuracy of the module, which in most cases is 0.02% of full scale. Use the Read Data (RD) command to obtain an output reading. If the output corresponds to the applied input, no calibration is necessary. If the output is in overload, check the circuit connections or use a different input value to obtain an output within the operating range of the module.

To trim the output, use the Trim Span (TS) command. The argument of the TS command should correspond to the desired module output. After performing the TS command, verify the trim with the RD command. For example to trim a DIN-112 module:

1. Clear the output offset register.

**Command:** \$1WE  
**Response:** \* (CZ is write protected)

**Command:** \$1CZ  
**Response:** \*

2. Apply an input voltage near 90% of rated full scale. In this case we use a +900mV input voltage accurate to at least 0.02%. Obtain an output reading.

**Command:** \$1RD  
**Response:** \*+00900.30

In this case, the output of the module is off by 300 $\mu$ V. To trim:

**Command:** \$1WE  
**Response:** \* (TS is write protected)

**Command:** \$1TS+00900.00  
**Response:** \*

This sequence will trim the output to +00900.00. Verify:

**Command:** \$1RD  
**Response:** \*+00900.00 (The module is calibrated.)

**Thermocouples:** Disable the cold junction compensation by setting bit 4 in byte 3 of the setup data with the SetUp (SU) command. The module may now be calibrated using a known input voltage. Perform the calibration as described for a voltage input module. Table 9.1 gives recommended calibration points. Due to the nonlinear nature of thermocouples, it may be necessary to repeat the TS command to obtain the desired output. After calibration is complete, enable the cold junction compensation by clearing bit 4 in byte 3 of the setup data.

**RTD:** Use a calibrated resistor mounted directly on the module connector to avoid lead resistance errors. The resistor must be accurate to 0.01% for proper calibration. Recommended calibration points are listed in Table 9.1. Follow the command sequence described for voltage inputs to calibrate the module. Due to the nonlinear nature of RTD's it may be necessary to repeat the TS command to obtain the desired output.

**Table 9.1 Calibration Values**

Model	Input Stimulus	Output Data
DIN-110	+9000 $\mu$ V	+09000.00
DIN-111	+90mV	+00090.00
DIN-112	+900mV	+00900.00
DIN-113	+4.5V	+04500.00
DIN-114	+9V	+09000.00
DIN-115	+90V	+00090.00
DIN-125	+20mA	+00020.00
DIN-131	+39.13mV	+00700.00
DIN-132	+41.269mV	+01000.00
DIN-133	+17.816mV	+00350.00
DIN-134	+68.783mV	+01000.00
DIN-135	+17.445mV	+01500.00
DIN-136	+15.576mV	+01500.00
DIN-137	+10.094mV	+01500.00
DIN-138	+33.442mV	+01982.00
DIN-141	300.00 $\Omega$	+00558.00
DIN-142	300.00 $\Omega$	+00547.60
DIN-143	134.91 $\Omega$	+00115.00
DIN-145	206.1 $\Omega$	+00090.00
DIN-146	3018 $\Omega$	+00140.00
DIN-151	25mV	+00025.00
DIN-152	25mV	+00025.00
DIN-153	90mV	+00090.00
DIN-154	90mV	+00090.00
DIN-161	18Khz	+18000.00

## Chapter 10

# Extended Addressing

The DIN-100 may be configured to a special command format called Extended Addressing. This mode uses a different prompt, either '{' or '}' to distinguish it from the regular command syntax. The major difference in syntax for the Extended Addressing mode is that it uses a two-character address. A typical command in Extended Address mode would look like this:

**Command:**    {01WE  
**Response:**    \*

Both the command and response are terminated with carriage returns. Note that the command uses a two-character address, '01.'

There are two benefits to using Extended Addressing with the DIN-100:

- 1) Greatly expanded addressing capability.
- 2) Allow for a more structured addressing method in large systems.

With single-byte addressing of the normal command structure, address space is limited to 122 points. Extended addressing allows an addressing range of 249 points.

### Structured Addressing

Even for a relatively small system, it can be advantageous to employ a hierarchical addressing system as used in Fig. 7.1. This is particularly true in systems that consist of many sites that are identical. From a host software standpoint, each site can be treated identically with the same module addresses, with each site having a different DIN-100 address.

### Extended Address Syntax

The command syntax used with Extended Addressing is quite similar to the normal protocol. The Extended Address commands are initiated with a '{' character (left curly brace, ASCII \$7B), or a '}' character (right curly brace, ASCII \$7E). The '{' prompt is analogous to the '\$' prompt in that it returns the shortest possible response to complete the command. The '}' prompt is similar to the '#' prompt in that the command is echoed and a checksum is generated along with the other data necessary to complete the response. The '\*' response prompt is used in all command forms.



The Extended Address commands use a two-character ASCII address, each character may be one of 122 legal possibilities. Illegal characters are: NULL (\$00), CR (\$0D), \$ (\$24), # (\$23), { (\$7B), and } (\$7E).

Command examples with Extended Address '01':

**Command:** {01WE  
**Response:** \*

**Command:** }01WE  
**Response:** \*01WE27

**Command:** {01RS  
**Response:** \*31070000 (typical)

**Command:** }01RS  
**Response:** \*01RS31070000BB (typical)

Checksums may be appended to commands:

**Command:** {01WE78  
**Response:** \*

All commands that are available with single-byte addressing may be accessed with Extended Addressing, and vice-versa.

## Appendix A ASCII Table

Table of ASCII characters (A) and their equivalent values in Decimal (D), Hexadecimal (Hex), and Binary. Claret (^) represents Control function.

A	D	Hex	Binary	D	Hex	Binary
^@	0	00	00000000	128	80	10000000
^A	1	01	00000001	129	81	10000001
^B	2	02	00000010	130	82	10000010
^C	3	03	00000011	131	83	10000011
^D	4	04	00000100	132	84	10000100
^E	5	05	00000101	133	85	10000101
^F	6	06	00000110	134	86	10000110
^G	7	07	00000111	135	87	10000111
^H	8	08	00001000	136	88	10001000
^I	9	09	00001001	137	89	10001001
^J	10	0A	00001010	138	8A	10001010
^K	11	0B	00001011	139	8B	10001011
^L	12	0C	00001100	140	8C	10001100
^M	13	0D	00001101	141	8D	10001101
^N	14	0E	00001110	142	8E	10001110
^O	15	0F	00001111	143	8F	10001111
^P	16	10	00010000	144	90	10010000
^Q	17	11	00010001	145	91	10010001
^R	18	12	00010010	146	92	10010010
^S	19	13	00010011	147	93	10010011
^T	20	14	00010100	148	94	10010100
^U	21	15	00010101	149	95	10010101
^V	22	16	00010110	150	96	10010110
^W	23	17	00010111	151	97	10010111
^X	24	18	00011000	152	98	10011000
^Y	25	19	00011001	153	99	10011001
^Z	26	1A	00011010	154	9A	10011010
^[	27	1B	00011011	155	9B	10011011
^\	28	1C	00011100	156	9C	10011100
^]	29	1D	00011101	157	9D	10011101
^^	30	1E	00011110	158	9E	10011110
^_	31	1F	00011111	159	9F	10011111
	32	20	00100000	160	A0	10100000
!	33	21	00100001	161	A1	10100001
"	34	22	00100010	162	A2	10100010

A	D	Hex	Binary	D	Hex	Binary
#	35	23	00100011	163	A3	10100011
\$	36	24	00100100	164	A4	10100100
%	37	25	00100101	165	A5	10100101
&	38	26	00100110	166	A6	10100110
'	39	27	00100111	167	A7	10100111
(	40	28	00101000	168	A8	10101000
)	41	29	00101001	169	A9	10101001
*	42	2A	00101010	170	AA	10101010
+	43	2B	00101011	171	AB	10101011
,	44	2C	00101100	172	AC	10101100
-	45	2D	00101101	173	AD	10101101
.	46	2E	00101110	174	AE	10101110
/	47	2F	00101111	175	AF	10101111
0	48	30	00110000	176	B0	10110000
1	49	31	00110001	177	B1	10110001
2	50	32	00110010	178	B2	10110010
3	51	33	00110011	179	B3	10110011
4	52	34	00110100	180	B4	10110100
5	53	35	00110101	181	B5	10110101
6	54	36	00110110	182	B6	10110110
7	55	37	00110111	183	B7	10110111
8	56	38	00111000	184	B8	10111000
9	57	39	00111001	185	B9	10111001
:	58	3A	00111010	186	BA	10111010
;	59	3B	00111011	187	BB	10111011
<	60	3C	00111100	188	BC	10111100
=	61	3D	00111101	189	BD	10111101
>	62	3E	00111110	190	BE	10111110
?	63	3F	00111111	191	BF	10111111
@	64	40	01000000	192	C0	11000000
A	65	41	01000001	193	C1	11000001
B	66	42	01000010	194	C2	11000010
C	67	43	01000011	195	C3	11000011
D	68	44	01000100	196	C4	11000100
E	69	45	01000101	197	C5	11000101
F	70	46	01000110	198	C6	11000110
G	71	47	01000111	199	C7	11000111
H	72	48	01001000	200	C8	11001000
I	73	49	01001001	201	C9	11001001
J	74	4A	01001010	202	CA	11001010
K	75	4B	01001011	203	CB	11001011

A	D	Hex	Binary	D	Hex	Binary
L	76	4C	01001100	204	CC	11001100
M	77	4D	01001101	205	CD	11001101
N	78	4E	01001110	206	CE	11001110
O	79	4F	01001111	207	CF	11001111
P	80	50	01010000	208	D0	11010000
Q	81	51	01010001	209	D1	11010001
R	82	52	01010010	210	D2	11010010
S	83	53	01010011	211	D3	11010011
T	84	54	01010100	212	D4	11010100
U	85	55	01010101	213	D5	11010101
V	86	56	01010110	214	D6	11010110
W	87	57	01010111	215	D7	11010111
X	88	58	01011000	216	D8	11011000
Y	89	59	01011001	217	D9	11011001
Z	90	5A	01011010	218	DA	11011010
[	91	5B	01011011	219	DB	11011011
\	92	5C	01011100	220	DC	11011100
]	93	5D	01011101	221	DD	11011101
^	94	5E	01011110	222	DE	11011110
_	95	5F	01011111	223	DF	11011111
`	96	60	01100000	224	E0	11100000
a	97	61	01100001	225	E1	11100001
b	98	62	01100010	226	E2	11100010
c	99	63	01100011	227	E3	11100011
d	100	64	01100100	228	E4	11100100
e	101	65	01100101	229	E5	11100101
f	102	66	01100110	230	E6	11100110
g	103	67	01100111	231	E7	11100111
h	104	68	01101000	232	E8	11101000
i	105	69	01101001	233	E9	11101001
j	106	6A	01101010	234	EA	11101010
k	107	6B	01101011	235	EB	11101011
l	108	6C	01101100	236	EC	11101100
m	109	6D	01101101	237	ED	11101101
n	110	6E	01101110	238	EE	11101110
o	111	6F	01101111	239	EF	11101111
p	112	70	01110000	240	F0	11110000
q	113	71	01110001	241	F1	11110001
r	114	72	01110010	242	F2	11110010
s	115	73	01110011	243	F3	11110011
t	116	74	01110100	244	F4	11110100

A	D	Hex	Binary	D	Hex	Binary
u	117	75	01110101	245	F5	11110101
v	118	76	01110110	246	F6	11110110
w	119	77	01110111	247	F7	11110111
x	120	78	01111000	248	F8	11111000
y	121	79	01111001	249	F9	11111001
z	122	7A	01111010	250	FA	11111010
{	123	7B	01111011	251	FB	11111011
	124	7C	01111100	252	FC	11111100
}	125	7D	01111101	253	FD	11111101
~	126	7E	01111110	254	FE	11111110
	127	7F	01111111	255	FF	11111111

## Appendix B

### DIN-160 Data Sheet

The Frequency Input modules feature a versatile input stage that can be used in a variety of applications. Figure B-1 is a block diagram of the input signal conditioning.

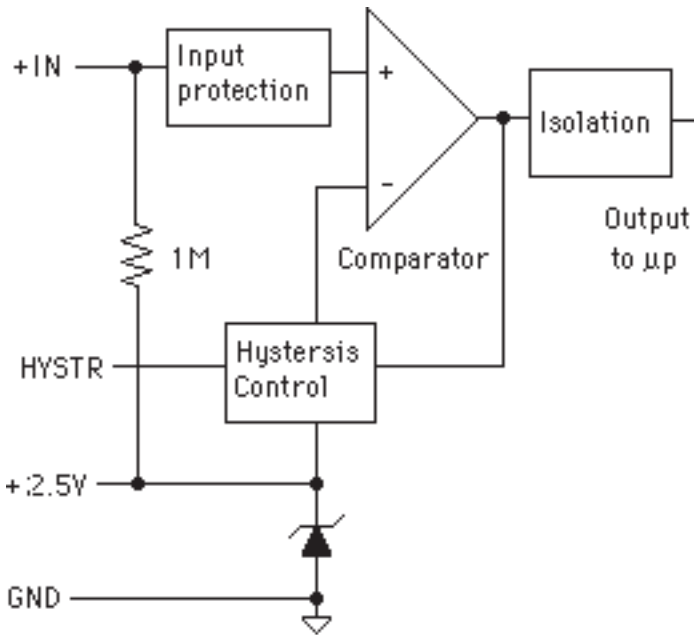


Figure B-1. DIN-161 Input Signal Conditioning Block Diagram.

The input signal is applied to a precision comparator through the + Input. Input protection is provided to withstand inputs up to 230Vac. The comparator output is then fed through an opto-isolator to the module's microprocessor for scaling and formatting. The input section is completely isolated from the power and communications lines. The isolation allows up to 500V of common-mode voltage between the input ground and the power connections.

The input comparator employs hysteresis to provide reliable readings with noisy or slow input signals. The amount of hysteresis may be controlled by connecting the hysteresis control line (HYSTR) to ground or the 2.5V terminal through an external resistor. Figure 2 shows the most frequently used connection.



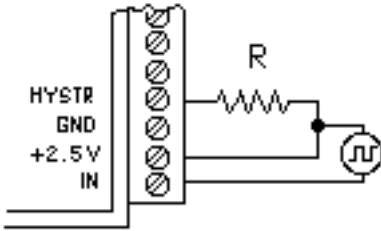
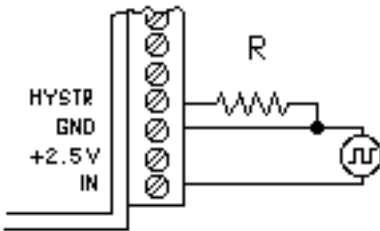


Figure B-3. Controlling Hysteresis For Bipolar Signals.

Figure B-4. Controlling Switching Level and Hysteresis.



R	$V_{\text{switching}} \pm V_{\text{hysteresis}}$
Open	$2.5V \pm 0.5V$
$\emptyset\Omega$	$1.7V \pm 5mV$

For  $V_{\text{hysteresis}} > 5mV$  and  $< 0.5V$ :

$$R \text{ (in K}\Omega\text{)} = \frac{34 V_{\text{hysteresis}}}{0.5 - V_{\text{hysteresis}}}$$

$$V_{\text{switching}} = 2.5 - \frac{14}{17 + R}$$

The hysteresis control may also be connected to ground (GND), which produces another set of switching levels. This connection is shown in figure B-4. If the HYSTR terminal is shorted to GND the nominal switching point is 1.6V with  $\pm 5mV$  of hysteresis.

To measure AC signals super-imposed on a DC value, the input may be AC coupled by simply placing a capacitor in series with the +IN terminal. The module contains an internal 1M $\Omega$  resistor connected from the +IN to +2.5V for biasing. A .01 uf cap may be used for frequencies down to 10HZ.



# Appendix C

## DIN-140 Data Sheet

SPECIFICATIONS: (Typical @ 25°C, V+ = +5V)

RTD Types: =.00385, .00388, .00392 100Ω @ 0°C

Resolution: 0.1°

Accuracy: ±0.3°C

Input connections: 2, 3, or 4 wire

Excitation current: .25 mA

Max. Lead resistance: 50Ω

Input protection to 120Vac

Automatic linearization and lead compensation

Lead resistance effect: 3 wire—2.5°C per Ω of imbalance

4 wire—Negligible

### Sensor Hookups

The RTD sensor must be connected as shown in the accompanying diagrams to insure proper operation.

**3-Wire:** The DIN-140 modules are shipped from the factory configured for 3-wire operation. Connect the RTD sensor as shown in the diagram. The wires connected to the +I and -I terminals should be matched in length and gauged for proper lead compensation. The +I and +SENSE terminals must be tied together at the connector with a short wire jumper. For proper 3-wire lead compensation, the RTD 3/4 wire set-up bit must be 0 (see Set-Up (SU) command). A typical set-up for 3-wire operation would be 31070182.

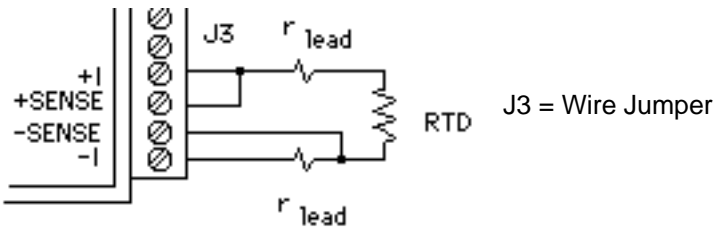


Figure C-1. 3-wire RTD Configuration

**4-Wire:** For 4-wire operation, connect the RTD as shown in the diagram. If the RTD has heavy excitation wires, they should be connected to the +I and -I terminals. For proper 4-wire operation, the RTD set-up bit must be set to 1 (see Set-Up (SU) command). A typical set-up for 4-wire operation would be 31071182.

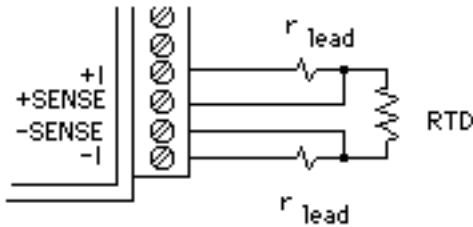


Figure C-2. 4-Wire RTD Configuration.

**2-Wire:** The 2-wire connection requires two jumpers on the connector (J1 & J2) as shown in the diagram. This connection provides no lead compensation. The RTD set-up bit can be either 0 or 1 for this connection.

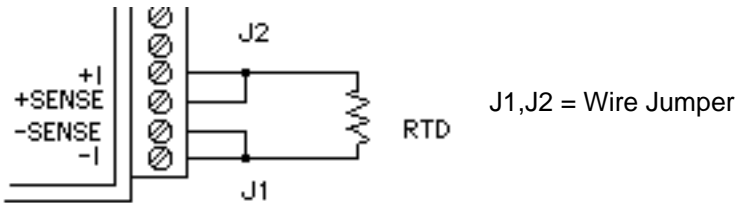


Figure C-3. 2-Wire RTD Configuration.

**Start-Up:** During normal operation, the RTD lead resistance is periodically scanned and filtered by the DIN-140 module. This may result in large initial errors if the RTD sensor is connected while the DIN-140 is powered up. To avoid this error, the sensor should be wired to the connector before power is applied. The error may also be eliminated by performing a Remote Reset (RR) command.

**Lead Resistance Overload:** If the lead resistance exceeds 50Ω, the output data is set to +99999.99.

**Sensor Grounding:** The sensor input is electrically isolated from the power and communications inputs for common-mode voltages up to 500V. If the sensor is to be grounded or shielded, the ground connection should be made to the -I terminal.

# Appendix D

## DIN-150 Data Sheet

The DIN-150 Bridge Sensor Interface Modules contain all of the signal conditioning functions necessary to interface Strain Gage and other resistive bridge devices to an RS-485 computer port. Each module contains excitation, an instrumentation amplifier, and a smart analog to digital converter to convert resistive bridge sensor signals to ASCII data.

The user should become familiar with the generic DIN-100 information described in the DIN-100 User's Manual before attempting any of the procedures outlined below.

### Data Format

The ASCII output data is expressed in millivolts with 10 microvolt resolution.

For Example:

**Command:**     **\$1RD**       **(Read Data)**  
**Response:**    **\*+00012.34**

In this case, the output data is 12.34 millivolts.

Modules that are configured for  $\pm 30\text{mV}$  and have a usable span of  $\pm 60\text{mV}$ . Modules configured for  $\pm 100\text{mV}$  have a usable span of  $\pm 120\text{mV}$ . The extra overhead is used to trim any bridge offsets.

### Setup Data

The factory setup for all versions of DIN-150 modules is 310701C2

### Sensor Connections

See Figure 1 for the proper bridge sensor connections. Shields or grounds should be connected to the -Excitation terminal.

### Offset Trim

The DIN-150 modules do not provide any means of trimming the analog offset of the sensor bridge. However, sensor offsets may be nulled from the output data with the Trim Zero (TZ) command. This method of trimming is convenient because the offset may be trimmed through the communications port at any time. There is no need to have access to the module since the trimming is performed remotely.

The input signal conditioning circuitry of the DIN-150 modules have a wide input range to accommodate large sensor offsets without the need for external trims. Modules rated for  $\pm 30\text{mV}$  have an input range capability of  $\pm 60\text{mV}$ . Modules rated for  $\pm 100\text{mV}$  have an input range of  $\pm 120\text{mV}$ .

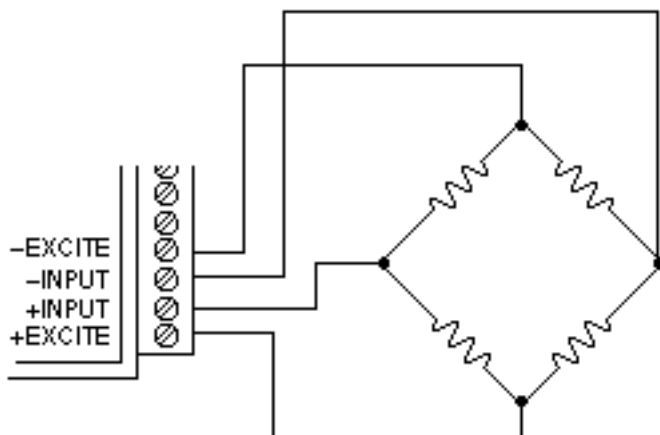


Figure D-1 Bridge Circuit Wiring

To perform an initial offset trim, attach the bridge unit to the module (as shown in Figure D-1). Clear out any previous offset trims with the Clear Zero (CZ) command. Apply the desired zero condition to the bridge sensor. For a Strain Gage Bridge this would be the relaxed or unstrained condition. For load cells, the zero condition could include any tare weight due to a weighing platform or other attachments that would affect the zero balance. Obtain an initial reading using the Read Data (RD) command. The output data will indicate the total offset of the system. Subtract the offset value from the usable input range of your module, either  $\pm 60\text{mV}$  or  $\pm 120\text{mV}$ . The result is the maximum usable "input overhead". If the overhead is not sufficient for your application, the bridge must be trimmed externally to lower the offset to an acceptable value. The bridge may be trimmed with a small series resistance or a large shunt resistance to the appropriate leg of the bridge (as shown in Figure D-2). If the initial offset is acceptable, the offset may be trimmed with the Trim Zero (TZ) command.

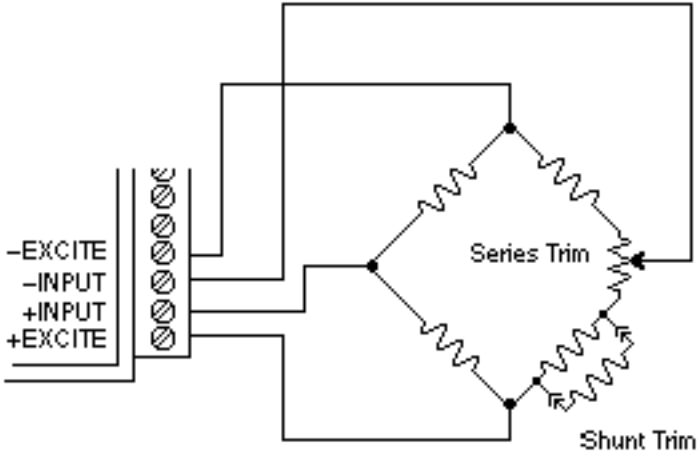


Figure D-2 Bridge Circuit Trim

Example 1:

A load cell to be used in a weighing application is mated to a DIN-152 module. The load cell is rated for 3mV/V, which results in a maximum  $\pm 30\text{mV}$  with 10V excitation. However, in this application, the load cell is used only in tension so its ideal output will be from 0 to +30mV.

The load cell is mounted in position with the weighing attachments. Clear any offset data that may be stored in the DIN-152 module:

**Command:** \$1WE (CZ is write-protected)  
**Response:** \*

**Command:** \$1CZ (Clear Zero)  
**Response:** \*

Verify that the Zero Trim is cleared:

**Command:** \$1RZ (Read Zero)  
**Response:** \*+00000.00

Obtain an initial offset reading from the load cell with no weight attached:

**Command:** \$1RD (Read Data)  
**Response:** \*+00002.34

The initial offset is +2.34mV. The DIN-152 has a useful input range of  $\pm 60\text{mV}$ . After subtracting the offset the "input overhead" is -62.34mV and +57.66mV. The expected 0 to +30mV output of the load cell easily falls within the overhead range and no external trimming is necessary.

To Trim Zero:

**Command:** \$1WE (TZ is write protected)

**Response:** \*

**Command:** \$1TZ+00000.00 (zero output)

**Response:** \*

Now read the data output to verify the trim:

**Command:** \$1RD (Read Data)

**Response:** \*+00000.00

The load cell system has been trimmed to zero.

Example 2:

A strain gage bridge will be used to measure both compression and tensile strains on a structural member. The bridge is attached to a DIN-152 module and the ideal output from the bridge is  $\pm 30\text{mV}$  full scale.

Clear the Zero Trim:

**Command:** \$1WE

**Response:** \*

**Command:** \$1CZ (Clear Zero)

**Response:** \*

Measure the initial offset from the bridge:

**Command:** \$1RD

**Response:** \*-00043.21

In this case, the bridge exhibits a large initial offset of -43.21mV. Subtract this value from the  $\pm 60\text{mV}$  useful range of the DIN-152 to obtain an "input overhead" value of -16.79mV to 103.21mV. In this case the -16.79mV overhead is not large enough to cover the -30mV that may be obtained from the bridge. The bridge must be trimmed externally to bring the offset to within  $\pm 30\text{mV}$ . It is not necessary to obtain an exact zero with the external trim.

After the external trim has been performed, check the offset:

**Command:** \$1RD

**Response:** \*-00022.22

This value is within the  $\pm 30\text{mV}$  offset necessary to provide enough headroom for the strain gage bridge.

Trim out the remaining offset with the Trim Zero (TZ) command:

**Command:** \$1WE

**Response:** \*

**Command:** \$1TZ+00000.00

**Response:** \*

The bridge is now trimmed to zero. Verify:

**Command:** \$1RD

**Response:** \* +00000.00

The Trim Zero (TZ) command may be used at any time to balance out offsets due to temperature, residual stress, tare, etc.

### Excitation

DIN-150 modules may be ordered with either 5V or 10V excitation. Maximum excitation current available is 40mA. Modules with 10V excitation may be used with bridges that have input impedances of 166 ohms or greater. Half-bridges of 120  $\Omega$  strain gages may be used with 10V excitation if the bridge is completed with 350  $\Omega$  resistors. Modules with 5V excitation will source bridges of 85  $\Omega$  and up.

The actual excitation voltage may vary  $\pm 0.5\text{V}$  from the nominal values of +10V and +5V. However, the module's internal microprocessor constantly monitors the actual excitation voltage and provides compensation for any deviation from the nominal value. This results in a constant data output for a constant bridge load even if the excitation changes. From a user's point of view, the excitation voltage will appear to be exactly +10V or +5V.

### Calibration

Since the DIN-150 modules use a ratiometric technique to compensate for variances in the excitation voltage, special consideration is required to properly calibrate the unit. Figure D-3 shows the calibration setup. The Digital Voltmeter (DVM) must be capable of measuring the excitation voltage to 4 digit accuracy. The voltage source must be able to provide millivolt signals accurate to  $\pm 5$  microvolts. The resistive divider may be constructed from 1% resistors of equal value from 100 to 1000  $\Omega$ . The resistor divider places the voltage source in the center of the common-mode range of the input amplifier for best accuracy.

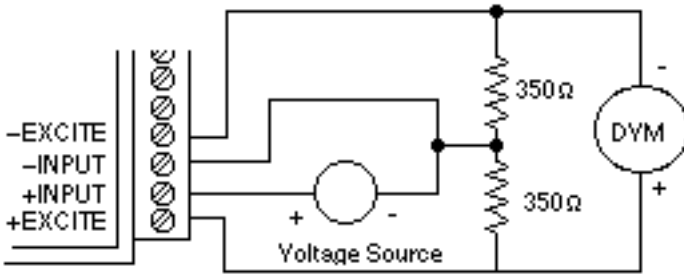


Figure D-3 DIN-150 Calibration

Step 1: power up the unit under test and let it warm up for at least two minutes.

Step 2: set the voltage source to 0 volts (short). Perform a TZ+00000.00 (Trim Zero) command to eliminate any common-mode offset errors.

Step 3: measure the excitation voltage with the DVM. Divide the result by the nominal excitation voltage, either 10V or 5V, to obtain a "compensation factor" = CF.

Step 4: calculate the correct calibration voltage to apply to the unit.

For  $\pm 30\text{mV}$  units the voltage is  $V = +50\text{mV} \times \text{CF}$

For  $\pm 100\text{mV}$  units the voltage is  $V = +100\text{mV} \times \text{CF}$

Set the voltage source to the calculated voltage V.

Step 5: trim the unit with the Trim Span (TS) command.

For  $\pm 30\text{mV}$  modules the command is \$1TS+00050.00

For  $\pm 100\text{mV}$  modules the command is \$1TS+00100.00

Step 6: verify the trim using the \$1RD command. The result should be either \*+00050.00 or \*+00100.00

Calibration Example:

We wish to calibrate a DIN-151 module. This unit contains 5V excitation and a  $\pm 30\text{mV}$  input.

Step 1 is straightforward and needs no further explanation.

Step 2: set the voltage source to 0 volts. Trim zero:

**Command:** \$1WE

**Response:** \*





**Command:** \$1TZ+00000.00

**Response:** \*

Step 3: measure the excitation voltage with the DVM. In this example the measured voltage is 4.954V Calculate the “compensation factor”:

$$CF = 4.954 / 5 = 0.9908$$

Step 4: calculate the calibration voltage:

$$V = +50\text{mV} \times 0.9908 = +49.54\text{mV}.$$

Set the voltage standard to +49.54mV.

Step 5: perform the Trim Span command:

**Command:** \$1WE

**Response:** \*

**Command:** \$1TS+00050.00

**Response:** \*

Step 6: verify the calibration, continuing to apply +49.54mV to the input:

**Command:** \$1RD

**Response:** \*+00050.00

The span trim is now complete. The Trim Zero (TZ) command may be used to trim sensor offsets without affecting the span trim.

# Appendix E

## DIN-100 Specifications

**Specifications** (typical @ +25° C and nominal power supply unless otherwise noted.)

### Analog

- Single channel analog input.
- Maximum CMV, input to output at 60Hz: 500V rms.
- Leakage current, input to output at 115Vrms, 60Hz: <2μA rms.
- 15 bit measurement resolution.
- 8 conversions per second.
- Autozero & autocalibration—no adjustment pots.

### Digital

- 8-bit CMOS microcomputer.
- Digital scaling, linearization and calibration.
- Nonvolatile memory eliminates pots and switches.

### Digital filtering

- Small and large signal with user selectable time constants from 0 to 16 seconds.

### Communications

- Communications in ASCII via RS-232C, RS-485 ports.
- Selectable baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400.
- NRZ asynchronous data format; 1 start bit, 7 data bits, 1 parity bit and 1 stop bit.
- Parity: odd, even, none.
- User selectable channel address.
- ASCII format command/response protocol.
- Up to 122 multidrop modules per host serial port.
- Communications distance up to 4,000 feet (RS-485).
- Transient suppression on RS-485 communications lines.
- Communications error checking via checksum.
- Can be used with "dumb terminal".
- Scan up to 250 channels per second.
- All communications setups stored in EEPROM.

### Power

Requirements: 5V±0.5Vdc, 0.75W max (DIN-150, 2.0W max.).  
Internal switching regulator.  
Protected against power supply reversals.

**Environmental**

Temperature Range: Operating  $-25^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$ .

Storage  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

Relative Humidity: 0 to 95% noncondensing.

**Warranty**

12 months on workmanship and material.

**DIN-110 Voltage Inputs**

- Voltage ranges:  $\pm 10\text{mV}$ ,  $\pm 100\text{mV}$ ,  $\pm 1\text{V}$ ,  $\pm 5\text{V}$ ,  $\pm 10\text{V}$ ,  $\pm 100\text{Vdc}$ .
- Resolution: 0.01% of FS (4 digits).
- Accuracy:  $\pm 0.02\%$  of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^{\circ}\text{C}$  max.
- Input burnout protection to 250Vac .
- Input impedance:  $\leq \pm 1\text{V}$  input =  $100\text{M}\Omega$  min.  
 $\geq \pm 5\text{V}$  input =  $1\text{M}\Omega$  min.

**DIN-120 Current Inputs**

- Current ranges: 4-20mAdc.
- Resolution:  $\pm 0.04\%$  of FS.
- Accuracy:  $\pm 0.04\%$  of FS (4-20mA).
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^{\circ}\text{C}$  max.
- Voltage drop:  $\pm 0.1\text{V}$  max.

**DIN-130 Thermocouple Inputs**

- Thermocouple types: J, K, T, E, R, S, B, C (factory set).
- Ranges: J =  $-200^{\circ}\text{C}$  to  $+760^{\circ}\text{C}$       B =  $0^{\circ}\text{C}$  to  $+1820^{\circ}\text{C}$   
           K =  $-150^{\circ}\text{C}$  to  $+1250^{\circ}\text{C}$       S =  $0^{\circ}\text{C}$  to  $+1750^{\circ}\text{C}$   
           T =  $-200^{\circ}\text{C}$  to  $+400^{\circ}\text{C}$       R =  $0^{\circ}\text{C}$  to  $+1750^{\circ}\text{C}$   
           E =  $-100^{\circ}\text{C}$  to  $+1000^{\circ}\text{C}$       C =  $0^{\circ}\text{C}$  to  $+2315^{\circ}\text{C}$
- Resolution:  $\pm 1^{\circ}$ .
- Overall Accuracy (error from all sources) from 0 to  $+40^{\circ}\text{C}$  ambient:  
 $\pm 1.0^{\circ}\text{C}$  max (J, K, T, E).  
 $\pm 2.5^{\circ}\text{C}$  max (R, S, B, C)( $300^{\circ}\text{C}$  TO FS).
- Common mode rejection: 100dB at 50/60Hz.
- Input impedance:  $100\text{M}\Omega$  min.
- Lead resistance effect:  $< 20\mu\text{V}$  per  $350\Omega$ .
- Open thermocouple indication.
- Input burnout protection to 250Vac.
- Overrange indication.
- Automatic cold junction compensation and linearization.

**DIN-140RTDInputs**

- RTD types:  $\alpha = .00385, .00392, 100\Omega$  at  $0^{\circ}\text{C}$ ,  
 $.00388, 100\Omega$  at  $25^{\circ}\text{C}$ .
- Ranges:  $.00385 = -200^{\circ}\text{C}$  to  $+850^{\circ}\text{C}$ .  
 $.00392 = -200^{\circ}\text{C}$  to  $+600^{\circ}\text{C}$ .  
 $.00388 = -100^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .
- Resolution:  $0.1^{\circ}$ .
- Accuracy:  $\pm 0.3^{\circ}\text{C}$ .
- Span tempco:  $\pm 50$  ppm/ $^{\circ}\text{C}$  max.
- Common mode rejection: 100dB at 50/60Hz.
- Input connections: 2, 3, or 4 wire.
- Excitation current: 0.25mA.
- Lead resistance effect: 3 wire -  $2.5^{\circ}\text{C}$  per  $\Omega$  of imbalance.  
4 wire - negligible.
- Max lead resistance:  $50\Omega$ .
- Input burnout protection to 120Vac .
- Automatic linearization and lead compensation.

**DIN-145 Thermistor Inputs**

- Thermistor types:  $2252\Omega$  at  $25^{\circ}\text{C}$ , TD Series
- Ranges:  $2252\Omega = -0^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$ .  
TD =  $-40^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ .
- Resolution:  $2252\Omega = 0.01^{\circ}\text{C}$  or F.  
TD =  $0.1^{\circ}\text{C}$  or F
- Accuracy:  $2252\Omega = \pm 0.1^{\circ}\text{C}$ .  
TD =  $\pm 0.2^{\circ}\text{C}$
- Common mode rejection: 100dB at 50/60Hz.
- Input protection to 30Vdc .

**DIN-150 Bridge Inputs**

- Voltage Ranges:  $\pm 30\text{mV}$ ,  $\pm 100\text{mV}$ .
- Resolution:  $10\mu\text{V}$  (mV spans).  
0.02% of FS (V span).
- Accuracy:  $\pm 0.05\%$  of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Input burnout protection to 30Vdc .
- Offset Control: Full input range.
- Excitation Voltage: 5V, 10Vdc, 60mA max.
- Zero drift:  $\pm 1\mu\text{V}/^{\circ}\text{C}$  max.
- Span tempco:  $\pm 50\text{ppm}/^{\circ}\text{C}$  max.

**DIN-160 Timer and Frequency Inputs**

- Input impedance:  $1\text{M } \Omega$ .
- Switching level: selectable 0V, +2.5V.
- Hysteresis: Adjustable 10mV-1.0V.
- Input burnout protection: 250Vac.

### **Frequency Input**

- Range: 1Hz to 20KHz.
- Resolution: 0.005% of reading + 0.01Hz.
- Accuracy:  $\pm 0.01\%$  of reading  $\pm 0.01$ Hz.
- Tempco:  $\pm 20$ ppm/  $^{\circ}$ C.

### **DIN-170 Digital Inputs/Outputs**

- 6 digital inputs or 6 output bits.
- Input voltage levels: 0-30V without damage.
- Input switching levels: High, 3.5V min., Low, 1.0V max.
- Outputs: Open collector to 30V, 100mA max. load.
- $V_{sat}$ : 1.0V max @ 100mA.
- Inputs/Outputs are read/set in parallel.
- Isolated from power supply ground.

### **DIN-190 RS-232/485 Converter/Repeater**

- Baud Rates: 300-115200 (Dip-switch selectable).
- Termination and biasing resistors included (selectable via internal jumpers).

# Appendix F

## Modbus Protocol

### MODBUS PROTOCOL OVERVIEW

This document describes the Modbus RTU protocol option included in the DIN-100 series of data acquisition modules. This implementation of the Modbus protocol is a subset of the protocol as described in the Modicon Modbus Protocol Reference Guide PI-MBUS-300 Rev F. Only the RTU version of the protocol has been implemented.

Modbus RTU mode communicates in standard NRZ asynchronous format with one start bit, eight data bits, one parity bit, and one stop bit. Even and odd parity is supported. If no parity is specified, the number of stop bits can be user configured for either one or two stop bits.

Baud rates supported at this time are: 300, 600, 1200, 2400, 4800, 9600, 19,200 and 38,400.

Modbus uses the RS-485 electrical specification for multidrop communications. The RS-232 electrical specification is not supported.

Modbus is a registered trademark of AEG Modicon Inc.

The Modbus RTU protocol transmits data in 8-bit binary bytes (not ASCII). To illustrate the data in this document, the 8-bit byte is described as two hexadecimal nibbles. For example, the binary byte value "0101 1101" will be written as 5D.

A typical Modbus RTU command may look like this:

01 04 00 00 00 01 31 CA

***Remember, this command string and others throughout this document are actually transmitted to a module as eight 8-bit binary characters.***

The actual format of the data is dependent on the type of command desired. The example above is the Modbus 'Read Input Registers' function.

The '01' is the address of the slave device (DIN-100 module) being commanded. Each slave device must have its own unique address.

The '04' specifies the Modbus 'Read Input Registers' function. This is equivalent to the 'Read Data' command to obtain analog input data.

The next two characters '00 00' specify the starting address of the registers to be read. The first Modicon input register 30001 is addressed as '00 00'. Register 30005 is addressed as '00 04', etc.

The next two characters of this command specify the number of registers to be read, including the starting register. In this case the two binary characters '00 01' indicates only one register is to be read.

The final two characters of the command string make up the Cyclical Redundancy Check (CRC), used to check for errors in the message.

There are no prompt or terminating characters in the messages. All messages must be transmitted as continuous strings. Messages are terminated by a 'silent' interval of at least 3.5 character times. A 'silent' interval of more than 1.5 character times marks the beginning of the next message. Therefore it is mandatory that the RS-485 bus must be biased in the MARK condition during the 'silent' interval. This is usually accomplished by pull-up and pull-down resistors on the communications line.

A typical response to this example command could be:

01 04 02 80 00 D8 F0

The '01' and '04' characters echo the slave address and the command function.

For this particular command function, the '02' character indicates the number of data characters to follow, in this case, 2 characters.

The two character string '80 00' is the value read from Modicon input register 30001. Register data is read back as 16 bits.

The remaining two characters, 'D8 F0' is the CRC for the response.

The A1000 and DIN-190 series of RS-232 to RS-485 protocol converters and repeaters will not operate with the 9-bit data characters used by the Modbus protocol.

## **Getting Started**



The DIN-100 series modules are initialized at the factory to communicate using the DIN-100 ASCII protocol. This allows for all setup and configurations to be easily performed using the DIN-100 setup software or a dumb terminal. After the setup process has been completed the DIN-100 can be placed in Modbus RTU protocol mode using the "MBR" command. Disable the Modbus RTU mode using the Modbus Disable ("MBD") command.

Quick start steps:

- 1 Connect a power supply to the DIN-100 between +Vs terminal and GND terminal. The regulated supply voltage must be +5.0Vdc.
2. Properly connect the DIN-100 series to a computer using the "quick hook-up" diagrams in chapter #1 of this manual using either an RS-232 or RS-485 serial port.
3. Locate the Windows Utility software CD-ROM and run the setup.exe file to install the software. A DGH Data Acquisition menu selection will be added to the Windows "Start, Programs" menu. The Utility Software will be listed under that selection.
4. Configure the host computer serial ports by selecting main menu selection "Edit" and "Serial Ports". Select the correct COMx: port, baud rate and Parity type. Note: If the "Default\*" pin on DIN-100 is connected to GND then select 300 baud as host computer baud rate and select no parity.
5. Select main menu "Setup" and enter the DIN-100 device address and model number. For example, select "111 DIN +/-100mV/RS-485 Out".
6. At the next configuration screen make the necessary alterations to Baud Rate, Parity type and other required parameters. Drop down the "Communications Protocol" list box and select "Modbus RTU Protocol". Specify the correct Modbus slave address and press the <APPLY> to transmit the new setup values. Once the values have been transmitted press the <ESC> key back to the program main menu.
7. Remove the connection between "Default\*" and GND, which performs internal reset, to enable Modbus RTU mode. If there was no connection between "Default\*" and GND then cycle the power on device to force a reset and enable Modbus Mode.

The device is now configured for Modbus RTU mode and can be connected

to a RS-485 based Modbus master system.

### **MODBUS Function Codes**

Modbus protocol compatible devices communicate using a master-slave technique similar to that used in ASCII protocol. In a master-slave communications system only one device (the master) can initiate a communications sequence. All other devices (the slaves) respond when requested by the master. Typical master devices can be personal computers or PLCs. Typical slave devices are DIN-100 modules.

The master can address any slave device. Slave devices return a message to any command that was addressed specifically to them. The returned messages are considered response messages.

The Modbus protocol format used by a master consists of a device address, a command function code which defines the operation to be performed, data required with the command, and an error checking value. The slave response message contains any required data and an error checking value. If an error occurs, an exception code will be generated.

The supported master function codes are discussed below.

- 01 - Read Coil Status (Digital Inputs)
- 04 - Read Input Register (Analog Inputs)
- 05 - Force Single Coil (Digital Output)
- 06 - Preset Single Register (Return to ASCII protocol)
- 15 - Force Multiple Coils (Digital Outputs)

### **Function (01) Read Coil Status (Digital Inputs)**

Modbus function (01) Read Coil Status will read the status of both the digital inputs and digital outputs. Digital outputs are read as the state of the data on the microprocessor output port before being buffered by the open-collector transistor. If the coil status of a digital output returns as '1', this means that this particular bit (coil) is turned "on" or sinking current on the corresponding module digital output pin. Depending on the module type, some of the digital outputs may not be implemented.

Modbus relay input coils are considered digital inputs on the DIN-100 series modules. Modbus relay output coils are considered digital outputs on the DIN-100 series modules. This function can be used to read status of the digital inputs or the combined status of both the digital inputs and digital outputs.

DIN-100 digital output bits B00 to B05 correspond to Modbus coils 00 00 to 00 05.

DIN-100 digital input bits B00 to B05 correspond to Modbus coils 00 08 to 00 0D.

The DIN-100 series digital inputs and outputs are register mapped as two 8-bit bytes (16-bits), one byte for inputs and one byte for outputs. The least-significant byte represent the status of up to 8 digital outputs. The most-significant byte represents the status of up to 8 digital input bits. The register contents can be interrogated as 8-bits of digital input data or together as 16-bits of digital inputs and outputs data.

Exception errors will be generated by the module if attempting to read or write to more than 16 bits.

The following example can be used to read only the digital input status:

**Command:**    01 01 00 08 00 08 BC 0E  
**Response:**    01 01 01 FF 11 C8

In the command string:

01 is the slave address

01 is the Read Coil Status command

00 08 is the starting coil number

00 08 is the number of bits to read

BC 0E is the CRC to this message

In the response string:

01 is the slave address

01 is the Read Coil Status command

01 is the number of data bytes returned

FF is the Digital Inputs status data

11 C8 is the CRC for this message

The following example can be used to read the status of both the digital inputs and outputs:

**Command:**    01 01 00 00 00 10 3D C6  
**Response:**    01 01 02 09 FF FF EC

In the command string:

01 is the slave address  
 01 is the Read Coil Status command  
 00 00 is the starting coil address  
 00 10 is the number digital bits to read  
 3D C6 is the CRC to this message

In the response string:

01 is the slave address  
 01 is the Read Coil Status command  
 02 is the number of data bytes returned  
 09 is the Digital Output status  
 FF is the Digital Inputs status  
 FF EC is the CRC for this message

### **Function (04) - Read Input Register (Analog Inputs)**

Read Input Register function (04) is the primary command to acquire analog input data. This command function supports reading of up to 16 input registers starting from Modbus slave register 30001. The registers are addressed starting from zero meaning registers 1-16 are addressed as 0-15.

The response data for each channel is returned as two bytes that represent a 16-bit binary value. The 16-bit value is scaled as a percentage of the full scale input range. The first byte contains the high order bits and the second contains the low order bits. The binary analog values for each channel can range from 0000-FFFF (hexadecimal).

Only the register values for channel one are valid as each module contains a single analog input. The remaining data values for channels 2-16 will always return as 0000 (hexadecimal).

A typical command and response to read the analog input value from Modbus device address 01 is:

**Command:    01 04 00 00 00 01 31 CA**  
**Response:    01 04 02 14 57 F7 CE**

In the command string:

01 is the slave address  
 04 is the Read Input Registers command  
 00 00 is the starting register to be read (Modbus address 30001)  
 00 01 specifies the number of registers to be read, in this case, one register.

31 CA is the CRC for this message

In the response string:

01 is the slave address

04 is the command

02 indicated the number of data bytes in the message, in this case, two bytes

14 57 is the analog data

F7 CE is the CRC for this message

This sample command reads two registers:

**Command: 01 04 00 00 00 02 71 CB**

**Response: 01 04 04 14 58 00 00 7F A7**

The analog data from Modbus register 30001 is 14 58.

The data from Modbus register 30002 is set to 00 00.

The analog data is scaled so that 00 01 represents the Negative Full Scale value programmed into the module. FF FE represents the Positive Full Scale value programmed into the module.

For example, for a  $\pm 10$  volt input module:

00 01 corresponds to -10 volts

80 00 corresponds to 0 volts

FF FE corresponds to +10 volts

A negative overload where the analog input exceeds minus full scale value is represented by 00 00 (hexadecimal).

A positive overload where the analog input exceeds the positive full scale value is represented by FF FF (hexadecimal).

### **Function (05) - Force Single Coil (Digital Output)**

The Force Single Coil function (05) is used to set or clear a single Modbus output relay coil. Each output relay coil is considered a digital output on the DIN-100 series modules. Modbus Coil #1 equals DIN-100 series digital output bit B00 and Coil #6 equals digital output bit B05.

The following example can be used to turn on digital output bit B00:

**Command:**    01 05 00 00 FF 00 8C 3A  
**Response:**    01 05 00 00 FF 00 8C 3A

In the command string:

01 is the slave address

05 is the Force Single Coil command

00 00 is the address of the digital output bit, 00 07 would equal B07

FF 00 indicates that the desired bit will be set or turned on

8C 3A is the CRC for this message

The valid address range of digital output bits is 00 00 to 00 07. Any other address will produce an exception (error) response.

To clear or turn off digital output bit B03, replace the FF 00 string with 00 00. For example:

**Command:**    01 05 00 03 00 00 3D CA  
**Response:**    01 05 00 03 00 00 3D CA

Command values other than FF 00 or 00 00 will result in an exception (error) response.

### **Function (06) - Preset Single Register (Return to DIN-100 ASCII Protocol)**

The Preset Single Register function (06) can be used to temporarily suspend the Modbus RTU protocol and force the module into DIN-100 ASCII protocol. Write a value of 0000 to Modbus register 40001 to temporarily suspend Modbus RTU mode. The module will then communicate using the DIN-100 ASCII protocol only.

The DIN-100 ASCII protocol can be used to alter or check setup information and/or for troubleshooting purposes. The module will continue to communicate using the ASCII protocol until either a Remote Reset (RR) command (RR) is received or the power is cycled. At which time, the module will return to the Modbus RTU protocol mode.

Refer to the DIN-100 ASCII Modbus Disable command (MBD) for more information on disabling the Modbus protocol.

**Command:**    01 06 00 00 00 00 89 CA  
**Response:**    01 06 00 00 00 00 89 CA

### **Function (15) - Force Multiple Coils (Digital Outputs)**

The Force Multiple Coils function (15) is used to force multiple Modbus output relay coils to a desired ON or OFF state. This function is similar in operation to the DIN-100 ASCII digital output command (DO) in that it updates the status of all available output coils at once. The state of each output coil is set ON or OFF according to the digital data value received with the function.

The digital output bits are referred to as “output relay coils” in the Modbus protocol. The DIN-100 series digital output bit B00 equals Modbus output relay Coil#1 and digital output bit B05 equals output relay Coil#6. DIN-100 series modules with less than eight digital outputs also equate output bit B00 with output relay Coil#1 and count up by one for each additional output bit.

The following example can be used to turn on two digital output bits on a DIN-113 module.

**Command:**    01 0F 00 00 00 02 00 03 9F 06  
**Response:**    01 0F 00 00 00 02 D4 0A

In the command string:

01 is the slave address

05 is the Force Single Coil command

00 00 is the starting address of the digital output bits to be changed, 00 07 would equal B07

00 02 specifies the number of output relay coils to be changed

00 03 specifies the digital output data value in HI byte LO byte format.

Note: The HI byte will always be zero as DIN-100 series modules contain up to eight digital outputs

9F 06 is the CRC for this message

The valid address range of digital output bits is 00 00 to 00 07. Any other address will produce an exception (error) response.

To clear or turn off the digital output bits, replace the 00 03 string with 00 00. For example:

**Command:**    01 0F 00 00 00 02 00 00 DF 07  
**Response:**    01 0F 00 00 00 02 D4 0A

## **Modbus RTU Enable (MBR)**

To place any DIN-100 module in Modbus protocol mode use the Modbus RTU (MBR) command. The MBR command must be used to specify the Modbus device address and enable the Modbus protocol mode. The device address consists of a two character hexadecimal value and is stored in EEPROM. The two byte address specified is translated to a one byte, 8 bit address required by the Modbus protocol. The example below can be used to specify a Modbus device address of "01".

**Command:**     **\$1MBR01**

**Response:**     **\***

**Command:**     **#1MBR01**

**Response:**     **\*1MBR019D**

After the Modbus address is specified, a reset is necessary to activate the Modbus protocol mode. The reset may be accomplished in one of three ways:

- 1) Removing power for about 10 seconds to perform a power-up reset.
- 2) Momentarily grounding the Default\* pin.
- 3) Issue a Write Enable (WE) command followed by a Remote Reset (RR) command.

After a reset is performed, the module is in Modbus protocol mode.

### **Modbus Disable (MBD)**

The Modbus Disable (MBD) command is used to disable the Modbus protocol. Any DIN-100 series module in Modbus mode can be returned to DIN-100 ASCII protocol mode by connecting a jumper wire between module pins GND and Default\* pin. This places the module in Default Mode, where the module will only communicate at 300 baud, no parity, DIN-100 ASCII protocol, and answer to any address. While in Default mode, transmit an MBD command to internally disable the Modbus protocol.

Following the MBD command a device reset must occur. The reset is necessary to activate the DIN-100 ASCII protocol. A reset can occur by removing the Default\* jumper, performing a power-up reset or by transmitting a Write Enable (WE) and Remote Reset (RR) command sequence.

After a reset is performed, the module is in DIN-100 ASCII protocol mode.



**Command:**    **\$1MBD**

**Response:**    **\***

**Command:**    **#1MBD**

**Response:**    **\*1MBD2E**

### **Modbus Exception Responses**

The following standard Modbus exception codes (error messages) are supported:

#### **01      Illegal Function**

This exception code is generated when the function code is not recognized by the module.

#### **02      Illegal Data Address**

This code is generated when the specified data address in the command is not supported by the module.

#### **03      Illegal Data Value**

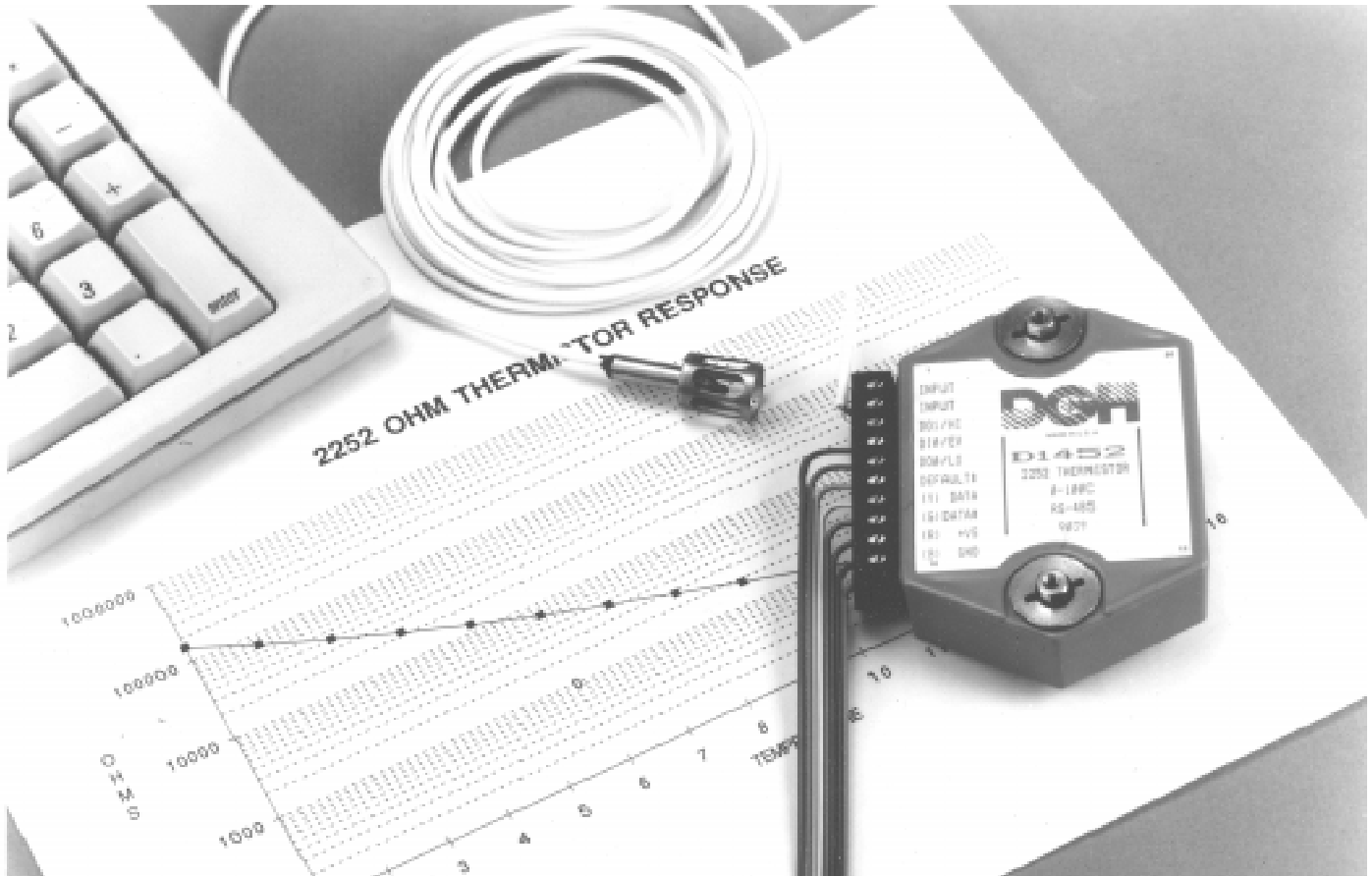
This exception code is returned if the command data is out of range for the function.

#### **06      Slave Device Busy**

After the module is reset by power-up, a 'RR' command, or return from Default Mode, the module performs an initial self-calibration for a period of about 3 seconds. During this time any command sent to the module will result in a 'busy' exception response.



## D1000 and D2000 SERIES SENSOR TO COMPUTER INTERFACE MODULES



### D1000 and D2000 FEATURES

- Complete sensor to RS-485 or RS-232C interface.
- ASCII format command/response protocol.
- 500V rms analog input isolation.
- 15 bit measurement resolution.
- Continuous self-calibration; no adjustments of any kind.
- Programmable digital filter.
- Digital limit setting and alarm capability.
- Digital inputs and outputs connect to solid state relays.
- Events counter to 10 million.
- Requires +10V to +30Vdc unregulated supply.
- Transient suppression on RS-485 communications lines.
- Screw terminal plug connectors supplied.

### D2000 PROGRAMMABLE FEATURES

Provides intelligent features not found in the D1000.

- ASCII output scaled to desired engineering units.
- User programmable nonlinear transfer function.
- Straight-line segment approximation: up to 24 segments.

### APPLICATIONS

- Process monitoring and control
- Remote data logging to any host computer
- Product testing
- Direct connection to modems

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## D1000 and D2000 SPECIFICATIONS (typical at +25°C and nominal power supply unless otherwise noted)

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### Analog

- Single channel analog input.
- Maximum CMV, input to output at 60Hz: 500V rms.
- Leakage current, input to output at 115Vrms, 60Hz: <2 $\mu$ A rms.
- 15 bit measurement resolution.
- 8 conversions per second.
- Autozero & autocalibration—no adjustment pots.

### Digital

- 8-bit CMOS microcomputer.
- Digital scaling, linearization and calibration .
- Nonvolatile memory eliminates pots and switches.

### Digital filtering

- Small and large signal with user selectable time constants from 0 to 16 seconds.

### Events counter

- Up to 10 million positive transitions at 60Hz max., filtered for switch debounce.

### Digital inputs

- Voltage levels:  $\pm 30$ V without damage.
- Switching levels: High, 3.5V min., Low, 1.0V max.
- Internal pull up resistors for direct switch input.

### Digital outputs

- Open collector to 30V, 30mA max. load.

### Alarm outputs

- HI/LO limit checking by comparing input values to down-loaded HI/LO limit values stored in memory.
- Alarms: latching (stays on if input returns to within limits) or momentary (turns off if input returns to within limits).

### Communications

- Communications in ASCII via RS-232C, RS-485 ports.
- Selectable baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400.
- NRZ asynchronous data format; 1 start bit, 7 data bits, 1 parity bit and 1 stop bit.
- Parity: odd, even, none.
- User selectable channel address.
- ASCII format command/response protocol.
- Up to 124 multidrop modules per host serial port.
- Communications distance up to 4,000 feet (RS-485).
- Transient suppression on RS-485 communications lines.
- Communications error checking via checksum.
- Can be used with "dumb terminal".
- Scan up to 250 channels per second.
- All communications setups stored in EEPROM.

### Power

Requirements: Unregulated +10V to +30Vdc ,  
0.75W max (D1500/D2500, 2.0W max.).  
Internal switching regulator.  
Protected against power supply reversals.

### Environmental

Temperature Range: Operating -25°C to +70°C.  
Storage -25°C to +85°C.  
Relative Humidity: 0 to 95% noncondensing.

### Warranty

12 months on workmanship and material.

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### D1100/D2100 Voltage Inputs

- Voltages:  $\pm 10$ mV,  $\pm 100$ mV,  $\pm 1$ V,  $\pm 5$ V,  $\pm 10$ V,  $\pm 100$ Vdc.
- Resolution: 0.01% of FS (4 digits).
- Accuracy:  $\pm 0.02$ % of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50$ ppm/ $^{\circ}$ C max.
- Input burnout protection to 250Vac .
- Input impedance:  $\leq \pm 1$ V input = 100M $\Omega$  min.  
 $\geq \pm 5$ V input = 1M $\Omega$  min.
- 1 Digital input/Event counter, 2 Digital outputs.

### D1200/D2200 Current Inputs

- Currents:  $\pm 1$ mA,  $\pm 10$ mA,  $\pm 100$ mA,  $\pm 1$ A, 4-20mAdc.
- Resolution: 0.01% of FS (4 digits), 0.04% of FS (4-20mA).
- Accuracy:  $\pm 0.02$ % of FS, 0.04% of FS (4-20mA).
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50$ ppm/ $^{\circ}$ C max. ( $\pm 1$ A =  $\pm 80$  ppm/ $^{\circ}$ C max.)
- Voltage drop:  $\pm 0.1$ V max.
- 1 Digital input/Event counter, 2 Digital outputs.

### D1300 Thermocouple Inputs

- Thermocouple types: J, K, T, E, R, S, B, C (factory set).
- Ranges: J = -200°C to +760°C      B = 0°C to +1820°C  
K = -150°C to +1250°C      S = 0°C to +1750°C  
T = -200°C to +400°C      R = 0°C to +1750°C  
E = -100°C to +1000°C      C = 0°C to +2315°C
- Resolution:  $\pm 1^{\circ}$ .
- Overall Accuracy (error from all sources) from 0 to +40°C ambient:  $\pm 1.0^{\circ}$  C max (J, K, T, E).  
 $\pm 2.5^{\circ}$  C max (R, S, B, C)(300°C TO FS).
- Common mode rejection: 100dB at 50/60Hz.
- Input impedance: 100M $\Omega$  min.
- Lead resistance effect: <20 $\mu$ V per 350 $\Omega$ .
- Open thermocouple indication.
- Input burnout protection to 250Vac.
- User selectable  $^{\circ}$ C or  $^{\circ}$ F.
- Overrange indication.
- Automatic cold junction compensation and linearization.
- 2 Digital inputs, Event counter, 3 Digital outputs.

### D1400 RTD Inputs

- RTD types:  $\alpha = .00385$ ,  $.00392$ , 100 $\Omega$  at 0°C,  
 $.00388$ , 100 $\Omega$  at 25°C.
  - Ranges:  $.00385 = -200^{\circ}$ C to +850°C.  
 $.00392 = -200^{\circ}$ C to +600°C.  
 $.00388 = -100^{\circ}$ C to +125°C.
  - Resolution: 0.1 $^{\circ}$ .
  - Accuracy:  $\pm 0.3^{\circ}$ C.
  - Common mode rejection: 100dB at 50/60Hz.
  - Input connections: 2, 3, or 4 wire.
  - Excitation current: 0.25mA.
  - Lead resistance effect: 3 wire - 2.5°C per  $\Omega$  of imbalance.  
4 wire - negligible.
  - Max lead resistance: 50 $\Omega$ .
  - Input protection to 120Vac .
  - Automatic linearization and lead compensation.
  - User selectable  $^{\circ}$ C or  $^{\circ}$ F.
  - 1 Digital output.
-

### D1450 Thermistor Inputs

- Thermistor types: 2252Ω at 25°C, TD Series
- Ranges: 2252Ω = -0°C to +100°C.  
TD = -40°C to +150°C.
- Resolution: 2252Ω = 0.01°C or F.  
TD = 0.1°C or F
- Accuracy: 2252Ω = ±0.1°C.  
TD = ±0.2°C
- Common mode rejection: 100dB at 50/60Hz.
- Input protection to 30Vdc .
- User selectable °C or °F.
- 1 Digital input/ Event counter, 2 Digital outputs.

### D1500/D2500 Bridge Inputs

- Voltage Ranges: ±30mV, ±100mV, 1-6Vdc.
- Resolution: 10μV (mV spans).  
0.02% of FS (V span).
- Accuracy: ±0.05% of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Input protection to 30Vdc .
- Offset Control: Full input range.
- Excitation Voltage: 5V, 8V, 10Vdc, 60mA max.
- Zero drift: ±1μV/°C max.
- Span tempco: ±50ppm/°C max.
- 1 Digital output.

### D1600/D2600 Timer and Frequency Inputs

- Input impedance: 1MΩ.
- Switching level: selectable 0V, +2.5V.
- Hysteresis: Adjustable 10mV-1.0V.
- Input protection: 250Vac .
- 1 Digital input/Event counter.

### Frequency Input

- Range: 1Hz to 20KHz.
- Resolution: 0.005% of reading + 0.01Hz.
- Accuracy: ±0.01% of reading ±0.01Hz.
- Tempco: ±20ppm/°C.

### Timer Input

- Range: 100μs to 30 s.
- Resolution: 0.005% of reading +10μs.
- Accuracy: ±0.01% of reading ±10μs.
- Tempco: ±20ppm/°C.

### Event Counter Input

- Input Bandwidth: 60Hz, (optional 20KHz max.).
- Up to 10 million positive transitions.

### Accumulator Input

- Input Frequency Range: 1Hz to 10KHz.
- Input Timer Range: 100μs to 30s.
- Pulse Count: Up to 10 million positive transitions.
- Resolution: 0.005% of reading +0.01Hz (Frequency).  
0.005% of reading +10μs (Timer) .
- Accuracy: ±0.01% of frequency reading ±0.01Hz.  
±0.01% of timer reading ±10μs.
- Tempco: ±20ppm/°C.

Specifications are subject to change without notice

### D1700 Digital Inputs/Outputs

- D1711, D1712: 15 digital input/output bits.
- User can define any bit as an input or an output.
- Input voltage levels: 0-30V without damage.
- Input switching levels: High, 3.5V min., Low, 1.0V max.
- Outputs: Open collector to 30V, 100mA max. load.
- Vsat: 1.0V max @ 100mA.
- Single bit or parallel I/O addressing.

D1701, D1702: 7 digital inputs and 8 digital outputs.

- Input voltage levels: ±30V without damage.
- Input switching levels: High, 3.5V min., Low, 1.0V max.
- Outputs: open collector to 30V, 30mA max. load.
- Vsat: 0.2V max @ 30mA.
- Internal pull up resistors for direct switch input.
- Inputs/Outputs are read/set in parallel.

Specifications are subject to change without notice.

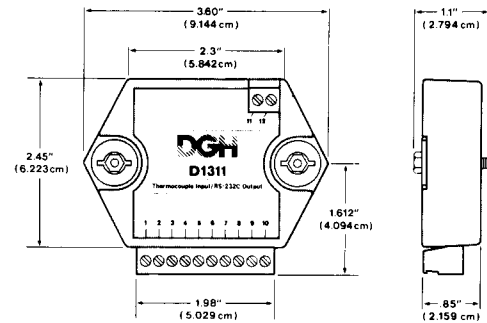
### Mechanicals and Dimensions

Case: ABS with captive mounting hardware.

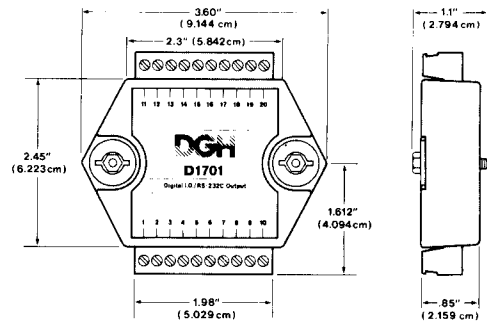
Connectors: Screw terminal barrier plug (supplied).

Replace with Phoenix MSTB 1.5/10 ST 5.08 or equivalent.

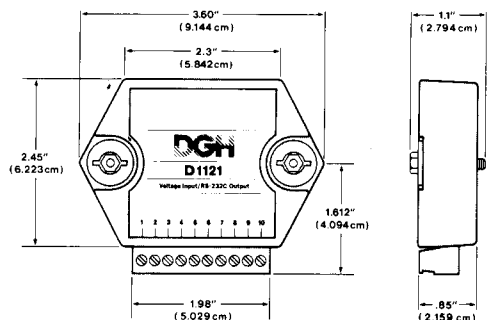
#### D1300 Series



#### D1700 Series



#### D1000/D2000 Series



**NOTE:** Spacing for mounting screws = 2.700" (6.858 cm).  
Screw threads are 6 X 32.

## GENERAL DESCRIPTION

The D1000 and D2000 Sensor to Computer Modules are a family of complete solutions designed for data acquisition systems based on personal computers and other processor-based equipment with standard serial I/O ports. The modules convert analog input signals to engineering units and transmit in ASCII format to any host with standard RS-485 or RS-232C ports. These modules can measure temperature, pressure, voltage, current and various types of digital signals. The modules provide direct connection to a wide variety of sensors and perform all signal conditioning, scaling, linearization and conversion to engineering units. Each module also provides digital I/O lines for controlling devices through solid state relays or TTL signals. These digital I/O lines along with built-in limit setting capability provide alarm and control outputs.

The modules contain no pots or switches to be set. Features such as address, baud rate, parity, alarms, echo, etc. are selectable using simple commands over the communications port—without requiring access to the module. The selections are stored in nonvolatile EEPROM which maintains data even after power is removed.

The key to the DGH product concept is that the modules are easy to use. You do not need engineering experience in complicated data acquisition hardware. With the DGH modules, anyone familiar with a personal computer can construct a data acquisition system. This modular approach to data acquisition is extremely flexible, easy to use and cost effective. Data is acquired on a per channel basis so you only buy as many channels as you need. The modules can be mixed and matched to fit your application. They can be placed remote from the host and from each other. You can string up to 124 modules on one set of wires by using RS-485 with repeaters.

The D2000 series is an enhanced version of the D1000 series of sensor interfaces. The D2000 series allows the user to scale the output data in any desired engineering units. The D2000 also provides the ability to program nonlinear transfer functions. This feature may be used to linearize nonstandard sensors or to provide outputs in engineering units which are nonlinear functions of the input.

The D2000 can be programmed to approximate square law, root, log, high-order polynomial or any other nonlinear function. The D2000 may also be empirically field-programmed when the exact transfer function is unknown.

The D1000 and D2000 modules are isolated data acquisition systems for real-time distributed processing and control. By distributing computer power to each sensor location, the host computer is unburdened from interpreting data from sensor inputs. Instead of scaling and linearizing sensor data, the host computer can be used more efficiently to scan a greater number of inputs and to provide faster control output.

The D1000 and D2000 are compatible with the DGH D3000 and D4000 series and may be mixed in any combination. The D3000 and D4000 series convert ASCII format input commands to voltage or current output signals.

All modules are supplied with screw terminal plug connectors and captive mounting hardware. The connectors allow system expansion, reconfiguration or repair without disturbing field wiring.

## UTILITY SOFTWARE

Complimentary Utility Software is included with each purchase order. The software is compatible with Windows 95, 98, NT 4.0+, 2000 operating systems and distributed on CD-ROM. The Utility Software simplifies configuration of all user-selectable options such as device address, baud rate and filtering constants. The latest version of our software is always downloadable from our web site at [www.dghcorp.com](http://www.dghcorp.com).

## THEORY OF OPERATION

Each DGH module is a complete single-channel data acquisition system. Each unit contains analog signal conditioning circuits optimized for a specific input type. The amplified sensor signals are converted to digital data with a microprocessor-controlled integrating A/D converter. Offset and gain errors in the analog circuitry are continuously monitored and corrected using microprocessor techniques. The D1000 converts the digital signal data into engineering units using look-up tables. The D2000 converts the digital signal data into engineering units using look-up tables that are customer-programmed. The resultant data is stored in ASCII format in a memory buffer. The modules continuously convert data at the rate of 8 conversions per second and store the latest result in the buffer. The host computer may request data by sending simple ASCII commands to the module. The D1000 will then instantly respond by communicating the ASCII buffer data back to the host. Up to 124 modules may be linked to a single RS-232C or RS-485 host computer port. Each module on a serial line is identified by a unique user-programmable address. This addressing technique allows modules to be interrogated in any order.

## DIGITAL INPUTS/OUTPUTS

D1000 and D2000 modules also contain up to three digital outputs and two digital inputs. The digital outputs are open-collector transistor switches that may be controlled by the host computer. These switches may be used to control solid-state relays which in turn may control heaters, pumps and other power equipment. The digital inputs may be read by the host computer and used to sense the state of a remote digital signal. They are ideal for sensing the state of limit or safety switches. Digital I/O capability may be expanded by using the DGH D1700 modules.

## EVENT COUNTER

With the exception of D1400 RTD, D1500 and D2500 bridge input modules, every module contains an onboard event counter. The event counter will count up to 10 million transitions that occur on the digital input. The event counter may be read and cleared by the host computer at any time. The counter has many applications where a host computer must read an accumulated count of events. It may be used in production line applications to keep a record of repetitious operations. For applications that only require counting, DGH offers the D1621 and D1622 Event Counter modules. These modules have no analog input but count events up to 10 million at either 60Hz or 20KHz bandwidths.

For applications that require reading and accumulating pulse-type information DGH offers the Accumulator modules. The Accumulators can read both the rate and the total count of a frequency or pulse input signal. They can keep track of power consumption when connected to a power meter or accumulate the output of pulse-type flow meters.

## ALARM OUTPUTS

The D1000 and D2000 modules include digital high and low alarm functions. High and low alarm limits may be downloaded into the module by the host computer. The limit data is compared against the analog input data after every A/D conversion. The result of the limit comparison may be read by the host. The high and low limits may also be used to control the digital outputs on the module. The limits may be used to turn on alarms or to shut down a process independent of a host computer. Limit data may be changed at any time with commands from the host computer. Limit values are stored in nonvolatile memory to preserve the values even when module power is removed. Limit data is downloaded in the same engineering units as output data. Alarm outputs may be programmed to be latching to record the occurrence of a single alarm event. Alarm outputs may also be configured to form simple on-off controllers that are independent of the host computer.

## USER OPTIONS

To provide maximum flexibility, the D1000 and D2000 offer a variety of user-selectable options including choice of address, baud rate, parity, alarm options, echo, etc. All options are selectable using simple commands over the communications port. All option selections are stored in a nonvolatile EEPROM which maintains data even after power is removed. The modules contain no pots or switches to be set. All options may be changed remotely without requiring access to the module.

## DIGITAL FILTER

The D1000 and D2000 options include a unique programmable single pole digital filter. The filter is used to smooth analog data in noisy environments. Separate time constants may be specified for small and large signal changes. Typically a large time constant is specified for small signal changes to filter out noise and provide stable

output readings. A smaller time constant may be chosen for large signal changes to provide fast response to such changes.

## COMMUNICATIONS

The D1000 and D2000 are designed to be easy to interface to all popular computers and terminals. All communications to and from the module are performed with printable ASCII characters. This allows the information to be processed with string functions common to most high-level languages such as BASIC. For computers that support standard ports such as RS-232C, no special machine language software drivers are necessary for operation. The modules can also be connected to auto-answer modems for long-distance operation without the need for a remote supervisory computer. The ASCII format makes system debugging easy with a dumb terminal.

RS-232C is the most widely used communications standard for information transfer between computing equipment. RS-232C versions of the D1000 and D2000 will interface to virtually any computer without additional hardware. RS-232C is not designed to be used as a multiparty system; however the modules can be daisy-chained, as shown in figure 1, to allow many modules to be connected to a single communications port. In this network, any characters transmitted by the host are received by each module in the chain and passed on to the next station until the information is echoed back to the host. In this way all commands given by the host are examined by every module in the chain. If a module is correctly addressed and receives a valid command, it transmits a response on the daisy chain network. The response will be rippled through any other modules in the chain until it reaches the host.

RS-485 is a communications standard developed for multidropped systems that can communicate at high data rates over long distances, as shown in figure 2. RS-485 is similar to RS-422 in that it uses a balanced differential pair of wires switching from 0 to 5V to communicate data. RS-485 receivers can handle common mode voltages from -7

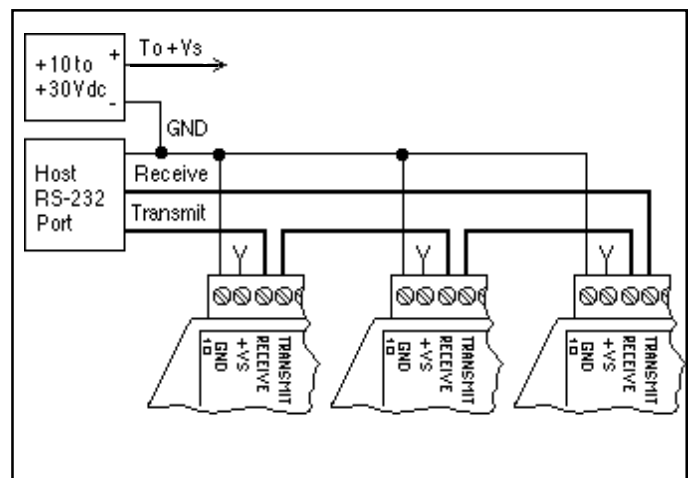


Figure 1 RS-232 Daisy Chain Network.

to +12V without loss of data, making them ideal for transmission over great distances. RS-485 differs from RS-422 by using one balanced pair of wires for both transmitting and receiving. Since an RS-485 system cannot transmit and receive at the same time it is a half-duplex system. For systems requiring many modules, high speed or long wiring distances the RS-485 standard is recommended.

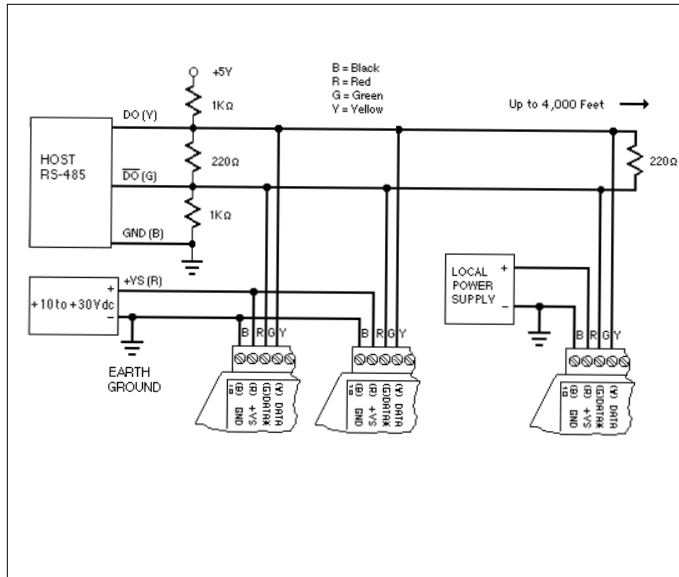


Figure 2. RS-485 Multidrop Network.

## COMMAND SET

All DGH products use a simple command/response protocol for communication. A module must be interrogated by the host to obtain data. A module can never initiate a command sequence. A typical command/response sequence could look like this:

**Command:** \$1RD  
**Response:** \*+00075.00

A command is initiated with a command prompt, which may be a dollar sign (\$) or a pound sign (#). Following the prompt a single address character must be transmitted. Each module on a communications bus must be setup with a unique address. The command is directed in this case to module address '1'. The address is followed by a two-character command which in this case is RD for Read Data. The command is terminated with a carriage return.

After module address '1' receives the command it will respond with the analog input data. The response begins with a response prompt, which is an asterisk (\*). The data is read back in a standardized format of sign, 5 digits, decimal point, and 2 more digits. All DGH modules represent data in the same standard format.

Table 1 shows all the D1000 and D2000 commands. For each case, a sample command and response is shown. Notice that some commands only respond with an \* acknowledgment.

Table 1. D1000 and D2000 Series Command Set.

Command and Definition	Typical Command Message (\$ prompt)	Typical Response Message
DI Read Alarms/Digital Inputs	\$1DI	*0003
DO Set Digital Outputs	\$1DOFF	*
ND New Data	\$1ND	*+00072.00
RD Read Data	\$1RD	*+00072.00
RE Read Event Counter	\$1RE	*0000107
RL Read Low Alarm Value	\$1RL	*+00000.00 L
RH Read High Alarm Value	\$1RH	*+00510.00 L
RS Read Setup	\$1RS	*31070142
RZ Read Zero	\$1RZ	*+00000.00
WE Write Enable	\$1WE	*

## Write Protected Commands.

CA Clear Alarms	\$1CA	*
CE Clear Events	\$1CE	*
CZ Clear Zero	\$1CZ	*
DA Disable Alarms	\$1DA	*
EA Enable Alarms	\$1EA	*
EC Events Clear	\$1EC	*0000107
HI Set High Alarm Limit	\$1HI+12345.67L	*
LO Set Low Alarm Limit	\$1LO+12345.67L	*
RR Remote Reset	\$1RR	*
SU Setup Module	\$1SU31070142	*
SP Set Setpoint	\$1SP+00600.00	*
TS Trim Span	\$1TS+00600.00	*
TZ Trim Zero	\$1TZ+00000.00	*

## D2000 Programming Commands (Write Protected).

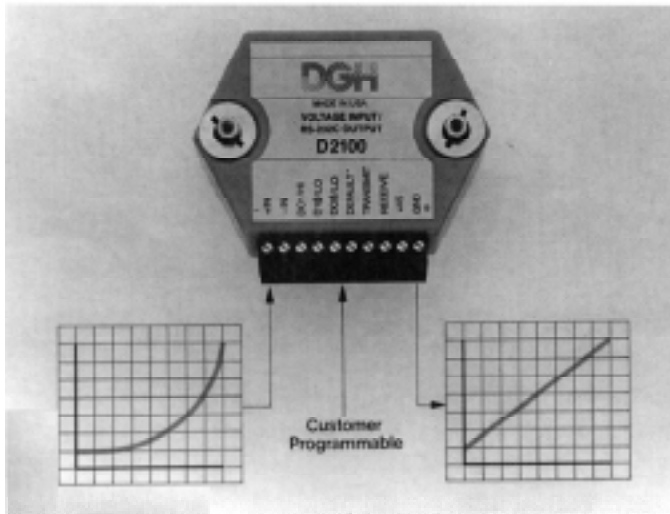
BP Set Breakpoint	\$1BP00-00200.00	*
EB Erase Breakpoint Table	\$1EB	*
MN Set Minimum Value	\$1MN-00200.00	*
MX Set Maximum Value	\$1MX+00750.00	*

For greater data security, options are available to echo transmitted commands and to send and receive checksums. The # command prompt requests a response message from the module that begins with an \*, followed by the channel address, command, data (if necessary) and checksum. This response echoes the channel address and command for verification and adds checksum for error checking. Checksum is a two character hexadecimal value that can be added to the end of any command message, regardless of prompt, at your option. Checksum verifies that the message received is exactly the same as the message sent.

The DGH modules perform extensive error checking on commands and will respond with an error message if necessary. For example:

**Command:** \$1AB  
**Response:** ?1 COMMAND ERROR

All error messages start with an error prompt (?) followed by the channel address and error description. In this case, the module did not recognize 'AB' as a valid command.



### D2000 PROGRAMMING

The outstanding feature of the D2000 series is its user-programmable output scaling. The transfer function from analog input to data output may be specified to an infinite spectrum of functions, both linear and nonlinear. Sensor data may be scaled to any desired engineering units for easy interpretation.

The D2000 uses a piece-wise linear technique to approximate nonlinear functions. Figure 3 shows this technique. The first step in programming a function is to establish the functions endpoints, as shown in figure 3a. This is accomplished by using the Minimum (MN) and Maximum (MX) commands. In cases where only linear scaling is necessary, the programming task is now complete. For nonlinear functions, the linear curve may be broken into segments by describing a breakpoint using the BreakPoint (BP) command. The breakpoint establishes an intersection between two linear segments. Figures 3b & 3c show the effect of breakpoints.

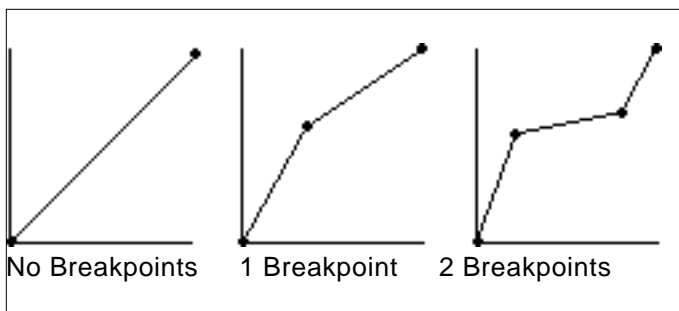


Figure 3. Piece-wise linear technique.

Up to 23 breakpoints are available to define 24 linear segments. Only two restrictions apply to the shape of the programmed transfer function:

1. The output data value must be a single-valued function of the input.
2. The output values must lie between the limits set by the endpoints.

In general, breakpoints are defined by applying a known analog signal to the input of the module. This establishes the x-axis position of the breakpoint. The y-axis position is defined in the argument of the breakpoint (BP) command. The breakpoint data is stored in nonvolatile EEPROM. The transfer function may be reprogrammed many times.

### RESOLUTION

All DGH modules represent data in the same fixed format of sign, five digits, decimal point, and two more digits; +00100.00 for example. The user can structure the D2000 output data for the best compromise between resolution and readability. For example, a +0.05 volt output indication may be structured in three output formats:

Input Voltage	Output Format	Resolution
+0.05Volts	+00000.05	5
+50 millivolts	+00050.00	5,000
+50,000 microvolts	+50000.00	5,000,000

The microvolt output format extracts the best resolution but the output data will tend to be noisy. For a 0 to 0.05V output, millivolts is the best output format choice. This gives 5,000 counts of resolution in easy to interpret units.

In a typical application a D2000 module is used to output data in units of specific gravity. The specific gravity output range is between 0.5 and 2. If the output data format range is +0000.50 to +00002.00 there are only 150 counts of resolution between the minimum and maximum outputs. However, since the specific gravity of water is defined to be 1, the output may be scaled in percent. The specific gravity of water becomes 100 %. The output data range in % is from +00050.00 to +00200.00. This format allows up to 15,000 counts of resolution in easily interpreted units.

### D2000 SCALING

The D2000 can output data in easy-to-understand engineering units that may be instantly read and interpreted, without data conversion, by a host computer. For example, a pressure sensor provides a 1 to 5V linear output for pressures of 0 to 1000 psi. A D2131 reads the sensor output in millivolts. But the real parameter of interest is pressure, not voltage, and voltage readings may be difficult to interpret. To make the output data more meaningful, program the D2131 output in psi:

Pressure (psi)	Sensor Output	D2131 Output (mV)	D2131 Output (psi)
0	1.0V	+01000.00	+00000.00
500	3.0V	+03000.00	+00500.00
1000	5.0V	+05000.00	+01000.00

In many cases, the desired output data is specific to an application. Assume that the same pressure sensor is used to measure the "fullness" of a pressure vessel, such as a cylinder of compressed air. The output units could be



in units of "percent" and in this case we will assume that if the cylinder reads 750 psi it is 100% full:

Pressure (psi)	Sensor Output	D2131 Output (%)
0	1.0V	+00000.00
375	2.5V	+00050.00
750	4.0V	+00100.00

The real power of the D2000 is their ability to provide output data in engineering units for nonlinear sensors. A nonlinear transfer function may be programmed into a D2000 module by approximating the curve with a series of linear segments, using the Break Point (BP) command. A Break Point specifies the intersection between two linear segments. Up to 23 Break Points may be used to specify 24 linear segments in a curve.

The following example uses a D2131 to linearize the output of a pyrometer that uses an infrared temperature sensor. The infrared temperature sensor is inherently nonlinear and its output ranges from 0.717 to 1.406V for a temperature span of 600 to 1600°C.

Breakpoint	Input Voltage	Output Value
Minimum	+00717.00	+00600.00
00	+00844.00	+00700.00
01	+00948.00	+00800.00
02	+01036.00	+00900.00
03	+01110.00	+01000.00
04	+01174.00	+01100.00
05	+01230.00	+01200.00
06	+01280.00	+01300.00
07	+01325.00	+01400.00
08	+01367.00	+01500.00
Maximum	+01406.00	+01600.00

### Scaling a nonlinear transfer function in the field

Assume that a water tower with an irregular shape is 30 feet tall and holds about 10,000 gallons. A pressure sensor may be used to measure the height of the water in the tower. The pressure sensor produces 0.1V per foot of water starting at 0V. To create a nonlinear function in the module, the endpoints must be set first. The minimum value is known and may be programmed by applying 0V to the module corresponding to 0 gallons. A "dummy" maximum value, which we know can never be exceeded, may be used to specify the maximum endpoint. In this case we apply +5V to the module and program the maximum value to be 15,000 gallons. Starting with an empty tower, read the pressure at fixed known volumes of water, every 1000 gallons for example, and set breakpoints in the module corresponding to known amounts of water in the tower. Once the curve is programmed, the module converts the pressure signal to gallons.

The preceding example shows that D2000 modules may be programmed in the field to specific test inputs where the actual nonlinearity is unknown. Since all programming

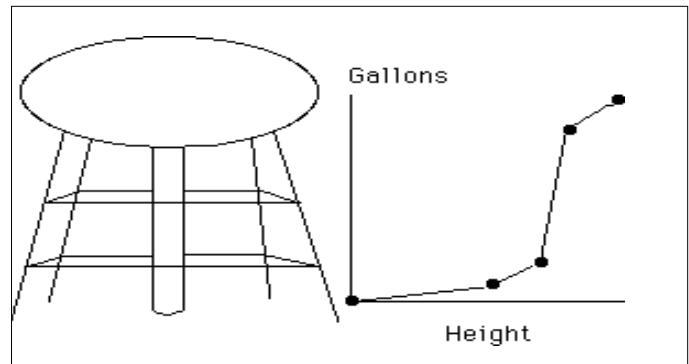


Figure 4. Scaling when the exact transfer function is unknown

is done through the communications port, access to a module is not necessary and ranging may be done remotely.

### Scaling to desired engineering units

The D2000 allows you to scale an input to desired engineering units. For example, many sensor output signals are transmitted as 4 to 20mA signals. The following example demonstrates scaling a 4 to 20mA signal to 0 to 100% using a DGH D2251 or D2252 module. The actual input range of these modules is 0 to 25mA to make it easier to adjust for zero and span and to allow for drift in the end points of the input.

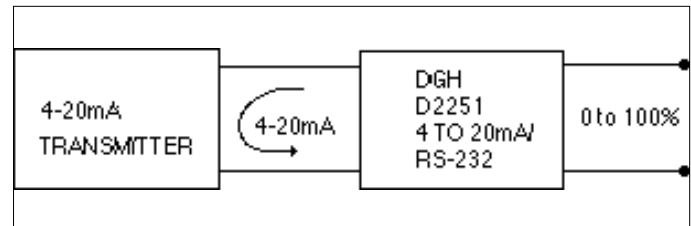


Figure 5. Scaling to desired engineering units

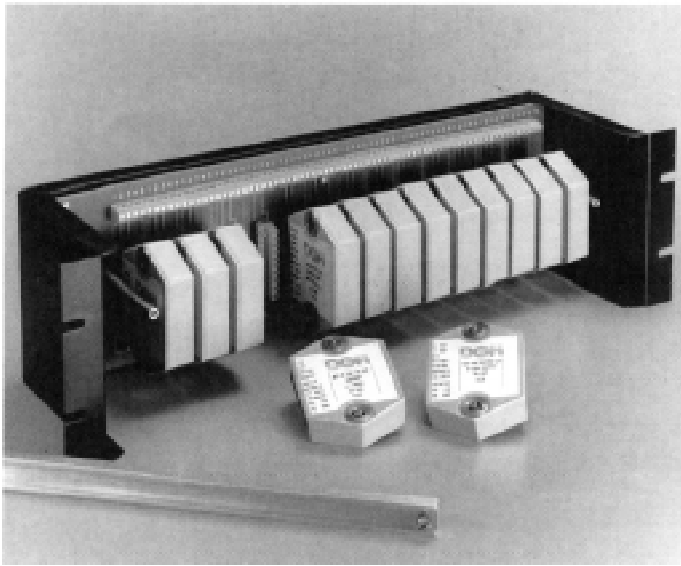
Since the input range is 0 to 25mA and you want to use a portion of that range, you must determine the new minimum and maximum values. The two desired values: 4mA, 0% and 20mA, 100% determines the desired transfer function. Extrapolate this function to the full-scale range of the module, which is 0-25mA. This results in endpoints at 0mA, -25% and 25mA, 131.25%.

Input the new minimum and maximum values with the following procedure. In these steps, we assume a channel address of 1.

1. Connect module to computer, or terminal and establish communications.
2. Apply 0mA to the input.
3. Send a Write Enable command, \$1WE, followed by a Minimum Value command, \$1MN-00025.00. The response to both commands should be an \*.
4. Apply +25mA to the input.
5. Send a \$1WE command followed by a Maximum Value command, \$1MX+00131.25. The response to both commands should be an \*.

The entire range is rescaled and all values are read in percent.

## BP-8 and BP-14 8 and 14 CHANNEL MOUNTING BACKPLANES

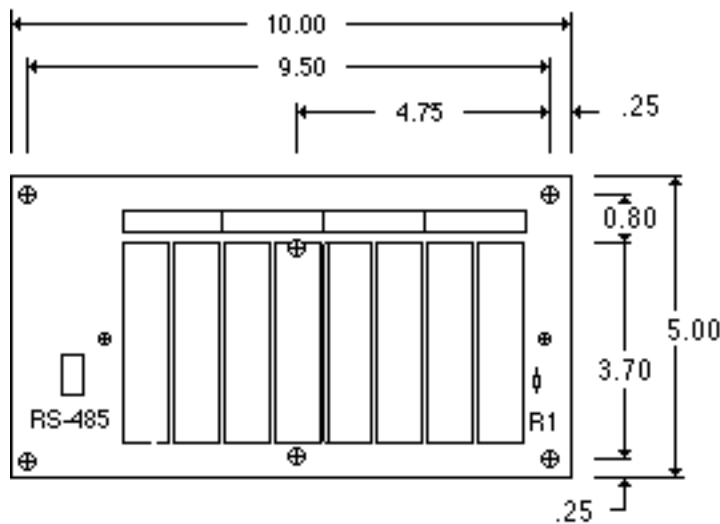


(Bracket not supplied)

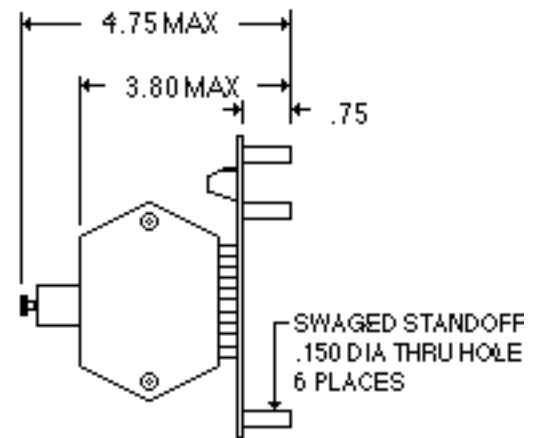
The BP-8 and BP-14 are 8 and 14 channel mounting backplanes for DGH modules. The backplanes accept any RS-485 DGH analog input or analog output modules and are designed to be mounted in standard 19 inch racks. RS-485 modules are used because RS-485 is the preferred communications standard for high channel count applications. Although analog modules are used it must be noted that every DGH module has some digital I/O capability. Therefore the combination of DGH modules with the backplanes make a cost effective high density remote analog and digital data acquisition system.

The BP-8 and BP-14 reduce wiring costs by providing all common connections on the backplane. Each backplane includes screw terminals for all inputs, outputs, power connections and communications signals. The backplanes also include swaged thru-hole stand-offs for mounting, a hold-down bar, and holes for an RS-485 termination resistor.

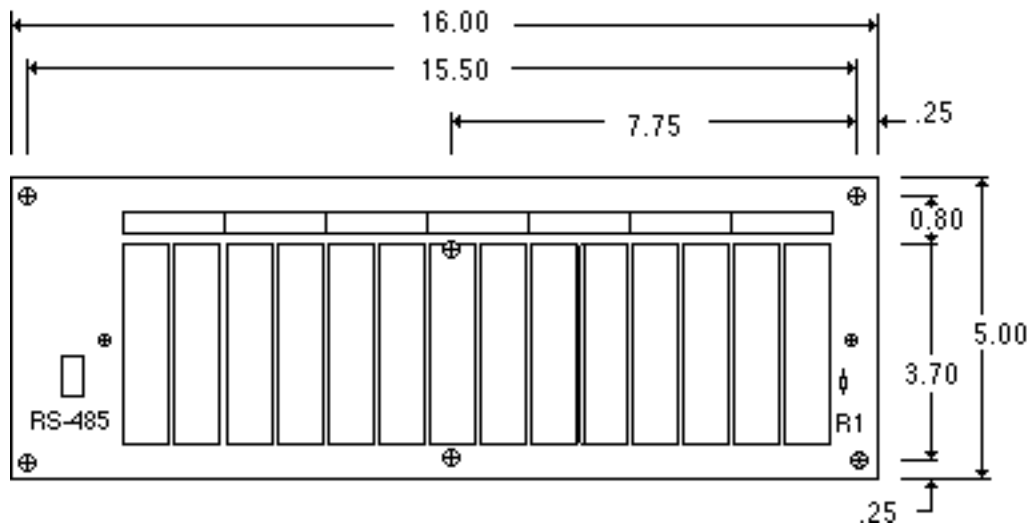
### BP-8 DIMENSIONS



### SIDE VIEW



### BP-14 DIMENSIONS



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## ORDERING GUIDE

### MODEL INPUT/OUTPUT

#### Voltage Input

D1101/D2101 10mV Input/RS-232C Output  
D1102/D2102 10mV Input/RS-485 Output  
D1111/D2111 100mV Input/RS-232C Output  
D1112/D2112 100mV Input/RS-485 Output  
D1121/D2121 1V Input/RS-232C Output  
D1122/D2122 1V Input/RS-485 Output  
D1131/D2131 5V Input/RS-232C Output  
D1132/D2132 5V Input/RS-485 Output  
D1141/D2141 10V Input/RS-232C Output  
D1142/D2142 10V Input/RS-485 Output  
D1151/D2151 100V Input/RS-232C Output  
D1152/D2152 100V Input/RS-485 Output

#### Current Inputs

D1211/D2211 10mA Input/RS-232C Output  
D1212/D2212 10mA Input/RS-485 Output  
D1221/D2221 1mA Input/RS-232C Output  
D1222/D2222 1mA Input/RS-485 Output  
D1231/D2231 100mA Input/RS-232C Output  
D1232/D2232 100mA Input/RS-485 Output  
D1241/D2241 1A Input/RS-232C Output  
D1242/D2242 1A Input/RS-485 Output  
D1251/D2251 4-20mA Input/RS-232C Output  
D1252/D2252 4-20mA Input/RS-485 Output

#### Thermocouple Inputs

D1311 J Thermocouple Input/RS-232C Output  
D1312 J Thermocouple Input/RS-485 Output  
D1321 K Thermocouple Input/RS-232C Output  
D1322 K Thermocouple Input/RS-485 Output  
D1331 T Thermocouple Input/RS-232C Output  
D1332 T Thermocouple Input/RS-485 Output  
D1341 E Thermocouple Input/RS-232C Output  
D1342 E Thermocouple Input/RS-485 Output  
D1351 R Thermocouple Input/RS-232C Output  
D1352 R Thermocouple Input/RS-485 Output  
D1361 S Thermocouple Input/RS-232C Output  
D1362 S Thermocouple Input/RS-485 Output  
D1371 B Thermocouple Input/RS-232C Output  
D1372 B Thermocouple Input/RS-485 Output  
D1381 C Thermocouple Input/RS-232C Output  
D1382 C Thermocouple Input/RS-485 Output

### MODEL INPUT/OUTPUT

#### RTD Inputs

D1411 .00385 RTD Input/RS-232C Output  
D1412 .00385 RTD Input/RS-485 Output  
D1421 .00392 RTD Input/RS-232C Output  
D1422 .00392 RTD Input/RS-485 Output  
D1431 .00388 RTD Input/RS-232C Output  
D1432 .00388 RTD Input/RS-485 Output  
D1451 2252 $\Omega$  Thermistor Input/RS-232C Output  
D1452 2252 $\Omega$  Thermistor Input/RS-485 Output  
D1461 TD Thermistor Input/RS-232C Output  
D1462 TD Thermistor Input/RS-485 Output

#### Bridge Inputs

D1511/D2511 30mV Bridge Input, 5V Excitation/RS-232C Output  
D1512/D2512 30mV Bridge Input, 5V Excitation/RS-485 Output  
D1521/D2521 30mV Bridge Input, 10V Excitation/RS-232C Output  
D1522/D2522 30mV Bridge Input, 10V Excitation/RS-485 Output  
D1531/D2531 100mV Bridge Input, 5V Excitation/RS-232C Output  
D1532/D2532 100mV Bridge Input, 5V Excitation/RS-485 Output  
D1541/D2541 100mV Bridge Input, 10V Excitation/RS-232C Output  
D1542/D2542 100mV Bridge Input, 10V Excitation/RS-485 Output  
D1551/D2551 1-6V Bridge Input, 8V Excitation/RS-232C Output  
D1552/D2552 1-6V Bridge Input, 8V Excitation/RS-485 Output  
D1561/D2561 1-6V Bridge Input, 10V Excitation/RS-232C Output  
D1562/D2562 1-6V Bridge Input, 10V Excitation/RS-485 Output

#### Timer and Frequency Inputs

D1601/D2601 Frequency Input/RS-232C Output  
D1602/D2602 Frequency Input/RS-485 Output  
D1611/D2611 Timer Input/RS-232C Output  
D1612/D2612 Timer Input/RS-485 Output  
D1621 Event Counter/RS-232C Output  
D1622 Event Counter/RS-485 Output  
D1631/D2631 Accumulator, Frequency Input/RS-232C Output  
D1632/D2632 Accumulator, Frequency Input/RS-485 Output  
D1641/D2641 Accumulator, Timer Input/RS-232C Output  
D1642/D2642 Accumulator, Timer Input/RS-485 Output

#### Digital Inputs/Outputs

D1701 7 Digital Inputs, 8 Digital Outputs/RS-232C Output  
D1702 7 Digital Inputs, 8 Digital Outputs/RS-485 Output  
D1711 15 Digital Inputs and/or Outputs/RS-232C Output  
D1712 15 Digital Inputs and/or Outputs/RS-485 Output

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# **D1000 SERIES USERS MANUAL**

**REVISED: 10/1/97**

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The information in this publication has been carefully checked and is believed to be accurate; however, no responsibility is assumed for possible inaccuracies or omissions. Applications information in this manual is intended as suggestions for possible use of the products and not as explicit performance in a specific application. Specifications may be subject to change without notice.

D1000 modules are not intrinsically safe devices and should not be used in an explosive environment unless enclosed in approved explosion-proof housings.

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## **WARRANTY**

DGH warrants each D1000 and D2000 series module to be free from defects in materials and workmanship under normal conditions of use and service and will replace any component found to be defective, on its return to DGH, transportation charges prepaid within one year of its original purchase. DGH assumes no liability, expressed or implied, beyond its obligation to replace any component involved. Such warranty is in lieu of all other warranties expressed or implied.

## **WARNING**

**The circuits and software contained in D1000 and D2000 series modules are proprietary. Purchase of these products does not transfer any rights or grant any license to the circuits or software used in these products. Disassembling or decompiling of the software program is explicitly prohibited. Reproduction of the software program by any means is illegal.**

**As explained in the setup section, all setups are performed entirely from the outside of the D1000 module. There is no need to open the module because there are no user-serviceable parts inside. Removing the cover or tampering with, modifying, or repairing by unauthorized personnel will automatically void the warranty. DGH is not responsible for any consequential damages.**

## **RETURNS**

When returning products for any reason, contact the factory and request a Return Authorization Number and shipping instructions. Write the Return Authorization Number on the outside of the shipping box. DGH strongly recommends that you insure the product for value prior to shipping. Items should not be returned collect as they will not be accepted.

### **Shipping Address:**

DGH Corporation  
Hillhaven Industrial Park  
146 Londonderry Turnpike  
Hooksett, NH 03106

# Chapter 1

## Getting Started

### Default Mode

All D1000 modules contain an EEPROM (Electrically Erasable Programmable Read Only Memory) to store setup information and calibration constants. The EEPROM replaces the usual array of switches and pots necessary to specify baud rate, address, parity, etc. The memory is nonvolatile which means that the information is retained even if power is removed. No batteries are used so it is never necessary to open the module case.

The EEPROM provides tremendous system flexibility since all of the module's setup parameters may be configured remotely through the communications port without having to physically change switch and pot settings. There is one minor drawback in using EEPROM instead of switches; there is no visual indication of the setup information in the module. It is impossible to tell just by looking at the module what the baud rate, address, parity and other settings are. It is difficult to establish communications with a module whose address and baud rate are unknown. To overcome this, each module has an input pin labeled DEFAULT\*. By connecting this pin to Ground, the module is put in a known communications setup called Default Mode.

**The Default Mode setup is: 300 baud, one start bit, eight data bits, one stop bit, no parity, any address is recognized.**

Grounding the DEFAULT\* pin does not change any of the setups stored in EEPROM. The setup may be read back with the Read Setup (RS) command to determine all of the setups stored in the module. In Default Mode, all commands are available.

A module in Default Mode will respond to any address except the six identified illegal values (NULL, CR, \$, #, {, }). A dummy address must be included in every command for proper responses. The ASCII value of the module address may be read back with the RS command. An easy way to determine the address character is to deliberately generate an error message. The error message outputs the module's address directly after the "?" prompt.

Setup information in a module may be changed at will with the SetUp (SU) command. Baud rate and parity setups may be changed without affecting the Default values of 300 baud and no parity. When the DEFAULT\* pin is released, the module automatically performs a program reset and configures itself to the baud rate and parity stored in the setup information.

The Default Mode is intended to be used with a single module connected to a terminal or computer for the purpose of identifying and modifying setup

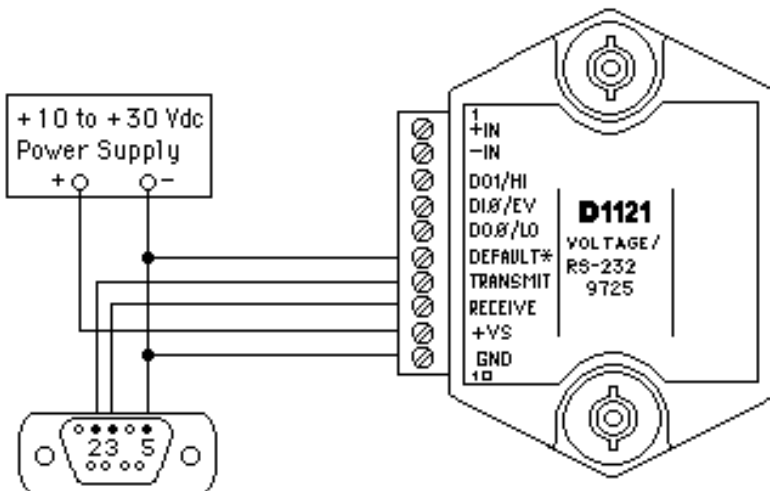
values. In most cases, a module in Default Mode may not be used in a string with other modules.

### RS-232 & RS-485 Quick Hook-Up

Software is not required to begin using your D1000 module. We recommend that you begin to get familiar with the module by setting it up on the bench. Start by using a dumb terminal or a computer that acts like a dumb terminal. Make the connections shown in the quick hook-up drawings, Figures 1.1 or 1.2. Put the module in the default mode by grounding the Default\* terminal. Initialize the terminal communications package on your computer to put it into the "terminal" mode. Since this step varies from computer to computer, refer to your computer manual for instructions.

Begin by typing \$1RD and pressing the Enter or Return key. The module will respond with an \* followed by the data reading at the input. The data includes sign, seven digits and a decimal point. For example, if you are using a thermocouple module and measuring room temperature your reading might be \*+00025.00. The temperature reading will initially be in °C which has been preset at the factory. Once you have a response from the module you can turn to the Chapter 4 and get familiar with the command set.

All modules are shipped from the factory with a setup that includes a channel address of 1, 300 baud rate, no linefeeds, no parity, alarms off, no echo and two-character delay. Refer to the Chapter 5 to configure the module to your application.



Note: If using a DB-25 connector ground is tied to pin 7. Pin 3 is tied to TRANSMIT and pin 2 is tied to RECEIVE on the module.

Figure 1.1 RS-232C Quick Hook-Up.



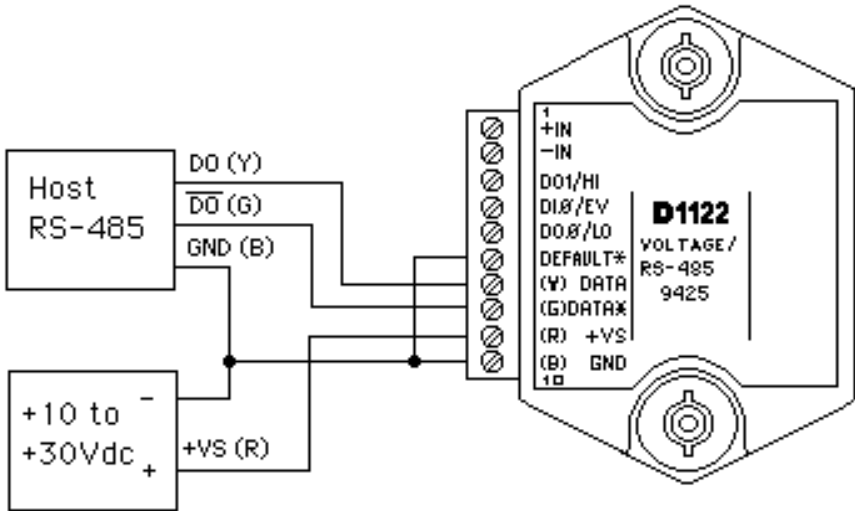


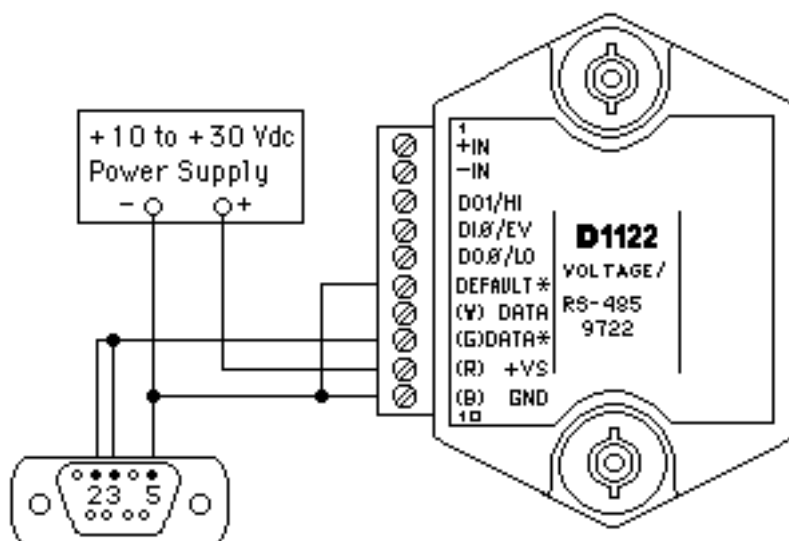
Figure 1.2 RS-485 Quick Hook-Up.

### RS-485 Quick Hook-up to a RS-232 port

An RS-485 module may be easily interfaced to an RS-232C terminal for evaluation purposes. This connection is only suitable for benchtop operation and should never be used for a permanent installation. Figure 1.3 shows the hook-up. This connection will work provided the RS-232C transmit output is current limited to less than 50mA and the RS-232C receive threshold is greater than 0V. All terminals that use 1488 and 1489 style interface IC's will satisfy this requirement. With this connection, characters generated by the terminal will be echoed back. To avoid double characters, the local echo on the terminal should be turned off.

If the current limiting capability of the RS-232C output is uncertain, insert a 100 $\Omega$  to 1k $\Omega$  resistor in series with the RS-232 output.

In some rare cases it may be necessary to connect the module's DATA pin to ground through a 100 $\Omega$  to 1k $\Omega$  resistor.



Note: If using a DB-25 connector ground is tied to pin 7.

Figure 1.3 RS-485 Quick Hook-Up with RS-232C Port.

## Chapter 2

### Functional Description

A functional diagram of a typical module is shown in Figure 2.1. It is a useful reference that shows the data path in the module and to explain the function of many of the module's commands.

The first step is to acquire the sensor signal and convert it to digital data. In Figure 2.1, all the signal conditioning circuitry has been lumped into one block, the analog/digital converter (A/D). Autozero and autocalibration is performed internally and is transparent to the user.

The full-scale output of the A/D converter may be trimmed using the Trim Span (TS) command. The TS command adjusts calibration values stored internally in the EEPROM. The TS command should only be used to trim the accuracy of the unit with a laboratory standard reference applied to the sensor input.

The trimmed data flows into either of two digital filters. The filter selection is performed automatically by the microprocessor after every A/D conversion. The filter selection depends on the difference of the current A/D output data and the previous data stored in the output data register. If the least significant decimal digit from the A/D differs from the old output data by more than 10 counts, the large signal filter is selected. If the change is less than 10 counts, the small signal filter is used.

The two-filter system allows for different degrees of filtering depending on the rate of the input change. For steady-state signals, the small-signal filter averages out noise and small input changes to give a stable steady-state output. The large-signal filter is activated by step changes or very noisy input signals. The time constants for the two filters can be specified independently with the SetUp (SU) command. The filter values are stored in nonvolatile memory. Typically, the small-signal filter is set to a larger time constant than the large-signal filter. This gives very good noise rejection along with fast response to step inputs.

The modules allow user selectable output scaling in °C or °F on temperature data. This selection is shown in Figure 2.1 as a switch following the digital filters. The default scaling in the modules is °C, but this may be converted to °F by feeding the data through a conversion routine. The switch position is controlled by a bit in the setup data and may be changed with the SetUp (SU) command. The scaling selection is nonvolatile. In non-temperature applications, °C should always be selected.

The scaled data is summed with data stored in the Output Offset Register to obtain the final output value. The output offset is controlled by the user and has many purposes. The data in the Output Offset Register may be used to trim any offsets caused by the input sensor. It may be used to null out

undesired signal such as a tare weight. The Trim Zero (TZ) command is used to adjust the output to any desired value by loading the appropriate value in the offset register. The offset register data is nonvolatile.

The output offset may also be modified using the Set Point (SP) command. The data value specified by the SP command is multiplied by -1 before being loaded into the register. The Set Point command specifies a null value that is subtracted from the input data. The output reading becomes a deviation value from the downloaded setpoint. This feature is very useful in on-off controllers as described in Chapter 6 of this manual.

The value stored in the offset register may be read back using the Read Zero (RZ) command. Data loaded in with the SP command will be read back with the sign changed. The output register may be reset to zero with the Clear Zero (CZ) command.

The output data may be read with the Read Data (RD) command. In some cases when a computer is used as a host, the same data value may be read back several times before it is updated with a new A/D conversion. To guarantee that the same data is not read more than once, the New Data (ND) command is used. Each time an RD or ND command is performed, the New Data Flag is cleared. The flag is set each time the output data register is loaded as the result of a new A/D conversion. The ND command waits until the flag is set before it outputs the data reading.

The remainder of Figure 2.1 shows several functions: a versatile alarm function, an event counter and general-purpose digital inputs and outputs. These functions are described in detail in Chapter 6.

The alarm section consists of two registers that are used to store high and low alarm limit values. These registers may be down-loaded with data values by using the HI and LO alarm commands. The alarm values are loaded with the same data format that is used with the output data. The high and low alarm registers are nonvolatile so they will not be lost when the unit is powered down. The values held in the alarm registers may be read back at any time with the Read High (RH) and Read Low (RL) commands.

The data held in the alarm registers is continually compared with the calculated output data. The result of the comparison is used to trip alarms that may be used as control outputs. The high alarm is turned on when the output data exceeds the high limit value. The low alarm is activated if the output data is less than the low alarm value. Each alarm has two user selectable modes, either Momentary (M) or Latching (L). Momentary alarms are activated only while the alarm condition is met; if the output data returns within limits, the alarm is turned off. Conversely, when latching alarms are activated, they remain on even if the output data returns within limits.

Latching alarms are turned off with the Clear Alarms (CA) command or if the opposite alarm limit is exceeded.

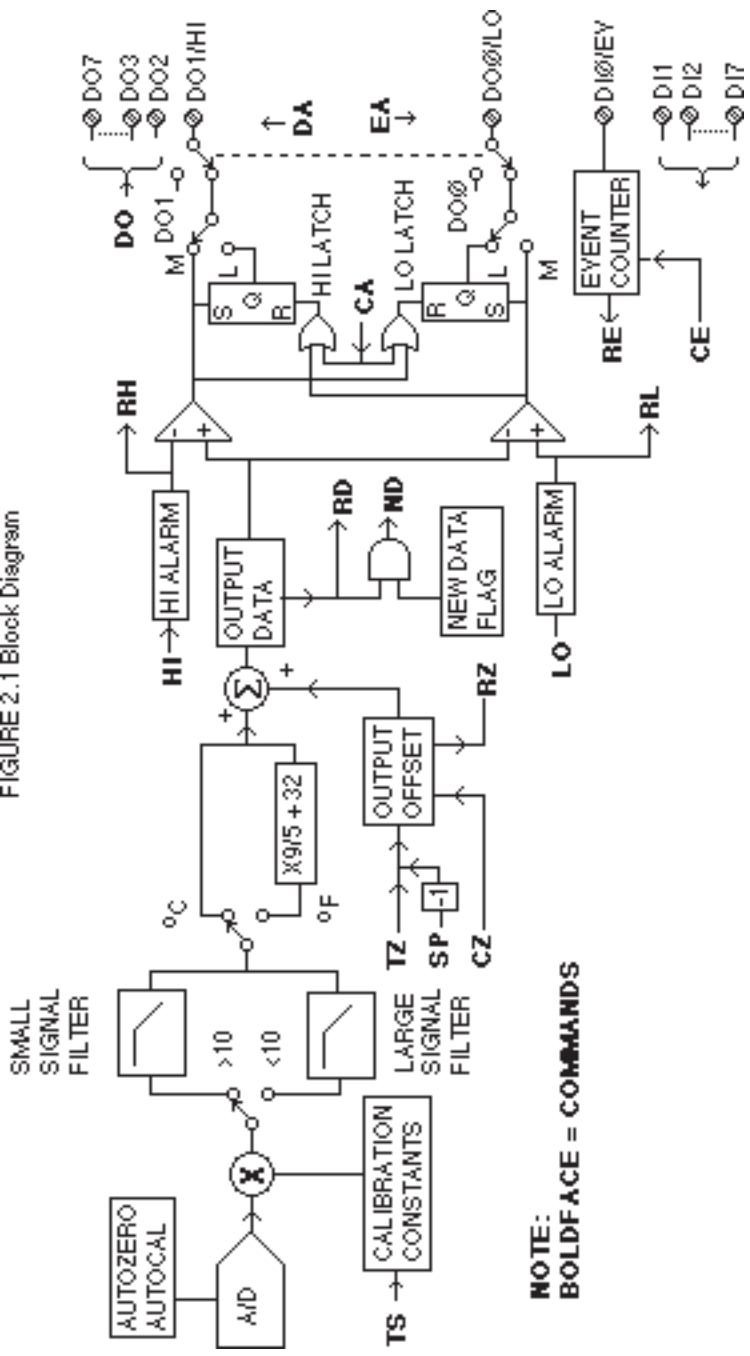
The state of the alarms may be read with the Digital Input (DI) command. Also, the alarm outputs may be used to activate digital outputs on the module to turn on alarms or to perform simple control functions. The alarm outputs are shared with the general purpose digital output bits DO0 and DO1. To connect the alarm outputs to the module connector, the Enable Alarm (EA) command is used. The connector pins may be switched back to the general-purpose digital outputs using the Disable Alarms (DA) command. The EA/DA selection is nonvolatile.

The general-purpose digital outputs are open-collector transistor switches that may be controlled by the host with the Digital Output (DO) command. They are designed to activate external solid-state relays to control AC or DC power circuits. The output may also be used to interface to other logic-level devices. The number of digital outputs available depends on the module type.

The Digital Input (DI) command is used to sense the logic levels on the digital input pins DI0-DI7. The digital inputs are used to read logic levels generated by other devices. They are also useful to sense the state of electro-mechanical limit switches. The number of digital inputs available varies with the module type.

The DI0 input is shared with the input to the Event Counter. The Event Counter accumulates the number of positive transitions that occur on the DI0/EV connector pin. The counter can accumulate up to 9999999 (decimal) events and may be read with the Read Events (RE) command. The counter input is filtered and uses a Schmitt-trigger input to provide a bounce-free input for mechanical switches. The counter value may be zeroed with the Clear Events (CE) command or the write-protected Events Clear (EC) command.

FIGURE 2.1 Block Diagram



# Chapter 3

## Communications

### Introduction

The D1000 modules has been carefully designed to be easy to interface to all popular computers and terminals. All communications to and from the modules are performed with printable ASCII characters. This allows the information to be processed with string functions common to most high-level languages such as BASIC. For computers that support RS-232C, no special machine language software drivers are necessary for operation. The modules can be connected to auto-answer modems for long-distance operation without the need for a supervisory computer. The ASCII format makes system debugging easy with a dumb terminal.

This system allows multiple modules to be connected to a communications port with a single 4-wire cable. Up to 32 RS-485 modules may be strung together on one cable; 122 with repeaters. A practical limit for RS-232C units is about ten, although a string of 122 units is possible. The modules communicate with the host on a polling system; that is, each module responds to its own unique address and must be interrogated by the host. A module can never initiate a communications sequence. A simple command/response protocol must be strictly observed to avoid communications collisions and data errors.

Communications to the D1000 modules is performed with two-character ASCII command codes such as RD to Read Data from the analog input. A complete description of all commands is given in the Chapter 4. A typical command/response sequence would look like this:

**Command:**     \$1RD  
**Response:**    \*+00123.00

A command/response sequence is not complete until a valid response is received. The host may not initiate a new command until the response from a previous command is complete. Failure to observe this rule will result in communications collisions. A valid response can be in one of three forms:

- 1) a normal response indicated by a ' \* ' prompt
- 2) an error message indicated by a ' ? ' prompt
- 3) a communications time-out error

When a module receives a valid command, it must interpret the command, perform the desired function, and then communicate the response back to the host. Each command has an associated delay time in which the module is busy calculating the response. If the host does not receive a response in an appropriate amount of time specified in Table 3.1, a communications time-out error has occurred. After the communications time-out it is assumed that no response data is forthcoming. This error usually results when

an improper command prompt or address is transmitted. The table below lists the timeout specification for each command:

Mnemonic	Timeout
DI,DO,RD	10 mS
ND	See text
All other commands	100 mS

Table 3.1 Response Timeout Specifications.

The timeout specification is the turn-around time from the receipt of a command to when the module starts to transmit a response.

### Data Format

**All modules communicate in standard NRZ asynchronous data format. This format provides one start bit, seven data bits, one parity bit and one stop bit for each character.**

### RS-232C

RS-232C is the most widely used communications standard for information transfer between computing equipment. RS-232C versions of the D1000 will interface to virtually all popular computers without any additional hardware. Although the RS-232C standard is designed to connect a single piece of equipment to a computer, the D1000 system allows for several modules to be connected in a daisy-chain network structure. The advantages offered by the RS-232C standard are:

- 1) widely used by all computing equipment
- 2) no additional interface hardware in most cases
- 3) separate transmit and receive lines ease debugging
- 4) compatible with dumb terminals

However, RS-232C suffers from several disadvantages:

- 1) low noise immunity
- 2) short usable distance
- 3) greater communications delay in multiple-module systems
- 4) less reliable—loss of one module; communications are lost
- 5) wiring is slightly more complex than RS-485
- 6) host software must handle echo characters

### Single Module Connection



Figure 1.1 shows the connections necessary to attach one module to a host. Use the Default Mode to enter the desired address, baud rate, and other setups (see Setups). The use of echo is not necessary when using a single module on the communications line.

### Multi-party Connection

RS-232C is not designed to be used in a multiparty system; however the D1000 modules can be daisy-chained to allow many modules to be connected to a single communications port. The wiring necessary to create the daisy-chain is shown in Figure 3.1. Notice that starting with the host, each Transmit output is wired to the Receive input of the next module in the daisy chain. This wiring sequence must be followed until the output of the last module in the chain is wired to the Receive input of the host. All modules in the chain must be setup to the same baud rate and must echo all received data (see Setups). Each module must be setup with its own unique address to avoid communications collisions (see Setups). In this network, any characters transmitted by the host are received by each module in the chain and passed on to the next station until the information is echoed back to the Receive input of the host. In this manner all the commands given by the host are examined by every module. If a module in the chain is correctly addressed and receives a valid command, it will respond by transmitting the response on the daisy chain network. The response data will be ripple through any other modules in the chain until it reaches its final destination, the Receive input of the host.

The daisy chain network must be carefully implemented to avoid the pitfalls

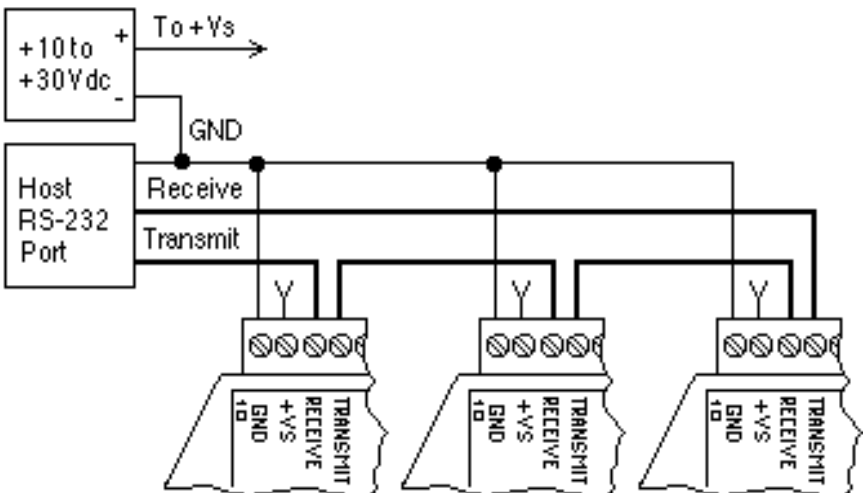


Figure 3.1 RS-232 Daisy Chain Network.

inherent in its structure. The daisy-chain is a series-connected structure and any break in the communications link will bring down the whole system. Several rules must be observed to create a working chain:

1. All wiring connections must be secure; any break in the wiring, power, ground or communications breaks the chain.
2. All modules must be plugged into their own connectors.
3. All modules must be setup for the same baud rate.
4. All modules must be setup for echo.

### Software Considerations

If the host device is a computer, it must be able to handle the echoed command messages on its Receive input along with the responses from the module. This can be handled by software string functions by observing that a module response always begins with a '\*' or '?' character and ends with a carriage return.

A properly addressed D1000 module in a daisy chain will echo all of the characters in the command including the terminating carriage return. Upon receiving the carriage return, the module will immediately calculate and transmit the response to the command. During this time, the module will not echo any characters that appear on its receive input. However, if a character is received during this computation period, it will be stored in the module's internal receive buffer. This character will be echoed after the response string is transmitted by the module. This situation will occur if the host computer appends a linefeed character on the command carriage return. In this case the linefeed character will be echoed after the response string has been transmitted.

The daisy chain also affects the command timeout specifications. When a module in the chain receives a character it is echoed by retransmitting the character through the module's internal UART. This method is used to provide more reliable communications since the UART eliminates any slewing errors caused by the transmission lines. However, this method creates a delay in propagating the character through the chain. The delay is equal to the time necessary to retransmit one character using the baud rate setup in the module:

Baud Rate	Delay	Baud Rate	Delay
300	33.30ms	9600	1.04ms
600	16.70ms	19200	0.52ms
1200	8.33ms	38400	0.26ms
2400	4.17ms	57600	173.6μs
4800	2.08ms	115200	86.8μs

One delay time is accumulated for each module in the chain. For example,

if four modules are used in a chain operating at 1200 baud, the accumulated delay time is  $4 \times 8.33 \text{ mS} = 33.3 \text{ mS}$ . This time must be added to the times listed in Table 3.1 to calculate the correct communications time-out error.

For modules with RS-232C outputs, the programmed communications delay specified in the setup data (see Chapter 5) is implemented by sending a NULL character (00) followed by an idle line condition for one character time. This results in a delay of two character periods. For longer delay times specified in the setup data, this sequence is repeated. Programmed communications delay is seldom necessary in an RS-232C daisy chain since each module in the chain adds one character of communications delay.

### **Changing Baud Rate**

It is possible to change the baud rate of an RS-232C daisy chain on-line. This process must be done carefully to avoid breaking the communications link.

1. Use the SetUp (SU) command to change the baud rate setup on each module in the chain. Be careful not to generate a reset during this process. A reset can be caused by the Remote Reset (RR) command or power interruptions.
2. Verify that all the modules in the chain contain the new baud rate setup using the Read Setup (RS) command. Every module in the chain must be setup for the same baud rate.
3. Remove power from all the modules for at least 10 seconds. Restore power to the modules. This generates a power-up reset in each module and loads in the new baud rate.
4. Change the host baud rate to the new value and check communications.
5. Be sure to compensate for a different communications delay as a result of the new baud rate.

### **Using A Daisy-Chain With A Dumb Terminal**

A dumb terminal can be used to communicate to a daisy-chained system. The terminal is connected in the same manner as a computer used as a host. Any commands typed into the dumb terminal will be echoed by the daisy chain. To avoid double characters when typing commands, set the terminal to full duplex mode or turn off the local echo. The daisy chain will provide the input command echo.

**RS-485**

RS-485 is a recently developed communications standard to satisfy the need for multidropped systems that can communicate at high data rates over long distances. RS-485 is similar to RS-422 in that it uses a balanced differential pair of wires switching from 0 to 5V to communicate data. RS-485 receivers can handle common mode voltages from -7V to +12V without loss of data, making them ideal for transmission over great distances. RS-485 differs from RS-422 by using one balanced pair of wires for both transmitting and receiving. Since an RS-485 system cannot transmit and receive at the same time it is inherently a half-duplex system. RS-485 offers many advantages over RS-232C:

- 1) balanced line gives excellent noise immunity
- 2) can communicate with D1000 modules at 115200 baud
- 3) communications distances up to 4,000 feet.
- 4) true multidrop; modules are connected in parallel
- 5) can disconnect modules without losing communications
- 6) up to 32 modules on one line; 122 with repeaters
- 7) no communications delay due to multiple modules
- 8) simplified wiring using standard telephone cable

RS-485 does have disadvantages. Very few computers or terminals have built-in support for this new standard. Interface boards are available for the IBM PC and compatibles and other RS-485 equipment will become available as the standard gains popularity. An RS-485 system usually requires an interface.

We offer the A1000 and A2000 interface converters that will convert RS-232 signals to RS-485 or repeat RS-485 signals. The A1000 converters also include a +24Vdc, one amp power supply for powering D1000 series modules. The A1000 or A2000 connected as an RS-485 repeater can be used to extend an existing RS-485 network or connect up to 122 modules on one serial communications port.

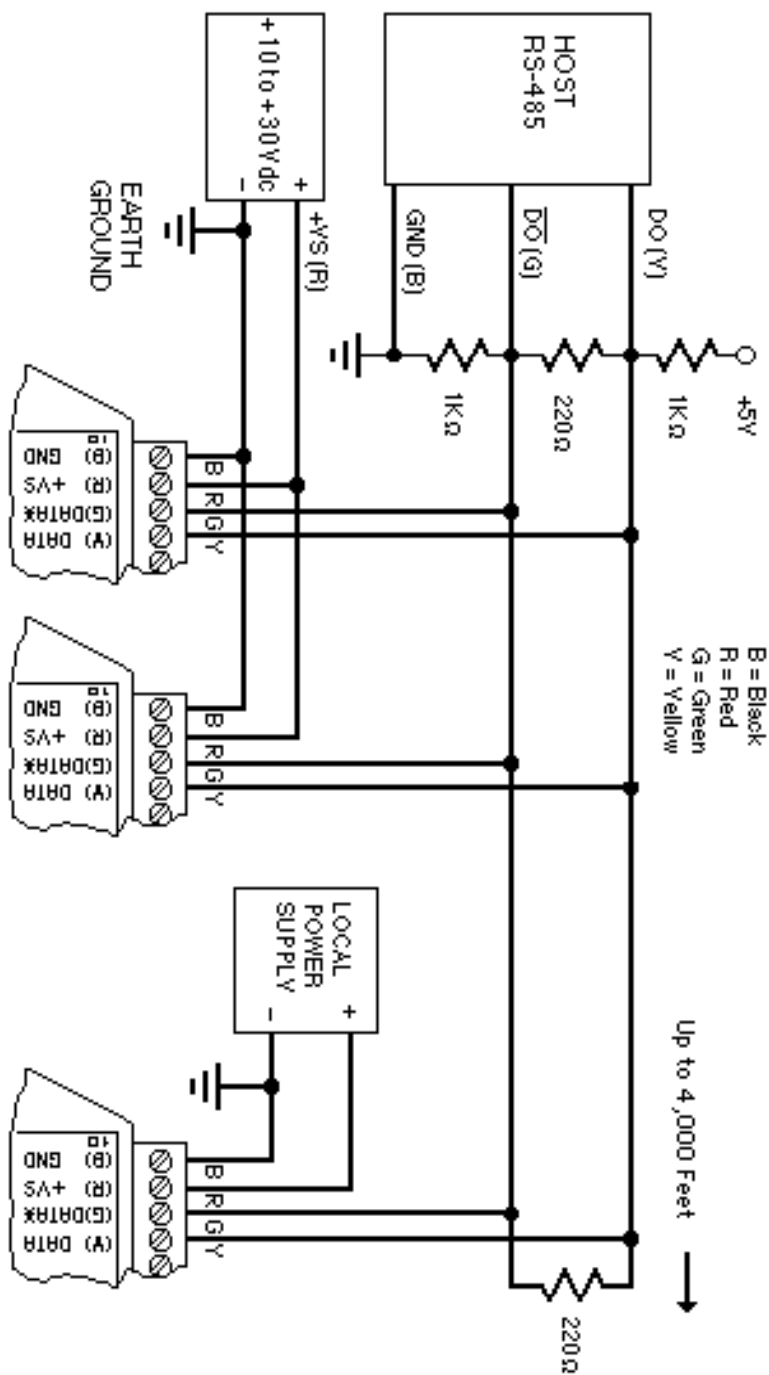


Figure 3.2.RS-485 Network.

### RS-485 Multidrop System

Figure 3.2 illustrates the wiring required for multiple-module RS-485 system. Notice that every module has a direct connection to the host system. Any number of modules may be unplugged without affecting the remaining modules. Each module must be setup with a unique address and the addresses can be in any order. All RS-485 modules must be setup for no echo to avoid bus conflicts (see Setup). Also note that the connector pins on each module are labelled with notations (B), (R), (G), and (Y). This designates the colors used on standard 4-wire telephone cable:

Label	Color
(B) GND	Black
(R) V+	Red
(G) DATA* (-)	Green
(Y) DATA (+)	Yellow

This color convention is used to simplify installation. If standard 4-wire telephone cable is used, it is only necessary to match the labeled pins with the wire color to guarantee correct installation.

DATA\* on the label is the complement of DATA (negative true).

To minimize unwanted reflections on the transmission line, the bus should be arranged as a line going from one module to the next. 'Tree' or random structures of the transmission line should be avoided. When using long transmission lines and/or high baud rates, the data lines should be terminated at each end with 200 ohm resistors. Standard values of 180 ohms or 220 ohms are acceptable.

During normal operation, there are periods of time where all RS-485 drivers are off and the communications lines are in an 'idle' high impedance condition. During this condition, the lines are susceptible to noise pickup which may be interpreted as random characters on the communications line. To prevent noise pickup, all RS-485 systems should incorporate 1K ohm bias resistors as shown in Figure 3.2. The resistors will maintain the data lines in a 'mark' condition when all drivers are off.

A1000 series converter boxes have the 1K $\Omega$  resistors built-in. The resistors are user-selectable via dip switch located on the rear panel of the A1000.

Special care must be taken with very long busses (greater than 1000 feet) to ensure error-free operation. Long busses must be terminated as described above. The use of twisted cable for the DATA and DATA\* lines will greatly enhance signal fidelity. Use parity and checksums along with the '#' form of all commands to detect transmission errors. In situations where many modules are used on a long line, voltage drops in the power leads

becomes an important consideration. The GND wire is used both as a power connection and the common reference for the transmission line receivers in the modules. Voltage drops in the GND leads appear as a common-mode voltage to the receivers. The receivers are rated for a maximum of -7V. of common-mode voltage. For reliable operation, the common mode voltage should be kept below -5V.

To avoid problems with voltage drops, modules may be powered locally rather than transmitting the power from the host. Inexpensive 'calculator' type power supplies are useful in remote locations. When local supplies are used, be sure to provide a ground reference with a third wire to the host or through a good earth ground. With local supplies and an earth ground, only two wires for the data connections are necessary.

### **Communications Delay**

All D1000 modules with RS-485 outputs are setup at the factory to provide two units of communications delay after a command has been received (see Chapter 5). This delay is necessary when using host computers that transmit a carriage return as a carriage return-linefeed string. Without the delay, the linefeed character may collide with the first transmitted character from the module, resulting in garbled data. If the host computer transmits a carriage return as a single character, the delay may be set to zero to improve communications response time.

## Chapter 4

### Command Set

The D1000 modules operate with a simple command/response protocol to control all module functions. A command must be transmitted to the module by the host computer or terminal before the module will respond with useful data. A module can never initiate a communications sequence. A variety of commands exists to exploit the full functionality of the modules. A list of available commands and a sample format for each command is listed in Table 4.1.

#### Command Structure

Each command message from the host must begin with a command prompt character to signal to the modules that a command message is to follow. There are four valid prompt characters; a dollar sign character (\$) is used to generate a short response message from the module. A short response is the minimum amount of data necessary to complete the command. The second prompt character is the pound sign character (#) which generates long responses (will be covered later in this chapter). The other two prompt characters: left curly brace ( { ) and right curly brace ( } ) are part of the Extended Addressing mode described in chapter 10

The prompt character must be followed by a single address character identifying the module to which the command is directed. Each module attached to a common communications port must be setup with its own unique address so that commands may be directed to the proper unit. Module addresses are assigned by the user with the SetUp (SU) command. Printable ASCII characters such as '1' (ASCII \$31) or 'A' (ASCII \$41) are the best choices for address characters.

The address character is followed by a two-character command that identifies the function to be performed by the module. All of the available commands are listed in Table 4.1 along with a short function definition. All commands are described in Chapter 4. Commands must be transmitted as upper-case characters.

A two-character checksum may be appended to any command message as a user option. See 'Checksum' in Chapter 4 .

All commands must be terminated by a Carriage Return character (ASCII \$0D). (In all command examples in this text the Carriage Return is either implied or denoted by the symbol 'CR'.)

In addition to the command structure discussed above there is a special command format called Extended Addressing. This mode uses a different prompt, either '{' or '}' to distinguish it from the regular command syntax. The Extended Addressing mode is described in chapter 10.



## Data Structure

Many commands require additional data values to complete the command definition as shown in the example commands in Table 4.1. The particular data necessary for these commands is described in full in the complete command descriptions.

The most common type of data used in commands and responses is analog data. Analog data is always represented in the same format for all models in the D1000 series. Analog data is represented as a nine-character string consisting of a sign, five digits, decimal point, and two additional digits. The string represents a decimal value in engineering units. Examples:

```
+12345.68
+00100.00
-00072.10
-00000.00
```

When using commands that require analog data as an argument, the full nine-character string must be used, even if some digits are not significant. Failure to do this results in a SYNTAX ERROR.

Analog data responses from the module will always be transmitted in the nine-character format. This greatly simplifies software parsing routines since all analog data is in the same format for all module types.

In many cases, some of the digits in the analog data may not be significant. For instance, the D1300 thermocouple input modules feature 1 degree output resolution. A typical analog data value from this type of module could be +00123.00. The two digits to the right of the decimal point have no significance in this particular model. However, the data format is always adhered to in order to maintain compatibility with other module types.

The maximum computational resolution of the module is 16 bits, which is less than the resolution that may be represented by an analog data variable. This may lead to round-off errors in some cases. For example, an alarm value may be stored in a D1000 module using the 'HI' command:

```
Command:  $1HI+12345.67M
Response:  *
```

The alarm value is read back with the Read High (RH) command:

```
Command:  $1RH
Response:  *+12345.60M
```

It appears that the data read back does not match the value that was originally saved. The error is caused by the fact that the value saved exceeds the computational resolution of the module. This type of round-off error only

appears when large data values saved in the module's EEPROM are read back. In most practical applications, the problem is non-existent.

Overload values of analog data are +99999.99 and -99999.99 .

Data read back from the Event Counter with the Read Events (RE) command is in the form of a seven-digit decimal number with no sign or decimal point. Round-off errors do not occur on the event counter. For example:

**Command:** \$1RE  
**Response:** \*000123

The Digital Input, Digital Output, and Setup commands use hexadecimal representations of data. The data structures for these commands are detailed in the command descriptions.

### **Write Protection**

Many of the commands listed in Table 4.1 are under the heading of 'Write Protected Commands'. These commands are used to alter setup data in the module's EEPROM. They are write protected to guard against accidental loss of setup data. All write-protected commands must be preceded by a Write Enable (WE) command before the protected command may be executed.

### **Miscellaneous Protocol Notes**

The address character must be transmitted immediately after the command prompt character. After the address character the module will ignore any character below ASCII \$23 (except CR). This allows the use of spaces (ASCII \$20) within the command message for better readability if desired.

The length of a command message is limited to 20 printable characters. If a properly addressed module receives a command message of more than 20 characters the module will abort the whole command sequence and no response will result.

If a properly addressed module receives a second command prompt before it receives a CR, the command will be aborted and no response will result.

### **Response Structure**

Response messages from the module begin with either an asterisk '\*' (ASCII \$2A) or a question mark '?' (ASCII \$3F) prompt. The '\*' prompt indicates acknowledgment of a valid command. The '?' prompt precedes an error message. All response messages are terminated with a CR. Many commands simply return a '\*' character to acknowledge that the command has been executed by the module. Other commands send data information

following the '\*' prompt. The response format of all commands may be found in the detailed command description.

The maximum response message length is 20 characters.

A command/response sequence is not complete until a valid response is received. The host may not initiate a new command until the response from a previous command is complete. Failure to observe this rule will result in communications collisions. A valid response can be in one of three forms:

- 1) a normal response indicated by a '\*' prompt
- 2) an error message indicated by a '?' prompt
- 3) a communications time-out error

When a module receives a valid command, it must interpret the command, perform the desired function, and the communicate the response back to the host. Each command has an associated delay time in which the module is busy calculating the response. If the host does not receive a response in an appropriate amount of time specified in Table 4.1, a communications time-out error has occurred. After the communications time-out it is assumed that no response data is forthcoming. This error usually results when an improper command prompt or address is transmitted.

### Long Form Responses

When the pound sign '#' command prompt is used, the module responds with a 'long form' response. This type of response will echo the command message, supply the necessary response data and will add a two-character checksum to the end of the message. Long form responses are used when the host wishes to verify the command received by the module. The checksum is included to verify the integrity of the response data. The '#' command prompt may be used with any command. For example:

**Command:** \$1RD (short form)  
**Response:** \*+00072.10

**Command:** #1RD (long form)  
**Response:** \*1RD+00072.10A4 (A4=checksum)

### Checksum

Checksum is a two character hexadecimal value appended to the end of a message. It verifies that the message received is exactly the same as the message sent. The checksum ensures the integrity of the information communicated.

### Command Checksum

A two-character checksum may be appended to any command to the module as a user option. When a module interprets a command, it looks for

the two extra characters and assumes that it is a checksum. If the checksum is not present, the module will perform the command normally. If the two extra characters are present, the module calculates the checksum for the message. If the calculated checksum does not agree with the transmitted checksum, the module responds with a 'BAD CHECKSUM' error message and the command is aborted. If the checksums agree, the command is executed. If the module receives a single extra character, it responds with 'SYNTAX ERROR' and the command is aborted. For example:

**Command:** \$1RD (no checksum)  
**Response:** \*+00072.10

**Command:** \$1RDEB (with checksum)  
**Response:** \*+00072.10

**Command:** \$1RDAB (incorrect checksum)  
**Response:** ?1 BAD CHECKSUM

**Command:** \$1RDE (one extra character)  
**Response:** ?1 SYNTAX ERROR

### Response Checksums

If the long form ' #' version of a command is transmitted to a module, a checksum will be appended to the end of the response. For example:

**Command:** \$1RD (short form)  
**Response:** \*+00072.10

**Command:** #1RD (long form)  
**Response:** \*1RD+00072.10A4 (A4=checksum)

### Checksum Calculation

The checksum is calculated by summing the hexadecimal values of all the ASCII characters in the message. The lowest order two hex digits of the sum are used as the checksum. These two digits are then converted to their ASCII character equivalents and appended to the message. This ensures that the checksum is in the form of printable characters.

Example: Append a checksum to the command #1DOFF

Characters:	#	1	D	O	F	F
ASCII hex values:	23	31	44	4F	46	46
Sum (hex addition)	23 + 31 + 44 + 4F + 46 + 46 = 173					

The checksum is 73 (hex). Append the characters 7 and 3 to the end of the message: #1DOFF73

Example: Verify the checksum of a module response \*1RD+00072.10A4

The checksum is the two characters preceding the CR: A4

Add the remaining character values:

$$* \quad 1 \quad R \quad D \quad + \quad 0 \quad 0 \quad 0 \quad 7 \quad 2 \quad . \quad 1 \quad 0$$

$$2A + 31 + 52 + 44 + 2B + 30 + 30 + 30 + 37 + 32 + 2E + 31 + 30 = A4$$

The two lowest-order hex digits of the sum are A4 which agrees with the transmitted checksum.

The transmitted checksum is the character string equivalent to the calculated hex integer. The variables must be converted to like types in the host software to determine equivalency.

If checksums do not agree, a communications error has occurred.

If a module is setup to provide linefeeds, the linefeed characters are not included in the checksum calculation.

Parity bits are never included in the checksum calculation.

**Table 4.1 D1000 Command Set**

Command and Definition		Typical Command Message	Typical Response Message (\$ prompt)
DI	Read Alarms/Digital Inputs	\$1DI	*0003
DO	Set Digital Outputs	\$1DOFF	*
ND	New Data	\$1ND	*+00072.00
RD	Read Data	\$1RD	*+00072.00
RE	Read Event Counter	\$1RE	*0000107
REA	Read Extended Address	\$1REA	*3031
RH	Read High Alarm Value	\$1RH	*+00510.00L
RID	Read IDentification	\$1RID	* BOILER
RL	Read Low Alarm Value	\$1RL	*+00000.00L
RPT	Read Pulse Transition	\$1RPT	*+-
RS	Read Setup	\$1RS	*31070142
RZ	Read Zero	\$1RZ	*+00000.00
WE	Write Enable	\$1WE	*
Write Protected Commands			
CA	Clear Alarms	\$1CA	*
CE	Clear Events	\$1CE	*
CZ	Clear Zero	\$1CZ	*
DA	Disable Alarms	\$1DA	*
EA	Enable Alarms	\$1EA	*

EC	Events Read & Clear	\$1EC	*0000107
HI	Set High Alarm Limit	\$1HI+12345.67L	*
ID	IDentification	\$1ID BOILER	*
LO	Set Low Alarm Limit	\$1LO+12345.67L	*
PT	Pulse Transition	\$1PT+-	*
RR	Remote Reset	\$1RR	*
SU	Setup Module	\$1SU31070142	*
SP	Set Setpoint	\$1SP+00600.00	*
TS	Trim Span	\$1TS+00600.00	*
TZ	Trim Zero	\$1TZ+00000.00	*
WEA	Write Extended Address	\$1WEA3031	*

### D1000 User Commands

Note that in all command and response examples given below, a carriage return is implied after every character string.

#### Clear Alarms (CA)

The clear alarms command turns both the HI and LO alarms OFF. This command does not affect the enable/disable or momentary/latching alarm conditions. The alarms will continue to be compared to the input data after the CA command is given. In cases where the alarm condition persists, the alarms will be set at the end of the next input data conversion. The primary purpose of the CA command is to clear latching alarms. See the Alarm Output section of Chapter 6 for more information.

**Command:** \$1CA

**Response:** \*

**Command:** #1CA

**Response:** \*1CADF

#### Clear Events (CE)

Clear Events command clears the events counter to 0000000.

**Command:** \$1CE

**Response:** \*

**Command:** #1

**Response:** \*1CEE3

**Note:** When the events counter reaches 9999999, it stops counting. A CE command must be sent to resume counting.

#### Clear Zero (CZ)

The Clear Zero command clears the output offset register value to +00000.00. This command clears any data resulting from a Trim Zero (TZ)

or SetPoint (SP) command.

**Command:** \$1CZ

**Response:** \*

**Command:** #1CZ

**Response:** \*1CZF8

### Disable Alarms (DA)

Most D1000 modules feature LO/DO0 and HI/DO1 pins on the module connector. These pins serve a dual function and can be used to output either the alarm outputs or digital outputs 0 and 1. The Disable Alarms command is used to connect the digital outputs 0 and 1 to the connector pins. The alarm settings are not affected in any way except that the alarm outputs are disconnected from the module connector. The alarm status can still be read with the Digital Input (DI) command. The complement to the DA command is the Enable Alarms (EA) command.

**Command:** \$1DA

**Response:** \*

**Command:** #1DA

**Response:** \*1DAE0

### Digital Input (DI)

The DI command reads the status of the digital inputs and the alarms. The response to the DI command is four hex characters representing two bytes of data. The first byte contains the alarm status. The second byte contains the digital input data.

**Command:** \$1DI

**Response:** \*0003

**Command:** #1DI

**Response:** \*1DI0003AB

Listed below are the four possible alarm states in the first digital input byte and their hex values.

- 00 Both HI and LO alarms off.
- 01 HI alarm off. LO alarm on.
- 02 HI alarm on. LO alarm off.
- 03 Both HI and LO alarms on.

The second byte displays the hex value of the digital input status. The number of digital inputs varies depending on module type.

Digital Inputs	DI7	DI6	DI5	DI4	DI3	DI2	DI1	DI0
Data Bits	7	6	5	4	3	2	1	0

For example: A typical response from a \$1DI command could be: \*01FE. This response indicates that the HI alarm is off, the LO alarm is on, D10 = 0 and all other digital inputs are = 1

All digital inputs that are not implemented or left unconnected are read as '1'

Digital input 0 serves a dual function. It is both a digital input and the Event Counter input.

When reading digital inputs with a checksum, be sure not to confuse the checksum with the data.

### Digital Output (DO)

The DO command controls eight bits of digital outputs on the module connector. The number of digital outputs implemented depends on the model used. The digital outputs allow the module to control external circuits under host command. The DO command requires an argument of two hex characters specifying the eight bits of output data.

Digital Outputs	DO7	DO6	DO5	DO4	DO3	DO2	DO1	DO0
Data Bits	7	6	5	4	3	2	1	0

The electrical implementation of the digital output consists of open-collector transistors wired to the module connector. If a digital output is set to '1' the corresponding transistor is turned on and sinks current. Note that when a digital output bit is set to '1' the electrical output is near 0 volts. If a digital output is set to '0' the corresponding transistor is turned off and sinks no current.

Assume a module has two digital outputs, and you wish to turn both outputs on (sinking current). Set data bit 0 and data bit 1 to '1'. Since the module has only two digital outputs, all the other bits are 'don't cares'. For example, this command will turn both outputs 'on':

**Command:** \$1DOFF  
**Response:** \*

To turn both outputs off you could use the command:

**Command:** \$1DO00  
**Response:** \*

Digital outputs 0 and 1 share connector pins with the HI and LO alarms. The Disable Alarms (DA) command is used to configure these pins as digital outputs.

Digital output settings are not stored in nonvolatile memory. If a power failure occurs, all digital outputs will be 0 upon power up.



**Enable Alarms (EA)**

Digital outputs DO0/LO and DO1/HI serve a dual purpose as both digital outputs and alarms. Digital output 0 is shared with the LO alarm and digital output 1 is shared with the HI alarm. The Enable Alarms (EA) command configures the shared outputs to indicate alarm conditions and disconnects digital outputs 0 and 1. The EA command only affects the electrical output of the alarms to the pins. The alarm status can be read at any time with the Digital Input (DI) command. The complement to the EA command is the Disable Alarms (DA) command.

**Command:** \$1EA

**Response:** \*

**Command:** #1EA

**Response:** \*1EAE1

**Events Read & Clear (EC)**

The EC command is used to read the value of the Events Counter and automatically clears the count to zero:

**Command:** \$1EC

**Response:** \*0000123

**Command:** #1EC

**Response:** \*1EC000012339

The EC command eliminates a problem that may occur with a Read Events (RE) and Clear Events (CE) command sequence. Any counts that may occur between the RE-CE sequence will be lost. The EC command guarantees that the counter is read and cleared without missing any counts.

**High Alarm Limit (HI)**

The high alarm command sets the value and type of the high alarm. The data specified by the HI command is stored in nonvolatile memory and compared with the sensor data after every A/D conversion. The high alarm is activated if the input data is greater than the value stored by the HI command. The high alarm status may be read using the Digital Input (DI) command. The alarm may be used to activate a digital output by using the Enable Alarms (EA) command. The HI command also specifies whether the high alarm is momentary or latching. A letter indicating the alarm type, "L" for latching or "M" for momentary, must follow the alarm value. For example:

**Command:** \$1HI+00100.00M

**Response:** \*

**Command:** #1HI+00100.00M

**Response:** \*1HI+00100.00ME3

The alarm limit should be set within the output range of the module. If the alarm limit is set beyond the output range, the alarm will be activated only on an overload condition.

The high alarm value may be read back with the Read High Alarm (RH) command.

A latched alarm may be cleared with the Clear Alarms (CA) command. More information on alarms may be found in Chapter 6.

### Identification (ID)

The IDentification command allows the user to write a message into the internal nonvolatile memory which may be read back at any time using the Read IDentification (RID) command. The message may be up to 16 characters long and has no affect on the module operation. Useful information such as the module location, calibration date or model number may be stored for later retrieval.

The ID command is write protected and checksums are not supported. The module will abandon any ID command with a message length in excess of 16 characters.

**Command:** \$1IDBOILER ROOM  
**Response:** \*

**Command:** #1IDBOILER ROOM  
**Response:** \*1IDBOILER ROOM02

### Low Alarm Limit (LO)

The low alarm command sets the value and type of the low alarm. The data specified with the LO command is stored in nonvolatile memory and compared with the sensor data after every A/D conversion. If the input data is less than the low limit, the low alarm is activated. The low alarm status may be read using the Digital Input (DI) command. The alarm may be used to activate a digital output by using the Enable Alarms (EA) command. A letter indicating the alarm type, "L" for latching or "M" for momentary, must follow the alarm value. For example:

**Command:** \$1LO+00000.00M  
**Response:** \*

**Command:** #1LO+00000.00M  
**Response:** \*1LO+00000.00MEC

The alarm limit should be set within the output range of the module. If the alarm limit is set beyond the output range, the alarm will be activated only on an overload condition.

The low limit value may be read back with the Read Low Limit (RL) command. More information on alarms may be found in Chapter 6.

### **New Data Command (ND)**

The New Data (ND) command is a variation of the Read Data (RD) command used to read sensor data from the module. The ND command guarantees that the output data has not been previously read.

The D1000 module acquires analog input data eight times a second and stores the result in the output buffer (see Figure 2.1). The Read Data (RD) command simply reads the results stored in the output buffer. A fast host communicating at a high baud rate could possibly read the output buffer several times before the information is updated with a new A/D conversion. This results in redundant information which may be confusing or may be a waste of host processor time.

Associated with the output buffer is the New Data Flag (see Figure 2.1). This flag is cleared each time an RD or ND command is performed. The flag is set when the module's microprocessor loads the output buffer with the result of the most recent A/D conversion. The ND command will output data only when the New Data Flag is set. If the flag is cleared when an ND command is received, the module will wait until new data is present in the output buffer before responding to the command. Thus, the output data obtained with an ND command is always the result of a new A/D conversion.

The ND command is especially useful with computers that handle communications on an interrupt basis. The ND command is used to get maximum throughput without producing redundant data.

**Command:** \$1ND  
**Response:** \*+00072.00

**Command:** #1ND  
**Response:** \*1ND+00072.009F

A special condition exists when using the ND command with the D1600 frequency/pulse modules. These modules differ from the other sensor input modules in that they require an input trigger signal to obtain new data. If no signal exists on the input of the D1600, an ND command will wait indefinitely for new data and the module will not respond.

In order to escape this condition, a single control-C (\$03) may be issued by the host to abort the ND command. The aborted ND command will respond with the data value currently stored in the output buffer. Be aware that on an RS-485 system, the control-C character may interfere with the ND output data, causing a communications collision.

**Pulse Transition (PT)**

The Pulse Transition command is used on Frequency and Timer input modules. It is used to set the direction of the edge used to trigger the measurement cycle. There are four possible edge transitions: (+ to -), (- to +), (- to -), (+ to +). For example:

**Command:** \$1PT+ -  
**Response:** \*  
**Command:** #1PT  
**Response:** \*1PT+ -50

**Read Data (RD)**

The read data command is the basic command used to read the buffered sensor data. The output buffer (Figure 2.1) allows the data to be read immediately without waiting for an input A/D conversion. For example:

**Command:** \$1RD  
**Response:** \*+00072.00  
**Command:** #1RD  
**Response:** \*1RD+00072.10A4

Since the RD command is the most frequently used command in normal operation, a special shortened version of the command is available. If a module is addressed without a two-letter command, the module interprets the string as an RD command.

**Command:** \$1  
**Response:** \*+00072.10  
**Command:** #1  
**Response:** \*1RD+00072.10A4

**Read Events (RE)**

The Read Events command reads the number of events that have been accumulated in the Events Counter. The output is a seven-digit decimal number. For example:

**Command:** \$1RE  
**Response:** \*0000107  
**Command:** #1RE  
**Response:** \*1RE00001074A

The maximum accumulated count is 9999999. When this count is reached, the Events Counter stops counting. The counter may be cleared at any time with the Clear Events (CE) command.

The Event Counter count is stored in volatile memory. If power is removed, the Event Counter will reset to all 0's upon power up.

The Remote Reset (RR) command or a line break does not effect the value of the Event Counter.

When reading the Event Counter with a checksum, be sure not to confuse the checksum with the data.

### Read Extended Address (REA)

The Read Extended Address is used to read back two character address stored by the Extended Address (EA) command. The response message is four characters representing the hex ASCII codes for the two-character address :

**Command:** \$1REA  
**Response:** \*3031

**Command:** #1REA  
**Response:** \*1REA3031FA

In this example the '30' and '31' are the hex ASCII codes for the characters '0' and '1' respectively. The Extended Address is '01'.

### Read High Alarm (RH)

The Read High alarm command reads the value and type of the high alarm previously loaded by the HI command. The alarm type can be either latching or momentary. A letter indicating the alarm type, "L" for latching or "M" for momentary, will follow the alarm value. For example:

**Command:** \$1RH  
**Response:** \*+00510.00L

**Command:** #1RH  
**Response:** \*1RH+00510.00LF0

The RH command may be used to verify the data loaded into nonvolatile memory by the HI command.

### Read IDentification (RID)

The Read Identification (RID) command is used to read data previously stored by the ID command. The RID command response message length is variable depending on the stored message length. The maximum response length can be up to 25 characters using the long form prompt and linefeeds enabled.

**Command:** \$1RID  
**Response:** \*BOILER ROOM

**Command:** #1RID  
**Response:** \*1RIDBOILER ROOM54

**Read Low Alarm (RL)**

The Read Low alarm command reads the value and type of the low alarm. The alarm type can be either latching or momentary. A letter indicating the alarm type, "L" for latching or "M" for momentary, will follow the alarm value. For example:

```

Command:  $1RL
Response:  *+00000.00L
Command:  #1RL
Response:  *1RL+00000.00LEE

```

The RL command may be used to verify data loaded into the nonvolatile memory with the LO command.

**Read Pulse Transition (RPT)**

The Read Pulse Transition command is used on the Timer and Frequency input modules. The RPT command reads the direction of the edge used to trigger the measurement cycle. The direction of the pulse transition is set by the user using the Pulse Transition (PT) command. There are four possible edge transitions: (+ to -), (- to +), (- to -), (+ to +). For example:

```

Command:  $1RPT
Response:  *+ -
Command:  #1RPT
Response:  *1RPT+ -A2

```

**Remote Reset (RR)**

The reset command allows the host to perform a program reset on the module's microprocessor. This may be necessary if the module's internal program is disrupted by static or other electrical disturbances. Once a reset command is received, the module will recalibrate itself. The calibration process takes approximately 3 seconds. For example:

```

Command:  $1RR
Response:  *
Command:  #1RR
Response:  *1RRFF

```

In general, the state of the digital outputs and the event counter will not be affected by the RR command. However, if data in the microprocessor's RAM (Random Access Memory) has been lost, the RR command will result in a full power-up reset.

Any commands sent to the module during the self-calibration sequence will result in a NOT READY error.

### Read Setup (RS)

The read setup command reads back the setup information loaded into the module's nonvolatile memory with the SetUp (SU) command. The response to the RS command is four bytes of information formatted as eight hex characters.

**Command:** \$1RS  
**Response:** \*31070142

**Command:** #1RS  
**Response:** \*1RS3107014292

The response contains the module's channel address, baud rate and other parameters. Refer to the setup command (SU), and Chapter 5 for a list of parameters in the setup information.

When reading the setup with a checksum, be sure not to confuse the checksum with the setup information.

### Read Zero (RZ)

The Read Zero command reads back the value stored in the Output Offset Register (Figure 2.1).

**Command:** \$1RZ  
**Response:** \*+00000.00

**Command:** #1RZ  
**Response:** \*1RZ+00000.00B0

The data read back from the Output Offset Register may be interpreted in several ways. The commands that affect this value are: Trim Zero (TZ), SetPoint (SP) and Clear Zero (CZ).

### Setpoint (SP)

Data specified by the setpoint command is multiplied by -1 and loaded into the Output Offset Register (Figure 2.1). The SP command is useful in on-off controllers—see Chapter 6. The SP command may be used to null out sensor data to obtain a deviation output when using RD or ND commands.

**Command:** \$1SP+00450.00  
**Response:** \*

**Command:** #1SP+00450.00  
**Response:** \*1SP+00450.00B0

It is possible to load setpoint data that is beyond the output range of the sensor. In this case, the setpoint is never reached by the sensor data unless an overload is present.

To clear a setpoint, use the Clear Zero (CZ) command.

The SP command writes over data written into the Output Offset Register by the Trim Zero (TZ) command. If the Output Offset Register is used as a trim value, this must be accounted for by the host before using the SP command. The value stored in this register may be read back using the Read Zero (RZ) command.

The setpoint data or trim data in the Output Offset Register is saved in nonvolatile memory.

### Setup Command (SU)

Each D1000 module contains an EEPROM (Electrically Erasable Programmable Read Only Memory) which is used to store module setup information such as address, baud rate, parity, etc. The EEPROM is a special type of memory that will retain information even if power is removed from the module. The EEPROM is used to replace the usual array of DIP switches normally used to configure electronic equipment.

The SetUp command is used to modify the user-specified parameters contained in the EEPROM to tailor the module to your application. Since the SetUp command is so important to the proper operation of a module, a whole section of this manual has been devoted to its description. See Chapter 5.

The SU command requires an argument of eight hexadecimal digits to describe four bytes of setup information:

**Command:** \$1SU31070182

**Response:** \*

**Command:** #1SU31070182

**Response:** \*1SU3107018299

### Trim Span (TS)

The trim span command is the basic means of trimming the accuracy of a D1000 module. The TS command loads a calibration factor into nonvolatile memory to trim the full-scale output of the signal conditioning circuitry. It is intended only to compensate for long-term drifts due to aging of the analog circuits, and has a useful trim value of  $\pm 10\%$  of the nominal calibration set at the factory. It is not to be used to change the basic transfer function of the module. Full information on the use of the TS command may be found in Chapter 9.

**Command:** \$1TS+00500.00

**Response:** \*

**Command:** #1TS+00500.00

**Response:** \*1TS+00500.00B0



**Caution! TS** is the only command associated with the span trim. There is no provision to read back or clear errors loaded by the TS command. Misuse of the TS command may destroy the calibration of the unit which can only be restored by using laboratory calibration instruments in a controlled environment. An input signal must be applied when using this command.

### Trim Zero (TZ)

The Trim Zero command is used to load a value into the Output Offset Register (Figure 2.1) to null out an offset in the output data. It may be used to trim offsets created by sensors. It may also be used to null out data to create a deviation output.

Example: Assume a D1511 bridge input module is being used with a load cell for weight measurement. An initial reading of the load cell with no weight applied may reveal an initial offset error:

**Command:** \$1RD  
**Response:** \*+00005.00

With no weight applied, trim the output to read zero. To trim, use the TZ command and specify the desired output reading:

**Command:** \$1TZ+00000.00 (zero output)  
**Response:** \*

The TZ command will load a data value into the Output Offset Register to force the output to read zero. The module will compensate for any previous value loaded into the Output Offset Register. If another output reading is taken, it will show that the offset has been eliminated:

**Command:** \$1RD  
**Response:** \*+00000.00

Although the TZ command is most commonly used to null an output to zero, it may be used to offset the output to any specified value. Assume that with the previously nulled load cell system we performed this command:

**Command:** \$1TZ-00100.00  
**Response:** \*

The new data output with no load applied would be:

**Command:** \$1RD  
**Response:** \*-00100.00

The load cell output is now offset by -100.

The offset value stored by the TZ command is stored in nonvolatile memory and may be read back with the Read Zero (RZ) command and cleared with the Clear Zero (CZ) command.

The SetPoint (SP) command will write over any value loaded by the TZ command.

### Write Enable (WE)

Each module is write protected against accidental changing of alarms, limits, setup, or span and zero trims. To change any of these write protected parameters, the WE command must precede the write-protected command. The response to the WE command is an asterisk indicating that the module is ready to accept a write-protected command. After the write-protected command is successfully completed, the module becomes automatically write disabled. Each write-protected command must be preceded individually with a WE command. For example:

**Command:** \$1WE  
**Response:** \*

**Command:** #1WE  
**Response:** \*1WEF7

If a module is write enabled and the execution of a command results in an error message other than WRITE PROTECTED, the module will remain write enabled until a command is successfully completed resulting in an ' \* ' prompt. This allows the user to correct the command error without having to execute another WE command.

### Write Extended Address (WEA)

The Write Extended Address (WEA) command allows the user to set the two-byte address to be used with Extended Addressing (see Chapter 7). The argument of the command specifies the hex ASCII values of the two characters to be used as the Extended Address. For example, if the address is to be set for characters '01':

**Command:** \$1WEA3031  
**Response:** \*

**Command:** #1WEA3031  
**Response:** \*1WEA3031FF

Note that '30' and '31' are the hex ASCII values for characters '0' and '1' respectively.

The EA command is write-protected and must be preceded with a WE command.

The address data may be read back with the Read Extended Address (REA) command.

## **ERROR MESSAGES**

The D1000 modules feature extensive error checking on input commands to avoid erroneous operation. Any errors detected will result in an error message and the command will be aborted.

All error messages begin with “?”, followed by the channel address, a space and error description. The error messages have the same format for either the ‘ \$ ’ or ‘ # ’ prompts. For example:

### **?1 SYNTAX ERROR**

There are eight error messages, and each error message begins with a different character. It is easy for a computer program to identify the error without having to read the entire string.

### **ADDRESS ERROR**

There are six ASCII values that are illegal for use as a module address: NULL (\$00), CR (\$0D), \$ (\$24), # (\$23), { (\$7B) and } (\$7D). The ADDRESS ERROR will occur when an attempt is made to load an illegal address into a module with the SetUp (SU) command. An attempt to load an address greater than \$7F will produce an error.

### **BAD CHECKSUM**

This error is caused by an incorrect checksum included in the command string. The module recognizes any two hex characters appended to a command string as a checksum. Usually a BAD CHECKSUM error is due to noise or interference on the communications line. Often, repeating the command solves the problem. If the error persists, either the checksum is calculated incorrectly or there is a problem with the communications channel. More reliable transmissions might be obtained by using a lower baud rate.

### **COMMAND ERROR**

This error occurs when the two-character command is not recognized by the module. Often this error results when the command is sent with lower-case letters. All valid commands are upper-case.

### **NOT READY**

If a module is reset, it performs a self-calibration routine which takes 2-3 seconds to complete. Any commands sent to the module during the self-calibration period will result in a NOT READY error. When this occurs, simply wait a couple seconds and repeat the command.

The module may be reset in three ways: a power-up reset, a Remote Reset (RR) command, or an internal reset. All modules contain a ‘watchdog’ timer

to ensure proper operation of the microprocessor. The timer may be tripped if the microprocessor is executing its program improperly due to power transients or static discharge.

If the NOT READY error persists for more than 30 seconds, check the power supply to be sure it is within specifications.

### **PARITY ERROR**

A parity error can only occur if the module is setup with parity on (see Setup). Usually a parity error results from a bit error caused by interference on the communications line. Random parity errors are usually overcome by simply repeating the command. If too many errors occur, the communications channel may have to be improved or a slower baud rate may be used.

A consistent parity error will result if the host parity does not match the module parity. In this situation, the easiest solution may be to change the parity in the host to obtain communication. At this point the parity in the module may be changed to the desired value with the SetUp (SU) command.

The parity may be changed or turned off by using Default Mode.

### **SYNTAX ERROR**

A SYNTAX ERROR will result if the structure of the command is not correct. This is caused by having too few or too many characters, signs or decimal points missing or in the wrong place. Table 4.1 lists the correct syntax for all the commands.

### **VALUE ERROR**

This error results when an incorrect character is used as a numerical value. Data values can only contain decimal digits 0-9. Hex values used in the SetUp (SU) and Digital Output (DO) commands can range from 0-F.

### **WRITE PROTECTED**

All commands that write data into nonvolatile memory are write-protected to prevent accidental erasures. These commands must be preceded with a Write Enable (WE) command or else a WRITE PROTECTED error will result.

# Chapter 5

## Setup Information/SetUp Command

The D1000 modules feature a wide choice of user configurable options which gives them the flexibility to operate on virtually any computer or terminal based system. The user options include a choice of baud rate, parity, address, and many other parameters. The particular choice of options for a module is referred to as the setup information.

The setup information is loaded into the module using the SetUp (SU) command. The SU command stores 4 bytes (32 bits) of setup information into a nonvolatile memory contained in the module. Once the information is stored, the module can be powered down indefinitely (10 years minimum) without losing the setup data. The nonvolatile memory is implemented with EEPROM so there are no batteries to replace.

The EEPROM has many advantages over DIP switches or jumpers normally used for option selection. The module never has to be opened because all of the options are selected through the communications port. This allows the setup to be changed at any time even though the module may be located thousands of feet away from the host computer or terminal. The setup information stored in a module may be read back at any time using the Read Setup command (RS).

**The following options can be specified by the SetUp command:**

**Channel address (122 values)**

**Linefeeds**

**Parity (odd, even, none)**

**Baud rate (300 to 115,200)**

**Addressing Mode: Extended/Normal**

**Alarm enable/disable**

**Alarm momentary / latching**

**CJC disable (D1300 series)**

**RTD 3/4 wire (D1400 series)**

**Fahrenheit / Celsius**

**Echo**

**Communication delay (0-6 characters)**

**Number of displayed digits**

**Large-signal filter constant**

**Small-signal filter constant**

Each of these options will be described in detail below. For a quick look-up chart on all options, refer to Tables 5.1-4.

## Command Syntax

The general format for the SetUp (SU) command is:

**\$1SU[byte 1][byte 2][byte 3][byte 4]**

A typical SetUp command would look like: \$1SU31070182.

Notice that each byte is represented by its two-character ASCII equivalent. In this example, byte 1 is described by the ASCII characters '31' which is the equivalent of binary 0011 0001 (31 hex). The operand of a SU command must contain exactly 8 hex (0-F) characters. Any deviation from this format will result in a SYNTAX ERROR. The Appendix contains a convenient hex-to-binary conversion chart.

For the purposes of describing the SetUp command, 'bit 7' refers to the highest-order bit of a byte of data. 'Bit 0' refers to lowest-order bit:

'bit number':	7	6	5	4	3	2	1	0	
binary data:	0	0	1	1	0	0	0	1	= \$31 (hex)

The SU command is write protected to guard against erroneous changes in the setup data; therefore each SU command must be preceded by a Write Enable (WE) command. To abort an SU command in progress, simply send a non-hex character (an 'X' for example) to generate a SYNTAX ERROR, and try again.

**CAUTION:** Care must be exercised in using the SU command. Improper use may result in changing communications parameters (address, baud rate, parity) which will result in a loss of communications between the host and the module. In some cases the user may have to resort to using Default Mode to restore the proper setups. The recommended procedure is to first use the Read Setup (RS) command to examine the existing setup data before proceeding with the SU command.

### Byte 1

Byte 1 contains the module (channel) address. The address is stored as the ASCII code for the string character used to address the module. In our example command \$1SU31070080, the first byte '31' is the ASCII code for the character '1'. If our sample command is sent to a module, the EEPROM will be loaded with the address '1', which in this particular case remains unchanged. To change the module address to '2', byte 1 of the SetUp command becomes '32', which is the ASCII code for the character '2'. Now the command will look like this: \$1SU32070080. When this command is sent, the module address is changed from '1' to '2' and will no longer respond to address '1'.

When using the SU command to change the address of a module, be sure to record the new address in a place that is easily retrievable. The only way to communicate with a module with an unknown address is with the Default Mode.

The most significant bit of byte 1 (bit 7) must be set to '0'. In addition, there are six ASCII codes that are illegal for use as an address. These codes are \$00, \$0D, \$24, \$23, \$7B, \$7D which are ASCII codes for the characters NUL, CR, \$, #, { and }. Using these codes for an address will cause an ADDRESS ERROR and the setup data will remain unchanged. This leaves a total of 122 possible addresses that can be loaded with the SU command. It is highly recommended that only ASCII codes for printable characters be used (\$21 to \$7E) which greatly simplifies system debugging with a dumb terminal. Refer to Appendix A for a list of ASCII codes. Table 5.1 lists the printable ASCII codes that may be used as addresses.

**Table 5.1 Byte 1 ASCII Printable Characters.**

HEX	ASCII	HEX	ASCII	HEX	ASCII	HEX	ASCII
21	!	3A	:	51	Q	68	h
22	"	3B	;	52	R	69	i
25	%	3C	<	53	S	6A	j
26	&	3D	=	54	T	6B	k
27	'	3E	>	55	U	6C	l
28	(	3F	?	56	V	6D	m
29	)	40	@	57	W	6E	n
2A	*	41	A	58	X	6F	o
2B	+	42	B	59	Y	70	p
2C	,	43	C	5A	Z	71	q
2D	-	44	D	5B	[	72	r
2E	.	45	E	5C	\	73	s
2F	/	46	F	5D	]	74	t
30	0	47	G	5E	^	75	u
31	1	48	H	5F	_	76	v
32	2	49	I	60	`	77	w
33	3	4A	J	61	a	78	x
34	4	4B	K	62	b	79	y
35	5	4C	L	63	c	7A	z
36	6	4D	M	64	d	7B	{
37	7	4E	N	65	e	7C	
38	8	4F	O	66	f	7D	}
39	9	50	P	67	g	7E	~

## Byte 2

Byte 2 is used to configure some of the characteristics of the communications channel; linefeeds, parity, and baud rate.

### Linefeeds

The most significant bit of byte 2 (bit 7) controls linefeed generation by the module. This option can be useful when using the module with a dumb terminal. All responses from the D1000 are terminated with a carriage return (ASCII \$0D). Most terminals will generate a automatic linefeed when a carriage return is detected. However, for terminals that do not have this capability, the D1000 module can generate the linefeed if desired. By setting bit 7 to '1' the module will send a linefeed (ASCII \$0A) before and after each response. If bit 7 is cleared (0), no linefeeds are transmitted.

When using the '#' command prompt, the linefeed characters are not included in the checksum calculation.

### Parity

Bits 5 and 6 select the parity to be used by the module. Bit 5 turns the parity on and off. If bit 5 is '0', the parity of the command string is ignored and the parity bit of characters transmitted by the module is set to '1'.

If bit 5 is '1', the parity of command strings is checked and the parity of characters output by the module is calculated as specified by bit 6.

If bit 6 is '0', parity is even; if bit 6 is '1', parity is odd.

If a parity error is detected by the module, it will respond with a PARITY ERROR message. This is usually caused by noise on the communications line.

If parity setup values are changed with the SU command, the response to the SU command will be transmitted with the old parity setup. The new parity setup becomes effective immediately after the response message from the SU command.

### Baud Rate

Bits 0-3 specify the communications baud rate. The baud rate can be selected from ten values between 300 and 115200 baud. Refer to Table 5.2 for the desired code.

The baud rate selection is the only setup data that is not implemented directly after an SU command. In order for the baud rate to be actually changed, a module reset must occur. A reset is performed by sending a Remote Reset (RR) command (see Communications) or powering down. This extra level of write protection is necessary to ensure that communications to the module is not accidentally lost. This is very important when



changing the baud rate of an RS-232C string. For more information on changing baud rate, refer to Chapter 3.

Let's run through an example of changing the baud rate. Assume our sample module contains the setup data value of '31070080'. Byte 2 is '07'. By referring to the SU command chart we can determine that the module is set for no linefeeds, no parity, and baud rate 300. If we perform the Read Setup command with this module we would get:

**Command:** \$1RS  
**Response:** \*31070080

Let's say we wish to change the baud rate to 9600 baud. The code for 9600 baud is '0010' (from Table 5.2). This would change byte 2 to '02'. To perform the SU command we must first send a Write Enable command because SU is write protected:

**Command:** \$1WE  
**Response:** \*  
**Command:** \$1SU31020080  
**Response:** \*

This sequence of messages is done in 300 baud because that was the original baud rate of the module. The module remains in 300 baud after this sequence. We can use the Read Setup (RS) command to check the setup data:

**Command:** \$1RS  
**Response:** \*31020080

Notice that although the module is communicating in 300 baud, the setup data indicates a baud rate of 9600 (byte 2 = '02'). To actually change the baud rate to 9600, send a Remote Reset (RR) command (RR is write protected):

**Command:** \$1WE  
**Response:** \*  
**Command:** \$1RR  
**Response:** \*

Up to this point all communications have been sent at 300 baud. The module will not respond to any further communications at 300 baud because it is now running at 9600 baud. At this point the host computer or terminal must be set to 9600 baud to continue operation.

If the module does not respond to the new baud rate, most likely the setup data is incorrect. Try various baud rates from the host until the module

responds. The last resort is to set the module to Default Mode where the baud rate is always 300.

Setting a string of RS-232C modules to a new baud rate requires special consideration. Refer to Chapter 3 for instructions.

#### Bit 4

Bit 4 is used to enable or disable extended addressing mode.

**Table 5.2 Byte 2: Linefeed, Parity, Addressing and Baud Rate.**

FUNCTION	DATA BIT							
	7	6	5	4	3	2	1	0
LINEFEED	1							
NO LINEFEED	0							
NO PARITY		0	0					
NO PARITY		1	0					
EVEN PARITY		0	1					
ODD PARITY		1	1					
NORMAL ADDRESSING				0				
EXTENDED ADDRESSING				1				
115200 BAUD					1	0	0	0
57600 BAUD					1	0	0	1
38400 BAUD					0	0	0	0
19200 BAUD					0	0	0	1
9600 BAUD					0	0	1	0
4800 BAUD					0	0	1	1
2400 BAUD					0	1	0	0
1200 BAUD					0	1	0	1
600 BAUD					0	1	1	0
300 BAUD					0	1	1	1

#### Byte 3

This byte contains the setup information for several seldom-used options. The default value for this byte is '01'.

#### Alarm Enable

Bit 7 determines if the outputs from the LO and HI alarms are connected to module terminal block. If the value is '0' the alarms are not connected to the terminal block. In this condition the outputs are controlled by the Digital Output (DO) command. If bit 7 is '1' the alarms are connected to the terminal block. This bit is also controlled by the Enable Alarms (EA) command which sets the bit to '1'. The Disable Alarms (DA) command clears the bit to '0'.

#### Low Alarm Latch

Bit 6 determines whether the LO Alarm is latching or momentary. A '1' indicates that the alarm is latching; '0' indicates a momentary alarm. Bit 6 is also controlled by the LO Alarm (LO) command.

### High Alarm Latch

Bit 5 determines whether the HI Alarm is latching or momentary. A '1' indicates latching. Bit 5 is also controlled individually by the HI Alarm (HI) command.

### Disable CJC

#### RTD 3/4 Wire

#### Trigger Edge Select

The setup information stored in bit 4 has different meanings depending on the D1000 model number.

**Disable CJC;** this function pertains only to the D1300 series of thermocouple input modules. If the bit is set to '1' the Cold Junction Compensation is disabled. The module calculates the temperature output with a fixed cold junction temperature of 0 degrees Celsius. This setup is useful for calibrating the module or in cases where remote CJC is used. Normally this bit is cleared to '0'.

**RTD 3/4 Wire;** this function pertains only to the D1400 series of RTD input modules. If the bit is set to '1', the module provides the correct lead-compensation calculation for 4-wire RTD's. If the bit is cleared to '0', the module calculates the correct lead compensation for 3-wire RTD's. Measurement errors may result if the module is not set to the correct sensor type. This function has no affect on D145X or D146X Thermistor inputs.

### Celsius/Fahrenheit

The default scaling for temperature output modules is Celsius which is selected by making bit 3 = 0. To change the scaling to Fahrenheit, set bit 3 to '1'. All modules that do not have temperature output must have bit 3 cleared to zero. The scaling factors are operative only on the sensor data; HI and LO limits and setpoints must be modified by appropriate commands to reflect a scaling change (see Figure 2.1).

### Echo

When bit 2 is set to '1', the D1000 module will retransmit any characters it has received on the communications line. This option is necessary to 'daisy-chain' multiple RS-232C modules. Echo is optional for systems with a single RS-232C module. Bit 2 must be cleared to '0' on RS-485 models. See Chapter 3 for a more complete description.

### Delay

Bits 0 and 1 specify a minimum turn-around delay between a command and the module response. This delay time is useful on host systems that are not fast enough to capture data from quick-responding commands such as RD. This is particularly true for systems that use software UART's. The specified



**Byte 4**

This setup byte specifies the number of displayed digits and the digital filter time constants.

**Number of displayed digits**

For ease of use, the data outputs of all modules are standardized to a common 7-digit output consisting of sign, 5 digits, decimal point, and two more digits. Typical output data looks like: +00100.00. However, best-case resolution of the A/D converter is 1 part in 32,768. In some cases, the resolution of the output format is much greater than the resolution of the measurement system. In such cases, the trailing digits of the response would display meaningless information. Bits 6 and 7 are used to insert trailing zeros into the output data to limit the output resolution and mask off meaningless digits.

<b>Bit 7</b>	<b>Bit 6</b>		
<b>0</b>	<b>0</b>	<b>XXXX0.00</b>	<b>(4 displayed digits)</b>
<b>0</b>	<b>1</b>	<b>XXXXX.00</b>	<b>(5 displayed digits)</b>
<b>1</b>	<b>0</b>	<b>XXXXX.X0</b>	<b>(6 displayed digits)</b>
<b>1</b>	<b>1</b>	<b>XXXXX.XX</b>	<b>(7 displayed digits)</b>

For example, the D1411 model for RTD's has 0.1 degree output resolution. The appropriate number of digits for this module is 6, to mask off the 0.01 digit which has no meaningful data. In some cases, the user may want to limit the output resolution to 1 degree. To do this, select bits 6 and 7 to display 5 digits. With this selection, the right-most two digits will always be set to '0'.

The number of displayed digits affects only data received from an RD or ND command.

**Large Signal Filter, Bits 3,4,5****Small Signal Filter, Bits 0,1,2**

The modules contain a versatile single-pole, low-pass digital filter to smooth out unwanted noise caused by interference or small signal variations. The digital filter offers many advantages over traditional analog filters. The filtering action is done completely in firmware and is not affected by component drifts, offsets, and circuit noise typically found in analog filters. The filter time constant is programmable through the SetUp (SU) command and can be changed at any time, even if the module is remote from the host.

The digital filter features separate time constants for large and small signal variations. The Large Signal Filter time constant is controlled by bits 3,4,5. This time constant is used when large signal variations are present on the input. The Small Signal Filter time constant is controlled by bits 0,1,2. This filter time constant is automatically selected when input signal variations are small. The microprocessor in the module automatically selects the correct

## Setup & SetUp Command 5-10

filter constant after every A/D conversion. The constant selected depends on the magnitude of the change of the input signal and the setup for the number of digits displayed. The microprocessor always keeps the value of the last calculated output to compare to a new data conversion. If the new data differs from the last output by more than ten counts of the last displayed digit, the large signal time constant is used in the digital filter. If the result of the most recent A/D conversion differs from the last output value by less than ten counts of the last displayed digit, the small signal time constant is used. Let's look at an example:

The D1411 RTD module has a standard output resolution of 0.1 degrees. The standard number-of-displayed-digits setup for this module is 6 digits, from byte 4 of the setup data. Therefore, the large signal filter will be selected if a new input conversion differs from the previous value by > 1.0 degree:

<b>Previous data</b>	<b>New data</b>	<b>Filter selected</b>
<b>+00100.00</b>	<b>+00100.50</b>	<b>small</b>
<b>+00100.00</b>	<b>+00101.50</b>	<b>large</b>
<b>+00100.00</b>	<b>+00099.90</b>	<b>small</b>
<b>+00100.00</b>	<b>+00098.90</b>	<b>large</b>
<b>-00050.50</b>	<b>-00050.00</b>	<b>small</b>
<b>-00050.50</b>	<b>-00060.00</b>	<b>small</b>

If the number of displayed digits is changed to reduce output resolution, filter selection is also affected. If the number of displayed digits in the previous example is changed to 5, the output resolution becomes 1.0 degree.

In this case the large signal time constant is used if the new reading differs from the old by more than 10.0 degrees:

<b>Previous data</b>	<b>New data</b>	<b>Filter selected</b>
<b>+00100.00</b>	<b>+00105.00</b>	<b>small</b>
<b>+00100.00</b>	<b>+00111.00</b>	<b>large</b>
<b>+00100.00</b>	<b>+00091.00</b>	<b>small</b>
<b>+00100.00</b>	<b>+00085.00</b>	<b>large</b>
<b>-00050.00</b>	<b>-00045.00</b>	<b>small</b>
<b>-00050.00</b>	<b>-00039.00</b>	<b>large</b>

### Large Signal Time Constant

The large signal filter time constant is specified by bits 3,4,5 of byte 4. It may be specified from 0 (no filter) to 16 seconds. The time constant for a first-order filter is the time required for the output to reach 63% of its final value for a step input.

### Small Signal Time Constant

Bits 0,1, 2 specify the filter time constant for small signals. Its values are similar to the ones for the large signal filter. Most sensors can benefit from a small amount of small signal filtering such as  $T = 0.5$  seconds. In most applications, the small signal time constant should be larger than the large signal time constant. This gives stable readings for steady-state inputs while providing fast response to large signal changes.

**Table 5.4 Byte 4 Displayed Digits and Filter Time Constants.**

#### BYTE 4

FUNCTION	DATA BIT							
	7	6	5	4	3	2	1	0
+XXXX0.00 DISPLAYED DIGITS	0	0						
+XXXXX.00 DISPLAYED DIGITS	0	1						
+XXXXX.X0 DISPLAYED DIGITS	1	0						
+XXXXX.XX DISPLAYED DIGITS	1	1						
NO LARGE SIGNAL FILTERING			0	0	0			
0.25 SECOND TIME CONSTANT			0	0	1			
0.5 SECOND TIME CONSTANT			0	1	0			
1.0 SECOND TIME CONSTANT			0	1	1			
2.0 SECOND TIME CONSTANT			1	0	0			
4.0 SECOND TIME CONSTANT			1	0	1			
8.0 SECOND TIME CONSTANT			1	1	0			
16.0 SECOND TIME CONSTANT			1	1	1			
NO SMALL SIGNAL FILTERING						0	0	0
0.25 SECOND TIME CONSTANT						0	0	1
0.5 SECOND TIME CONSTANT						0	1	0
1.0 SECOND TIME CONSTANT						0	1	1
2.0 SECOND TIME CONSTANT						1	0	0
4.0 SECOND TIME CONSTANT						1	0	1
8.0 SECOND TIME CONSTANT						1	1	0
16.0 SECOND TIME CONSTANT						1	1	1

### Setup Hints

Until you become completely familiar with the SetUp command, the best method of changing setups is to change one parameter at a time and to verify that the change has been made correctly. Attempting to modify all the setups at once can often lead to confusion. If you reach a state of total confusion, the best recourse is to reload the factory setup shown in Table 5.5 and try again, changing one parameter at a time. Use the Read Setup (RS) command to examine the setup information currently in the module as a basis for creating a new setup.

For example: Assume you have a D1111 unit and you wish to set the unit

to echo so that it may be used in a daisy-chain (See Communications). Read out the current setup with the Read Setup command:

**Command:** \$1RS  
**Response:** \*310701C2

By referring to Table 5.3, we find that the echo is controlled by bit 2 of byte 3. From the RS command we see that byte 3 is currently set to 01. This is the hexadecimal representation of binary 0000 0001. To set echo, bit 2 must be set to '1'. This results in binary 0000 0101. The new hexadecimal value of byte 3 is 05. To perform the SU command, use the data read out with the RS command, changing only byte 3:

**Command:** \$1WE (SU is write-protected)  
**Response:** \*  
**Command:** \$1SU310705C2  
**Response:** \*

Verify that the module is echoing characters and the setup is correct.

By using the RS command and changing one setup parameter at a time, any problems associated with incorrect setups may be identified immediately. Once a satisfactory setup has been developed, record the setup value and use it to configure similar modules.

If you commit an error in using the SetUp command, it is possible to lose communications with the module. In this case, it may be necessary to use the Default Mode to re-establish communications.

The DA, EA, HI, and LO commands affect some of the bits of the setup data that are associated with alarms. If these commands are performed, the setup data read back with the Read Setup command may not correspond exactly with the data previously written with the SetUp command.

### Table 5.5 Factory Setups by Model.

(All modules from the factory are set for address '1', 300 baud, no parity)

Model	Setup Message
D111X, D115X, D121X, D123X, D125X	310701C2
D112X, D124X	31070182
D110X, D113X, D114X	31070142
D13XX, D155X, D156X	31070142
D141X, D142X, D143X, D146X	31070182
D145X, D15XX	310701C2
D16XX	310701C0
D170X	31070100



## Chapter 6

### Digital I/O Functions

The D1000 series features versatile digital I/O capability to interface to auxiliary equipment. The functions available are:

- 1) Digital Outputs
- 2) Digital Inputs
- 3) Alarm Outputs
- 4) Events Counter

#### Digital Outputs

A digital output consists of an open-collector transistor controlled by the host, using the Digital Output (DO) command (See Figure 6.1). The number of digital outputs implemented depends on the specific D1000 model number. Most sensor modules contain two digital outputs and the D1701/2 has eight digital outputs. The open-collector configuration is used to provide maximum versatility in interfacing to solid state relays (SSR's) or to standard logic levels such as TTL or CMOS. Each digital output can sink up to 30mA and can withstand up to 30V. Power in the transistor must be limited to 300mW. The emitter of each transistor is tied to the GND terminal on the input connector.

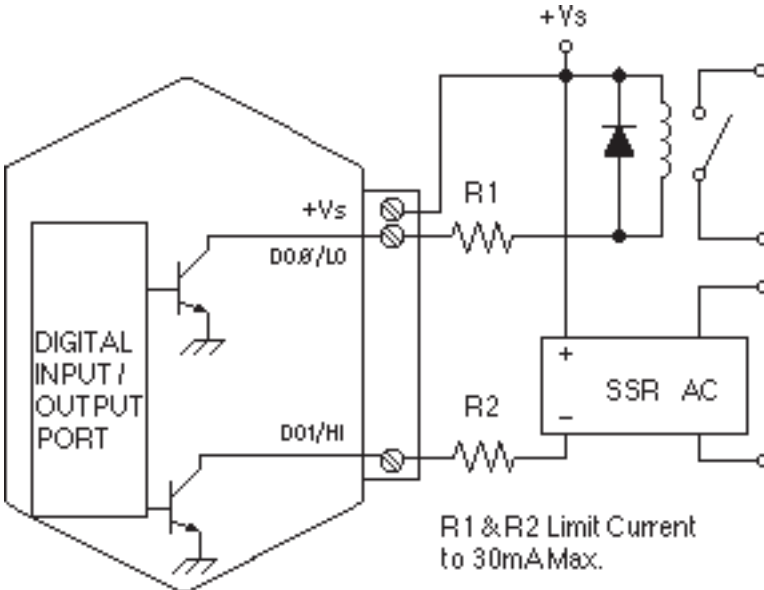


Figure 6.1 Digital Outputs Used With Relays

A typical connection of a digital I/O output is shown in Figure 6.1. In this case, a solid state relay is controlled by the D1000 module. The SSR can then be used to control AC power to alarms, heaters, pumps, etc. A typical

connection to a logic input is shown in Figure 6.2. In some cases, the common-mode voltage of the GND terminal may be significantly different from the ground potential of the logic input to be interfaced. This may occur when the module is powered remotely. In this case, an opto-isolator may be used to eliminate the common-mode voltage. See Figure 6.2. In all cases, the current switched by the transistor may not be more than 30mA.

Only three commands can effect the Digital Output. The Enable Alarms (EA) and Disable Alarms (DA) commands select the function of the DO0/LO and DO1/HI pin outputs. To route digital outputs to these pins, use the Disable Alarms (DA) command. The Enable Alarms (EA) command configures these two pins as alarm outputs. The Enable Alarms and Disable Alarms commands do not affect the other digital outputs, DO2-DO7. The digital outputs are controlled by the host with the Digital Output (DO) command.

If the module loses power, the digital outputs are turned off. The outputs will remain off until switched by a Digital Output (DO) command. The function of the shared pins, DO0/LO and DO1/HI is not affected if power is lost, since this information is stored in nonvolatile memory.

The digital outputs are not affected by the Remote Reset (RR) command.

## Digital Inputs

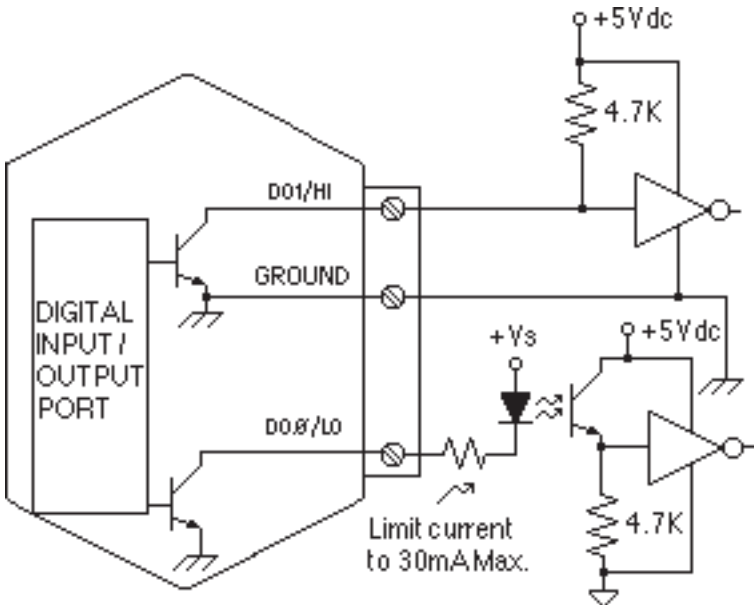


Figure 6.2 Digital Outputs Used With Logic

Digital inputs are used to sense switch closures and the state of digital signals. The inputs are protected to voltages up to  $\pm 30\text{V}$  and are normally pulled up to the logic "1" condition (see Figure 6.3). Digital inputs can be read by the Digital Input (DI) command. Voltage inputs less than  $1\text{ V}$  are read back as '0'. Signals greater than  $3.5\text{ V}$  are read as '1'. No other commands have any affect on the inputs.

Switch closures can be read by the digital input by simply connecting the switch between GND terminal and a digital input. Internal pull-ups are used so additional parts are unnecessary.

The pull-ups supply only  $0.5\text{ma}$ ; therefore, self-wiping switches designed for low current operation should be used. For other types of switches, it may be necessary to provide extra pull-up current with an external resistor. The resistor should be tied between the switch and  $+V$ .

Connection to logic outputs is shown in Figure 6.2. Opto-isolation is used for isolation and where common-mode exists between the D1000 module and the signal being sensed.

Digital inputs may be used to sense AC voltages by using isolated sensing modules offered by many manufacturers.

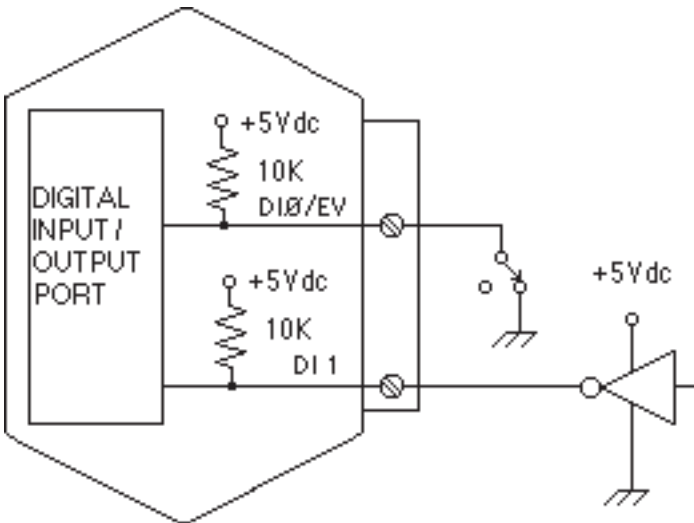


Figure 6.3 Digital Inputs

### Event Counter

The Event Counter input is connected to the Digital Input 0 terminal. It can be used to count any low speed event that occurs on the DI0/EV input. Any of the interfacing techniques described for Digital Inputs may be used. The input pulses must meet the specifications in Figure 6.4 to avoid missing counts. Switch inputs are filtered to eliminate contact bounce.

The Event Counter is read by using the Read Events (RE) command. The maximum accumulated count is 9,999,999. If the maximum count is reached, counting stops. The Event Counter may be cleared to zero with the Clear Events (CE) or Events Read & Clear (EC) command.

The Event Counter is not nonvolatile and the count will be lost if power to the module goes down. Upon power up, the counter is cleared to zero. The Remote Reset (RR) command or a line break will not affect the counter.

## ALARM OUTPUTS

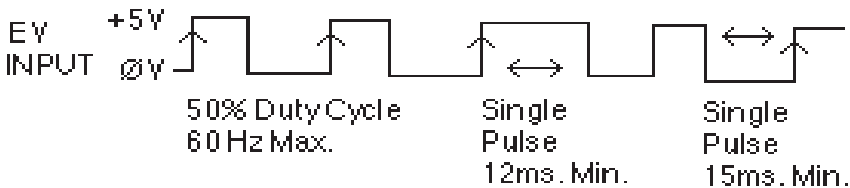
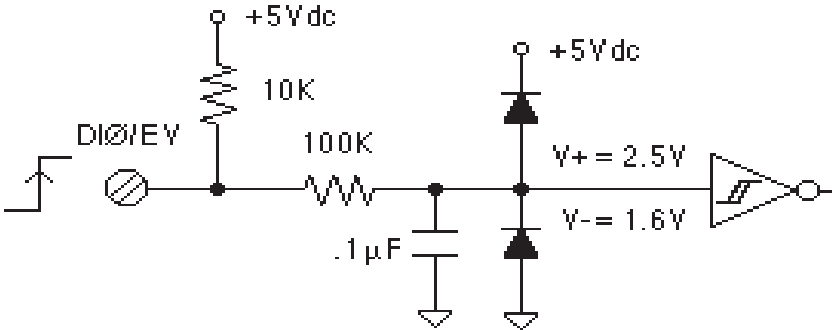


Figure 6.4 Events Counter Circuit

The D1000 sensor input modules perform HI/LO limit checking by comparing the sensor input value to downloaded HI/LO limit values stored in memory (see HI and LO commands). The result of the limit check can be used to control special HI and LO digital outputs.

The DO0/LO and DO1/HI output pins can be configured to be alarm outputs by using the Enable Alarms (EA) command. After performing an EA command, the state of the DO0/LO and DO1/HI pins will be controlled by the alarm settings. The EA command does not affect the other digital outputs, DO2-DO8. The Disable Alarms (DA) command is used to disconnect the alarms from the output pins whereupon they are controlled by the Digital Output (DO) command.

Since the Alarm Outputs share the same circuits with the Digital Outputs, all electrical interfacing considerations are the same.

Alarm limit values are loaded into the module with the Low limit (LO) and Hi limit (HI) commands. The limit values are stored in nonvolatile memory so they will not be lost when power is removed. The HI and LO commands are also used to specify whether the alarms are momentary or latching. If an alarm is specified as momentary, the alarm is activated as long as the alarm condition exists. The alarm output will turn off when the input is within limits. A Latching alarm is activated when the specified limit is exceeded and will remain on even if the input value returns within limits. A Latching alarm can be turned off with the Clear Alarms (CA) command. The HI alarm output is turned on (sinking current) when the measured sensor input is greater than the high limit loaded in with the HI command. The LO alarm output is turned on (sinking current) when the input value is less than the stored low limit.

The alarm limit values may be read back at any time using the Read Low (RL) or Read High (RH) commands.

### **ON-OFF CONTROLLERS**

The alarm capabilities of the D1000 sensor-input modules may be utilized to construct simple ON-OFF controllers that operate without host intervention. In fact, since all the alarm information is stored in nonvolatile memory, the module can act as a stand-alone controller with the communications lines disconnected.

The simplest controller connection is to use a momentary alarm output to control the process. A typical application would have a temperature input module controlling a heater, as shown in Figure 6.5. To maintain a constant temperature, set the low limit to the setpoint desired and specify the alarm output to be momentary. Use the LO alarm output to control the heater. If the temperature measurement exceeds the low limit, the heater will be turned off. When the temperature goes below the limit, the LO alarm output goes on, turning on the heater. The negative feedback action of the control output will keep the temperature at the desired value. The high limit is still available to activate an alarm or shut down the system if the temperature goes out of limit.

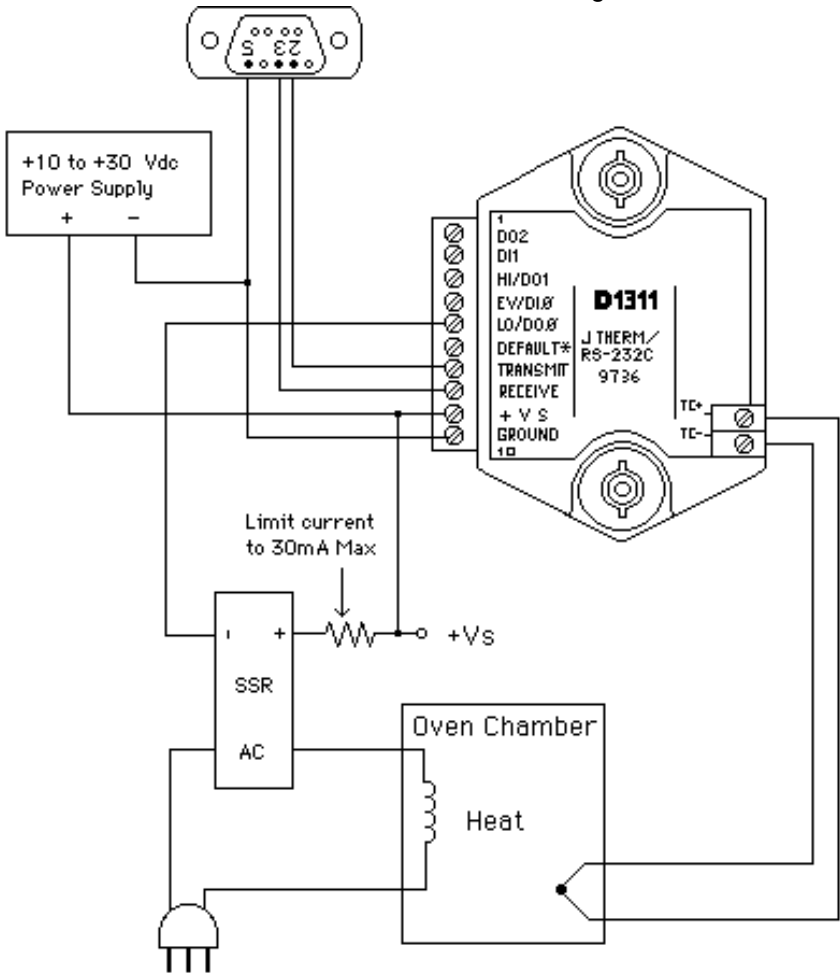


Figure 6.5 On-Off Controller

### ON-OFF CONTROLLER WITH HYSTERESIS

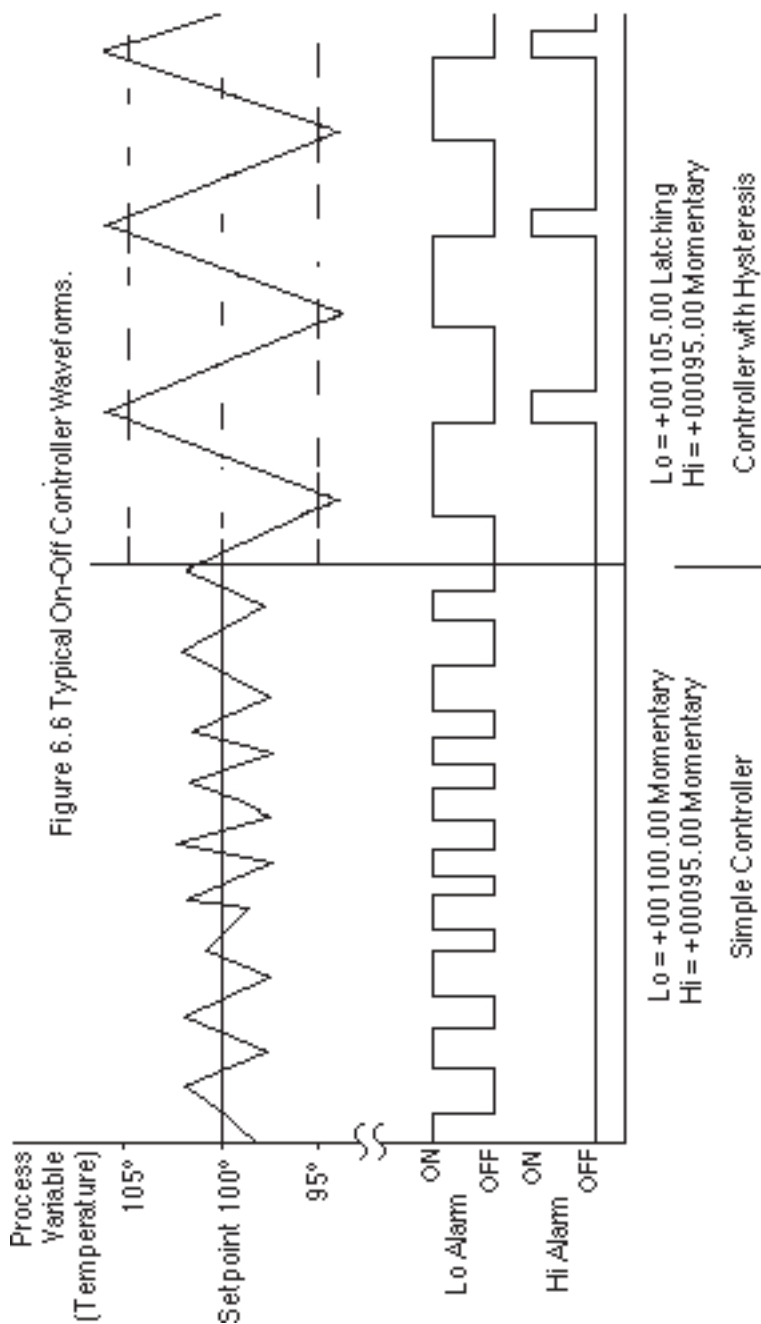
The simple single-value controller, by its very nature, suffers from erratic output that may not be acceptable, particularly when high-power equipment is being controlled. To lengthen the control cycle and to make the control action smoother, hysteresis (dead band) is often used in on-off controllers. With hysteresis, the process variable is controlled between the two setpoints in order to lengthen the duty cycle of the control output. To increase the control duty cycle, the hysteresis, or difference between the setpoints, must be increased. Figure 6.6 shows the effect of hysteresis on the control output.

The high and low alarm limits on the D1000 sensor modules may be set to provide on-off control with hysteresis. The two limits specify the two control setpoints. The difference between the high limit and the low limit is the hysteresis value. The high limit must be greater than the low limit for proper operation. The alarm output used to control the process must be set to the Latching mode. If the control output is turned on, it will remain on until the input data exceeds the second alarm value. At this point the control output is turned off.

A typical example of a controller with hysteresis is illustrated in Figure 6.5. A J-Thermocouple input module such as a D1311 maybe used to regulate the temperature of an oven. The thermocouple is used to sense the oven temperature. The LO alarm output controls a solid state relay (SSR) which in turn controls the oven heater. The Enable Alarms (EA) command must be used to activate the alarm outputs. In this case the desired regulated temperature is 100°C. The Lo alarm is set to 95°C in the latching mode with the LO command. The HI alarm command is used to set the upper limit to 105°C in the momentary mode. The total hysteresis is the difference between the two alarm values, or 10°C. In the steady state condition, the oven temperature will oscillate between 95°C and 100°C (ideally).

Assume the oven temperature is below 95°C. This value is less than the value loaded into the low limit, therefore the LO alarm output is turned on. Since the low alarm is set for latching mode, the control output stays on even as the oven temperature goes above the 95°C low limit. The control output will stay on until the temperature reaches the value loaded into the high limit, in this case 105°C. At this point the latched LO alarm is turned off, turning off the heater. The control output will remain off as the oven cools down through heat losses. When the oven cools to 95°C, the LO alarm is again turned on, and the control process repeats indefinitely. The control signals are shown in Figure 6.6.

In this case the high alarm was set to momentary mode. The high alarm could have been set to the latching mode without affecting the LO alarm output. However, the output at the HI alarm terminal would change. If the high alarm is set to Latching, the alarm output is simply the complement of the LO alarm. Either alarm output may be used for control depending on which one will result in negative feedback. For example, in a refrigeration system, the HI output may be used to control the refrigeration compressor and the low alarm value is used only to set the desired hysteresis value.





## SETPOINT

In the preceding example, the low and high alarm limits are used to specify a hysteresis value around a desired setpoint. To change the desired setpoint, both the low and high alarm values must be changed. In this type of controller operation, the Read Data (RD) or New Data (ND) commands will read out the actual value of the process variable.

The D1000 modules provide a means of downloading a setpoint value without affecting the desired hysteresis by using the Setpoint (SP) command. The Setpoint command is used to load the desired control value into the output offset register (see Figure 2.1). The value in the output offset register is always added to the data derived from the sensor input. For instance, if the sensor data is +00100.00 and the output offset register contains +00050.00, a Read Data command will yield an output of +00150.00. The Setpoint command loads a value into the offset register to null out the sensor data. If the command \$1SP+00100.00 is given to a module with address 1, the effect of the command is to load the output offset register with -00100.00. An RD command will now result in the deviation of the input data from the downloaded setpoint value.

A careful look at Figure 2.1 will reveal that the alarm limits are checked after the output offset is added the input data. To construct a controller using the SP command, the high and low alarms must be loaded with the hysteresis values referred to the deviation from the setpoint value. In the oven controller example, the hysteresis was set to  $\pm 5^{\circ}\text{C}$  from the desired control temperature of  $100^{\circ}\text{C}$ . When using the SP command, the high limit would be set to +00005.00 and the low limit would be set to -00005.00 to get the same hysteresis affect. The Latching modes of the alarm limits are used in the same manner as previously described.

Let's look at the oven controller again using the Setpoint command. The desired oven temperature is  $100^{\circ}\text{C}$ . This time we'll use the SP command to load the  $100^{\circ}\text{C}$  value into the temperature module. As before, we would like a hysteresis band of  $\pm 5^{\circ}\text{C}$  from the nominal temperature of  $100^{\circ}\text{C}$ . In this case, set the low limit to -00005.00 latching and the high limit to +00005.00. The high and low limits are now used solely to define the hysteresis band. If the oven temperature is low, say  $90^{\circ}\text{C}$ , the resulting deviation from the setpoint of  $100^{\circ}\text{C}$  is  $-10^{\circ}\text{C}$ . This value exceeds the low limit and the LO alarm control output is turned on to activate the heater. The latched LO alarm will stay on until the measured temperature exceeds  $105^{\circ}\text{C}$ . At this point the deviation from the setpoint is greater than  $\pm 5^{\circ}\text{C}$ , the value loaded into the high limit. When the high limit is exceeded, the latched LO alarm output is turned off, turning off the heater. The control action is identical to the controller described in Figure 6.6.

The benefit of using SP command is that only one command is necessary to change the setpoint value. The hysteresis is stored in the HI and LO alarm registers and does not have to be changed when a new setpoint is used.

The SP command makes it particularly easy to construct a controller whose setpoint is a time varying function downloaded from a host computer. The SP command can also be used without control functions whenever a deviation output is desired.

The setpoint value may be read back by using the Read Zero (RZ) command. The RZ simply reads back the contents of the output offset register. The RZ command will always read back the setpoint value with the sign changed.

The setpoint value is stored in the same register as the output offset trim (see TZ command). In cases where the output offset register is used to hold a calibration trim value, the SP command will erase the trim. In most cases, an offset calibration trim is not necessary and the trim value would read back as +00000.00 using the Read Zero (RZ) command. If the trim is non-zero, it must be read and stored by the host before the SP command is executed. To download setpoint values the host must then subtract the trim value from the desired setpoint to derive the proper data for the SP command. To restore the trim, use the SP command to download the negative of the trim that was previously read back with the RZ command.

## Chapter 7

### Power Supply

D1000 modules may be powered with an unregulated +10 to +30Vdc. Power-supply ripple must be limited to 5V peak-to-peak, and the instantaneous ripple voltage must be maintained between the 10 and 30 volt limits at all times. The modules contain a low voltage detection circuit that shuts down all circuits in the module at approximately 9.5 Vdc. All power supply specifications are referred to the module connector; the effects of line voltage drops must be considered when the module is powered remotely.

All D1000 modules employ an on-board switching regulator to maintain good efficiency over the 10 to 30 volt input range; therefore the actual current draw is inversely proportional to the line voltage. D1000 modules without sensor excitation consume a maximum of .75 watts and this figure should be used in determining the power supply current requirement. For example, assume a 24 volt power supply will be used to power four modules. The total power requirement is  $4 \times .75 = 3$  watts. The power supply must be able to provide  $3 / 24 = 0.125$  amps.

For modules with sensor excitation, consult individual data sheets for power requirements.

The low voltage detection circuit shuts down the module at approximately 9.5Vdc. If the module is interrogated while in a low power supply condition, the module will not respond. Random NOT READY error messages could indicate that the power supply voltage is periodically drooping below the 10V minimum.

In some cases, a small number of modules may be operated by “stealing” power from a host computer or terminal.

Small systems may be powered by using wall-mounted calculator-type modular power supplies. These units are inexpensive and may be obtained from many retail electronics outlets.

# Chapter 8

## Troubleshooting

### Symptom:

**RS-232 Module is not responding to commands**

**RS-485 Module is not responding to commands**

**Events counter not counting properly.**

**Error in displayed value.**

**Read Data (RD) values are factor of two times normal values.**

**Module responds with ?1 COMMAND ERROR to every command.**

**Characters in each response message appear as graphics characters**

### • **RS-232 Module is not responding to commands**

1. Using a voltmeter, measure the power supply voltage at the +Vs and GND terminals to verify the power supply voltage is constantly between +10 and +30Vdc.
2. Verify using an ohmmeter that there are no breaks in the communications data lines.
3. Connect the module to the host computer and power-up each device (module and computer) then using a voltmeter measure the voltage between RECEIVE and GND. This voltage should be approximately -10Vdc. Repeat the measurement between TRANSMIT and GND terminals and confirm the voltage value to be approximately -10Vdc. If either of the two readings is approximately 0.0Vdc then the communications data lines are wired backwards. Proper communications levels on both TRANSMIT and RECEIVE terminals should idle at -10Vdc.
4. If you are using a serial communications converter (A1000) ensure that the communications Baud Rate switch is set to the proper Baud Rate value.
5. Confirm software communications settings in Host computer match those values being used by the connected module(s).
6. If the Baud Rate value being used in the application is greater than 300 Baud and the module will only communicate 300 Baud then make sure that the DEFAULT\* terminal is not connected to Ground (GND).
7. If the module(s) are being used in a RS-232 daisy-chain communications configuration then ensure that the "Echo Bit" is enabled in the setup(SU) message of each module.
8. If the problem is not corrected after completing the steps above then connect the module by itself to a Host computer as outlined in Chapter 1.0 under "Quick Hook-up". Start the supplied Utility software and please call the factory for further assistance.

• **RS-485 Module is not responding to commands**

1. Perform steps 1, 2, 4, 5 and 6 listed above.
2. Ensure that module RS-485 "Data" line (module terminal pin #7) is connected to the Host RS-485 "Data+" line.
3. Ensure that module RS-485 "Data\*" line (module terminal pin #8) is connected to the Host RS-485 "Data-" line.
4. If the problem is not corrected after completing the steps above then connect the module by itself to a Host computer as outlined in Chapter 1.0 under "Quick Hook-up". Start the supplied Utility software and please call the factory for further assistance.

• **Events counter not counting properly.**

1. Check that the frequency of the signal, being counted is less than 60Hz.
2. Ensure that the signal levels are swinging below +1.0Vdc and greater than +3.5Vdc.

• **Error in displayed value**

Make sure that the °C/°F bit is set to a 0. Otherwise the values will be scaled by the °F equation.

• **Read Data (RD) values are factor of two times normal values**

Ensure that the Degree C/Degree F bit in the setup (SU) message is set to Degree C.

• **Module responds with ?1 COMMAND ERROR to every command**

Ensure that characters in the command message are uppercase characters. All commands consist of uppercase characters only.

• **Characters in each response message appear as graphics characters**

1. Set the communications software parity setting to "M" for 'MARK' parity type and 7 data bits. Or, utilize any parity type in both the module and software other than "NO" parity.
2. In custom written software routines, mask off the most significant bit of each received character to logic "0". Thus forcing the received character to 7-bit ASCII value.

## Chapter 9 Calibration

The D1000 module is initially calibrated at the factory and has a recommended calibration interval of one year. Calibration constants are stored in the EEPROM and may be trimmed using the Trim Span (TS) and Trim Zero (TZ) commands. There are no pots to adjust. Calibration procedure is as follows.

**Voltage and current inputs:** clear the output offset register using the Clear Zero (CZ) command. Zero trims are not necessary due to the built-in auto-zero function. Apply a known calibrated voltage or current to the input of the module. The calibrated stimulus should be adjusted to be near 90% of the full scale output of the modules for best results. Obviously, the accuracy of the calibrated voltage or current must be better than the rated accuracy of the module, which in most cases is 0.02% of full scale. Use the Read Data (RD) command to obtain an output reading. If the output corresponds to the applied input, no calibration is necessary. If the output is in overload, check the circuit connections or use a different input value to obtain an output within the operating range of the module.

To trim the output, use the Trim Span (TS) command. The argument of the TS command should correspond to the desired module output. After performing the TS command, verify the trim with the RD command. For example to trim a D1121 module:

1. Clear the output offset register.

**Command:** \$1WE  
**Response:** \* (CZ is write protected)

**Command:** \$1CZ  
**Response:** \*

2. Apply an input voltage near 90% of rated full scale. In this case we will use a +900mV input voltage that is accurate to at least 0.02%. Obtain an output reading.

**Command:** \$1RD  
**Response:** \*+00900.30

In this case, the output of the module is off by 300 $\mu$ V. To trim:

**Command:** \$1WE  
**Response:** \* (TS is write protected)

**Command:** \$1TS+00900.00  
**Response:** \*

This sequence will trim the output to +00900.00. Verify:

**Command:**    **\$1RD**  
**Response:**    **\*+00900.00**

The module is calibrated.

**Thermocouples:** Disable the cold junction compensation by setting bit 4 in byte 3 of the setup data with the SetUp (SU) command. The module may now be calibrated using a known input voltage. Perform the calibration as described for a voltage input module. Table 9.1 gives recommended calibration points. Due to the nonlinear nature of thermocouples, it may be necessary to repeat the TS command to obtain the desired output. After calibration is complete, enable the cold junction compensation by clearing bit 4 in byte 3 of the setup data.

**RTD:** Use a calibrated resistor mounted directly on the module connector to avoid lead resistance errors. The resistor must be accurate to 0.01% for proper calibration. Recommended calibration points are listed in Table 9.1. Follow the command sequence described for voltage inputs to calibrate the module. Due to the nonlinear nature of RTD's it may be necessary to repeat the TS command to obtain the desired output.

Table 9.1 Calibration Values

Model	Input Stimulus	Output Data	°F
D110X	+9000 $\mu$ V	+09000.00	
D111X	+90mV	+00090.00	
D112X	+900mV	+00900.00	
D113X	+4.5V	+04500.00	
D114X	+9V	+09000.00	
D115X	+90V	+00090.00	
D121X	+9000 $\mu$ A	+09000.00	
D122X	+900 $\mu$ A	+00900.00	
D123X	+90mA	+00090.00	
D124X	+900mA	+00900.00	
D125X	+20mA	+00020.00	
D131X	+39.13mV	+00700.00	+01292.00
D132X	+41.269mV	+01000.00	+01832.00
D133X	+17.816mV	+00350.00	+00662.00
D134X	+68.783mV	+01000.00	+01832.00
D135X	+17.445mV	+01500.00	+02732.00
D136X	+15.576mV	+01500.00	+02732.00
D137X	+10.094mV	+01500.00	+02732.00
D138X	+33.442mV	+01982.00	+03600.00
D141X	300.00 $\Omega$	+00558.00	+01036.40
D142X	300.00 $\Omega$	+00547.60	+01017.70
D143X	134.91 $\Omega$	+00115.00	+00239.00
D145X	206.1 $\Omega$	+00090.00	+00194.00
D146X	3018 $\Omega$	+00140.00	+00284.00
D151X	25mV	+00025.00	
D152X	25mV	+00025.00	
D153X	90mV	+00090.00	
D154X	90mV	+00090.00	
D155X	5.5V	+05500.00	
D156X	5.5V	+05500.00	
D160X	18Khz	+18000.00	
D161X	25 seconds	+25000.00	
D163X	9Khz	+09000.00	
D164X	25 seconds	+25000.00	



# Chapter 10

## Extended Addressing

The D1000 may be configured to a special command format called Extended Addressing. This mode uses a different prompt, either '{' or '}' to distinguish it from the regular command syntax. The major difference in syntax for the Extended Addressing mode is that it uses a two-character address. A typical command in Extended Address mode would look like this:

**Command:**    {01WE  
**Response:**    \*

Both the command and response are terminated with carriage returns. Note that the command uses a two-character address, '01.'

There are two benefits to using Extended Addressing with the D1000:

- 1) Greatly expanded addressing capability.
- 2) Allow for a more structured addressing method in large systems.

With single-byte addressing of the normal command structure, address space is limited to 122 points. Extended addressing allows an addressing range of 249 points.

### Structured Addressing

Even for a relatively small system, it can be advantageous to employ a hierarchical addressing system as used in Fig. 7.1. This is particularly true in systems that consist of many sites that are identical. From a host software standpoint, each site can be treated identically with the same module addresses, with each site having a different D1000 address.

### Extended Address Syntax

The command syntax used with Extended Addressing is quite similar to the normal protocol. The Extended Address commands are initiated with a '{' character (left curly brace, ASCII \$7B), or a '}' character (right curly brace, ASCII \$7E). The '{' prompt is analogous to the '\$' prompt in that it returns the shortest possible response to complete the command. The '}' prompt is similar to the '#' prompt in that the command is echoed and a checksum is generated along with the other data necessary to complete the response. The '\*' response prompt is used in all command forms.

The Extended Address commands use a two-character ASCII address, each character may be one of 122 legal possibilities. Illegal characters are: NULL (\$00), CR (\$0D), \$ (\$24), # (\$23), { (\$7B), and } (\$7E).

Command examples with Extended Address '01':

**Command:** {01WE  
**Response:** \*

**Command:** }01WE  
**Response:** \*01WE27

**Command:** {01RS  
**Response:** \*31070000 (typical)

**Command:** }01RS  
**Response:** \*01RS31070000BB (typical)

Checksums may be appended to commands:

**Command:** {01WE78  
**Response:** \*

All commands that are available with single-byte addressing may be accessed with Extended Addressing, and vice-versa.

## Appendix A ASCII Table

Table of ASCII characters (A) and their equivalent values in Decimal (D), Hexadecimal (Hex), and Binary. Claret (^) represents Control function.

A	D	Hex	Binary	D	Hex	Binary
^@	0	00	00000000	128	80	10000000
^A	1	01	00000001	129	81	10000001
^B	2	02	00000010	130	82	10000010
^C	3	03	00000011	131	83	10000011
^D	4	04	00000100	132	84	10000100
^E	5	05	00000101	133	85	10000101
^F	6	06	00000110	134	86	10000110
^G	7	07	00000111	135	87	10000111
^H	8	08	00001000	136	88	10001000
^I	9	09	00001001	137	89	10001001
^J	10	0A	00001010	138	8A	10001010
^K	11	0B	00001011	139	8B	10001011
^L	12	0C	00001100	140	8C	10001100
^M	13	0D	00001101	141	8D	10001101
^N	14	0E	00001110	142	8E	10001110
^O	15	0F	00001111	143	8F	10001111
^P	16	10	00010000	144	90	10010000
^Q	17	11	00010001	145	91	10010001
^R	18	12	00010010	146	92	10010010
^S	19	13	00010011	147	93	10010011
^T	20	14	00010100	148	94	10010100
^U	21	15	00010101	149	95	10010101
^V	22	16	00010110	150	96	10010110
^W	23	17	00010111	151	97	10010111
^X	24	18	00011000	152	98	10011000
^Y	25	19	00011001	153	99	10011001
^Z	26	1A	00011010	154	9A	10011010
^[	27	1B	00011011	155	9B	10011011
^\	28	1C	00011100	156	9C	10011100
^]	29	1D	00011101	157	9D	10011101
^^	30	1E	00011110	158	9E	10011110
^_	31	1F	00011111	159	9F	10011111
	32	20	00100000	160	A0	10100000
!	33	21	00100001	161	A1	10100001
"	34	22	00100010	162	A2	10100010

A	D	Hex	Binary	D	Hex	Binary
#	35	23	00100011	163	A3	10100011
\$	36	24	00100100	164	A4	10100100
%	37	25	00100101	165	A5	10100101
&	38	26	00100110	166	A6	10100110
'	39	27	00100111	167	A7	10100111
(	40	28	00101000	168	A8	10101000
)	41	29	00101001	169	A9	10101001
*	42	2A	00101010	170	AA	10101010
+	43	2B	00101011	171	AB	10101011
,	44	2C	00101100	172	AC	10101100
-	45	2D	00101101	173	AD	10101101
.	46	2E	00101110	174	AE	10101110
/	47	2F	00101111	175	AF	10101111
0	48	30	00110000	176	B0	10110000
1	49	31	00110001	177	B1	10110001
2	50	32	00110010	178	B2	10110010
3	51	33	00110011	179	B3	10110011
4	52	34	00110100	180	B4	10110100
5	53	35	00110101	181	B5	10110101
6	54	36	00110110	182	B6	10110110
7	55	37	00110111	183	B7	10110111
8	56	38	00111000	184	B8	10111000
9	57	39	00111001	185	B9	10111001
:	58	3A	00111010	186	BA	10111010
;	59	3B	00111011	187	BB	10111011
<	60	3C	00111100	188	BC	10111100
=	61	3D	00111101	189	BD	10111101
>	62	3E	00111110	190	BE	10111110
?	63	3F	00111111	191	BF	10111111
@	64	40	01000000	192	C0	11000000
A	65	41	01000001	193	C1	11000001
B	66	42	01000010	194	C2	11000010
C	67	43	01000011	195	C3	11000011
D	68	44	01000100	196	C4	11000100
E	69	45	01000101	197	C5	11000101
F	70	46	01000110	198	C6	11000110
G	71	47	01000111	199	C7	11000111
H	72	48	01001000	200	C8	11001000
I	73	49	01001001	201	C9	11001001
J	74	4A	01001010	202	CA	11001010
K	75	4B	01001011	203	CB	11001011

A	D	Hex	Binary	D	Hex	Binary
L	76	4C	01001100	204	CC	11001100
M	77	4D	01001101	205	CD	11001101
N	78	4E	01001110	206	CE	11001110
O	79	4F	01001111	207	CF	11001111
P	80	50	01010000	208	D0	11010000
Q	81	51	01010001	209	D1	11010001
R	82	52	01010010	210	D2	11010010
S	83	53	01010011	211	D3	11010011
T	84	54	01010100	212	D4	11010100
U	85	55	01010101	213	D5	11010101
V	86	56	01010110	214	D6	11010110
W	87	57	01010111	215	D7	11010111
X	88	58	01011000	216	D8	11011000
Y	89	59	01011001	217	D9	11011001
Z	90	5A	01011010	218	DA	11011010
[	91	5B	01011011	219	DB	11011011
\	92	5C	01011100	220	DC	11011100
]	93	5D	01011101	221	DD	11011101
^	94	5E	01011110	222	DE	11011110
_	95	5F	01011111	223	DF	11011111
`	96	60	01100000	224	E0	11100000
a	97	61	01100001	225	E1	11100001
b	98	62	01100010	226	E2	11100010
c	99	63	01100011	227	E3	11100011
d	100	64	01100100	228	E4	11100100
e	101	65	01100101	229	E5	11100101
f	102	66	01100110	230	E6	11100110
g	103	67	01100111	231	E7	11100111
h	104	68	01101000	232	E8	11101000
i	105	69	01101001	233	E9	11101001
j	106	6A	01101010	234	EA	11101010
k	107	6B	01101011	235	EB	11101011
l	108	6C	01101100	236	EC	11101100
m	109	6D	01101101	237	ED	11101101
n	110	6E	01101110	238	EE	11101110
o	111	6F	01101111	239	EF	11101111
p	112	70	01110000	240	F0	11110000
q	113	71	01110001	241	F1	11110001
r	114	72	01110010	242	F2	11110010
s	115	73	01110011	243	F3	11110011
t	116	74	01110100	244	F4	11110100

A	D	Hex	Binary	D	Hex	Binary
u	117	75	01110101	245	F5	11110101
v	118	76	01110110	246	F6	11110110
w	119	77	01110111	247	F7	11110111
x	120	78	01111000	248	F8	11111000
y	121	79	01111001	249	F9	11111001
z	122	7A	01111010	250	FA	11111010
{	123	7B	01111011	251	FB	11111011
	124	7C	01111100	252	FC	11111100
}	125	7D	01111101	253	FD	11111101
~	126	7E	01111110	254	FE	11111110
	127	7F	01111111	255	FF	11111111

## Appendix B

### D1600 Data Sheet

The Frequency and Timer Input modules feature a versatile input stage that can be used in a variety of applications. Figure 1 is a block diagram of the input signal conditioning.

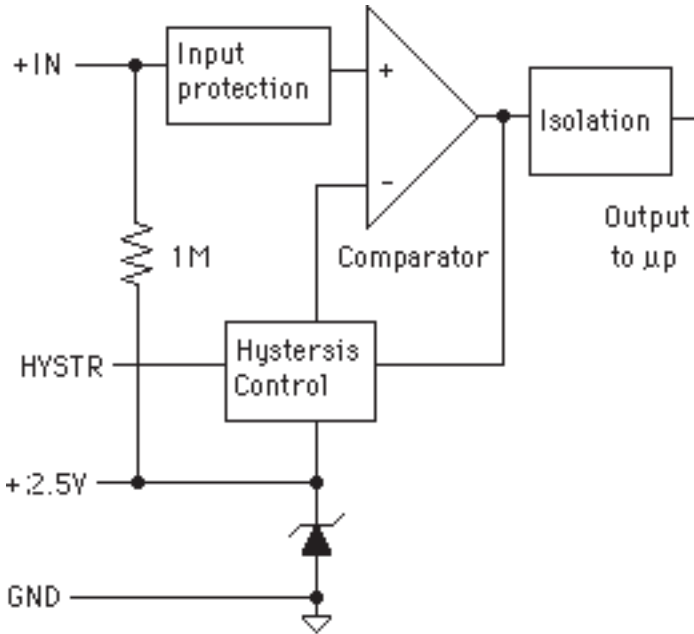
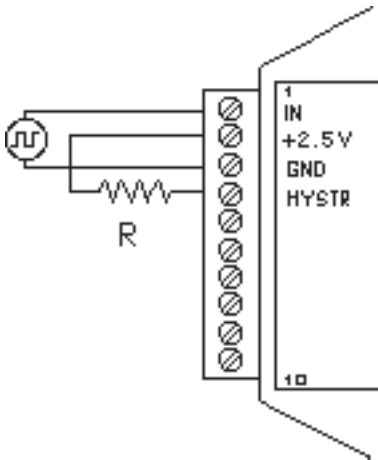


Figure B-1. D1601/2 Input Signal Conditioning Block Diagram.

The input signal is applied to a precision comparator through the + input. Input protection is provided to withstand inputs up to 230Vac. The comparator output is then fed through an opto-isolator to the module's microprocessor for scaling and formatting. The input section is completely isolated from the power and communications lines. The isolation allows up to 500V of common-mode voltage between the input ground and the power connections.

The input comparator employs hysteresis to provide reliable readings with noisy or slow input signals. The amount of hysteresis may be controlled by connecting the hysteresis control line (HYSTR) to ground or the 2.5V terminal through an external resistor. Figure 2 shows the most frequently used connection.



R	$V_{\text{switching}} \pm V_{\text{hysteresis}}$
Open	$2.5V \pm 0.5V$
$\emptyset \Omega$	$2.5V \pm 5mV$
For $V_{\text{hysteresis}} > 5mV$ and	
$< 0.5V$ :	
$34 V_{\text{hysteresis}}$	
$R \text{ (in K}\Omega\text{)} =$	$0.5 - V_{\text{hysteresis}}$

Figure B-2. Controlling Hysteresis For Positive-Going Signals

This connection is used for unipolar positive-going frequency signals. The hysteresis is centered around a +2.5V switching level. If R is left open, the switching levels are +3V and +2V, or  $2.5V \pm 0.5V$ . If R is shorted, the hysteresis decreases with resulting switching levels of  $2.5V \pm 5mV$ . Any hysteresis value from  $\pm 5mV$  to  $\pm 0.5V$  may be obtained by selecting an appropriate value for R. Figure B-2 shows the relationship between the hysteresis and R.

The input comparator may be setup for comparisons around zero volts by using the connections in Figure B-3. This connection is useful for AC or bipolar signals. Since the input section is isolated, the +2.5V pin may be connected to any signal with a common-mode voltage up to 500V. With the hysteresis control connected as in Figure B-3, the switching points occur symmetrically on either side of the +2.5V level. Since the low side of the input signal is connected to the +2.5V pin, the switching points appear to be symmetrical to zero, as referenced to the input signal. The hysteresis may be varied from  $\pm 5mV$  to  $\pm 0.5V$  as shown in Figure B-2.



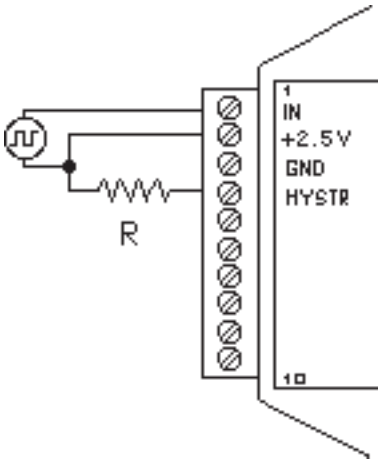
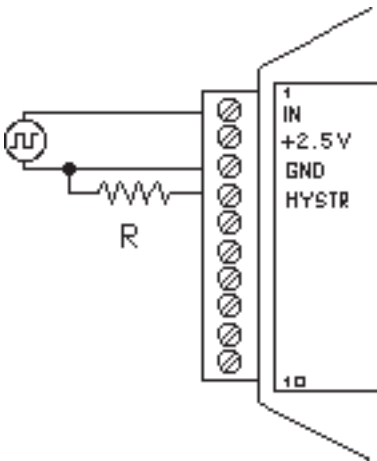


Figure B-3. Controlling Hysteresis For Bipolar Signals.



R	$V_{\text{switching}} \pm V_{\text{hysteresis}}$
Open	$2.5V \pm 0.5V$
$\emptyset \Omega$	$1.7V \pm 5mV$

For  $V_{\text{hysteresis}} > 5mV$  and  $< 0.5V$ :

$$R \text{ (in } K\Omega) = \frac{34 V_{\text{hysteresis}}}{0.5 - V_{\text{hysteresis}}}$$

$$V_{\text{switching}} = 2.5 - \frac{14}{17 + R}$$

Figure B-4. Controlling Switching Level and Hysteresis.

The hysteresis control may also be connected to ground (GND), which produces another set of switching levels. This connection is shown in figure B-4. If the HYSTR terminal is shorted to GND the nominal switching point is 1.6V with  $\pm 5mV$  of hysteresis.

To measure AC signals super-imposed on a DC value, the input may be AC coupled by simply placing a capacitor in series with the +IN terminal. The

module contains an internal 1M $\Omega$  resistor connected from the +IN to +2.5V for biasing. A .01 uf cap may be used for frequencies down to 10HZ.

### D1630/D1640 Accumulator Modules

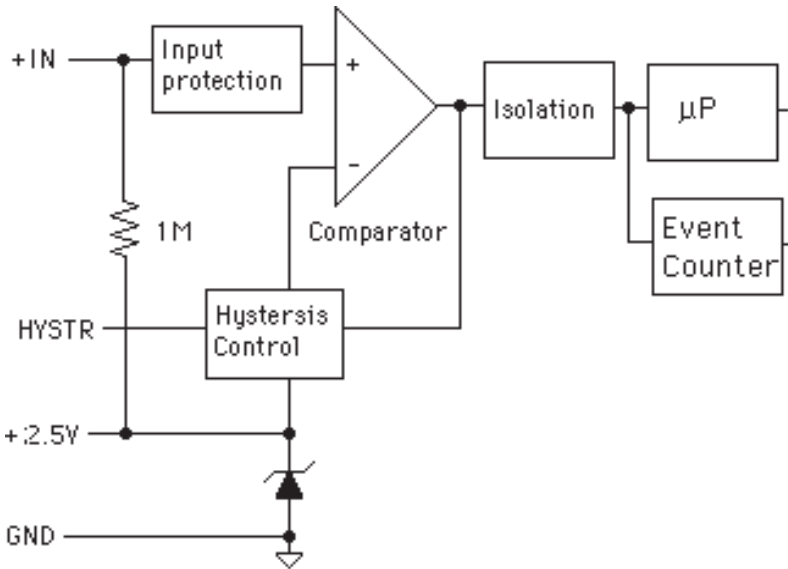


Figure B-5. Accumulator Block Diagram.

The Accumulator models are: D1631, D2631, D1632, D2632, D1641, D2641, D1642 and D2642 are designed for applications that require reading and accumulating pulse type information. They can accumulate the output of pulse type flow meters or keep track of power consumption by interfacing with a power meter. The Accumulator modules combine a frequency or pulse input circuit with an event counter. These modules allow a host computer to read both rate and total count of events. As shown in figure B-5 the input signal is passed through a comparator and the output of the comparator is sent to the microprocessor and to an event counter. Use the Read Data (RD) command to read the instantaneous value or rate of the frequency or pulse input. Use the Read Events (RE) command to read the total of events since the last time the event counter was cleared. Use the Events Clear (EC) command to read the total of events since the last time the event counter was cleared and clear the counter. The event counter will count up to 10 million transitions.

## Event Counter

The Event Counter input is connected to the Digital Input 0 terminal. It can be used to count any low speed event that occurs on the DI0/EV input. Any of the interfacing techniques described for Digital Inputs may be used. The input pulses must meet the specifications in Figure 6.4 to avoid missing counts. Switch inputs are filtered to eliminate contact bounce.

The Event Counter is read by using the Read Events (RE) command. The maximum accumulated count is 9,999,999. If the maximum count is reached, counting stops. The Event Counter may be cleared to zero with the Clear Events (CE) or Events Read & Clear (EC) command. The Events Read & Clear (EC) command reads the number of events since the counter was last cleared and automatically clears the count to zero. The EC command eliminates a problem that may occur with a Read Events (RE) and Clear Events (CE) command sequence. Any counts that may occur between the RE-CE sequence will be lost. The EC command guarantees that the counter is read and cleared without missing any counts.

The Event Counter is not nonvolatile and the count will be lost if power to the module goes down. Upon power up, the counter is cleared to zero. The Remote Reset (RR) command or a line break will not affect the counter.

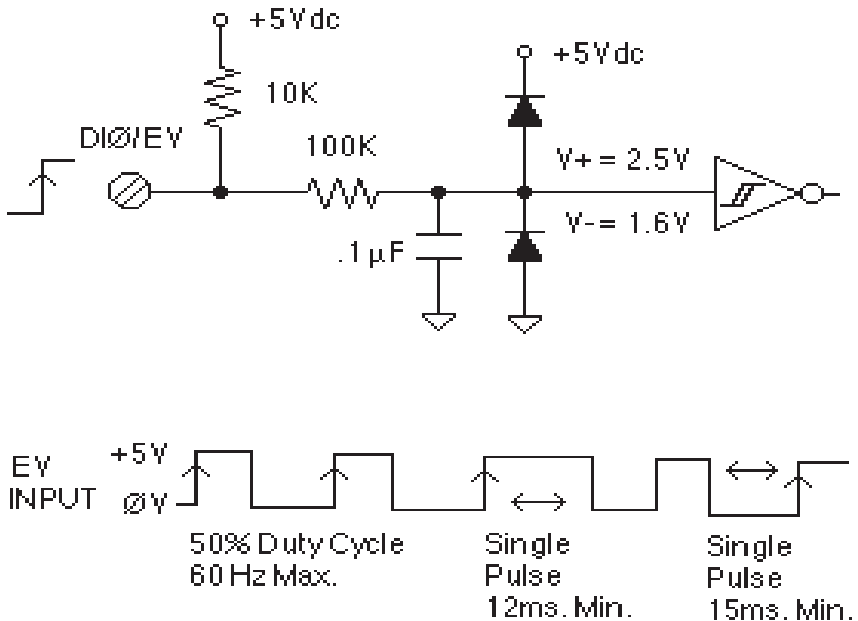


Figure B-6 Events Counter Circuit.

# Appendix C

## D1400 Data Sheet

SPECIFICATIONS: (Typical @ 25°C, V+ = +15V)

RTD Types: .00385, .00388, .00392 100Ω @ 0°C

Resolution: 0.1°

Accuracy: ±0.3°C

Input connections: 2, 3, or 4 wire

Excitation current: .25 mA

Max. Lead resistance: 50Ω

Input protection to 120Vac

Automatic linearization and lead compensation

User selectable °C or °F

Lead resistance effect: 3 wire—2.5°C per Ω of imbalance

4 wire—Negligible

1 Digital Output

### Sensor Hookups

The RTD sensor must be connected as shown in the accompanying diagrams to insure proper operation.

**3-Wire:** The D1400 modules are shipped from the factory configured for 3-wire operation. Connect the RTD sensor as shown in the diagram. The wires connected to the +I and -I terminals should be matched in length and gauged for proper lead compensation. The +I and +SENSE terminals must be tied together at the connector with a short wire jumper. For proper 3-wire lead compensation, the RTD 3/4 wire set-up bit must be 0 (see Set-Up (SU) command). A typical set-up for 3-wire operation would be 31070182.

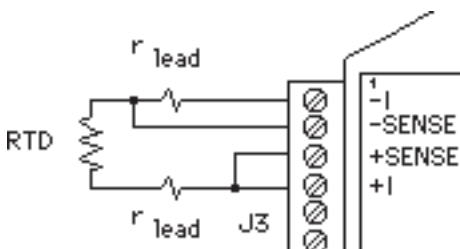


Figure C-1. 3-wire RTD Configuration

**4-Wire:** For 4-wire operation, connect the RTD as shown in the diagram. If the RTD has heavy excitation wires, they should be connected to the +I and -I terminals. For proper 4-wire operation, the RTD set-up bit must be set to 1 (see Set-Up (SU) command). A typical set-up for 4-wire operation would be 31071182.

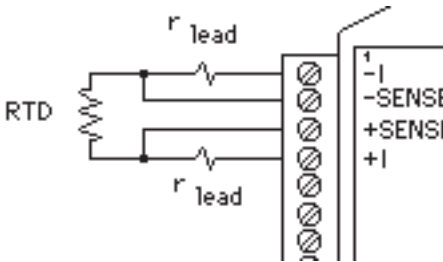


Figure C-2. 4-Wire RTD Configuration.

**2-Wire:** The 2-wire connection requires two jumpers on the connector (J1 & J2) as shown in the diagram. This connection provides no lead compensation. The RTD set-up bit can be either 0 or 1 for this connection.

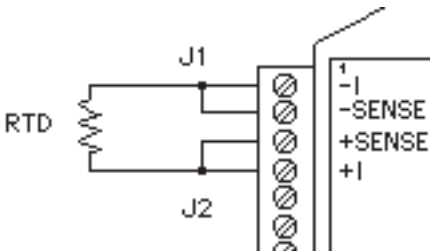


Figure C-3. 2-Wire RTD Configuration.

**Start-Up:** During normal operation, the RTD lead resistance is periodically scanned and filtered by the D1400 module. This may result in large initial errors if the RTD sensor is connected while the D1400 is powered up. To avoid this error, the sensor should be wired to the connector before power is applied. The error may also be eliminated by performing a Remote Reset (RR) command.

**Lead Resistance Overload:** If the lead resistance exceeds 50Ω, the output data is set to +99999.99.

**Sensor Grounding:** The sensor input is electrically isolated from the power and communications inputs for common-mode voltages up to 500V. If the sensor is to be grounded or shielded, the ground connection should be made to the -I terminal.

# Appendix D

## D1500 Data Sheet

The D1500 Bridge Sensor Interface Modules contain all of the signal conditioning functions necessary to interface Strain Gage and other resistive bridge devices to an RS-232C or RS-485 computer port. Each module contains excitation, an instrumentation amplifier, and a smart analog to digital converter to convert resistive bridge sensor signals to ASCII data.

The user should become familiar with the generic D1000 information described in the D1000 User's Manual before attempting any of the procedures outlined below.

### Data Format

The ASCII output data is expressed in millivolts with 10 microvolt resolution. For Example:

**Command:**     **\$1RD**        **(Read Data)**  
**Response:**    **\*+00012.34**

In this case, the output data is 12.34 millivolts.

Modules that are configured for  $\pm 30\text{mV}$  and have a usable span of  $\pm 60\text{mV}$ . Modules configured for  $\pm 100\text{mV}$  have a usable span of  $\pm 120\text{mV}$ . The extra overhead is used to trim any bridge offsets. Modules configured for 1-6V have a usable span of 0-6V with a resolution of 1mV.

### Setup Data

The factory setup for all versions of D1500 modules is 310701C2

### Sensor Connections

See Figure 1 for the proper bridge sensor connections. Shields or grounds should be connected to the -Excitation terminal.

### Offset Trim

The D1500 modules do not provide any means of trimming the analog offset of the sensor bridge. However, sensor offsets may be nulled from the output data with the Trim Zero (TZ) command. This method of trimming is convenient because the offset may be trimmed through the communications port at any time. There is no need to have access to the module since the trimming is performed remotely.

The input signal conditioning circuitry of the D1500 modules have a wide input range to accommodate large sensor offsets without the need for external trims. Modules rated for  $\pm 30\text{mV}$ . have an input range capability of  $\pm 60\text{mV}$ . Modules rated for  $\pm 100\text{mV}$  have an input range of  $\pm 120\text{mV}$ .

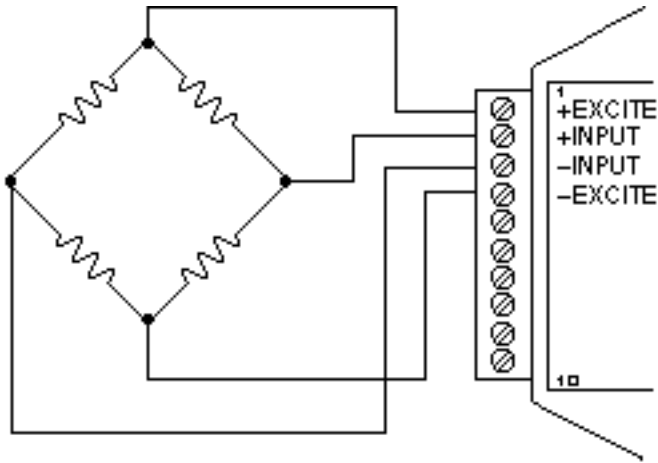


Figure D-1 Bridge Circuit Wiring

To perform an initial offset trim, attach the bridge unit to the module (as shown in Figure 1). Clear out any previous offset trims with the Clear Zero (CZ) command. Apply the desired zero condition to the bridge sensor. For a Strain Gage Bridge this would be the relaxed or unstrained condition. For load cells, the zero condition could include any tare weight due to a weighing platform or other attachments that would affect the zero balance. Obtain an initial reading using the Read Data (RD) command. The output data will indicate the total offset of the system. Subtract the offset value from the usable input range of your module, either  $\pm 60\text{mV}$  or  $\pm 120\text{mV}$ . The result is the maximum usable "input overhead". If the overhead is not sufficient for your application, the bridge must be trimmed externally to lower the offset to an acceptable value. The bridge may be trimmed with a small series resistance or a large shunt resistance to the appropriate leg of the bridge (as shown in Figure 2). If the initial offset is acceptable, the offset may be trimmed with the Trim Zero (TZ) command.

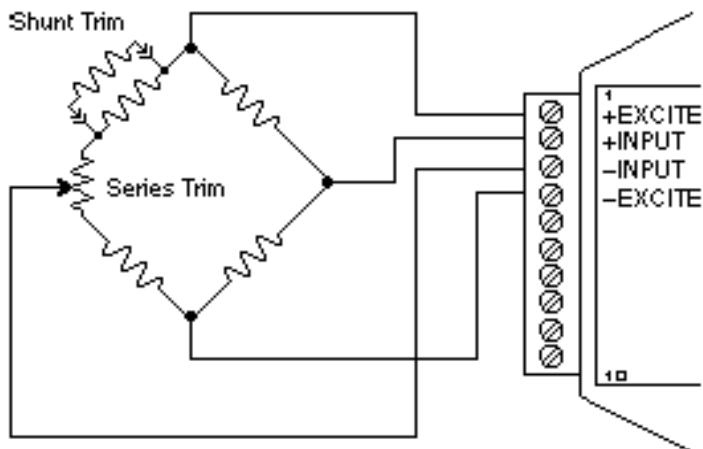


Figure D-2 Bridge Circuit Trim

## Example 1:

A load cell to be used in a weighing application is mated to a D1521 module. The load cell is rated for 3mV/V, which results in a maximum  $\pm 30\text{mV}$  with 10V excitation. However, in this application, the load cell is used only in tension so its ideal output will be from 0 to +30mV.

The load cell is mounted in position with the weighing attachments. Clear any offset data that may be stored in the D1521 module:

**Command:** \$1WE (CZ is write-protected)

**Response:** \*

**Command:** \$1CZ (Clear Zero)

**Response:** \*

Verify that the Zero Trim is cleared:

**Command:** \$1RZ (Read Zero)

**Response:** \*+00000.00

Obtain an initial offset reading from the load cell with no weight attached:

**Command:** \$1RD (Read Data)

**Response:** \*+00002.34



The initial offset is +2.34mV. The D1521 has a useful input range of  $\pm 60\text{mV}$ . After subtracting the offset the "input overhead" is -62.34mV and +57.66mV. The expected 0 to +30mV output of the load cell easily falls within the overhead range and no external trimming is necessary.

To Trim Zero:

**Command:** \$1WE (TZ is write protected)  
**Response:** \*  
**Command:** \$1TZ+00000.00 (zero output)  
**Response:** \*

Now read the data output to verify the trim:

**Command:** \$1RD (Read Data)  
**Response:** \*+00000.00

The load cell system has been trimmed to zero.

Example 2:

A strain gage bridge will be used to measure both compression and tensile strains on a structural member. The bridge is attached to a D1521 module and the ideal output from the bridge is  $\pm 30\text{mV}$  full scale.

Clear the Zero Trim:

**Command:** \$1WE  
**Response:** \*  
**Command:** \$1CZ (Clear Zero)  
**Response:** \*

Measure the initial offset from the bridge:

**Command:** \$1RD  
**Response:** \*-00043.21

In this case, the bridge exhibits a large initial offset of -43.21mV. Subtract this value from the  $\pm 60\text{mV}$  useful range of the D1521 to obtain an "input overhead" value of -16.79mV to 103.21mV. In this case the -16.79mV overhead is not large enough to cover the -30mV that may be obtained from the bridge. The bridge must be trimmed externally to bring the offset to within  $\pm 30\text{mV}$ . It is not necessary to obtain an exact zero with the external trim.

After the external trim has been performed, check the offset:

**Command:** \$1RD  
**Response:** \*-00022.22

This value is within the  $\pm 30\text{mV}$  offset necessary to provide enough headroom for the strain gage bridge.

Trim out the remaining offset with the Trim Zero (TZ) command:

**Command:** \$1WE  
**Response:** \*

**Command:** \$1TZ+00000.00  
**Response:** \*

The bridge is now trimmed to zero. Verify:

**Command:** \$1RD  
**Response:** \* +00000.00

The Trim Zero (TZ) command may be used at any time to balance out offsets due to temperature, residual stress, tare, etc.

### Excitation

D1500 modules may be ordered with either 5V or 10V excitation. Maximum excitation current available is 60mA. Modules with 10V excitation may be used with bridges that have input impedances of 166 ohms or greater. Half-bridges of  $120\ \Omega$  strain gages may be used with 10V excitation if the bridge is completed with  $350\ \Omega$  resistors. Modules with 5V excitation will source bridges of  $85\ \Omega$  and up.

The actual excitation voltage may vary  $\pm 0.5\text{V}$  from the nominal values of +10V and +5V. However, the module's internal microprocessor constantly monitors the actual excitation voltage and provides compensation for any deviation from the nominal value. This results in a constant data output for a constant bridge load even if the excitation changes. From a user's point of view, the excitation voltage will appear to be exactly +10V or +5V.

### Calibration

Since the D1500 modules use a ratiometric technique to compensate for variances in the excitation voltage, special consideration is required to properly calibrate the unit. Figure 3 shows the calibration setup. The Digital Voltmeter (DVM) must be capable of measuring the excitation voltage to 4 digit accuracy. The voltage source must be able to provide millivolt signals accurate to  $\pm 5$  microvolts. The resistive divider may be constructed from 1% resistors of equal value from 100 to  $1000\ \Omega$ . The resistor divider places the voltage source in the center of the common-mode range of the input amplifier for best accuracy.

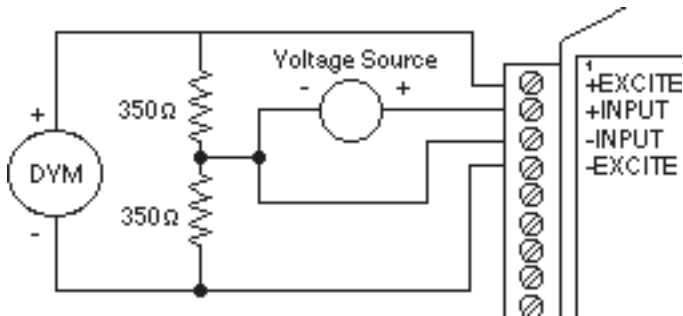


Figure D-3 D1500 Calibration

Step 1: power up the unit under test and let it warm up for at least two minutes.

Step 2: set the voltage source to 0 volts (short). Perform a TZ+00000.00 (Trim Zero) command to eliminate any common-mode offset errors.

Step 3: measure the excitation voltage with the DVM. Divide the result by the nominal excitation voltage, either 10V or 5V, to obtain a "compensation factor" = CF.

Step 4: calculate the correct calibration voltage to apply to the unit.

For  $\pm 30\text{mV}$  units the voltage is  $V = +50\text{mV} \times \text{CF}$

For  $\pm 100\text{mV}$  units the voltage is  $V = +100\text{mV} \times \text{CF}$

Set the voltage source to the calculated voltage V.

Step 5: trim the unit with the Trim Span (TS) command.

For  $\pm 30\text{mV}$  modules the command is \$1TS+00050.00

For  $\pm 100\text{mV}$  modules the command is \$1TS+00100.00

Step 6: verify the trim using the \$1RD command. The result should be either \*+00050.00 or \*+00100.00

**Calibration Example:**

We wish to calibrate a D1511 module. This unit contains 5V excitation and a  $\pm 30\text{mV}$  input.

Step 1 is straightforward and needs no further explanation.

Step 2: set the voltage source to 0 volts. Trim zero:

**Command:** \$1WE  
**Response:** \*

**Command:** \$1TZ+00000.00  
**Response:** \*

Step 3: measure the excitation voltage with the DVM. In this example the measured voltage is 4.954V Calculate the “compensation factor”:

$$CF = 4.954/5 = 0.9908$$

Step 4: calculate the calibration voltage:

$$V = +50\text{mV} \times 0.9908 = +49.54\text{mV}.$$

Set the voltage standard to +49.54mV.

Step 5: perform the Trim Span command:

**Command:** \$1WE  
**Response:** \*

**Command:** \$1TS+00050.00  
**Response:** \*

Step 6: verify the calibration, continuing to apply +49.54mV to the input:

**Command:** \$1RD  
**Response:** \*+00050.00

The span trim is now complete. The Trim Zero (TZ) command may be used to trim sensor offsets without affecting the span trim.

**Options**

All D1500 units come standard with a Digital Output/Low Alarm output. This connector pin may be factory configured for a Digital Input/Event Counter input. Consult factory.

**Continuous Output**

Any of the D1000 sensor input modules may be factory configured to provide continuous output data without interrogation from the host. This option is ideal for use with LED display panels to provide a continuous visual output.

To specify continuous output, add a "C" suffix to the model number; D1511C for example.

### **Programmable Scaling**

The D2500 series of interface modules are bridge units similar to the D1500 series except that the input/output transfer function may be programmed by the user. Output data may be scaled to any desired engineering units such as pounds, psi, Newtons, etc. Nonlinear functions may also be programmed into the module. All scaling data is stored in nonvolatile memory and may be reprogrammed any number of times. Call factory for details.

### **Bridge Completion Resistors**

For convenience, standard bridge completion resistors may be obtained from the factory. Standard values available are 120  $\Omega$  and 350  $\Omega$ .

## Appendix E

### D2000 Series

The D2000 series is an enhancement of the D1000 series. As shipped from the factory, the D2000 modules operate in the same manner as their D1000 counterparts. For example, a D2111 shipped from the factory contains the same transfer function as a D1111 module; in this case they are both  $\pm 100$  mV inputs and communicate with RS-232C.

**Before any attempt is made to program a D2000, you must first be familiar with the operation of a D1000 module as described in this manual. That is why you received both the D1000 manual and the D2000 programming manual with your purchase of the D2000. Please refer to Chapter 1 "Getting Started" of this manual.**

The D2000 series hardware is similar to the D1000 series in every respect except that the D2000 contains built-in commands to create custom input-to-output transfer functions. All programming is performed through the communications port of the D2000 module. There is never any need to open the module case. Modules may be re-ranged remotely as many times as desired. Function data is stored in nonvolatile memory to retain the scaling even if power is removed.

## **Appendix F**

### **D1000/2000 Continuous Operation**

All D1000/2000 computer interface modules may be factory-configured to provide continuous output of analog input data. A D1000/2000 continuous module is intended for applications where no host computer is present. The limitation to the continuous mode is that only one module can be on the communications line.

Continuous output may be ordered by adding a "C" suffix to the model number. For example, a D1111 with the continuous output option may be ordered by specifying model number D1111C.

Interfaces with the "C" option have one connector pin labeled CONT\*. This input pin is used to activate the continuous mode. The "\*" in CONT\* label indicates that the signal is active low. The CONT\* signal is pulled up internally in the module and is voltage protected up to  $\pm 30\text{Vdc}$ .

If the CONT\* line is left open or pulled high ( $>3.5\text{Vdc}$ ), the module will operate normally as described in the manual. The only change is that the CONT\* input occupies a pin normally used for a digital input or output.

If the CONT\* input is pulled low or shorted to GND, the module will continuously output the analog input data. The data output is transmitted in the "short form" response format. For example, a typical output would look like \*+00100.00. Each data message starts with an asterisk (\*) and is terminated with a carriage return. Communication delays and line feeds may be added if necessary using the Set Up Command (see manual).

When the CONT\* input is held low, the module will not respond to any input commands. Usually this is not a problem since in most cases a continuous-output module is used in a dedicated output-only application. If it is necessary to send commands to the module, some means of switching the CONT\* line must be employed. This may be in the form of a simple toggle switch between the CONT\* line and GND. The switch may be located local to the module or a dedicated wire may be run from the module to the host.

If a module with RS-232 communications is used with a host computer, the continuous mode may be controlled by running a wire from the CONT\* pin to an RS-232 control signal, such as Request To Send (RTS). The RTS signal may be turned on and off by the computer to select continuous or normal mode. The CONT\* input will handle the RS-232 voltage levels since it is protected to  $\pm 30\text{Vdc}$ .

For dedicated output-only applications the RECEIVE input of RS-232 modules serves no purpose and may be disconnected to eliminate one wire connection to the host. In this case, be sure to connect the RECEIVE input to GND to prevent a line break condition.

In continuous mode, a module will output data after every A/D conversion, or approximately eight times a second. For baud rates of 300 and 600, the repetition rate is limited by the time required for communications.

When using higher baud rates, you may notice a slight pause in the data output after every 15 conversions. This pause is created when the module performs an internal auto-calibration cycle and is part of normal operation.

### **Setup with computer**

The first issue before configuring the modules is to determine the application baud rate. This is the data rate for communicating information from the analog input module to the analog output module. This value is normally governed by the modems being used or the length of cable in hard-wired systems. Some modems communicate at many baud rates while others are limited to one or two baud rate values. Hard-wired systems that run over long distance should consider baud rates of 9600 baud or less. Remember, only eight new readings will be transmitted from the analog input module in one second and those readings will be transmitted about once every 125 milliseconds. Therefore, the highest baud rates are not really necessary.

Once baud rate is determined, the modules can be properly configured. In most cases, the majority of other pre-installed factory settings in both the analog input and output module will work "as is". The Baud Rate is the only parameter that must be changed in the analog input module. The Baud Rate and "Continuous Enabled" bit must be changed in the analog output module.

**Step1.** The S1000 utility software is the best way to alter the setup message in each module. This program will run on any personal computer that is DOS compatible. The configuration process for both modules should take about 10 minutes after all wiring connections have been made.

Connect the analog input module to a computer serial port (either COM1: or COM2:) using the "Figure 1.1 RS-232C Quick Hook-Up" drawing in Chapter 1 of this users manual. Note that a power supply is also required. Once the connections are made turn the power supply on and



execute the S1000 utility software (filename = 100030.exe). At the main menu, select HOST and specify the correct serial computer port. All remaining host values should not have to be changed. Press <ESC> key and return to main menu when port selection is complete.

**Step 2.** Select main menu “SETUP” and enter a module address and model number. If the module “DEFAULT\*” pin is grounded (connected to GND terminal) then enter address “1” and press <ENTER>. Enter the correct model number located on the module label and press <ENTER>. The module setup information will then be read and displayed for editing.

The Baud Rate value is the only value that must change in most cases. With the mouse pointer, double-click on the Baud Rate box and increment to the desired value. Press the “+” key to increment the value if a mouse is not available. After the value has been changed, depress the <F10> function key to download the new setup value. Press “N” not to reset the remote device. The analog input module is now configured.

Press the <ESC> key and return to the main menu. Turn the module power supply off and remove the black screw terminal plug from the side of the analog input module.

**Step 3.** Plug the screw terminal plug, that is connected to the computer, into the side of the analog output module and turn the power supply on. Select main menu “SETUP” and re-enter the address and new model number. If the “DEFAULT\*” pin is grounded, enter address “1” and press <ENTER>. Enter the analog output module model number and press <ENTER>.

The Baud Rate value and “Continuous Enabled” bit are the only values that must change in most cases. With the mouse pointer, double-click on the Baud Rate box and increment to the desired value. Double-click on the “Continuous Input” selection box to “enable” that option. Press the “+” key to increment either value if a mouse is not available. After the values have been changed, depress the <F10> function key to download the new values. Press “N” not to reset the remote device.

The analog output module is now configured. Press the <ESC> key and return to the main menu. Turn the module power supply off and remove the black screw terminal plug from the side of the analog output module. Both modules are now properly configured.

**Install/Test the configuration**

The module setup modifications are complete. Both modules may now be bench tested or installed into the final application. The module power supply and communications connections should be straight forward during installation.

Make sure that the “DEFAULT\*” pin on each module IS NOT connected to ground. For proper “continuous” operation, another pin on each module MUST BE connected to ground. The “CONT\*” pin on the analog input module and the “DI2” pin on the analog output module must both be connected to ground (GND pin).

Turn the power supplies on for both modules, apply an test or real signal input into the analog input module and some corresponding signal level should be output from the output module.

## Appendix G

### RTS Operation

The D1000R/2000R series analog input modules interface to radio and leased telephone line modems. Many of these modems require an RS-232 signal to activate, or “key-up”, the transmitter. They also require adequate delay time for the transmitter to turn on before transmitting data. The amount of delay time required varies between modem types and manufacturers. Typical time periods range from 150ms for leased line modems to 500ms for radio modems.

D1000/2000 modules have a quick response turnaround time. After a module receives a valid command, it takes typically 10ms (RD command) for a module to begin transmitting data. This response time is much too fast for the transmitter delays associated with radio frequency and leased-line modems. The R series is designed to solve this problem.

The D1000R/2000R series modules each contain a Request-To-Send (RTS) output to synchronize RS-232 data to radio frequency or leased-line modems. The RTS signal is used as a hand-shaking signal to activate and deactivate a modem transmitter. Once the transmitter turns on, it is safe to transmit the data. The RTS signal normally remains on until immediately after the last data character is transmitted.

The D1000R/2000R series modules are designed for applications that contain one analog process point per modem. For applications containing multiple analog points per modem the A2400 Radio Modem Interface is recommended. The A2400 converts RS-232 modem data to RS-485 and provides RS-232 handshaking signals to the modem. The A2400 is used with standard D1000R/2000R series RS-485 modules.

The D1000R/2000R series is similar to the standard D1000/2000 series. This manual is an appendix to the D1000 series manual. Users of the D1000R/2000R RTS modules should read the D1000 series manual. The commands listed below are additional commands found only in the D1000R/2000R series.

#### **THEORY OF OPERATION**

The D1000R/2000R series analog input modules each contain an RS-232 Request-To-Send (RTS) output signal. The RTS signal may be activated using simple ASCII commands. The RTS output signal works together with three user programmable time delays that control the operation of the RTS signal. Each delay has a user-programmable range of 0 to 2000ms and may be set to 1ms resolution. The delay values are stored in EEPROM and must

## RTS Operation G-2

be specified using the standard data format '+#####.##'. Use the write protected commands T1, T2 and T3 to specify the delay time values.

The RTS output function is activated using the RTS+ or RTS- commands. The + and - polarity characters determine the active polarity of the RTS signal while data is being transmitted. The signal polarity can be either active high (typically +Vs) or low (zero volts). Use the RTS+ command to specify an active high output or the RTS- command to specify an active low output. Once the RTS+ or RTS- command is received, the module will store the polarity information in internal EEPROM and the RTS output function will be enabled. The RTS output function will remain enabled until an RTSD command is received by the module.

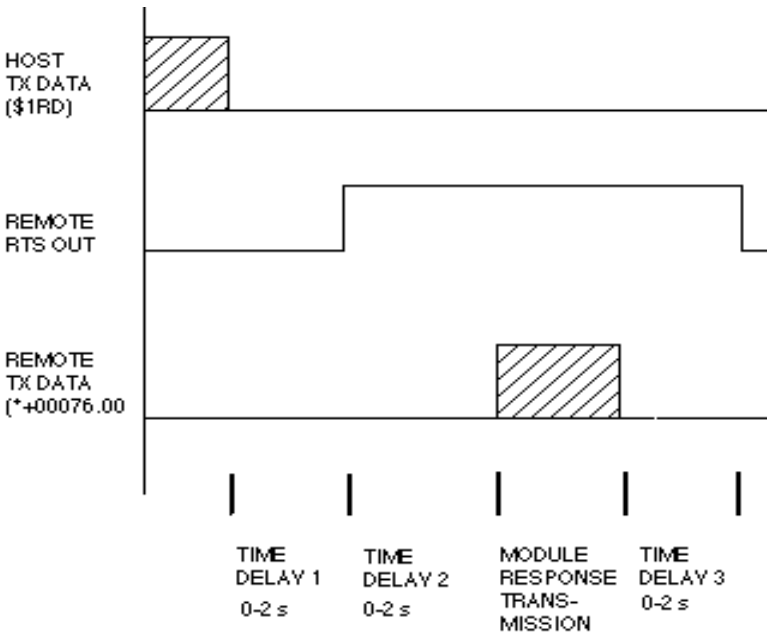


Figure G-1. Timing Diagram.

In addition to the RTS signal three user programmable time delays are provided in the RTS series. As shown in Figure G-1, when the RTS module receives a command it begins the first delay time, T1. After T1 is completed, the module activates the RTS signal to key the radio transmitter. After the RTS signal is activated, delay time T2 started to allow the transmitter adequate time to turn-on. After T2 is completed the module outputs the buffered response data to the RS-232 Transmit line. When the data transmission is complete, the module starts delay time T3. After time T3, the module's RTS signal turns off and is now ready for the next command.

The RTS output and the delay time values are disabled while in Default Mode.

The RTS output is located on digital output bit 0 (DO0/RTS). The digital output is an open-collector transistor and will require an external pull-up resistor. The external pull-up may be eliminated if a module contains one unused digital input bit. All D1000R/2000R series digital input bits contain an internal 10K ohm pull-up resistor to +5Vdc. Simply connect the DO0/RTS terminal to the unused digital input.

## RTS COMMAND SET

Command and Definition		Typical Command Message	Typical Response Message (\$ prompt)
RID	Read Identification	\$1RID	*BOILER
RT1	Read Time Delay #1	\$1RT1	*+00300.00
RT2	Read Time Delay #2	\$1RT2	*+00155.00
RT3	Read Time Delay #3	\$1RT3	*+00035.00
WE	Write Enable	\$1WE	*

### Write Protected Commands

ID	Identification	\$1ID BOILER	*
RTS+	RTS Active HIGH	\$1RTS+	*
RTS-	RTS Active LOW	\$1RTS-	*
RTSD	RTS Disable	\$1RTSD	*
T1	Set Time Delay #1	\$1T1+00300.00	*
T2	Set Time Delay #2	\$1T2+00250.00	*
T3	Set Time Delay #3	\$1T3+00035.00	*

## Identification (ID)

The IDentification command allows the user to write a message into the internal nonvolatile memory which may be read back at any time using the Read IDentification (RID) command. The message may be up to 16 characters long and has no affect on the module operation. Useful information such as the module location, calibration date or model number may be stored for later retrieval.

The ID command is write protected and checksums are not supported. The module will abandon any ID command with a message length in excess of 16 characters.

**Command:** \$1IDBOILER ROOM  
**Response:** \*

**Command:** #1IDBOILER ROOM  
**Response:** \*1IDBOILER ROOM02

### **Read IDentification (RID)**

The Read Identification (RID) command is used to read data previously stored by the ID command. The RID command response message length is variable depending on the stored message length. The maximum response length can be up to 25 characters using the long form prompt and linefeeds enabled.

**Command:** \$1RID  
**Response:** \*BOILER ROOM

**Command:** #1RID  
**Response:** \*1RIDBOILER ROOM54

### **Read Time Delay 1 (RT1)**

The RT1 command is used to read the time delay value previously stored with the T1 command. The value returned is scaled in milliseconds and has a range of 0 to 2000ms.

**Command:** \$1RT1  
**Response:** \*+00100.00

**Command:** #1RT1  
**Response:** \*1RT1+00100.00DC

### **Read Time Delay 2 (RT2)**

The RT2 command is used to read the time delay value previously stored with the T2 command. The value returned is scaled in milliseconds and has a range of 0 to 2000ms.

**Command:** \$1RT2  
**Response:** \*+00550.00

**Command:** #1RT2  
**Response:** \*1RT2+00550.00E6

### **Read Time Delay 3 (RT3)**

The RT3 command is used to read the time delay value previously stored with the T3 command. The value returned is scaled in milliseconds and has a range of 0 to 2000ms.

**Command:** \$1RT3  
**Response:** \*+00035.00

**Command:** #1RT3  
**Response:** \*RT3+00035.00E5

### **Request-To-Send+ (RTS+)**

The RTS+ command enables the RTS output function and sets the active signal polarity to high (positive voltage). The RTS+ command should be selected for modems that require a positive signal level to enable the transmitter. During the idle state, while no data is being transmitted, the RTS output terminal will be low (zero volts).

The RTS+ command is write protected and the polarity value is stored in EEPROM memory. Therefore, all subsequent power ups will activate the RTS+ mode eliminating the need for software initialization. The RTS+ mode will remain active until the module receives a RTSD command.

NOTE: The RTS output function will override any alarm or digital output commands associated with digital output 0.

**Command:** \$1RTS+  
**Response:** \*

**Command:** #1RTS+  
**Response:** \*1RTS+7F

### **Request-To-Send- (RTS-)**

The RTS- command enables the RTS output function and sets the active signal polarity to low (zero volts). The RTS- command should be selected for modems that require a low signal level to enable the transmitter. During the idle state, while no data is being transmitted, the RTS output terminal will be high (positive voltage).

## RTS Operation **G-6**

The RTS- command is write protected and the polarity value is stored in EEPROM memory. Therefore, all subsequent power ups will activate the RTS- mode eliminating the need for software initialization. The RTS- mode will remain active until the module receives a RTSD command.

NOTE: The RTS output function will override any alarm or digital output commands associated with digital output 0.

**Command:** \$1RTS-  
**Response:** \*

**Command:** #1RTS-  
**Response:** \*1RTS-81

### **Request-To-Send Disable (RTSD)**

The RTSD command disables the RTS+ or RTS- function. This command returns digital output DO0/RTS to a normal digital or alarm output. This output will now respond to Digital Output (DO) commands or as alarms.

The RTSD command is write protected and stored in EEPROM. Therefore, the RTS function will remain disabled until another RTS+ or RTS- command is received.

**Command:** \$1RTSD  
**Response:** \*

**Command:** #1RTSD  
**Response:** \*1RTSD98

### **Set Time Delay 1 (T1)**

Time delay T1 is used to guarantee a certain amount of dead time between the completion of a host transmitted command and the beginning of a remote module response transmission. This delay starts immediately after a carriage return character (\$0D) is received by the RTS module.

Time delay T1 has a user programmable time range from 0 to 2000 milliseconds. Once T1 expires the RTS signal will be asserted active and delay time T2 will begin. The examples below would specify a time delay value of 100ms.

**Command:** \$1T1+00100.00  
**Response:** \*



**Command:** #1T1+00100.00  
**Response:** \*1T1+00100.008A

### **Set Time Delay 2 (T2)**

Time delay T2 is used to ensure adequate time is allowed for the modem transmitter to turn on before any data is transmitted. Delay T2 starts immediately after the RTS signal is enabled. Once T2 expires, RS-232 data will be transmitted thru the modem to the host computer. The amount of delay time required is hardware specific and can usually be found in the modem users manual.

Time delay T2 has a user programmable time range from 0 to 2000 milliseconds. The examples below would specify a time delay value of 450ms.

**Command:** \$1T2+00450.00  
**Response:** \*

**Command:** #1T2+00450.00  
**Response:** \*1T2+00450.0093

### **Set Time Delay 3 (T3)**

Time delay T3 is required to hold the RTS signal active for a short period of time after the response data transmission is complete. Delay T3 begins immediately after the module has transmitted the last response message character. Once T3 expires the RTS signal will return to the disabled (off) state.

Time delay T3 has a user programmable time range from 0 to 2000 milliseconds. The examples below would specify a time delay value of 35ms.

**Command:** \$1T3+00035.00  
**Response:** \*

**Command:** #1T3+00035.00  
**Response:** \*1T3+00035.0093

### **Write Enable (WE)**

The EEPROM in each RTS module is write protected against accidental changes of setup or time delay data. To change these write protected values, the WE command must precede each write protected command.

The response to a WE command is an asterisk indicating that the module is ready to accept a write protected command. Once the write protected command is successfully completed, the module will automatically become write disabled. Each write protected command must be individually preceded by a WE command.

If a module is write enabled and the execution of a command results in an error message other than WRITE PROTECTED, the module will remain write enabled until a command is successfully completed resulting in a '\*' response.

**Command:** \$1WE

**Response:** \*

**Command:** #1WE

**Response:** \*1WEF7

# Appendix H

## D1000/2000 Specifications

**Specifications** (typical @ +25° C and nominal power supply unless otherwise noted.)

### Analog

- Single channel analog input.
- Maximum CMV, input to output at 60Hz: 500V rms.
- Leakage current, input to output at 115Vrms, 60Hz: <2 $\mu$ A rms.
- 15 bit measurement resolution.
- 8 conversions per second.
- Autozero & autocalibration—no adjustment pots.

### Digital

- 8-bit CMOS microcomputer.
- Digital scaling, linearization and calibration.
- Nonvolatile memory eliminates pots and switches.

### Digital filtering

- Small and large signal with user selectable time constants from 0 to 16 seconds.

### Events counter

- Up to 10 million positive transitions at 60Hz max., filtered for switch debounce.

### Digital inputs

- Voltage levels:  $\pm$ 30V without damage.
- Switching levels: High, 3.5V min., Low, 1.0V max.
- Internal pull up resistors for direct switch input.

### Digital outputs

- Open collector to 30V, 30mA max. load.

### Alarm outputs

- HI/LO limit checking by comparing input values to down-loaded HI/LO limit values stored in memory.
- Alarms: latching (stays on if input returns to within limits) or momentary (turns off if input returns to within limits).

### Communications

- Communications in ASCII via RS-232C, RS-485 ports.
- Selectable baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200.
- NRZ asynchronous data format; 1 start bit, 7 data bits, 1 parity bit and 1 stop bit.

- Parity: odd, even, none.
- User selectable channel address.
- ASCII format command/response protocol.
- Up to 122 multidrop modules per host serial port.
- Communications distance up to 4,000 feet (RS-485).
- Transient suppression on RS-485 communications lines.
- Communications error checking via checksum.
- Can be used with "dumb terminal".
- Scan up to 250 channels per second.
- All communications setups stored in EEPROM.

### Power

Requirements: Unregulated +10V to +30Vdc, 0.75W max (D1500/D2500, 2.0W max.).

Internal switching regulator.

Protected against power supply reversals.

### Environmental

Temperature Range: Operating -25°C to +70°C.

Storage -25°C to +85°C.

Relative Humidity: 0 to 95% noncondensing.

### Warranty

12 months on workmanship and material.

### D1100/D2100 Voltage Inputs

- Voltage ranges:  $\pm 10\text{mV}$ ,  $\pm 1\text{V}$ ,  $\pm 5\text{V}$ ,  $\pm 10\text{V}$ ,  $\pm 100\text{Vdc}$ .
- Resolution: 0.01% of FS (4 digits).
- Accuracy:  $\pm 0.02\%$  of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max.
- Input burnout protection to 250Vac .
- Input impedance:  $\leq \pm 1\text{V}$  input =  $100\text{M}\Omega$  min.  
 $\geq \pm 5\text{V}$  input =  $1\text{M}\Omega$  min.
- 1 Digital input/Event counter, 2 Digital outputs.

### D1200/D2200 Current Inputs

- Current ranges:  $\pm 1\text{mA}$ ,  $\pm 10\text{mA}$ ,  $\pm 100\text{mA}$ ,  $\pm 1\text{A}$ , 4-20mA<sub>dc</sub>.
- Resolution: 0.01% of FS (4 digits), 0.04% of FS (4-20mA).
- Accuracy:  $\pm 0.02\%$  of FS, 0.04% of FS (4-20mA).
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max. ( $\pm 1\text{A} = \pm 80\text{ppm}/^\circ\text{C}$  max.)
- Voltage drop:  $\pm 0.1\text{V}$  max.
- 1 Digital input/Event counter, 2 Digital outputs.

**D1300 Thermocouple Inputs**

- Thermocouple types: J, K, T, E, R, S, B, C (factory set).
- Ranges: J = -200°C to +760°C      B = 0°C to +1820°C  
           K = -150°C to +1250°C      S = 0°C to +1750°C  
           T = -200°C to +400°C      R = 0°C to +1750°C  
           E = -100°C to +1000°C      C = 0°C to +2315°C
- Resolution:  $\pm 1^\circ$ .
- Overall Accuracy (error from all sources) from 0 to +40°C ambient:  
 $\pm 1.0^\circ\text{C}$  max (J, K, T, E).  
 $\pm 2.5^\circ\text{C}$  max (R, S, B, C)(300°C TO FS).
- Common mode rejection: 100dB at 50/60Hz.
- Input impedance: 100M $\Omega$  min.
- Lead resistance effect: <20 $\mu\text{V}$  per 350 $\Omega$ .
- Open thermocouple indication.
- Input burnout protection to 250Vac.
- User selectable  $^\circ\text{C}$  or  $^\circ\text{F}$ .
- Overrange indication.
- Automatic cold junction compensation and linearization.
- 2 Digital inputs, Event counter, 3 Digital outputs.

**D1400RTDInputs**

- RTD types:  $\alpha = .00385, .00392, 100\Omega$  at 0°C,  
                     .00388, 100 $\Omega$  at 25°C.
- Ranges: .00385 = -200°C to +850°C.  
             .00392 = -200°C to +600°C.  
             .00388 = -100°C to +125°C.
- Resolution: 0.1 $^\circ$ .
- Accuracy:  $\pm 0.3^\circ\text{C}$ .
- Span tempco:  $\pm 50$  ppm/ $^\circ\text{C}$  max.
- Common mode rejection: 100dB at 50/60Hz.
- Input connections: 2, 3, or 4 wire.
- Excitation current: 0.25mA.
- Lead resistance effect: 3 wire - 2.5 $^\circ\text{C}$  per  $\Omega$  of imbalance.  
   4 wire - negligible.
- Max lead resistance: 50 $\Omega$ .
- Input burnout protection to 120Vac .
- Automatic linearization and lead compensation.
- User selectable  $^\circ\text{C}$  or  $^\circ\text{F}$ .
- 1 Digital output.

**D1450 Thermistor Inputs**

- Thermistor types: 2252 $\Omega$  at 25°C, TD Series
- Ranges: 2252 $\Omega$  = -0°C to +100°C.  
           TD = -40°C to +150°C.
- Resolution: 2252 $\Omega$  = 0.01 $^\circ\text{C}$  or F.  
           TD = 0.1 $^\circ\text{C}$  or F

- Accuracy:  $2252\Omega = \pm 0.1^\circ\text{C}$ .  
TD =  $\pm 0.2^\circ\text{C}$
- Common mode rejection: 100dB at 50/60Hz.
- Input protection to 30Vdc .
- User selectable  $^\circ\text{C}$  or  $^\circ\text{F}$ .
- 1 Digital input/ Event counter, 2 Digital outputs.

### D1500/D2500 Bridge Inputs

- Voltage Ranges:  $\pm 30\text{mV}$ ,  $\pm 100\text{mV}$ , 1-6Vdc.
- Resolution:  $10\mu\text{V}$  (mV spans).  
0.02% of FS (V span).
- Accuracy:  $\pm 0.05\%$  of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Input burnout protection to 30Vdc .
- Offset Control: Full input range.
- Excitation Voltage: 5V, 8V, 10Vdc, 60mA max.
- Zero drift:  $\pm 1\mu\text{V}/^\circ\text{C}$  max.
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max.
- 1 Digital output.

### D1600/D2600 Timer and Frequency Inputs

- Input impedance:  $1\text{M}\ \Omega$ .
- Switching level: selectable 0V, +2.5V.
- Hysteresis: Adjustable 10mV-1.0V.
- Input burnout protection: 250Vac.
- 1 Digital input/Event counter.

### Frequency Input

- Range: 1Hz to 20KHz.
- Resolution: 0.005% of reading + 0.01Hz.
- Accuracy:  $\pm 0.01\%$  of reading  $\pm 0.01\text{Hz}$ .
- Tempco:  $\pm 20\text{ppm}/^\circ\text{C}$ .

### Timer Input

- Range: 100  $\mu\text{s}$  to 30s.
- Resolution: 0.005% of reading + 10  $\mu\text{s}$ .
- Accuracy:  $\pm 0.01\%$  of reading  $\pm 10\mu\text{s}$ .
- Tempco:  $\pm 20\text{ppm}/^\circ\text{C}$ .

### Event Counter Input

- Input Bandwidth: 60Hz, (optional 20KHz max) .
- Upto 10 million positive transitions.

### Accumulator Input

- Input Frequency Range: 1Hz to 10KHz.

- Input Timer Range: 100  $\mu$ s to 30s.
- Pulse Count: Up to 10 million positive transitions.
- Resolution: 0.005% of reading + 0.01 Hz (Frequency).  
0.005% of reading + 10  $\mu$ s (Timer).
- Accuracy:  $\pm 0.01\%$  of frequency reading  $\pm 0.01$  Hz.  
 $\pm 0.01\%$  of timer reading  $\pm 10 \mu$ s.
- Tempco:  $\pm 20$  ppm/ $^{\circ}$ C.

### D1700 Digital Inputs/Outputs

D1711, D1712: 15 digital input/output bits.

- User can define any bit as an input or an output.
- Input voltage levels: 0-30V without damage.
- Input switching levels: High, 3.5V min., Low, 1.0V max.
- Outputs: Open collector to 30V, 100mA max. load.
- V<sub>sat</sub>: 1.0V max @ 100mA.
- Single bit or parallel I/O addressing.

D1701, D1702: 7 digital inputs and 8 digital outputs.

- Input voltage levels:  $\pm 30$ V without damage.
- Input switching levels: High, 3.5V min., Low, 1.0V max.
- Outputs: open collector to 30V, 30mA max. load.
- V<sub>sat</sub>: 0.2V max @ 30mA.
- Internal pull up resistors for direct switch input.
- Inputs/Outputs are read/set in parallel.



## D1000 SERIES FOR MODBUS SENSOR TO COMPUTER INTERFACE MODULES



### D1000 FEATURES

- Complete sensor to RS-232/RS-485 interface.
- 500V rms analog input isolation.
- 15 bit measurement resolution.
- Continuous self-calibration; no adjustments of any kind.
- Programmable digital filter.
- Digital inputs and outputs connect to solid state relays.
- Requires +10V to +30Vdc unregulated supply.
- Transient suppression on RS-485 communications lines.
- Screw terminal plug connectors supplied.

### APPLICATIONS

- Process monitoring and control
- Remote data logging to any host computer
- Product testing



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## D1000M SPECIFICATIONS (typical at +25°C and nominal power supply unless otherwise noted)

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### Analog

- Single channel analog input.
- Maximum CMV, input to output at 60Hz: 500V rms.
- Leakage current, input to output at 115Vrms, 60Hz: <math><2\mu\text{A}</math> rms.
- 15 bit measurement resolution.
- 8 conversions per second.
- Autozero & autocalibration—no adjustment pots.

### Digital

- 8-bit CMOS microcomputer.
- Digital scaling, linearization and calibration .
- Nonvolatile memory eliminates pots and switches.

### Digital filtering

- Small and large signal with user selectable time constants from 0 to 16 seconds.

### Digital inputs

- Voltage levels:  $\pm 30\text{V}$  without damage.
- Switching levels: High, 3.5V min., Low, 1.0V max.
- Internal pull up resistors for direct switch input.

### Digital outputs

- Open collector to 30V, 30mA max. load.

### Communications

- Communications in MODBUS-RTU via RS-485 ports.
- Selectable baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200.
- NRZ asynchronous data format; 1 start bit, 8 data bits, 1 parity bit and 1 stop bit.
- Parity: odd, even, none.
- User selectable channel address.
- Up to 246 multidrop modules per host serial port.
- Communications distance up to 4,000 feet (RS-485).
- Transient suppression on RS-485 communications lines.
- All communications setups stored in EEPROM.

### Power

Requirements: Unregulated +10V to +30Vdc ,  
0.75W max (D1500M, 2.0W max.).

Internal switching regulator.

Protected against power supply reversals.

### Environmental

Temperature Range: Operating -25°C to +70°C.  
Storage -25°C to +85°C.

Relative Humidity: 0 to 95% noncondensing.

### Warranty

12 months on workmanship and material.

Specifications are subject to change without notice.

---

### D1100M Voltage Inputs

- Voltages:  $\pm 10\text{mV}$ ,  $\pm 100\text{mV}$ ,  $\pm 1\text{V}$ ,  $\pm 5\text{V}$ ,  $\pm 10\text{V}$ ,  $\pm 100\text{Vdc}$ .
- Resolution: 0.01% of FS (4 digits).
- Accuracy:  $\pm 0.02\%$  of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max.
- Input burnout protection to 250Vac .
- Input impedance:  $\leq \pm 1\text{V}$  input = 100M $\Omega$  min.  
 $\geq \pm 5\text{V}$  input = 1M $\Omega$  min.
- 1 Digital input, 2 Digital outputs.

### D1200M Current Inputs

- Currents:  $\pm 1\text{mA}$ ,  $\pm 10\text{mA}$ ,  $\pm 100\text{mA}$ ,  $\pm 1\text{A}$ , 4-20mAdc.
- Resolution: 0.01% of FS (4 digits), 0.04% of FS (4-20mA).
- Accuracy:  $\pm 0.02\%$  of FS, 0.04% of FS (4-20mA).
- Common mode rejection: 100dB at 50/60Hz.
- Zero drift:  $\pm 1$  count max (autozero).
- Span tempco:  $\pm 50\text{ppm}/^\circ\text{C}$  max. ( $\pm 1\text{A} = \pm 80$  ppm/ $^\circ\text{C}$  max.)
- Voltage drop:  $\pm 0.1\text{V}$  max.
- 1 Digital input, 2 Digital outputs.

### D1300M Thermocouple Inputs

- Thermocouple types: J, K, T, E, R, S, B, C (factory set).
- Ranges: J = -200°C to +760°C    B = 0°C to +1820°C  
K = -150°C to +1250°C    S = 0°C to +1750°C  
T = -200°C to +400°C    R = 0°C to +1750°C  
E = -100°C to +1000°C    C = 0°C to +2315°C
- Resolution:  $\pm 1^\circ$ .
- Overall Accuracy (error from all sources) from 0 to +40°C ambient:  $\pm 1.0^\circ\text{C}$  max (J, K, T, E).  
 $\pm 2.5^\circ\text{C}$  max (R, S, B, C)(300°C TO FS).
- Common mode rejection: 100dB at 50/60Hz.
- Input impedance: 100M $\Omega$  min.
- Lead resistance effect:  $<20\mu\text{V}$  per 350 $\Omega$ .
- Open thermocouple indication.
- Input burnout protection to 250Vac.
- Overrange indication.
- Automatic cold junction compensation and linearization.
- 2 Digital inputs, 3 Digital outputs.

### D1400M RTD Inputs

- RTD types:  $\alpha = .00385$ , .00392, 100 $\Omega$  at 0°C,  
.00388, 100 $\Omega$  at 25°C.
  - Ranges: .00385 = -200°C to +850°C.  
.00392 = -200°C to +600°C.  
.00388 = -100°C to +125°C.
  - Resolution: 0.1 $^\circ$ .
  - Accuracy:  $\pm 0.3^\circ\text{C}$ .
  - Common mode rejection: 100dB at 50/60Hz.
  - Input connections: 2, 3, or 4 wire.
  - Excitation current: 0.25mA.
  - Lead resistance effect: 3 wire - 2.5°C per  $\Omega$  of imbalance.  
4 wire - negligible.
  - Max lead resistance: 50 $\Omega$ .
  - Input burnout protection to 120Vac .
  - Automatic linearization and lead compensation.
  - 1 Digital output.
-

### D1450M Thermistor Inputs

- Thermistor types: 2252Ω at 25°C, TD Series
- Ranges: 2252Ω = -0°C to +100°C.  
TD = -40°C to +150°C.
- Resolution: 2252Ω = 0.01°C or F.  
TD = 0.1°C or F
- Accuracy: 2252Ω = ±0.1°C.  
TD = ±0.2°C
- Common mode rejection: 100dB at 50/60Hz.
- Input burnout protection to 30Vdc .
- 1 Digital input, 2 Digital outputs.

### D1500M Bridge Inputs

- Voltage Ranges: ±30mV, ±100mV, 1-6Vdc.
- Resolution: 10μV (mV spans).  
0.02% of FS (V span).
- Accuracy: ±0.05% of FS max.
- Common mode rejection: 100dB at 50/60Hz.
- Input burnout protection to 30Vdc .
- Offset Control: Full input range.
- Excitation Voltage: 5V, 8V, 10Vdc, 60mA max.
- Zero drift: ±1μV/°C max.
- Span tempco: ±50ppm/°C max.
- 1 Digital output.

### D1600M Timer and Frequency Inputs

- Input impedance: 1MΩ.
- Switching level: selectable 0V, +2.5V.
- Hysteresis: Adjustable 10mV-1.0V.
- Input burnout protection: 250Vac .
- 1 Digital input.

### Frequency Input

- Range: 1Hz to 20KHz.
- Resolution: 0.005% of reading + 0.01Hz.
- Accuracy: ±0.01% of reading ±0.01Hz.
- Tempco: ±20ppm/°C.

### Timer Input

- Range: 100μs to 30 s.
- Resolution: 0.005% of reading +10μs.
- Accuracy: ±0.01% of reading ±10μs.
- Tempco: ±20ppm/°C.

### D1700M Digital Inputs/Outputs

- 7 digital inputs and 8 digital outputs.
- Input voltage levels: ±30V without damage.
- Input switching levels: High, 3.5V min., Low, 1.0V max.
- Outputs: open collector to 30V, 30mA max. load.
- Vsat: 0.2V max @ 30mA.
- Internal pull up resistors for direct switch input.
- Inputs/Outputs are read/set in parallel.

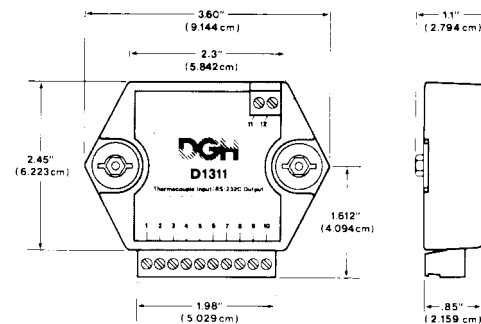
### Mechanicals and Dimensions

Case: ABS with captive mounting hardware.

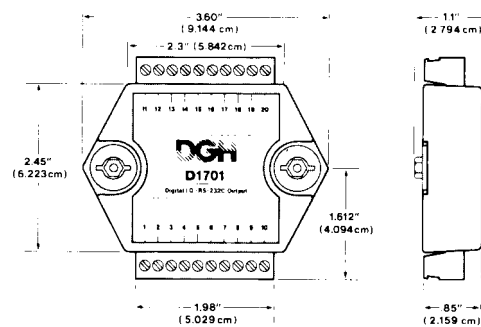
Connectors: Screw terminal barrier plug (supplied).

Replace with Phoenix MSTB 1.5/10 ST 5.08 or equivalent.

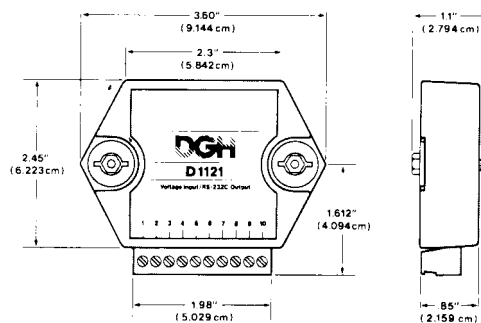
#### D1300 Series



#### D1700 Series



#### D1000/D2000 Series



**NOTE:** Spacing for mounting screws = 2.700" (6.858 cm).  
Screw threads are 6 X 32.

## GENERAL DESCRIPTION

The D1000M Sensor to Computer Modules are a family of data acquisition modules designed for systems based on the Modbus™ RTU protocol. The modules convert analog input signals to digital data and transmit in hexadecimal characters via RS-485 to a controller which may be a computer or other processor-based equipment. The modules can measure temperature, pressure, voltage, current and various types of digital signals. The modules provide direct connection to a wide variety of sensors and perform all signal conditioning, scaling, linearization and conversion to percent of full scale in binary units. Each module also provides digital I/O lines for controlling devices through solid state relays or TTL signals. These digital I/O lines along with built-in limit setting capability provide alarm and control outputs.

The modules contain no pots or switches to be set. Features such as address, baud rate, parity, alarms, echo, etc., are selectable using simple commands over the communications port-without requiring access to the module. The selections are stored in non-volatile EEPROM which maintains data even after power is removed.

The key to the DGH product concept is that the modules are easy to use. You do not need engineering experience in complicated data acquisition hardware. With the DGH modules, anyone familiar with a personal computer can construct a data acquisition system. This modular approach to data acquisition is extremely flexible, easy to use and cost effective. Data is acquired on a per channel basis so you only buy as many channels as you need. The modules can be mixed and matched to fit your application. They can be placed remote from the host and from each other. You can string up to 247 modules on one set of wires by using RS-485 with repeaters.

All modules are supplied with screw terminal plug connectors and captive mounting hardware. The connectors allow system expansion, reconfiguration or repair without disturbing field wiring. Their small size allows them to be mounted in virtually any location or position including explosion-proof housings and DIN rails.

Utility software (S1000) is available on IBM-compatible diskette from DGH to make the D1000M easier to learn and use. S1000 software is provided at no charge on request with a purchase order and is not copy protected.

## THEORY OF OPERATION

Each DGH module is a complete single-channel data acquisition system. Each unit contains analog signal conditioning circuits optimized for a specific input type. Sensor signals are converted to digital data with a microprocessor-controlled integrating A/D converter. Offset and gain errors in the analog circuitry are continuously monitored and corrected using microprocessor techniques. The D1000M converts the digital sig-

nal data and stores the resultant data as two hexadecimal characters in a memory buffer. The modules continuously convert data at the rate of 8 conversions per second and store the latest result in the buffer. Host processors may request data by sending a query to the module. The D1000M will instantly respond by communicating data back to the host processors. Up to 247 modules may be linked to a single RS-485 port. Each module on a serial line is identified by a unique user-programmable address. This addressing technique allows modules to be interrogated in any order.

## DIGITAL INPUTS/OUTPUTS

D1000M modules contain up to three digital outputs and two digital inputs. The digital outputs are open-collector transistor switches that may be controlled by the host processors. These switches may be used to control solid-state relays which in turn may control heaters, pumps and other power equipment. The digital inputs may be read by the host processor and used to sense the state of remote digital signals. They are ideal for sensing the state of limit or safety switches.

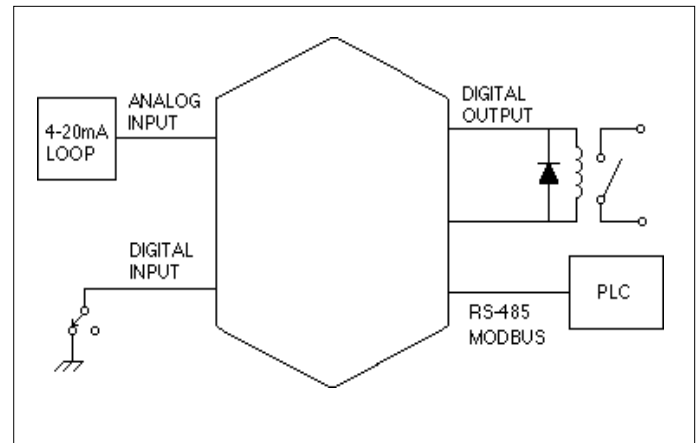


Figure 1 Typical D1000M application.

## USER OPTIONS

To provide maximum flexibility, the D1000M offer a variety of user-selectable options including choice of address, baud rate and parity. All options are selectable using simple commands over the communications port. All option selections are stored in a non-volatile EEPROM that maintains data even after power is removed. The modules contain no pots or switches to be set. All options may be changed remotely without requiring access to the module.

## DIGITAL FILTER

The D1000M options include a unique programmable single pole digital filter. The filter is used to smooth analog data in noisy environments. Separate time constants may be specified for small and large signal changes. Typically a large time constant is specified for small signal changes to filter out noise and provide stable output readings. A smaller time constant may be chosen for large signal changes to provide fast response to such changes.

## COMMAND SET

The D100M series uses the Modbus RTU protocol for communication. The Modbus protocol uses a master-slave technique, in which only the master device can initiate transactions. The slave devices respond by supplying the requested data to the master or by taking the action requested in the query.

The master can address any slave device. The returned messages are considered response messages.

The Modbus protocol format used by a master consists of a device address, a command function code which defines the operation to be performed, data required with the command, and an error checking value. The slave response message contains any required data and error checking value. If an error occurs, an exception code will be generated. The supported master codes are:

- 01 Read Coil Status
- 04 Read Input Register
- 05 Force Single Coil
- 06 Preset Single Register
- 15 Force Multiple Coils

01 Read Coil Status is a digital input such as contact status or contact closure.

04 Read Input Register is the analog input to the module.

05 Force Single Coil is used to set or clear a digital output.

06 Preset Single Register is used to temporarily suspend Modbus RTU mode and return to DGH ASCII protocol mode.

15 Force Multiple Coils is used to set or clear digital outputs.

### Typical Command/Response sequence

A typical Modbus RTU command to a module may look like this:

01 04 00 00 00 01 89 CA

This example is a Modbus Read Input Register command.

The 01 is the address of the slave DGH module being commanded. Each slave device must have its own unique address. The 04 character specifies the Read Input Register command. This is equivalent to the DGH Read Data command to obtain analog input data. The next two characters 00 00 specify the starting address of the registers to be read. The next two characters of this command specify the number of registers to be read, including the starting register. In this case the two binary characters 00 01 indicates only one register is to be read. The final two characters of the command make up the Cyclical Redundancy Check (CRC), used to check for errors in the message.

There are no prompt or terminating characters in the messages. All messages must be transmitted as continuous strings. Messages are terminated by a silent period of at least 3.5 character times.

A typical response to this example command could be:

01 04 02 14 57 F7 CE

The 01 and 04 characters echo the slave address and the command function. For this command function, the 02 character indicates the number of data characters to follow: 2 characters.

The two character string 14 57 is the value read from Modicon input register 30001. Register data is read back as 16 bits. The remaining two characters, F7 CE is the CRC for the response.

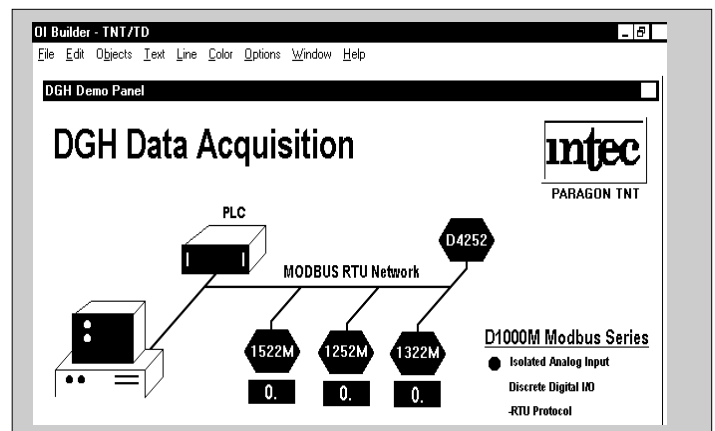
## SETUP

The D1000M series are initiated at the factory using the DGH ASCII protocol. This allows setup and configuration, including the Modbus device address, to be easily performed using the DGH setup software (S1000) or a dumb terminal. Each D1000M module must be properly configured before installation into a Modbus system.

## S1000 UTILITY SOFTWARE

The S1000 utility software diskette contains executable programs that make it easy to configure the D1000M series modules. The S1000 provides executable programs that can be run on IBM PC/XT/AT or compatible computers. An executable menu-driven setup program is provided to simplify configuration of all user-selectable options such as address, baud rate, parity. Context-sensitive help is available during configuration for each selectable parameter. The S1000 is provided at no charge on request with a purchase order and is not copy protected.

## PROCESS CONTROL SOFTWARE



Modbus protocol is supported by virtually all commercial process control software programs available today. These programs operate on IBM AT and compatible personal computers in the Windows, Windows 95, Windows NT and IBM OS/2 environments. Control algorithms such as PID, alarm management, real time and historical trending and system security via password are available in each package.

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## D1000M SERIES ORDERING GUIDE

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### Voltage Input

D1101M 10mV Input/RS-232 Output  
D1102M 10mV Input/RS-485 Output  
D1111M 100mV Input/RS-232 Output  
D1112M 100mV Input/RS-485 Output  
D1121M 1V Input/RS-232 Output  
D1122M 1V Input/RS-485 Output  
D1131M 5V Input/RS-232 Output  
D1132M 5V Input/RS-485 Output  
D1141M 10V Input/RS-232 Output  
D1142M 10V Input/RS-485 Output  
D1151M 100V Input/RS-232 Output  
D1152M 100V Input/RS-485 Output

### Current Inputs

D1211M 10mA Input/RS-232 Output  
D1212M 10mA Input/RS-485 Output  
D1221M 1mA Input/RS-232 Output  
D1222M 1mA Input/RS-485 Output  
D1231M 100mA Input/RS-232 Output  
D1232M 100mA Input/RS-485 Output  
D1241M 1A Input/RS-232 Output  
D1242M 1A Input/RS-485 Output  
D1251M 4-20mA Input/RS-232 Output  
D1252M 4-20mA Input/RS-485 Output

### Thermocouple Inputs

D1311M J Thermocouple Input/RS-232 Output  
D1312M J Thermocouple Input/RS-485 Output  
D1321M K Thermocouple Input/RS-232 Output  
D1322M K Thermocouple Input/RS-485 Output  
D1331M T Thermocouple Input/RS-232 Output  
D1332M T Thermocouple Input/RS-485 Output  
D1341M E Thermocouple Input/RS-232 Output  
D1342M E Thermocouple Input/RS-485 Output  
D1351M R Thermocouple Input/RS-232 Output  
D1352M R Thermocouple Input/RS-485 Output  
D1361M S Thermocouple Input/RS-232 Output  
D1362M S Thermocouple Input/RS-485 Output  
D1371M B Thermocouple Input/RS-232 Output  
D1372M B Thermocouple Input/RS-485 Output  
D1381M C Thermocouple Input/RS-232 Output  
D1382M C Thermocouple Input/RS-485 Output

### RTD Inputs

D1411M .00385 RTD Input/RS-232 Output  
D1412M .00385 RTD Input/RS-485 Output  
D1421M .00392 RTD Input/RS-232 Output  
D1422M .00392 RTD Input/RS-485 Output  
D1431M .00388 RTD Input/RS-232 Output  
D1432M .00388 RTD Input/RS-485 Output  
D1451M 2252 $\Omega$  Thermistor Input/RS-232 Output  
D1452M 2252 $\Omega$  Thermistor Input/RS-485 Output  
D1461M TD Thermistor Input/RS-232 Output  
D1462M TD Thermistor Input/RS-485 Output

### Bridge Inputs

D1511M 30mV Bridge Input, 5V Excitation/RS-232 Output  
D1512M 30mV Bridge Input, 5V Excitation/RS-485 Output  
D1521M 30mV Bridge Input, 10V Excitation/RS-232 Output  
D1522M 30mV Bridge Input, 10V Excitation/RS-485 Output  
D1531M 100mV Bridge Input, 5V Excitation/RS-232 Output  
D1532M 100mV Bridge Input, 5V Excitation/RS-485 Output  
D1541M 100mV Bridge Input, 10V Excitation/RS-232 Output  
D1542M 100mV Bridge Input, 10V Excitation/RS-485 Output  
D1551M 1-6V Bridge Input, 8V Excitation/RS-232 Output  
D1552M 1-6V Bridge Input, 8V Excitation/RS-485 Output  
D1561M 1-6V Bridge Input, 10V Excitation/RS-232 Output  
D1562M 1-6V Bridge Input, 10V Excitation/RS-485 Output

### Timer and Frequency Inputs

D1601M Frequency Input/RS-232 Output  
D1602M Frequency Input/RS-485 Output  
D1611M Timer Input/RS-232 Output Output  
D1612M Timer Input/RS-485 Output Output

### Digital Inputs/Outputs

D1701M 7 Digital Inputs, 8 Digital Outputs/RS-232 Output  
D1702M 7 Digital Inputs, 8 Digital Outputs/RS-485 Output

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# **D1000 MODBUS PROTOCOL**

## **USERS MANUAL**

**September 14, 1998**

DGH CORP.  
PO Box 5638  
Manchester, NH 03108  
Tel: (603) 622-0452  
Fax: (603) 622-0487

## **WARRANTY**

DGH warrants each D1000M series module to be free from defects in materials and workmanship under normal conditions of use and service and will replace any component found to be defective, on its return to DGH, transportation charges prepaid within one year of its original purchase. DGH assumes no liability, expressed or implied, beyond its obligation to replace any component involved. Such warranty is in lieu of all other warranties expressed or implied.

## **WARNING**

**The circuits and software contained in D1000M series modules are proprietary. Purchase of these products does not transfer any rights or grant any license to the circuits or software used in these products. Disassembling or decompiling of the software program is explicitly prohibited. Reproduction of the software program by any means is illegal.**

**As explained in the setup section, all setups are performed entirely from the outside of the D1000M module. There is no need to open the module because there are no user-serviceable parts inside. Removing the cover or tampering with, modifying, or repairing by unauthorized personnel will automatically void the warranty. DGH is not responsible for any consequential damages.**

## **RETURNS**

When returning products for any reason, contact the factory and request a Return Authorization Number and shipping instructions. Write the Return Authorization Number on the outside of the shipping box. DGH strongly recommends that you insure the product for value prior to shipping. Items should not be returned collect as they will not be accepted.

Shipping Address:  
DGH Corporation  
Hillhaven Industrial Park  
RT 28 Bypass  
Hooksett, NH 03106

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# D1000M USERS MANUAL 1

## MODBUS PROTOCOL OVERVIEW

This document describes the Modbus RTU protocol option included in the D1000 series of data acquisition modules. This implementation of the Modbus protocol is a subset of the protocol as described in the Modicon Modbus Protocol Reference Guide PI-MBUS-300 Rev F. Only the RTU version of the protocol has been implemented.

Modbus RTU mode communicates in standard NRZ asynchronous format with one start bit, eight data bits, one parity bit, and one stop bit. Even and odd parity is supported. If no parity is specified, the number of stop bits can be user configured for either one or two stop bits.

Baud rates supported at this time are: 300, 600, 1200, 2400, 4800, 9600, 19,200, 38,400, 57,600 and 115,200 baud.

Modbus uses the RS-485 electrical specification for multidrop communications. The RS-232 electrical specification is not supported.

Modbus is a registered trademark of AEG Modicon Inc.

The Modbus RTU protocol transmits data in 8-bit binary bytes (not ASCII). To illustrate the data in this document, the 8-bit byte is described as two hexadecimal nibbles. For example, the binary byte value "0101 1101" will be written as 5D.

A typical Modbus RTU command may look like this:

```
01 04 00 00 00 01 31 CA
```

***Remember, this command string and others throughout this document are actually transmitted to a module as eight 8-bit binary characters.***

The actual format of the data is dependent on the type of command desired. The example above is the Modbus 'Read Input Registers' function.

The '01' is the address of the slave device (D1000 module) being commanded. Each slave device must have its own unique address.

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The '04' specifies the Modbus 'Read Input Registers' function. This is equivalent to the 'Read Data' command to obtain analog input data.

The next two characters '00 00' specify the starting address of the registers to be read. The first Modicon input register 30001 is addressed as '00 00'. Register 30005 is addressed as '00 04', etc.

The next two characters of this command specify the number of registers to be read, including the starting register. In this case the two binary characters '00 01' indicates only one register is to be read.

The final two characters of the command string make up the Cyclical Redundancy Check (CRC), used to check for errors in the message.

There are no prompt or terminating characters in the messages. All messages must be transmitted as continuous strings. Messages are terminated by a 'silent' interval of at least 3.5 character times. A 'silent' interval of more than 1.5 character times marks the beginning of the next message. Therefore it is mandatory that the RS-485 bus must be biased in the MARK condition during the 'silent' interval. This is usually accomplished by pull-up and pull-down resistors on the communications line.

A typical response to this example command could be:

```
01 04 02 80 00 D8 F0
```

The '01' and '04' characters echo the slave address and the command function.

For this particular command function, the '02' character indicates the number of data characters to follow, in this case, 2 characters.

The two character string '80 00' is the value read from Modicon input register 30001. Register data is read back as 16 bits.

The remaining two characters, 'D8 F0' is the CRC for the response.

The A1000 series of RS-232 to RS-485 protocol converters and repeaters will not operate with the 9-bit data characters used by the Modbus protocol.

# D1000M USERS MANUAL 3

## Getting Started

The D1000M series modules are initialized at the factory to communicate using the D1000 ASCII protocol. This allows for all setup and configurations to be easily performed using the D1000 setup software or a dumb terminal. After the setup process has been completed the D1000M can be placed in Modbus RTU protocol mode using the "MBR" command. Disable the Modbus RTU mode using the Modbus Disable ("MBD") command.

Quick start steps:

1. Connect a power supply to the D1000M between +Vs terminal and GND terminal. The supply voltage must be between +10 and +30Vdc.
2. Properly connect the D1000M series to a computer using the "quick hook-up" diagrams in chapter #1 of this manual using either an RS-232 or RS-485 serial port.
3. Locate the S1000 Utility software diskette and copy files from the S1000 sub-directory on the computer hard drive and run the 1000.bat file.
4. Configure the main menu "Host" RS-232 Port settings and correct COMx: port baud rate. Note: If the "Default\*" pin on D1000M is connected to GND then select 300 baud as host computer baud rate and select no parity.
5. Select main menu "Setup" and enter the D1000M device address and four digit model number. For example, enter 1112 for a D1112M analog input module.
6. At the next configuration screen make alterations to Baud Rate, Parity type and any other required parameters. Press the <F10> function key to transmit the new setup values. Once the values have been transmitted press the <ESC> key back to the program main menu.
7. Select "Misc" followed by "Enable Modbus Mode" to specify the Modbus Slave address. Using the <+><-> keys, or left mouse button, increment the screen address value to desired Modbus Slave address and press <F10> to transmit the value.

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8. Remove the connection between "Default\*" and GND, which performs internal reset, to enable Modbus RTU mode. If there was no connection between "Default\*" and GND then cycle the power on device to force a reset and enable Modbus Mode.

The device is now configured for Modbus RTU mode and can be connected to a RS-485 based Modbus master system.

### **D1000 Modbus Protocol Setup Notes**

D1000M do not have local alarm output capability or Events counters. Therefore, the D1000 ASCII protocol commands CA, CE, DA, EA, EC, HI, LO, RE, RH and RL are not supported. A COMMAND ERROR will be generated in response to any of these commands.

Each D1000M module must contain a unique Modbus device address and the communications settings must be configured properly before installation into a Modbus system..

### **MODBUS Function Codes**

Modbus protocol compatible devices communicate using a master-slave technique similar to that used in ASCII protocol. In a master-slave communications system only one device (the master) can initiate a communications sequence. All others devices (the slaves) respond when requested by the master. Typical master devices can be personal computers or PLCs. Typical slave devices are D1000M modules.

The master can address any slave device. Slave devices return a message to any command that was addressed specifically to them. The returned messages are considered response messages.

The Modbus protocol format used by a master consists of a device address, a command function code which defines the operation to be performed, data required with the command, and an error checking value. The slave response message contains any required data and an error checking value. If an error occurs, an exception code will be generated. The supported master function codes are discussed below.

- 01 - Read Coil Status (Digital Inputs)
- 04 - Read Input Register (Analog Inputs)
- 05 - Force Single Coil (Digital Output)
- 06 - Preset Single Register (Return to D1000 ASCII protocol)
- 15 - Force Multiple Coils (Digital Outputs)

## **Function (01) Read Coil Status (Digital Inputs)**

Modbus function (01) Read Coil Status will read the status of both the digital inputs and digital outputs. Digital outputs are read as the state of the data on the microprocessor output port before being buffered by the open-collector transistor. If the coil status of a digital output returns as '1', this means that this particular bit (coil) is turned "on" or sinking current on the corresponding module digital output pin. Depending on the module type, some of the digital outputs may not be implemented.

Modbus relay input coils are considered digital inputs on the D1000M series modules. Modbus relay output coils are considered digital outputs on the D1000M series modules. This function can be used to read status of the digital inputs or the combined status of both the digital inputs and digital outputs.

D1000M digital output bits DO0 to DO7 correspond to Modbus coils 00 00 to 00 07.

D1000M digital input bits DI0 to DI7 correspond to Modbus coils 00 08 to 00 0F.

The D1000 series digital inputs and outputs are register mapped as two 8-bit bytes (16-bits), one byte for inputs and one byte for outputs. The least-significant byte represent the status of up to 8 digital outputs. The most-significant byte represents the status of up to 8 digital input bits. The register contents can be interrogated as 8-bits of digital input data or together as 16-bits of digital inputs and outputs data.

Exception errors will be generated by the module if attempting to read or write to more than 16 bits.

The following example can be used to read only the digital input status:

**Command: 01 01 00 08 00 08 BC 0E**  
**Response: 01 01 01 FF 11 C8**

In the command string:

01 is the slave address

01 is the Read Coil Status command

00 08 is the starting coil number

00 08 is the number of bits to read

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BC 0E is the CRC to this message

In the response string:

01 is the slave address

01 is the Read Coil Status command

01 is the number of data bytes returned

FF is the Digital Inputs status data

11 C8 is the CRC for this message

The following example can be used to read the status of both the digital inputs and outputs:

**Command: 01 01 00 00 00 10 3D C6**

**Response: 01 01 02 09 FF FF EC**

In the command string:

01 is the slave address

01 is the Read Coil Status command

00 00 is the starting coil address

00 10 is the number digital bits to read

3D C6 is the CRC to this message

In the response string:

01 is the slave address

01 is the Read Coil Status command

02 is the number of data bytes returned

09 is the Digital Output status

FF is the Digital Inputs status

FF EC is the CRC for this message

### **Function (04) - Read Input Register (Analog Inputs)**

Read Input Register function (04) is the primary command to acquire analog input data. This command function supports reading of up to 16 input registers starting from Modbus slave register 30001. The registers are addressed starting from zero meaning registers 1-16 are addressed as 0-15.

The response data for each channel is returned as two bytes that represent a 16-bit binary value. The 16-bit value is scaled as a percentage of the full scale input range. The first byte contains the high order bits and the second contains the low order bits. The binary analog values for each channel can range from 0000-FFFF (hexadecimal).

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Only the register values for channel one are valid as each module contains a single analog input. The remaining data values for channels 2-16 will always return as 0000 (hexadecimal).

A typical command and response to read the analog input value from Modbus device address 01 is:

**Command: 01 04 00 00 00 01 31 CA**  
**Response: 01 04 02 14 57 F7 CE**

In the command string:

01 is the slave address

04 is the Read Input Registers command

00 00 is the starting register to be read (Modbus address 30001)

00 01 specifies the number of registers to be read, in this case, one register.

31 CA is the CRC for this message

In the response string:

01 is the slave address

04 is the command

02 indicated the number of data bytes in the message, in this case, two bytes

14 57 is the analog data

F7 CE is the CRC for this message

This sample command reads two registers:

**Command: 01 04 00 00 00 02 71 CB**  
**Response: 01 04 04 14 58 00 00 7F A7**

The analog data from Modbus register 30001 is 14 58.

The data from Modbus register 30002 is set to 00 00.

The analog data is scaled so that 00 01 represents the Negative Full Scale value programmed into the module. FF FE represents the Positive Full Scale value programmed into the module.

For example, for a  $\pm 10$  volt input module:

00 01 corresponds to -10 volts



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80 00 corresponds to 0 volts  
FF FE corresponds to +10 volts

A negative overload where the analog input exceeds minus full scale value is represented by 00 00 (hexadecimal).

A positive overload where the analog input exceeds the positive full scale value is represented by FF FF (hexadecimal).

### Function (05) - Force Single Coil (Digital Output)

The Force Single Coil function (05) is used to set or clear a single Modbus output relay coil. Each output relay coil is considered a digital output on the D1000 series modules. Modbus Coil #1 equals D1000 series digital output bit DO0 and Coil #8 equals digital output bit DO7 (when available).

The following example can be used to turn on digital output bit DO0:

**Command: 01 05 00 00 FF 00 8C 3A**  
**Response: 01 05 00 00 FF 00 8C 3A**

In the command string:

01 is the slave address

05 is the Force Single Coil command

00 00 is the address of the digital output bit, 00 07 would equal DO7

FF 00 indicates that the desired bit will be set or turned on

8C 3A is the CRC for this message

The valid address range of digital output bits is 00 00 to 00 07. Any other address will produce an exception (error) response.

To clear or turn off digital output bit D03, replace the FF 00 string with 00 00. For example:

**Command: 01 05 00 03 00 00 3D CA**  
**Response: 01 05 00 03 00 00 3D CA**

Command values other than FF 00 or 00 00 will result in an exception (error) response.

## **Function (06) - Preset Single Register (Return to D1000 ASCII Protocol)**

The Preset Single Register function (06) can be used to temporarily suspend the Modbus RTU protocol and force the module into D1000 ASCII protocol. Write a value of 0000 to Modbus register 40001 to temporarily suspend Modbus RTU mode. The module will then communicate using the D1000 ASCII protocol only.

The D1000 ASCII protocol can be used to alter or check setup information and/or for troubleshooting purposes. The module will continue to communicate using the ASCII protocol until either a Remote Reset (RR) command (RR) is received or the power is cycled. At which time, the module will return to the Modbus RTU protocol mode.

Refer to the D1000 ASCII Modbus Disable command (MBD) for more information on disabling the Modbus protocol.

**Command: 01 06 00 00 00 00 89 CA**

**Response: 01 06 00 00 00 00 89 CA**

## **Function (15) - Force Multiple Coils (Digital Outputs)**

The Force Multiple Coils function (15) is used to force multiple Modbus output relay coils to a desired ON or OFF state. This function is similar in operation to the D1000 ASCII digital output command (DO) in that it updates the status of all available output coils at once. The state of each output coil is set ON or OFF according to the digital data value received with the function.

Any D1000M series module that contains one or more digital output bits can use Modbus Function 15. The digital output bits are referred to as "output relay coils" in the Modbus protocol. The D1000M series digital output bit DO0 equals Modbus output relay Coil#1 and digital output bit DO7 equals output relay Coil#8. D1000M series modules with less than eight digital outputs also equate output bit DO0 with output relay Coil#1 and count up by one for each additional output bit.

The following example can be used to turn on two digital output bits on a D1132M module.

**Command: 01 0F 00 00 00 02 00 03 9F 06**

**Response: 01 0F 00 00 00 02 D4 0A**

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In the command string:

01 is the slave address

0F is the Force Multiple Coils command

00 00 is the starting address of the digital output bits to be changed, 00 07 would equal DO7

00 02 specifies the number of output relay coils to be changed

00 03 specifies the digital output data value in HI byte LO byte format.

Note: The HI byte will always be zero as D1000M series modules contain up to eight digital outputs

9F 06 is the CRC for this message

The valid address range of digital output bits is 00 00 to 00 07. Any other address will produce an exception (error) response.

To clear or turn off the digital output bits, replace the 00 03 string with 00 00. For example:

**Command: 01 0F 00 00 00 02 00 00 DF 07**

**Response: 01 0F 00 00 00 02 D4 0A**

### **Modbus RTU Enable (MBR)**

To place any D1000M module in Modbus protocol mode use the Modbus RTU (MBR) command. The MBR command must be used to specify the Modbus device address and enable the Modbus protocol mode. The device address consists of a two character hexadecimal value and is stored in EEPROM. The two byte address specified is translated to a one byte, 8 bit address required by the Modbus protocol. The example below can be used to specify a Modbus device address of "01".

**Command: \$1MBR01**

**Response: \***

**Command: #1MBR01**

**Response: \*1MBR019D**

After the Modbus address is specified, a reset is necessary to activate the Modbus protocol mode. The reset may be accomplished in one of three ways:

1) Removing power for about 10 seconds to perform a power-up reset.

- 2) Momentarily grounding the Default\* pin.
- 3) Issue a Write Enable (WE) command followed by a Remote Reset (RR) command.

After a reset is performed, the module is in Modbus protocol mode.

## **Modbus Disable (MBD)**

The Modbus Disable (MBD) command is used to disable the Modbus protocol. Any D1000M series module in Modbus mode can be returned to D1000 ASCII protocol mode by connecting a jumper wire between module pins GND and Default\* pin. This places the module in Default Mode, where the module will only communicate at 300 baud, no parity, D1000 ASCII protocol, and answer to any address. While in Default mode, transmit an MBD command to internally disable the Modbus protocol.

Following the MBD command a device reset must occur. The reset is necessary to activate the D1000 ASCII protocol. A reset can occur by removing the Default\* jumper, performing a power-up reset or by transmitting a Write Enable (WE) and Remote Reset (RR) command sequence.

After a reset is performed, the module is in D1000 ASCII protocol mode.

**Command:** \$1MBD

**Response:** \*

**Command:** #1MBD

**Response:** \*1MBD2E

## **Modbus Exception Responses**

The following standard Modbus exception codes (error messages) are supported:

### **01 Illegal Function**

This exception code is generated when the function code is not recognized by the module.

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### 02 **Illegal Data Address**

This code is generated when the specified data address in the command is not supported by the module.

### 03 **Illegal Data Value**

This exception code is returned if the command data is out of range for the function.

### 06 **Slave Device Busy**

After the module is reset by power-up, a 'RR' command, or return from Default Mode, the module performs an initial self-calibration for a period of about 3 seconds. During this time any command sent to the module will result in a 'busy' exception response.

### **SetUp (SU)**

For convenience, ASCII-based D1000 commands are used to specify all setup values. The SetUp (SU) command is used to select the desired baud rate and parity for both the D1000 ASCII protocol as well as the Modbus protocol. It is also used to select the D1000 ASCII protocol address which may not be the same as the Modbus protocol address. The SU command should be used to establish these communications values before enabling the Modbus protocol. Use MBR command to specify the Modbus protocol device address and enable the Modbus protocol.

The following information details the module setup and hardware differences between the standard D1000 series modules and those that are Modbus compatible.

**Byte 1**

The first setup byte specifies the ASCII channel address. This address value is ONLY used while the module is configured for the D1000 ASCII protocol. The Modbus address is completely different and specified with the Modbus RTU (MBR) command.

**Table 5.1 Byte 1 ASCII Printable Characters.**

HEX	ASCII	HEX	ASCII	HEX	ASCII	HEX	ASCII
21	!	3A	:	51	Q	68	h
22	"	3B	;	52	R	69	i
25	%	3C	<	53	S	6A	j
26	&	3D	=	54	T	6B	k
27	'	3E	>	55	U	6C	l
28	(	3F	?	56	V	6D	m
29	)	40	@	57	W	6E	n
2A	*	41	A	58	X	6F	o
2B	+	42	B	59	Y	70	p
2C	,	43	C	5A	Z	71	q
2D	-	44	D	5B	[	72	r
2E	.	45	E	5C	\	73	s
2F	/	46	F	5D	]	74	t
30	0	47	G	5E	^	75	u
31	1	48	H	5F	_	76	v
32	2	49	I	60	`	77	w
33	3	4A	J	61	a	78	x
34	4	4B	K	62	b	79	y
35	5	4C	L	63	c	7A	z
36	6	4D	M	64	d	7B	{
37	7	4E	N	65	e	7C	
38	8	4F	O	66	f	7D	}
39	9	50	P	67	g	7E	~

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## SU Byte #2

**Table 5.2 Byte 2: Linefeed, Parity and Baud Rate.**

FUNCTION	DATA BIT							
	7	6	5	4	3	2	1	0
LINEFEED	1							
NO LINEFEED	0							
NO PARITY		0	0					
NO PARITY		1	0					
EVEN PARITY		0	1					
ODD PARITY	1	1						
115200 BAUD				X	1	0	0	0
57600 BAUD				1	0	0	1	
38400 BAUD				0	0	0	0	
19200 BAUD				0	0	0	1	
9600 BAUD					0	0	1	0
4800 BAUD					0	0	1	1
2400 BAUD					0	1	0	0
1200 BAUD					0	1	0	1
600 BAUD					0	1	1	0
300 BAUD					0	1	1	1

### Linefeeds

The 'Linefeeds Enable' setup bit is active during D1000 ASCII protocol mode and ignored by the Modbus protocol.

### Parity Type

The 'Parity Type' setup bits specify parity for both D1000 ASCII and Modbus protocols. The Modbus parity type must be specified using the D1000 ASCII SetUp (SU) command and is defined in byte #2 of the setup message. The following parity type definitions should be used to define the required parity type in Modbus mode. The four possible Modbus parity settings are.

FUNCTION	DATA BIT	
	6	5
NO Parity, 1 Stop	0	0
NO Parity, 2 Stop	1	0
EVEN, 1 Stop	0	1
ODD, 1 Stop	1	1

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*Note: The UART is ALWAYS set for 1 start bit, 7 data bits, 1 parity bit, and 1 stop bit in D1000 ASCII mode. The parity settings in the D1000 Users Manual Table 5.2 should be used to configure D1000 ASCII protocol parity type.*

### **Baud Rate**

The D1000M series Modbus compatible modules have been upgraded to include two new baud rates, 57,600 and 115,200. This new upgrade has not been included in the existing D1000 modules or manuals. The baud rate is selected with the four least significant bits of the second setup byte. The following settings replace those listed in table 5.2 of the D1000 Users Manual. The new baud rate selection bit settings are:

	<b>DATA BIT</b>			
	<b>3</b>	<b>2</b>	<b>1</b>	<b>0</b>
300 baud	0	1	1	1
600 baud	0	1	1	0
1200 baud	0	1	0	1
2400 baud	0	1	0	0
4800 baud	0	0	1	1
9600 baud	0	0	1	0
19,200 baud	0	0	0	1
38,400 baud	0	0	0	0
57,600 baud	1	0	0	1
115,200 baud	1	0	0	0



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## SU Byte #3

Table 5.3 Byte 3 Options.

FUNCTION	DATA BIT	7	6	5	4	3	2	1	0
NOT USED		X							
NOT USED			X						
NOT USED				X					
CJC ( D1300'S )					0				
NO CJC ( D1300'S )					1				
3 WIRE ( D1400'S )					0				
4 WIRE ( D1400'S )					1				
- STARTING EDGE (D1600'S)					0				
+ STARTING EDGE (D1600'S)					1				
NOT USED						X			
NOT USED							X		
NO DELAYS								0	0
2 BYTE TIME DELAYS								0	1
4 BYTE TIME DELAYS								1	0
6 BYTE TIME DELAYS								1	1

### Byte Time Delays

The 'Byte Time Delays' setup bits are active during D1000 ASCII protocol and ignored by Modbus protocol.

## SU Byte #4

### Displayed Digits

The Displayed Digits setup bits are active during D1000 ASCII protocol and ignored by Modbus protocol.

### Large and Small Signal Filters

The Large and Small Signal Filters are active during both D1000 ASCII and Modbus protocols.

Table 5.4 Byte 4 Displayed Digits and Filter Time Constants.

BYTE 4 FUNCTION	DATA BIT	7	6	5	4	3	2	1	0
+XXXX0.00 DISPLAYED DIGITS		0	0						
+XXXXX.00 DISPLAYED DIGITS		0	1						
+XXXXX.X0 DISPLAYED DIGITS		1	0						
+XXXXX.XX DISPLAYED DIGITS		1	1						
NO LARGE SIGNAL FILTERING				0	0	0			
0.25 SECOND TIME CONSTANT				0	0	1			
0.5 SECOND TIME CONSTANT				0	1	0			
1.0 SECOND TIME CONSTANT				0	1	1			
2.0 SECOND TIME CONSTANT				1	0	0			
4.0 SECOND TIME CONSTANT				1	0	1			
8.0 SECOND TIME CONSTANT				1	1	0			
16.0 SECOND TIME CONSTANT				1	1	1			
NO SMALL SIGNAL FILTERING							0	0	0
0.25 SECOND TIME CONSTANT							0	0	1
0.5 SECOND TIME CONSTANT							0	1	0
1.0 SECOND TIME CONSTANT							0	1	1
2.0 SECOND TIME CONSTANT							1	0	0
4.0 SECOND TIME CONSTANT							1	0	1
8.0 SECOND TIME CONSTANT							1	1	0
16.0 SECOND TIME CONSTANT							1	1	1

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### **Calibration**

The module may be calibrated in D1000 ASCII mode using the Trim Span (TS) and Trim Zero (TZ) commands as described in the D1000 Series Users manual. The calibrated scaling will be reflected accurately in the Modbus data as a percentage of Full Scale.

One note concerning the Trim Zero (TZ) command. The zero is trimmed digitally in the module after the analog to digital conversion is performed. In D1000 ASCII mode it is possible for the output data to exceed the designed full scale limits of the module. For example, on a +/-5 volt module the normal output range is -05000.00 to +05000.00. If a zero offset of +01000.00 is programmed into the module, the resulting output range will be -04000.00 to +06000.00.

However, in Modbus format, by definition, the span range is -5 volts to +5 volts. The lowest Modbus output value in this case would be 2000 hex, representing 4 volts. There will be a gap in output codes between the defined negative overload value of 0000 and the first valid output of 2000. In addition, readings above +5 volts will be truncated to the positive overload of FFFF hex.

## **PRESO FLOW HANDBOOK**

**This booklet has been prepared for the sole use of PRESO representatives. It brings necessary data together to accurately measure the flow of various fluids through the application of the following formulas.**

**All the formulas or flow equations discussed are from standard theories, principles, and laws of physics commonly used in the practice of engineering.**

**Bernoulli's theorem is the base equation and has been modified to be used with PRESO's flow sensors in determining the flow rate.**

**Of course many subjects and specific flow conditions are not treated by this handbook. We invite you to contact us at the factory for further information or assistance.**

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<b>Annular Flow Chart Air 14.7 PSIA 70 °F</b>	<b>40</b>
<b>Appendix - Engineering Data</b>	<b>41</b>

## FLOW EQUATIONS

<p><b><u>EQUATION # 1</u></b></p> <p><b>LIQUID VOLUME RATE OF FLOW</b></p>	$H_w : \left( \frac{Q}{C_1} \right)^2 \text{ or } Q : C_1 \times \sqrt{H_w}$ <p>WHERE</p> $C_1 : N \times K \times D_i^2 \times F_a \times F_{RE} \times F_{SGf}$
<p><b><u>EQUATION # 2</u></b></p> <p><b>LIQUID MASS RATE OF FLOW</b></p>	$H_w : \left( \frac{W}{C_1} \right)^2 \text{ or } W : C_1 \times \sqrt{H_w}$ <p>WHERE</p> $C_1 : N \times K \times D_i^2 \times F_a \times F_{RE} \times \sqrt{\rho_f}$
<p><b><u>EQUATION # 3</u></b></p> <p><b>STEAM &amp; GAS MASS RATE OF FLOW</b></p>	$H_w : \left( \frac{W}{C_1} \right)^2 \text{ or } W : C_1 \times \sqrt{H_w}$ <p>WHERE</p> $C_1 : N \times K \times D_i^2 \times F_a \times F_{RE} \times Y \times \sqrt{\rho_f}$
<p><b><u>EQUATION # 4</u></b></p> <p><b>AIR &amp; GAS VOLUME RATE OF FLOW (FOR STANDARD CONDITIONS)</b></p>	$H_w : \frac{1}{P_f} \times \left( \frac{Q_s}{C_1} \right)^2 \text{ or } Q_s : C_1 \times \sqrt{H_w \times P_f}$ <p>WHERE</p> $C_1 : N \times K \times D_i^2 \times F_a \times F_{RE} \times Y \times \frac{1}{F_{SGs} \times F_{Tb} \times F_{Tf} \times F_z}$
<p><b><u>EQUATION # 5</u></b></p> <p><b>AIR &amp; GAS VOLUME RATE OF FLOW (FOR ACTUAL CONDITIONS)</b></p>	$H_w : \left( \frac{Q_a}{C_1} \right)^2 \text{ or } Q_a : C \times \sqrt{H_w}$ <p>WHERE</p> $C_1 : N \times K \times D_i^2 \times F_a \times F_{RE} \times Y \times \sqrt{\frac{1}{\rho_f}}$

**SYMBOLS**

- Q : RATE OF FLOW
- N : UNITS CONVERSION FACTOR
- K : PRESO FLOW COEFFICIENT
- D<sub>i</sub> : INSIDE PIPE DIAMETER
- F<sub>a</sub> : THERMAL EXPANSION FACTOR
- Y : GAS EXPANSION FACTOR
- H<sub>w</sub> : DIFFERENTIAL PRESSURE IN INCHES OF WATER COLUMN AT 68°F
- C<sub>1</sub> : FLOW CONSTANT
- W : MASS RATE OF FLOW
- SG<sub>s</sub> : SPECIFIC GRAVITY (STANDARD)<sup>1</sup>
- SG<sub>f</sub> : SPECIFIC GRAVITY (FLOWING)<sup>2</sup>
- ρ<sub>f</sub> : FLOWING DENSITY, LBS / FT<sup>3</sup>
- μ<sub>cp</sub> : VISCOSITY, CENTIPOSE
- RE : REYNOLDS NUMBER
- P<sub>f</sub> : FLOWING PRESSURE, PSIA : (PSIA = PSIG +14.73)
- F<sub>z</sub> : COMPRESSIBILITY FACTOR
- F<sub>RE</sub> : REYNOLDS NUMBER FACTOR
- F<sub>Pb</sub> : PRESSURE BASE FACTOR
- F<sub>Tb</sub> : TEMPERATURE BASE FACTOR
- F<sub>Tf</sub> : FLOWING TEMPERATURE FACTOR
- F<sub>SGf</sub> : SPECIFIC GRAVITY FACTOR (FLOWING)<sup>1</sup>
- F<sub>SGs</sub> : SPECIFIC GRAVITY FACTOR (STANDARD)<sup>2</sup>

N : UNITS CONVERSION FACTOR :

USGPM	: 5.666	TONS / HR	: 0.17946
USGPH	: 340.0	DENSITY	: 1 / SPEC. VOLUME
ImpGPM	: 4.718	(SCFM) <sup>3</sup>	: 5.636
LBS / SEC	: 0.10	SCFH	: 338.17
LBS / MIN	: 5.9823	(ACFM) <sup>3</sup>	: 5.9823
LBS / HR	: 358.94	ACFH	: 358.94

RE : REYNOLDS NUMBER

LIQUID:  $\frac{3160 \times \text{GPM} \times \text{SG}_f^2}{D_i \times \mu_{cp}}$       STEAM :  $\frac{6.32 \times \text{LBS} / \text{HR}}{D_i \times \mu_{cp}}$

GAS :  $\frac{0.4830 \times \text{SCFH} \times \text{SG}_f^1}{D_i \times \mu_{cp}}$       or       $\frac{6.32 \times \text{ACFH} \times \rho_f}{D_i \times \mu_{cp}}$

NOTE : 1. STANDARD SPECIFIC GRAVITY ( BASED ON 60° F & 14.73 PSIA )  
 2. FLOWING SPECIFIC GRAVITY (BASED ON ACTUAL FLOWING CONDITIONS)

3. SCFM = ACFM  $\times \frac{\text{PSIG} + 14.73}{14.73} \times \frac{520}{460 + \text{°F (FLOWING)}}$



## ANNULAR

NOMINAL PIPE	TYPE OR SCHEDULE	INSIDE DIAMETER	K FACTOR
.5 "	" L "	.545 "	.3981 (1)
	40	.622 "	.4067 (1)
.75 "	" L "	.785 "	.4629 (1)
	40	.824 "	.4223 (1)
1 "	" L "	1.025 "	.5189 (1)
	40	1.049 "	.5191 (1)
1.25 "	" L "	1.265 "	.5630 (1)
	40	1.380 "	.5732 (1)
1.5 "	" L "	1.505 "	.5930 (1)
	40	1.610 "	.6175 (1)
2 "	" L "	1.985 "	.5971 (1)
			.6136 (2)
	40	2.067 "	.6216 (1)
			.6257 (2)
ELLIPSE	40	2.067 "	.6295 (3)*
2.5 "	" L "	2.465 "	.6369 (1)
			.6465 (2)
	40	2.469 "	.6617 (1)
			.6469 (2)
ELLIPSE	40	2.469 "	.6304 (3)*
3 "	" L "	2.945 "	.6509 (1)
			.6525 (2)
	40	3.068 "	.6765 (1)
			.6511 (2)
ELLIPSE	40	3.068 "	.6364 (3)*
4 "	40	4.026 "	.6527 (2)
	ELLIPSE	40	4.026 "
5 "	40	5.047 "	.6593 (2)
	ELLIPSE	40	5.047 "
6 "	40	6.065 "	.6642 (2)
	40	6.065 "	.7377 (3)*

Note: (1) TU SERIES SENSOR  
 (2) INSERT TYPE SENSOR. BIN, SEN, PRB  
 (3) ELLIPSE SENSORS. AR, AF, AS, ETC.  
 \* Sensor size = 7/8" (AR), For 1/2" Sensors (ARO) See Page # 8

## ANNULAR

NOMINAL PIPE	TYPE OR SCHEDULE	INSIDE DIAMETER	K FACTOR
8"	40	7.981"	.6675 (2)
ELLIPSE	40	7.981"	.8088 (3)
10"	40	10.020"	.6789 (2)
ELLIPSE	40	10.020"	.7829 (3)
12"	40	11.938"	.6872 (2)
	STD.	12.000"	.6874 (2)
ELLIPSE			
7/8"	40	11.938"	.7446 (3)
7/8"	STD.	12.000"	.7465 (3)
14"	40	13.124"	.6937 (2)
	STD.	13.250"	.6938 (2)
ELLIPSE			
1-1/4"	STD.	13.250"	.7257 (3)
2-1/4"			.7212 (3)
16"	40	15.000"	.6970 (2)
	STD.	15.250"	.6971 (2)
ELLIPSE			
1-1/4"	STD.	15.250"	.7144 (3)
2-1/4"			.7133 (3)
18"	40	16.876"	.7068 (2)
	STD.	17.250"	.7069 (2)
ELLIPSE			
1-1/4"	STD.	17.25"	.7125 (3)
2-1/4"			.7115 (3)
20"	40	18.812"	.7167 (2)
	STD.	19.250"	.7168 (2)
ELLIPSE			
1-1/4"	STD.	19.250"	.7105 (3)
2-1/4"			.7100 (3)
24"	40	22.624"	.7232 (2)
	STD.	23.250"	.7234 (2)
ELLIPSE			
1-1/4"	STD.	23.250"	.7050 (3)
2-1/4"			.6655 (3)

Note: (1) TU SERIES SENSOR  
 (2) INSERT TYPE SENSOR, BIN, SEN, PRB  
 (3) ELLIPSE SENSORS, AR, AF, AS, ETC.

## ANNULAR

NOMINAL PIPE	TYPE OR SCHEDULE	INSIDE DIAMETER	K FACTOR
30"			
	STD.	29.250"	.7240 (2)
ELLIPSE			
1-1/4"	STD.	29.250"	.7025 (3)
2-1/4"			.7015 (3)
36"	STD.	35.250"	.7155 (2)
ELLIPSE			
1-1/4"	STD.	35.250"	.7017 (3)
2-1/4"			.6985 (3)
42"	STD.	41.250"	.7096 (2)
ELLIPSE			
1-1/4"	STD.	41.250"	.6995 (3)
2-1/4"			.6979 (3)
> 42"	STD.		.7075 (2)
ELLIPSE			
1-1/4"	STD.		.6990 (3)
2-1/4"			.6975 (3)

## ANNULAR ARO

NOMINAL PIPE	TYPE OR SCHEDULE	INSIDE DIAMETER	K FACTOR
2"	40	2.067"	.6483
2 1/2"	40	2.465"	.6519
3"	40	3.068"	.6556
3 1/2"	40	3.548"	.6845
4"	40	4.026"	.7389
5"	40	5.047"	.7470

Note: (1) TU SERIES SENSOR  
 (2) INSERT TYPE SENSOR, BIN, SEN, PRB  
 (3) ELLIPSE SENSORS. AR, AF, AS, ETC.

## VENTURI

NOMINAL PIPE	TYPE OR SCHEDULE	VENTURI NUMBER	THROAT DIAMETER	BETA RATIO	K FACTOR	
.5"	"L"	04	.1094"	.2007	.0395	
		10	.1935"	.3550	.1077	
		38	.3125"	.5734	.2767	
		65	.4375"	.8028	.6222	
	40	ID: .545"	04	.1250"	.2010	.0396
			10	.2280"	.3666	.1146
			38	.3750"	.6029	.3072
			65	.5000"	.8039	.6241
.75"	"L"	04	.1562"	.1990	.0389	
		08	.2187"	.2786	.0763	
		10	.3125"	.3981	.1344	
		38	.4375"	.5573	.2608	
	40	ID: .785"	65	.6250"	.7962	.6064
			04	.1719"	.2086	.0479
			08	.2344"	.2845	.0796
			10	.3125"	.3792	.1223
40	ID: .824"	38	.4375"	.5309	.2364	
		65	.6250"	.7585	.5270	
		10	.3750"	.3575	.1092	
		20	.5000"	.4766	.1907	
1"	"L"	38	.6250"	.5958	.2996	
		65	.8125"	.7927	.5982	
		10	.5000"	.3953	.1326	
		20	.6875"	.5435	.2479	
1"	ID: 1.025"	38	.8750"	.6917	.4171	
		65	1.0312"	.8152	.6539	
		10	.5000"	.3623	.1120	
		20	.6875"	.4982	.2083	
1.25"	"L"	38	.8750"	.6341	.3423	
		65	1.1250"	.8152	.6539	
		10	.5000"	.3623	.1120	
		20	.6875"	.4982	.2083	
1.25"	ID: 1.265"	38	.8750"	.6341	.3423	
		65	1.1250"	.8152	.6539	
		10	.5000"	.3623	.1120	
		20	.6875"	.4982	.2083	
1.25"	ID: 1.380"	38	.8750"	.6341	.3423	
		65	1.1250"	.8152	.6539	
		10	.5000"	.3623	.1120	
		20	.6875"	.4982	.2083	

## VENTURI

NOMINAL PIPE	TYPE OR SCHEDULE	VENTURI NUMBER	THROAT DIAMETER	BETA RATIO	K FACTOR
1.5"	"L"	10	.6250"	.4153	.1460
	ID:1.505"	38	.9375"	.6229	.3293
		65	1.1875"	.7890	.5897
40	ID:1.610"	10	.6250"	.3882	.1280
		38	1.0000"	.6211	.3273
		65	1.3125"	.8152	.6539
2"	"L"	10	.7500"	.3778	.1215
	ID:1.985"	38	1.2500"	.6297	.3372
		65	1.6250"	.8186	.6629
40	ID:2.067"	10	.7500"	.3628	.1123
		38	1.3750"	.6652	.3810
		65	1.6875"	.8164	.6571
2.5"	40	10	.8750"	.3544	.1074
	ID:2.469"	20	1.3125"	.5316	.2363
		38	1.6250"	.6582	.3719
		65	2.0000"	.8100	.6401
3"	40	10	1.1250"	.3667	.1147
	ID:3.068"	38	2.0000"	.6519	.3641
		65	2.5000"	.8149	.6531
4"	40	10	1.4375"	.3571	.1089
	ID:4.026"	38	2.6250"	.6520	.3642
		65	3.2500"	.8073	.6334
5"	40	10	1.8125"	.3591	.1101
	ID:5.047"	38	3.2500"	.6439	.3541
		65	4.1250"	.8173	.6594
6"	40	10	2.1250"	.3504	.1050
	ID:6.065"	38	3.8750"	.6389	.3480
		65	4.9375"	.8141	.6510
8"	40	10	2.8750"	.3602	.1107
	ID:7.981"	38	4.8750"	.6108	.3158
		65	6.5000"	.8144	.6518

## VENTURI

NOMINAL PIPE	TYPE OR SCHEDULE	VENTURI NUMBER	THROAT DIAMETER	BETA RATIO	K FACTOR
10"	40:10.02"	10	3.5625"	.3555	.1080
		38	6.0000"	.5988	.3028
		65	8.1250"	.8109	.6425
12"	40:11.938"	10	4.250"	.3542	.1072
		38	8.000"	.6667	.3829
	STD:12"	65	9.750"	.8125	.6467
14"	STD:13.25"	10	4.7500"	.3585	.1097
		38	8.5000"	.6415	.3512
	40:13.124"	65	10.8125"	.8160	.6560
16"	STD:15.25"	10	5.3750"	.3525	.1063
		38	10.5000"	.6885	.4126
	40:15"	65	12.5000"	.8197	.6658
18"	STD:17.25"	10	6.0625"	.3514	.1056
		38	12.0000"	.6957	.4228
	40:16.876"	65	14.1250"	.8188	.6634
20"	STD:19.25"	10	6.7500"	.3506	.1051
		38	13.0000"	.6753	.3943
	40:18.812"	65	15.7500"	.8182	.6618
24"	STD:23.23"	10	8.2500"	.3548	.1076
		38	15.5000"	.6667	.3829
	40:22.624"	65	19.0000"	.8172	.6592
30"		10	10.3125"	.3526	.1054
	STD:29.25"	38	19.6250"	.6709	.3848
		65	24.0000"	.8205	.6587
36"		10	12.3375"	.35	.1101
	STD:35.25"	38	21.1500"	.60	.3032
		65	28.5525"	.81	.6587
42"		10	14.4375"	.35	.1101
	STD:41.25"	38	24.7500"	.60	.3032
		65	33.4125"	.81	.6581

## COIN

NOMINAL PIPE	TYPE OR SCHEDULE	COIN NUMBER	RATIO	K FACTOR
.5"	40 ID:0.622"	-1	.2	.1137
		-2	.3	.1990
		-3	.4	.3226
		-4	.5	.4627
1"	40 ID:1.049"	-1	.2	.1072
		-2	.3	.1917
		-3	.4	.3072
		-4	.5	.4280
1.5"	40 ID:1.610"	-1	.2	.1076
		-2	.3	.1929
		-3	.4	.2778
		-4	.5	.4101
2"	40 ID:2.067	-1	.2	.1098
		-2	.3	.1896
		-3	.4	.2860
		-4	.5	.4173
3"	40 ID:3.068"	-1	.2	.0984
		-2	.3	.1795
		-3	.4	.2805
		-4	.5	.4188
4"	40 ID:4.026"	-1	.2	.1086
		-2	.3	.1876
		-3	.4	.2918
		-4	.5	.4257
6"	40 ID:6.065"	-2	.3	.1876
		-3	.4	.2882
		-4	.5	.4051
8"	40 ID:7.981"	-2	.3	.1853
		-3	.4	.2873
		-4	.5	.4019

## COIN

NOMINAL PIPE	TYPE OR SCHEDULE	COIN NUMBER	RATIO	K FACTOR
10"	40	-2	.3	.1175
	ID:10.02"	-3	.4	.2809
		-4	.5	.3944
12"	40	-2	.3	.1875
	ID:12"	-3	.4	.2778
		-4	.5	.3889
14"	STD	-2	.3	.1857
	ID:13.25"	-3	.4	.2791
		-4	.5	.3816
16"	STD	-2	.3	.1849
	ID:15.25"	-3	.4	.2795
		-4	.5	.3784
18"	STD	-2	.3	.1848
	ID:17.25"	-3	.4	.2756
		-4	.5	.3764
20"	STD	-2	.3	.1862
	ID:19.25"	-3	.4	.2780
		-4	.5	.3778
24"	STD	-2	.3	.1850
	ID:23.25"	-3	.4	.2738
		-4	.5	.3765



### SSM / SSL VENTURIS (ALL SIZES)

MODEL	BETA RATIO	K FACTOR
SSM/SSL - 1	.35	.1215
SSM/SSL - 2	.49	.2436
SSM/SSL - 3	.63	.4259
SSM/SSL - 4	.75	.6701

$$\kappa = \frac{C_D \beta^2}{\sqrt{1 - \beta^4}}$$

$C_D$  ( Discharge Coefficient ) = .985

**F<sub>pb</sub>** : PRESSURE BASE FACTOR  
: To change from a pressure base of 14.73 to another pressure base.

$$F_{pb} : \frac{14.73}{\text{Base pressure in psia}}$$

**F<sub>tb</sub>** : TEMPERATURE BASE FACTOR  
: To change from a temperature base of 60° F to another temperature base.

$$F_{tb} : \frac{\text{base } \square + 460}{60 + 460}$$

**F<sub>tf</sub>** : FLOWING TEMPERATURE FACTOR  
: To adjust from flowing temperature of 60° F to actual flowing temperature.

$$F_{tf} : \sqrt{\frac{520}{460 + \text{actual flow. temp. deg. F}}}$$

**F<sub>sg</sub>** : SPECIFIC GRAVITY FACTOR  
: at flowing temperature , for Air = 1

$$F_{sg} : \sqrt{\frac{1}{S_g}}$$

**F<sub>Z</sub>** : GAS COMPRESSIBILITY AT FLOW PRESSURE & TEMPERATURE

$$F_Z : \sqrt{\frac{1}{Z}}$$

Z : Gas compressibility at Flow Pressure & Temperature.

**F<sub>re</sub>** : REYNOLDS NUMBER FACTOR (Experimental)

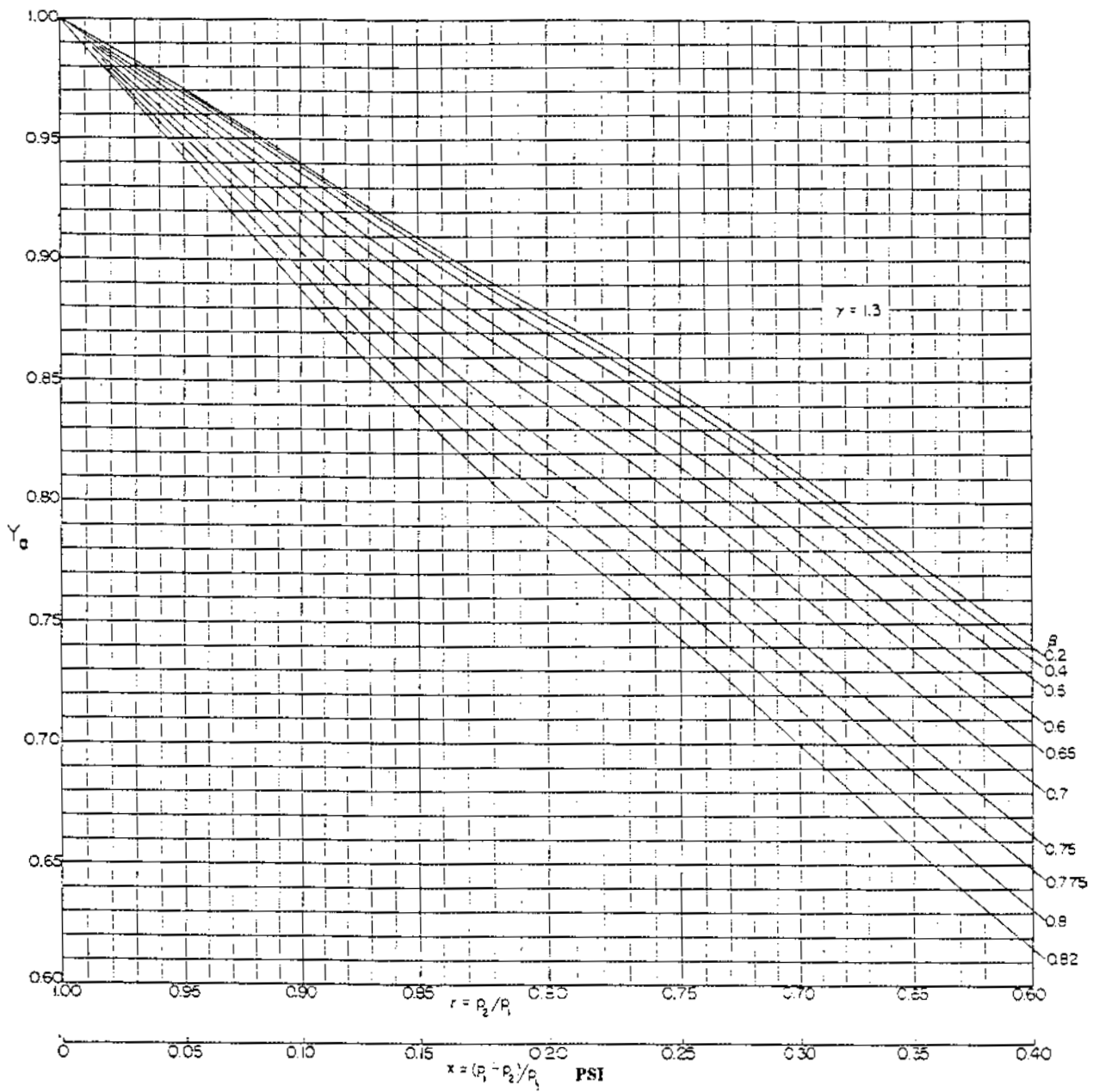
Use:       $F_{re} = 1$       for Pipe Reynolds between 100,000 to 1,000,000  
          $F_{re} = 1.025$     for Pipe Reynolds below 100,000  
          $F_{re} = .9985$     for Pipe Reynolds above 100,000

## THERMAL EXPANSION

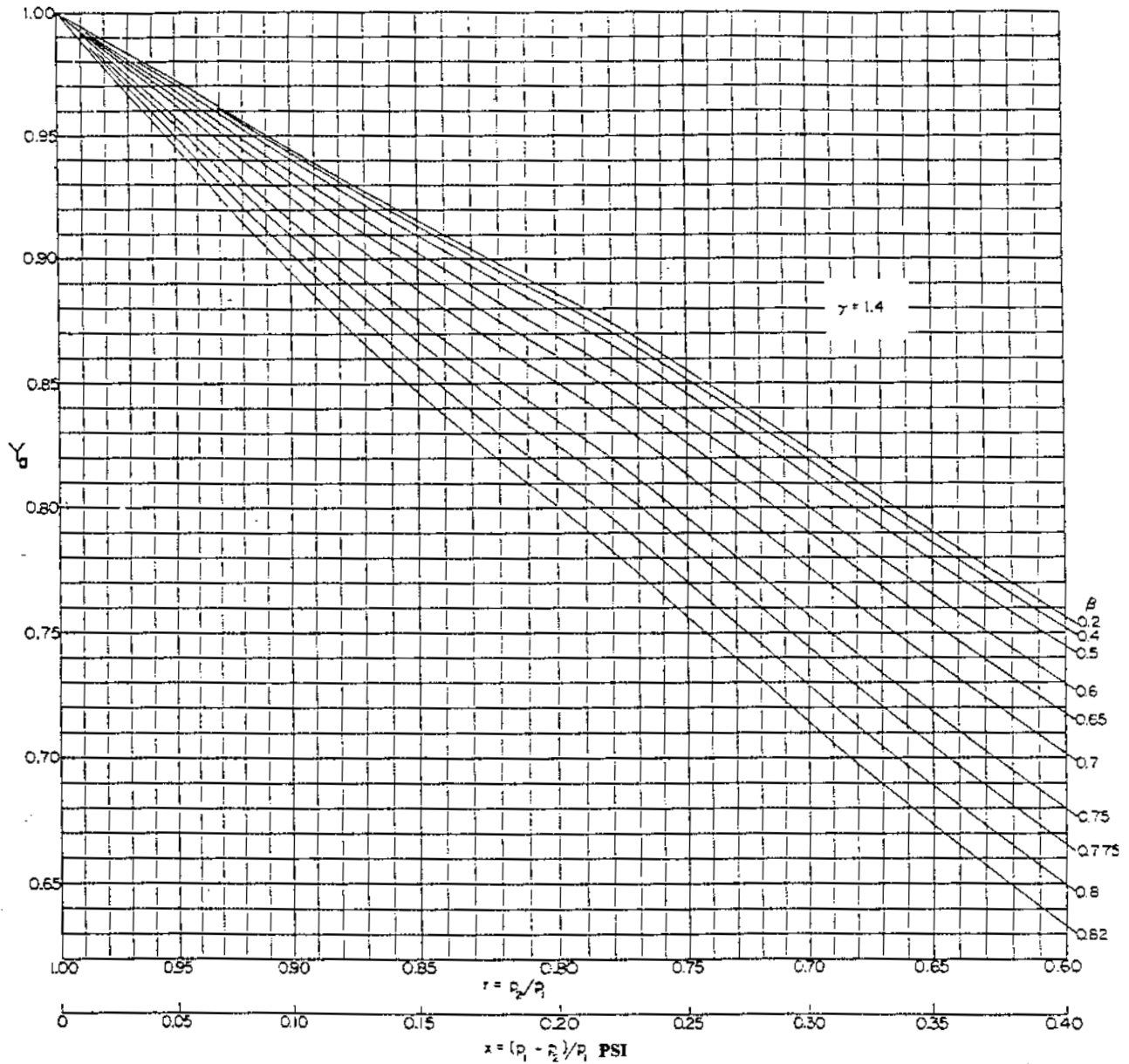
Alum.	Copper	Type 430	2% CR MO	5% CR MO	Bronze	Steel	Monel	Type 316 Or Type 304	Corr. Factor $F_a$
- 298					- 360				.992
- 230	- 378				- 273				.993
- 178	- 266				- 216			- 325	.994
- 131	- 194				- 163		- 281	- 226	.995
- 85	- 132				- 111		- 191	- 152	.996
- 41	- 72				- 60		- 108	- 86	.997
+ 3	- 15				- 8		- 33	- 24	.998
+ 47	+ 42	+ 24	+ 28	+ 27	+43	+ 31	+ 38	+ 38	.999
+ 91	+ 99	+ 112	+ 108	+ 110	+ 95	+ 106	+ 104	+ 101	1.000
		+ 202	+ 184	+ 191	+ 149	+ 181	+ 168	+ 158	1.001
		290	260	272	200	254	230	213	1.002
		374	331	352	249	324	290	266	1.003
		456	400	426	297	392	348	318	1.004
		531	468	493	345	457	405	367	1.005
		604	534	560	393	520	461	414	1.006
		677	597	628	440	542	516	463	1.007
		749	660	696		644	571	512	1.008
		817	720	763		705	626	560	1.009
		884	780	827		765	680	607	1.010
		952	842	888		823	733	655	1.011
		1020	899	948		879	785	703	1.012
		1087	956	1009		934	835	750	1.013
		1155	1011	1071		988	886	796	1.014
		223	1065	1133		1041	935	840	1.015

$F_a$  : Values, correction for thermal expansion.

Temperature of pipe in Deg. F.



EXPANSION FACTORS FOR FLOW NOZZLES AND VENTURI TUBES,  $\gamma = 1.3$



EXPANSION FACTORS FOR FLOWNOZZLES AND VENTURI TUBES,  $\gamma = 1.4$

## PROPERTIES OF SATURATED STEAM

<u>ABSOLUTE PRESSURE</u>		Vacuum Inches of Hg	Temperature  t Degrees F.	Heat of the Liquid  Btu / lb.	Latent Heat of Evaporation Btu / lb.	Total Heat of Steam hg Btu / lb.	Specific Volume  V Cu. ft. per lb.
Lbs. per Sq. In. P'	Inches of Hg						
0.20	0.41	29.51	53.14	21.21	1063.8	1085.0	1526.0
0.25	0.51	29.41	59.30	27.36	1060.3	1087.7	1235.3
0.30	0.61	29.31	64.47	32.52	1057.4	1090.0	1039.5
0.35	0.71	29.21	68.93	36.97	1054.9	1091.9	898.5
0.40	0.81	29.11	72.86	40.89	1052.7	1093.6	791.9
0.45	0.92	29.00	76.38	44.41	1050.7	1091.1	708.5
0.50	1.02	28.90	79.58	47.60	1048.8	1096.4	641.4
0.60	1.22	28.70	85.21	53.21	1045.7	1098.9	540.0
0.70	1.43	28.49	90.08	58.07	1042.9	1101.0	466.9
0.80	1.63	28.29	94.38	62.36	1040.4	1102.8	411.7
0.90	1.83	28.09	98.24	66.21	1038.3	1104.5	368.4
1.0	2.04	27.88	101.74	69.70	1036.3	1106.0	333.6
1.2	2.44	27.48	107.92	75.87	1032.7	1108.6	280.9
1.4	2.85	27.07	113.26	81.20	1029.6	1110.8	243.0
1.6	3.26	26.66	117.99	85.91	1026.9	1112.8	214.3
1.8	3.66	26.26	122.23	90.14	1024.5	1114.6	191.8
2.0	4.07	25.85	126.08	93.99	1022.2	1116.2	173.73
2.2	4.48	25.44	129.62	97.52	1020.2	1117.7	158.85
2.4	4.89	25.03	132.89	100.79	1018.3	1119.1	146.38
2.6	5.29	24.63	135.94	103.83	1016.5	1120.3	135.78
2.8	5.70	24.22	138.79	106.68	1014.8	1121.5	126.65
3.0	6.11	23.81	141.48	109.37	1013.2	1122.6	118.71
3.5	7.13	22.79	147.57	115.46	1009.6	1125.1	102.72
4.0	8.14	21.78	152.97	120.86	1006.4	1127.3	90.63
4.5	9.16	20.76	157.83	125.71	1003.6	1129.3	81.16
5.0	10.18	19.74	162.24	130.13	1001.0	1131.1	73.52
5.5	11.20	18.72	166.30	134.19	998.5	1132.7	67.24
6.0	12.22	17.70	170.06	137.96	996.2	1134.2	61.98
6.5	13.23	16.69	173.56	141.47	994.1	1135.6	57.50
7.0	14.25	15.67	176.85	144.76	992.1	1136.9	53.64
7.5	15.27	14.65	179.94	147.86	990.2	1138.1	50.29
8.0	16.29	13.63	182.86	150.79	988.5	1139.3	47.34
8.5	17.31	12.61	185.64	153.57	986.8	1140.4	44.73
9.0	18.32	11.60	188.28	156.22	985.2	1141.4	42.40
9.5	19.34	10.58	190.80	158.75	983.6	1142.3	40.31
10.0	20.36	9.56	193.21	161.17	982.1	1143.3	38.42
11.0	22.40	7.52	197.75	165.73	979.3	1145.0	35.14
12.0	24.43	5.49	201.96	169.96	976.6	1146.6	32.40
13.0	26.47	3.45	205.88	173.91	974.2	1148.1	30.06
14.0	28.50	1.42	209.56	177.61	971.9	1149.5	28.04

## PROPERTIES OF SATURATED STEAM - continued

PRESSURE Lbs. per Sq. In.		Temperature	Heat of the Liquid	Latent Heat of Evaporation	Total Heat of Steam	Specific Volume
Absolute P'	Gage P	t Degrees F.	Btu / lb.	Btu / lb.	hg Btu / lb.	— Cu. ft. per lb.
14.696	0.0	212.00	180.07	970.3	1150.4	26.80
15.0	0.3	213.03	181.11	969.7	1150.8	26.29
16.0	1.3	216.32	184.42	967.6	1152.0	24.75
17.0	2.3	219.44	187.56	965.5	1153.1	23.39
18.0	3.3	222.41	190.56	963.6	1154.2	22.17
19.0	4.3	225.24	193.42	961.9	1155.3	21.08
20.0	5.3	227.96	196.16	960.1	1156.3	20.089
21.0	6.3	230.57	198.79	958.4	1157.2	19.192
22.0	7.3	233.07	201.33	956.8	1158.1	18.375
23.0	8.3	235.49	203.78	955.2	1159.0	17.627
24.0	9.3	237.82	206.14	953.7	1159.8	16.938
25.0	10.3	240.07	208.42	952.1	1160.6	16.303
26.0	11.3	242.25	210.62	950.7	1161.3	15.715
27.0	12.3	244.36	212.75	949.3	1162.0	15.170
28.0	13.3	246.41	214.83	947.9	1162.7	14.663
29.0	14.3	248.40	216.86	946.5	1163.4	14.189
30.0	15.3	250.33	218.82	945.3	1164.1	13.746
31.0	16.3	252.22	220.73	944.0	1164.7	13.330
32.0	17.3	254.05	222.59	942.8	1165.4	12.940
33.0	18.3	255.84	224.41	941.6	1166.0	12.572
34.0	19.3	257.58	226.18	940.3	1166.5	12.226
35.0	20.3	259.28	227.91	939.2	1167.1	11.898
36.0	21.3	260.95	229.60	938.0	1167.6	11.588
37.0	22.3	262.57	231.26	936.9	1168.2	11.294
38.0	23.3	264.16	232.89	935.8	1168.7	11.015
39.0	24.3	265.72	234.48	934.7	1169.2	10.750
40.0	25.3	267.25	236.03	933.7	1169.7	10.498
41.0	26.3	268.74	237.55	932.6	1170.2	10.258
42.0	27.3	270.21	239.04	931.6	1170.7	10.029
43.0	28.3	271.64	240.51	930.6	1171.1	9.810
44.0	29.3	273.05	241.95	929.6	1171.6	9.601
45.0	30.3	274.44	243.36	928.6	1172.0	9.401
46.0	31.3	275.80	244.75	927.7	1172.4	9.209
47.0	32.3	277.13	246.12	926.7	1172.9	9.025
48.0	33.3	278.45	247.47	925.8	1173.3	8.848
49.0	34.3	279.74	248.79	924.9	1173.7	8.678
50.0	35.3	281.01	250.09	924.0	1174.1	8.515
51.0	36.3	282.26	251.37	923.0	1174.4	8.359
52.0	37.3	283.49	252.63	922.2	1174.8	8.208
53.0	38.3	284.70	253.87	921.3	1175.2	8.062
54.0	39.3	285.90	255.09	920.5	1175.6	7.922
55.0	40.3	287.07	256.30	919.6	1175.9	7.787
56.0	41.3	288.23	257.50	919.8	1176.3	7.656
57.0	42.3	289.37	258.67	917.9	1176.6	7.529
58.0	43.3	290.50	259.82	917.1	1176.9	7.407
59.0	44.3	291.61	260.96	916.3	1177.3	7.289
60.0	45.3	292.71	262.09	915.5	1177.6	7.175
61.0	46.3	293.79	263.20	914.7	1177.9	7.064
62.0	47.3	294.86	264.30	913.9	1178.2	6.957
63.0	48.3	295.90	265.38	913.1	1178.5	6.853
64.0	49.3	296.94	266.45	912.3	1178.8	6.752

**PROPERTIES OF SATURATED STEAM - continued**

PRESSURE Lbs. per Sq. In.		Temperature	Heat of the Liquid	Latent Heat of Evaporation	Total Heat of Steam	Specific Volume
Absolute P'	Gage P	t Degrees F.	Btu / lb.	Btu / lb.	hg Btu / lb.	— Cu. ft. per lb.
65.0	50.3	297.97	267.50	911.6	1179.1	6.655
66.0	51.3	298.99	268.55	910.8	1179.4	6.560
67.0	52.3	299.99	269.58	910.1	1179.7	6.468
68.0	53.3	300.98	270.60	909.4	1180.0	6.378
69.0	54.3	301.96	271.61	908.7	1180.3	6.291
70.0	55.3	302.92	272.61	907.9	1180.6	6.206
71.0	56.3	303.88	273.60	907.2	1180.8	6.124
72.0	57.3	304.83	274.57	906.5	1181.1	6.044
73.0	58.3	305.76	275.54	905.8	1181.3	5.966
74.0	59.3	306.68	276.49	905.1	1181.6	5.890
75.0	60.3	307.60	277.43	904.5	1181.9	5.816
76.0	61.3	308.50	278.37	903.7	1182.1	5.743
77.0	62.3	309.40	279.30	903.1	1182.4	5.673
78.0	63.3	310.29	280.21	902.4	1182.6	5.604
79.0	64.3	311.16	281.12	901.7	1182.8	5.537
80.0	65.3	312.03	282.02	901.1	1183.1	5.472
81.0	66.3	312.89	282.91	900.4	1183.3	5.408
82.0	67.3	313.74	283.79	899.7	1183.5	5.346
83.0	68.3	314.59	284.66	899.1	1183.8	5.285
84.0	69.3	315.42	285.53	898.5	1184.0	5.226
85.0	70.3	316.25	286.39	897.8	1184.2	5.168
86.0	71.3	317.07	287.24	897.2	1184.4	5.111
87.0	72.3	317.88	288.08	896.5	1184.6	5.055
88.0	73.3	318.68	288.91	895.9	1184.8	5.001
89.0	74.3	319.48	289.74	895.3	1185.1	4.948
90.0	75.3	320.27	290.56	894.7	1185.3	4.896
91.0	76.3	321.06	291.38	894.1	1185.5	4.845
92.0	77.3	321.83	292.18	893.5	1185.7	4.796
93.0	78.3	322.60	292.98	892.9	1185.9	4.747
94.0	79.3	323.36	293.78	892.3	1186.1	4.699
95.0	80.3	324.12	294.56	891.7	1186.2	4.652
96.0	81.3	324.87	295.34	891.1	1186.4	4.606
97.0	82.3	325.61	296.12	890.5	1186.6	4.561
98.0	83.3	326.35	296.89	889.9	1186.8	4.517
99.0	84.3	327.08	297.65	889.4	1187.0	4.474
100.0	85.3	327.81	298.40	888.8	1187.2	4.432
101.0	86.3	328.53	299.15	888.2	1187.4	4.391
102.0	87.3	329.25	299.90	887.6	1187.5	4.350
103.0	88.3	329.96	300.64	887.1	1187.7	4.310
104.0	89.3	330.66	301.37	886.5	1187.9	4.271
105.0	90.3	331.36	302.10	886.0	1188.1	4.232
106.0	91.3	332.05	302.82	885.4	1188.2	4.194
107.0	92.3	332.74	303.54	884.9	1188.4	4.157
108.0	93.3	333.42	304.26	884.3	1188.6	4.120
109.0	94.3	334.10	304.97	883.7	1188.7	4.084
110.0	95.3	334.77	305.66	883.2	1188.9	4.049
111.0	96.3	335.44	306.37	882.6	1189.0	4.015
112.0	97.3	336.11	307.06	882.1	1189.2	3.981
113.0	98.3	336.77	307.75	881.6	1189.4	3.947
114.0	99.3	337.42	308.43	881.1	1189.5	3.914



**PROPERTIES OF SATURATED STEAM - continued**

PRESSURE Lbs. per Sq. In.		Temperature	Heat of the Liquid	Latent Heat of Evaporation	Total Heat of Steam	Specific Volume
Absolute P'	Gage P	t Degrees F.	Btu / lb.	Btu / lb.	hg Btu / lb.	— Cu. ft. per lb.
115.0	100.3	338.07	309.11	880.6	1189.7	3.882
116.0	101.3	338.72	309.79	880.0	1189.8	3.850
117.0	102.3	339.36	310.46	879.5	1190.0	3.819
118.0	103.3	339.99	311.12	879.0	1190.1	3.788
119.0	104.3	340.62	311.78	878.4	1190.2	3.758
120.0	105.3	341.25	312.44	877.9	1190.4	3.728
121.0	106.3	341.88	313.10	877.4	1190.5	3.699
122.0	107.3	342.50	313.75	876.9	1190.7	3.670
123.0	108.3	343.11	314.40	876.4	1190.8	3.642
124.0	109.3	343.72	315.04	875.9	1190.9	3.614
125.0	110.3	344.33	315.68	875.4	1191.1	3.587
126.0	111.3	344.94	316.31	874.9	1191.2	3.560
127.0	112.3	345.54	316.94	874.4	1191.3	3.533
128.0	113.3	346.13	317.57	873.9	1191.5	3.507
129.0	114.3	346.73	318.19	873.4	1191.6	3.481
130.0	115.3	347.32	318.81	872.9	1191.7	3.455
131.0	116.3	347.90	319.43	872.5	1191.9	3.430
132.0	117.3	348.48	320.04	872.0	1192.0	3.405
133.0	118.3	349.06	320.65	871.5	1192.1	3.381
134.0	119.3	349.64	321.25	871.0	1192.2	3.357
135.0	120.3	350.21	321.85	870.6	1192.4	3.333
136.0	121.3	350.78	322.45	870.1	1192.5	3.310
137.0	122.3	351.35	323.05	869.6	1192.6	3.287
138.0	123.3	351.91	323.64	869.1	1192.7	3.264
139.0	124.3	352.47	324.23	868.7	1192.9	3.242
140.0	125.3	353.02	324.82	868.2	1193.0	3.220
141.0	126.3	353.57	325.40	867.7	1193.1	3.198
142.0	127.3	354.12	325.98	867.2	1193.2	3.177
143.0	128.3	354.67	326.56	866.7	1193.3	3.155
144.0	129.3	355.21	327.13	866.3	1193.4	3.134
145.0	130.3	355.76	327.70	865.8	1193.5	3.114
146.0	131.3	356.29	328.27	865.3	1193.6	3.094
147.0	132.3	356.83	328.83	864.9	1193.8	3.074
148.0	133.3	357.36	329.39	864.5	1193.9	3.054
149.0	134.3	357.89	329.95	864.0	1194.0	3.034
150.0	135.3	358.42	330.51	863.6	1194.1	3.015
152.0	137.3	359.46	331.61	862.7	1194.3	2.977
154.0	139.3	360.49	332.70	861.8	1194.5	2.940
156.0	141.3	361.52	333.79	860.9	1194.7	2.904
158.0	143.3	362.53	334.86	860.0	1194.9	2.869
160.0	145.3	363.53	335.93	859.2	1195.1	2.834
162.0	147.3	364.53	336.98	858.3	1195.3	2.801
164.0	149.3	365.51	338.02	857.5	1195.5	2.768
166.0	151.3	366.48	339.05	856.6	1195.7	2.736
168.0	153.3	367.45	340.07	855.7	1195.8	2.705
170.0	155.3	368.41	341.09	854.9	1196.0	2.675
172.0	157.3	369.35	342.10	854.1	1196.2	2.645
174.0	159.3	370.29	343.10	853.3	1196.4	2.616
176.0	161.3	371.22	344.09	852.4	1196.5	2.587
178.0	163.3	372.14	345.06	851.6	1196.7	2.559

**PROPERTIES OF SATURATED STEAM - continued**

PRESSURE Lbs. per Sq. In.		Temperature	Heat of the Liquid	Latent Heat of Evaporation	Total Heat of Steam	Specific Volume
Absolute P'	Gage P	t Degrees F.	Btu / lb.	Btu / lb.	hg Btu / lb.	— Cu. ft. per lb.
180.0	165.3	373.96	346.03	850.8	1196.9	2.532
182.0	167.3	373.96	347.00	850.0	1197.0	2.505
184.0	169.3	374.86	347.96	849.2	1197.2	2.479
186.0	171.3	375.75	348.92	848.4	1197.3	2.454
188.0	173.3	376.64	349.86	847.6	1197.5	2.429
190.0	175.3	377.51	350.79	846.8	1197.6	2.404
192.0	177.3	378.38	351.72	846.1	1197.8	2.380
194.0	179.3	379.24	352.64	845.3	1197.9	2.356
196.0	181.3	380.10	353.55	844.5	1198.1	2.333
198.0	183.3	380.95	354.46	843.7	1198.2	2.310
200.0	185.3	381.79	355.36	843.0	1198.4	2.288
205.0	190.3	383.86	357.58	841.1	1198.7	2.234
210.0	195.3	385.90	359.77	839.2	1199.0	2.183
215.0	200.3	387.89	361.91	837.4	1199.3	2.134
220.0	205.3	389.86	364.02	835.6	1199.6	2.087
225.0	210.3	391.79	366.09	833.8	1199.9	2.0422
230.0	215.3	393.68	368.13	832.0	1200.1	1.9992
235.0	220.3	395.54	370.14	830.3	1200.4	1.9579
240.0	225.3	397.37	372.12	828.5	1200.6	1.9183
245.0	230.3	399.18	374.08	826.8	1200.9	1.8803
250.0	235.3	400.95	376.00	825.1	1201.1	1.8438
255.0	240.3	402.70	377.89	823.4	1201.3	1.8086
260.0	245.3	404.42	379.89	821.8	1201.5	1.7748
265.0	250.3	406.11	381.60	820.1	1201.7	1.7422
270.0	255.3	407.78	383.42	818.5	1201.9	1.7107
275.0	260.3	409.43	385.21	816.9	1202.1	1.6804
280.0	265.3	411.05	386.98	815.3	1202.3	1.6511
285.0	270.3	412.65	388.73	813.7	1202.4	1.6228
290.0	275.3	414.23	390.46	812.1	1202.6	1.5954
295.0	280.3	415.79	392.16	810.5	1202.7	1.5689
300.0	285.3	417.33	393.84	809.0	1202.8	1.5433
320.0	305.3	423.29	400.39	803.0	1203.4	1.4485
340.0	325.3	428.97	406.66	797.1	1203.7	1.3645
360.0	345.3	434.40	412.67	791.4	1204.1	1.2895
380.0	365.3	439.60	418.45	785.8	1204.3	1.2222
400.0	385.3	444.59	424.0	780.5	1204.5	1.1613
420.0	405.3	449.39	429.4	775.2	1204.6	1.1061
440.0	425.3	454.02	434.6	770.0	1204.6	1.0556
460.0	445.3	458.50	439.7	764.9	1204.6	1.0094
480.0	465.3	462.82	444.6	759.9	1204.5	0.9670
500.0	485.3	467.01	449.4	755.0	1204.4	0.9278
520.0	505.3	471.07	454.1	750.1	1204.2	0.8915
540.0	525.3	475.01	458.6	745.4	1204.0	0.8578
560.0	545.3	478.85	463.0	740.8	1203.8	0.8265
580.0	565.3	482.53	467.4	736.1	1203.5	0.7973
600.0	585.3	486.21	471.6	731.1	1203.2	0.7698
620.0	605.3	489.75	475.7	727.2	1202.9	0.7440
640.0	625.3	493.21	479.8	722.7	1202.5	0.7198
660.0	645.3	496.58	483.8	718.3	1202.1	0.6971
680.0	665.3	499.88	487.7	714.0	1201.7	0.6757

**PROPERTIES OF SATURATED STEAM - continued**

PRESSURE Lbs. per Sq. In.		Temperature	Heat of the Liquid	Latent Heat of Evaporation	Total Heat of Steam	Specific Volume
Absolute P'	Gage P	t Degrees F.	Btu / lb.	Btu / lb.	hg Btu / lb.	— Cu. ft. per lb.
700.0	685.3	503.10	491.5	709.7	1201.2	0.6554
720.0	705.3	506.25	495.3	705.4	1200.7	0.6362
740.0	725.3	509.34	499.0	701.2	1200.2	0.6180
760.0	745.3	512.36	502.6	697.1	1199.7	0.6007
780.0	765.3	515.33	506.2	692.9	1199.1	0.5843
800.0	785.3	518.23	509.7	688.9	1198.6	0.5687
820.0	805.3	521.08	513.2	684.8	1198.0	0.5538
840.0	825.3	523.88	516.6	680.8	1197.4	0.5396
860.0	845.3	526.63	520.0	676.8	1196.8	0.5260
880.0	865.3	529.33	523.3	672.8	1196.1	0.5130
900.0	885.3	531.98	526.6	668.8	1195.4	0.5006
920.0	905.3	534.59	529.8	664.9	1194.7	0.4886
940.0	925.3	537.16	533.0	661.0	1194.0	0.4772
960.0	945.3	539.68	536.2	657.1	1193.3	0.4663
980.0	965.3	542.17	539.3	653.3	1192.6	0.4557
1000.0	985.3	544.61	542.4	649.4	1191.8	0.4456
1050.0	1035.3	550.57	550.0	639.9	1189.9	0.4218
1100.0	1085.3	556.31	557.4	630.4	1187.8	0.4001
1150.0	1135.3	561.86	564.6	621.0	1185.6	0.3802
1200.0	1185.3	567.22	571.7	611.7	1183.4	0.3619
1250.0	1235.3	572.42	578.6	602.4	1181.0	0.3450
1300.0	1285.3	577.46	585.4	593.2	1178.6	0.3293
1350.0	1335.3	582.35	592.1	584.0	1176.1	0.3148
1400.0	1385.3	587.10	598.7	574.7	1173.4	0.3012
1450.0	1435.3	591.73	605.2	565.5	1170.7	0.2884
1500.0	1485.3	596.23	611.6	556.3	1167.9	0.2765
1600.0	1585.3	604.90	624.1	538.0	1162.1	0.2548
1700.0	1685.3	613.15	636.3	519.6	1155.9	0.2354
1800.0	1785.3	621.03	648.3	501.1	1149.4	0.2179
1900.0	1885.3	628.58	660.1	482.4	1142.4	0.2021
2000.0	1985.3	635.82	671.7	463.4	1135.1	0.1878
2100.0	2085.3	642.77	683.3	444.1	1127.4	0.1746
2200.0	2185.3	649.46	694.8	424.4	1119.2	0.1625
2300.0	2285.3	655.91	706.5	403.9	1110.4	0.1513
2400.0	2385.3	662.12	718.4	382.7	1101.1	0.1407
2500.0	2485.3	668.13	730.6	360.5	1091.1	0.1307
2600.0	2585.3	673.94	743.0	337.2	1080.2	0.1213
2700.0	2685.3	679.55	756.2	312.1	1068.3	0.1123
2800.0	2785.3	684.99	770.1	284.7	1054.8	0.1035
2900.0	2885.3	690.26	785.4	253.6	1039.0	0.0947
3000.0	2985.3	695.36	802.5	217.8	1020.3	0.0858
3100.0	3085.3	700.31	825.0	168.1	993.1	0.0753
3200.0	3185.3	705.11	872.4	62.0	934.4	0.0580
3206.2	3191.3	705.40	902.7	0.0	902.7	0.0503

**PROPERTIES OF WATER AT VARIOUS TEMPERATURES FROM 40 TO 705.4 F**

Temp. F	Temp. C	Specific Volume Cu Ft / Lb	SPECIFIC GRAVITY			Wt in Lb / Cu Ft	Vapor Pressure Psi Abs
			39.2 F Reference	60 F Reference	70 F Reference		
40	4.4	.01602	1.000	1.001	1.002	62.42	0.1217
50	10.0	.01603	.999	1.001	1.002	62.38	0.1781
60	15.6	.01604	.999	1.000	1.001	62.34	0.2563
70	21.1	.01606	.998	.999	1.000	62.27	0.3631
80	26.7	.01608	.996	.998	.999	62.19	0.5069
90	32.2	.01610	.995	.996	.997	62.11	0.6982
100	37.8	.01613	.993	.994	.995	62.00	0.9492
120	48.9	.01620	.989	.990	.991	61.73	1.692
140	60.0	.01629	.983	.985	.986	61.39	2.889
160	71.1	.01639	.977	.979	.979	61.01	4.741
180	82.2	.01651	.970	.972	.973	60.57	7.510
200	93.3	.01663	.963	.964	.966	60.13	11.526
212	100.0	.01672	.958	.959	.960	59.81	14.696
220	104.4	.01677	.955	.956	.957	59.63	17.186
240	115.6	.01692	.947	.948	.949	59.10	24.97
260	126.7	.01709	.938	.939	.940	58.51	35.43
280	137.8	.01726	.928	.929	.930	58.00	49.20
300	148.9	.01745	.918	.919	.920	57.31	67.01
320	160.0	.01765	.908	.909	.910	56.66	89.66
340	171.1	.01787	.896	.898	.899	55.96	118.01
360	182.2	.01811	.885	.886	.887	55.22	153.04
380	193.3	.01836	.873	.874	.875	54.57	195.77
400	204.4	.01864	.859	.860	.862	53.65	247.31
420	215.6	.01894	.846	.847	.848	52.80	308.83
440	226.7	.01926	.832	.833	.834	51.92	381.59
460	237.8	.0196	.817	.818	.819	51.02	466.9
480	248.9	.0200	.801	.802	.803	50.00	566.1
500	260.0	.0204	.785	.786	.787	49.02	680.8
520	271.1	.0209	.765	.766	.767	47.85	812.4
540	282.2	.0215	.746	.747	.748	46.51	962.5
560	293.3	.0221	.726	.727	.728	45.3	1133.1
580	304.4	.0228	.703	.704	.704	43.9	1325.8
600	315.6	.0236	.678	.679	.680	42.3	1542.9
620	326.7	.0247	.649	.650	.650	40.5	1786.6
640	337.8	.0260	.617	.618	.618	38.5	2059.7
660	348.9	.0278	.577	.577	.578	36.0	2365.4
680	360.0	.0305	.525	.526	.527	32.8	2708.1
700	371.1	.0369	.434	.435	.435	27.1	3093.7
705.4	374.1	.0503	.319	.319	.320	19.9	3206.2

Computed from Keenan & Keyes' Steam Table.

NOTE: For viscosity of water and other liquids at various temperatures see "Pipe Friction Manual," published by the Hydraulic Institute.

# PHYSICAL PROPERTIES OF GASES

$C_p$  = specific heat at constant pressure

$C_v$  = specific heat at constant volume

Name of Gas	Chemical Formula or Symbol	Approx. Molecular Weight <i>M</i>	Weight Density, Pounds per Cubic Foot * <i>p</i>	Specific Gravity Relative To Air <i>S<sub>g</sub></i>	Individual Gas Constant <i>R</i>	Specific Heat Per Pound at Room Temperature		Heat Capacity Per Cubic Foot at Atmospheric Pressure and 68 °F		<i>k</i> equal to $C_p / C_v$
						$C_p$	$C_v$	$C_p$	$C_v$	
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.0	.06754	.897	59.4	.350	.2737	.0236	.0185	1.28
Air		29.0	.07528	1.000	53.3	.241	.1725	.0181	.0130	1.40
Ammonia	NH <sub>3</sub>	17.0	.04420	.587	90.8	.523	.4064	.0231	.0179	1.29
Argon	A	40.0	.1037	1.377	38.7	.124	.0743	.0129	.0077	1.67
Carbon Dioxide	CO <sub>2</sub>	44.0	.1142	1.516	35.1	.206	.1599	.0234	.0183	1.28
Carbon Monoxide	CO	28.0	.07269	.965	55.2	.243	.1721	.0177	.0125	1.41
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.0	.0728	.967	55.1	.40	.3292	.0291	.0240	1.22
Helium	He	4.0	.01039	.138	386.	1.25	.754	.0130	.0078	1.66
Hydrochloric Acid	HCl	36.5	.09460	1.256	42.4	.919	.1365	.0181	.0129	1.40
Hydrogen	H <sub>2</sub>	2.0	.005234	.0695	767.	3.42	2.436	.0179	.0127	1.40
Methane	CH <sub>4</sub>	16.0	.04163	.553	96.4	.593	.4692	.0247	.0195	1.26
Methyl Chloride	CH <sub>3</sub> Cl	50.5	.1309	1.738	30.6	.24	.2006	.0314	.0263	1.20
Nitrogen	N <sub>2</sub>	28.0	.07274	.966	55.2	.247	.1761	.0179	.0128	1.40
Nitric Oxide	NO	30.0	.07788	1.034	51.5	.231	.1648	.0180	.0128	1.40
Nitrous Oxide	N <sub>2</sub> O	44.0	.1143	1.518	35.1	.221	.1759	.0253	.0201	1.26
Oxygen	O <sub>2</sub>	32.0	.08305	1.103	48.3	.217	.1549	.0180	.0129	1.40
Sulphur Dioxide	SO <sub>2</sub>	64.0	.1663	2.208	24.1	.154	.1230	.0256	.0204	1.25

\* Weight density values are at atmospheric pressure and 68 °F.  
For values at 60 °F, multiply by 1.0154.

**Weight Density & Specific Gravity\* of Various Liquids**

LIQUID	TEMPERATURE <i>t</i> Deg. Fahr.	WEIGHT DENSITY $\rho$ <i>Lbs. per Cu. Ft.</i>	SPECIFIC GRAVITY <i>S</i>
Acetone	60	49.4	0.792
Ammonia, Saturated	10	40.9	...
Benzene	32	56.1	...
Brine, 10% Ca Cl	32	68.05	...
Brine, 10% Na Cl	32	67.24	...
Bunkers C Fuel Max.	60	63.25	.014
Carbon Disulphide	32	80.6	...
Distillate	60	52.99	0.850
Fuel 3 Max.	60	56.02	0.898
Fuel 5 Min.	60	60.23	0.966
Fuel 5 Max.	60	61.92	0.993
Fuel 6 Min.	60	61.92	0.993
Gasoline	60	46.81	0.751
Gasoline, Natural	60	42.42	0.680
Kerosene	60	50.85	0.815
M.C. Residuum	60	58.32	0.935
Mercury	20	849.74	...
Mercury	40	848.03	...
Mercury	60	846.32	13.570
Mercury	80	844.62	...
Mercury	100	842.93	...
Milk	...	†	...
Olive Oil	59	57.3	0.919
Pentane	59	38.9	0.624
SAE 10 Lube ‡	60	54.64	0.876
SAE 30 Lube ‡	60	56.02	0.898
SAE 70 Lube ‡	60	57.12	0.916
Salt Creek Crude	60	52.56	0.843
32 6° API Crude	60	53.77	0.862
35 6° API Crude	60	52.81	0.847
40° API Crude	60	51.45	0.825
48° API Crude	60	49.16	0.788

\* Liquid at 60° F referred to water at 60° F.  
 † Milk has a weight density of 64.2 to 64.6.  
 ‡ 100 Viscosity Index

## WEIGHT DENSITY & SPECIFIC VOLUME OF GASES & VAPORS

Air Temp. Deg. F	Weight Density of Air, in Pounds per Cubic Foot For Gauge Pressures Indicated <small>(based on an atmospheric pressure of 14.696 and a molecular weight of 28.97)</small>														
	0 psi	5 psi	10 psi	20 psi	30 psi	40 psi	50 psi	60 psi	70 psi	80 psi	90 psi	100 psi	110 psi	120 psi	130 psi
30°	.0811	.1087	.1363	.1915	.247	.302	.357	.412	.467	.522	.578	.633	.688	.743	.798
40	.0795	.1065	.1335	.1876	.242	.295	.350	.404	.458	.512	.566	.620	.674	.728	.782
50	.0782	.1048	.1314	.1846	.238	.291	.344	.397	.451	.504	.557	.610	.663	.717	.770
60	.0764	.1024	.1284	.1804	.232	.284	.336	.388	.440	.492	.544	.596	.648	.700	.752
70	.0750	.1005	.1260	.1770	.228	.279	.330	.381	.432	.483	.534	.585	.636	.687	.738
80	.0738	.0986	.1236	.1737	.224	.274	.324	.374	.424	.474	.524	.574	.624	.674	.724
90	.0722	.0968	.1214	.1705	.220	.269	.318	.367	.416	.465	.515	.564	.613	.662	.711
100	.0709	.0951	.1192	.1675	.216	.264	.312	.361	.409	.457	.505	.554	.602	.650	.698
110	.0697	.0934	.1171	.1645	.212	.259	.307	.354	.402	.449	.497	.544	.591	.639	.686
120	.0685	.0918	.1151	.1617	.208	.255	.302	.348	.395	.441	.488	.535	.581	.628	.674
130	.0673	.0902	.1131	.1590	.205	.251	.296	.342	.388	.434	.480	.525	.571	.617	.663
140	.0662	.0887	.1113	.1563	.201	.246	.291	.337	.382	.427	.472	.517	.562	.607	.652
150	.0651	.0873	.1094	.1537	.1981	.242	.287	.331	.375	.420	.464	.508	.553	.597	.641
175	.0626	.0834	.1051	.1477	.1903	.233	.275	.318	.361	.403	.446	.488	.531	.573	.616
200	.0602	.0807	.1011	.1421	.1831	.224	.265	.306	.347	.388	.429	.470	.511	.552	.593
225	.0580	.0777	.0974	.1369	.1764	.216	.255	.295	.334	.374	.413	.453	.492	.531	.571
250	.0559	.0750	.0940	.1321	.1702	.208	.246	.284	.322	.361	.399	.437	.475	.513	.551
275	.0540	.0724	.0908	.1276	.1644	.201	.238	.275	.311	.348	.385	.422	.459	.495	.532
300	.0523	.0700	.0878	.1234	.1590	.1945	.230	.266	.301	.337	.372	.408	.443	.479	.515
350	.0490	.0657	.0824	.1158	.1491	.1825	.216	.249	.283	.316	.349	.383	.416	.449	.483
400	.0462	.0619	.0776	.1090	.1405	.1719	.203	.235	.266	.298	.329	.360	.392	.423	.455
450	.0436	.0585	.0733	.1030	.1327	.1624	.1921	.222	.252	.281	.311	.341	.370	.400	.430
500	.0414	.0555	.0695	.0977	.1258	.1540	.1821	.210	.238	.267	.295	.323	.351	.379	.407
550	.0393	.0527	.0661	.0928	.1196	.1464	.1731	.1999	.227	.253	.280	.307	.334	.360	.387
600	.0375	.0502	.0630	.0885	.1140	.1395	.1649	.1904	.216	.241	.267	.292	.318	.343	.369
	140 psi	150 psi	175 psi	200 psi	225 psi	250 psi	300 psi	400 psi	500 psi	600 psi	700 psi	800 psi	900 psi	1000 psi	
30°	.853	.909	1.047	1.185	1.323	1.460	1.736	2.29	2.84	3.39	3.94	4.49	5.05	5.60	
40	.836	.890	1.026	1.161	1.296	1.431	1.702	2.24	2.78	3.32	3.86	4.40	4.95	5.49	
50	.823	.876	1.009	1.142	1.275	1.408	1.674	2.21	2.74	3.27	3.80	4.33	4.87	5.40	
60	.804	.856	.986	1.116	1.246	1.376	1.636	2.16	2.68	3.20	3.72	4.24	4.76	5.28	
70	.789	.840	.968	1.095	1.223	1.350	1.605	2.12	2.63	3.14	3.65	4.16	4.67	5.18	
80	.774	.824	.950	1.075	1.200	1.325	1.575	2.08	2.58	3.08	3.58	4.08	4.58	5.08	
90	.760	.809	.932	1.055	1.178	1.301	1.547	2.04	2.53	3.02	3.51	4.00	4.50	4.99	
100	.747	.795	.916	1.036	1.157	1.279	1.519	2.00	2.48	2.97	3.45	3.93	4.42	4.90	
110	.734	.781	.900	1.018	1.137	1.255	1.492	1.967	2.44	2.92	3.39	3.86	4.34	4.81	
120	.721	.768	.884	1.001	1.117	1.234	1.467	1.933	2.40	2.86	3.33	3.80	4.26	4.73	
130	.709	.755	.869	.984	1.098	1.213	1.442	1.900	2.36	2.82	3.27	3.73	4.19	4.65	
140	.697	.742	.855	.967	1.080	1.193	1.418	1.868	2.32	2.77	3.22	3.67	4.12	4.57	
150	.686	.730	.841	.951	1.062	1.173	1.395	1.838	2.28	2.72	3.17	3.61	4.05	4.50	
175	.659	.701	.807	.914	1.020	1.127	1.340	1.765	2.19	2.62	3.04	3.47	3.89	4.32	
200	.634	.675	.777	.879	.982	1.084	1.289	1.698	2.11	2.52	2.93	3.34	3.75	4.16	
225	.610	.650	.749	.847	.946	1.044	1.242	1.636	2.03	2.43	2.82	3.21	3.61	4.00	
250	.589	.627	.722	.817	.913	1.008	1.198	1.579	1.959	2.34	2.72	3.10	3.48	3.86	
275	.569	.606	.698	.790	.881	.973	1.157	1.525	1.893	2.28	2.63	3.00	3.36	3.73	
300	.550	.588	.675	.764	.852	.941	1.119	1.475	1.830	2.19	2.54	2.90	3.25	3.61	
350	.516	.550	.633	.716	.800	.883	1.050	1.384	1.717	2.05	2.38	2.72	3.05	3.39	
400	.486	.518	.596	.675	.753	.832	.989	1.303	1.618	1.932	2.25	2.56	2.87	3.19	
450	.459	.489	.563	.638	.712	.786	.934	1.232	1.529	1.826	2.12	2.42	2.72	3.01	
500	.436	.464	.534	.604	.675	.745	.886	1.167	1.449	1.731	2.01	2.29	2.58	2.86	
550	.414	.441	.508	.575	.641	.708	.842	1.110	1.377	1.645	1.912	2.18	2.45	2.72	
600	.394	.420	.484	.547	.611	.675	.802	1.057	1.312	1.567	1.822	2.08	2.33	2.59	

*Air Density Table: This table is calculated for the perfect gas law shown below. Correction for supercompressibility, the deviation from the perfect gas law, would be less than 3% and has not been applied. The weight density of gases other than air can be determined from this table by multiplying the density listed for air by the specific gravity of the gas relative to air.*

$$p = \frac{144 P^1}{RT} = \frac{MP^1}{10.72 T} = \frac{2.70 P^1 S_g}{T}$$

## CORROSIVE SERVICE GUIDE TO MATERIALS

CORRODENT	TEMP. °F	CONC. %	RECOM. MATERIAL	CORRODENT	TEMP. °F	CONC. %	RECOM. MATERIAL
Acetic Acid	212	ALL	Monel	Calcium Hypochlorite	SEE	BLEACHING	POWDER
Acetic Anhydride	300		Nickel	Carbolic Acid	SEE	PHENOL	
Acetone	212	ALL	304 SS	Carbon Dioxide, Dry	800	All	Brass
Acetylene	400		304 SS	Carbonated Water	212	All	304 SS
Alcohols	212	ALL	304 SS	Carbonated Beverages	212		304 SS
Alum. (Potassium or Sodium)	300	ALL	Hast. C	Carbon Disulfide	200		304 SS
Aluminum Chloride	212	ALL	Hast. B	Carbon Tetrachloride	125	All	Monel
Aluminum Sulfate	212	ALL	316 SS	Chlorine, Dry	100		Monel
Ammonia, Dry	212	ALL	304, 316 SS	Chlorine, Moist	100	All	Monel
Ammonium Hydroxide (Ammonia, Aqua)	212	ALL	304, 316 SS	Chloroacetic Acid	212	All	Monel
Ammonium Chloride	300	50%	Monel	Chloroform, Dry	212		Monel
Ammonium Nitrate	300	ALL	304 SS	Chromic Acid	300	ALL	Hast. C
Ammonium Sulfate	212	ALL	316 SS	Cider	300	ALL	304 SS
Amyl Acetate	300	ALL	304 SS	Citric Acid	212	ALL	Hast. C
Aniline	75		Monel	Copper (10) Chloride	212	ALL	Hast. C
Asphalt	250		304 SS	Copper (10) Nitrate	300	ALL	316 SS
Atmosphere, (Industrial or Marine)			304 SS	Copper (10) Sulphate	300	ALL	316 SS
Barium Compounds	SEE	CALCIUM		Copper Plating Solution (Cyanide)	180		304 SS
Beer	70		304 SS	Copper Plating Solution (Acid)	75		304 SS
Benzene (Benzol)	212		Steel	Corn Oil	200		304 SS
Benzoic Acid	212	ALL	316 SS	Creosote	200	ALL	304 SS
Bleaching Powder	70	16%	Monel	Crude Oil	300		Monel
Borax	212	ALL	Brass	Ethyl Acetate	SEE	LACQUER	THINNER
Bordeaux Mixture	200		304 SS	Ethyl Chloride, Dry	500		Steel
Boric Acid	400	ALL	316 SS	Ethanol	SEE	ALCOHOLS	
Bromine	125	DRY	Monel	Ethylene Glycol (Uninhibited)	212	ALL	304 SS
Butane	400	ALL	Steel	Ethylene Oxide	75		Steel
Butyl Alcohol	SEE	ALCOHOLS		Fatty Acids	600	ALL	316 SS
Butyric Acid	212		Hast. C	Ferric Chloride	75	ALL	Hast. C
Calcium Bisulphite	75	ALL	Hast. C	Ferric Sulfate	300	ALL	304 SS
Calcium Chloride	212	ALL	Hast. C	Formaldehyde	212	40%	316 SS
Calcium Hydroxide	300	20%	Hast. C	Formic Acid	300	ALL	316 SS

cont.,



## CORROSIVE SERVICE GUIDE TO MATERIALS - continued

CORRODENT	TEMP. °F	CONC. %	RECOM. MATERIAL	CORRODENT	TEMP. °F	CONC. %	RECOM. MATERIAL
Freon	300		Steel	Oleic Acid	SEE	FATTY	ACIDS
Fluorine, Anhydrous	100		304 SS	Oxalic Acid	212	ALL	Monel
Furfural	460		316 SS	Photographic Bleaching	100	ALL	304 SS
Gasoline	300		Steel	Palmitic Acid	SEE	FATTY	ACIDS
Glucose	300		304 SS	Phosphoric Acid	212	ALL	316 SS
Glue pH 6.8	300	ALL	304 SS	Phenol	212	ALL	316 SS
Glycerine	212	ALL	Brass	Potassium Compounds	SEE	SODIUM	COMPOUNDS
Hydrobromic Acid	212	ALL	Hast. C	Propane	300		Steel
Hydrochloric Acid (37.38%)	226	ALL	Hast. B	Resin	700	100%	316 SS
Hydrogen Chloride, Dry	600		304 SS	Sea Water	76		Monel
Hydrocyanic Acid	212	ALL	304 SS	Soap & Detergents	212	ALL	304 SS
Hydrofluoric Acid	212	60%	Monel	Sodium Bicarbonate	212	20%	316 SS
Hydrogen Fluoride, Dry	176		Steel	Sodium Bisulphite	212	20%	304 SS
Hydrofluogilic Acid	212	40%	Monel	Sodium Bisulphate	212	20%	304 SS
Hydrogen Peroxide	126	10-100%	304 SS	Sodium Carbinatate	212	40%	316 SS
Kerosene	300	ALL	Steel	Sodium Chloride	300	30%	Monel
Lacquers & Thinners	300	ALL	304 SS	Sodium Chromate	212	ALL	316 SS
Lactic Acid	300	ALL	316 SS	Salt or Brine	SEE	SODIUM	CHLORIDE
Lime	212	ALL	316 SS	Sodium Cyanide	212	ALL	304 SS
Linseed Oil	76		Steel	Sodium Hydroxide	212	30%	316 SS
Magnesium Chloride	212	60%	Nickel	Sodium Hypochlorite	76	10%	Hast. C
Magnesium Hydroxide (or Oxide)	76	ALL	304 SS	Sodium Nitrate	212	40%	304 SS
Magnesium Sulfate	212	40%	304 SS	Sodium Nitrate	76	20%	316 SS
Mercuric Chloride	76	10%	Hast. C	Sodium Phosphate	212	10%	Steel
Mercury	700	100%	Steel	Sodium Silicate	212	10%	Steel
Methylene Chloride	212	ALL	304 SS	Sodium Sulfate	212	30%	316 SS
Methyl Chloride, Dry	76		Steel	Sodium Sulfide	212	10%	316 SS
Milk, fresh or sour	180		304 SS	Sodium Sulfite	212	30%	304 SS
Molasses	SEE	GLUCOSE		Sodium Thiosulfate	212	ALL	304 SS
Natural Gas	70		304 SS	Steam			304 SS
Nitric Acid	76	ALL	304 SS	Stearic Acid	SEE	FATTY	ACIDS
Nitric Acid	300	ALL	316 SS	Sugar Solutions	SEE	GLUCOSE	
Oxygen	76	ALL	Steel	Sulfur	600		304 SS

cont...

## CORROSIVE SERVICE GUIDE TO MATERIALS - continued

CORRODENT	TEMP. °F	CONC. %	RECOM. MATERIAL
Sulfur Chloride	75	DRY	316 SS
Sulfur Dioxide	500	DRY	316 SS
Sulfur Trioxide	500	DRY	316 SS
Sulfuric Acid	212	10%	316 SS
Sulfuric Acid	212	10.90%	Hast. B
Sulfuric Acid	212	90.100%	316 SS
Sulfuric Acid, Fuming	175		Hast. C
Sulfurous Acid	75	20%	316 SS
Titanium Tetrachloride	75	ALL	316 SS
Tannic Acid	75	40%	Hast. B
Toluene	75		Steel
Trichloroacetic Acid	75	ALL	Hast. B
Trichloroethylene	300	DRY	Monel
Turpentine	75		316 SS
Varnish	150		Steel
Zinc Chloride	212	ALL	Hast. B
Zinc Sulfate	212	ALL	316 SS

**NOTE:** *In recommending these materials, consideration has been given to providing good service life without undue cost. Where two or more materials are satisfactory, the least expensive is listed. Consult the factory for information on materials or services not given.*

# FLOW APPLICATION DATA

NAME: _____ DATE: _____ COMPANY: _____ ADDRESS: _____ CITY: _____ STATE: _____ ZIP: _____ PHONE: _____ EXT: _____ SHIP TO _____  VIA: _____ SPEC. INST. _____	DATE: _____ CUST. P.O. # _____ MODEL # _____ TAG # _____ SERIAL # _____ REP: _____    
<b>SERVICE CONDITIONS</b>	
Liquid _____ Gas _____ Steam _____  Density _____ Viscosity _____ % of Concentration _____  Molecular Weight _____ Specific Gravity _____  Temp. (°F or °C) Normal _____ Max _____ Min _____  Pressure (PSIG) Normal _____ Max _____ Min _____  Flow Rate Normal _____ Max _____ Min _____  USGPM Lbs/HR _____ SCFM _____ Other _____	Pipe I.D. _____ (IN.)  SCHED. _____  Mat. _____  Duct: I.D. _____ X I.D. _____  Horizontal      Vertical  Meter Options: _____
<div style="border: 1px solid black; width: 100%; height: 100%; display: grid; grid-template-columns: repeat(20, 1fr); grid-template-rows: repeat(10, 1fr);"></div>	

*For simple, precise and economical FLOW METERING EQUIPMENT*

## PRESO INDUSTRIES - SCFM TO GPM CONVERSION TABLES

I - To convert SCFM (air) to GPM (water) use the following formula:

$$\text{GPM} = (\text{SCFM} / 3.8) \times T_c \times P_c$$

Where

$T_c$  = Temperature Correction Factor, Table (1)

$P_c$  = Pressure Correction Factor, Table (2)

II - EXAMPLE: 500 SCFM of air in 3" Sch. 40 pipe, at 10 PSIG and 70 °F

$$\text{GPM} = (500 / 3.8) \times 1 \times .771$$

$$\text{GPM} = 101.447$$

III - Use Venturi Curves for 3" Pipe. At 101.477 GPM use model - 38 with DP of 27" H2O.

TABLE 1 TEMPERATURE CORRECTION FACTOR ( $T_c$ )				TABLE 2 PRESSURE CORRECTION FACTOR ( $P_c$ )			
Deg. F	$T_c$	Deg. F	$T_c$	Psig	$P_c$	Psig	$P_c$
0	0.932	90	1.019	0	1.000	90	.375
2	0.933	100	1.028	2	.936	100	.358
4	0.936	120	1.046	4	.886	120	.330
6	0.938	140	1.064	6	.843	140	.308
8	0.940	160	1.081	8	.805	160	.290
10	0.942	180	1.099	10	.771	180	.275
12	0.944	200	1.116	12	.742	200	.261
14	0.946	225	1.137	14	.716	225	.247
16	0.948	250	1.157	16	.692	250	.235
18	0.950	275	1.177	18	.670	275	.225
20	0.952	300	1.197	20	.651	300	.216
25	0.956	325	1.217	25	.608	325	.208
30	0.961	350	1.236	30	.573	350	.201
35	0.966	375	1.255	35	.544	375	.194
40	0.971	400	1.274	40	.518	400	.188
50	0.981	425	1.292	50	.477	425	.183
60	0.990	450	1.310	60	.443	450	.178
70	1.000	475	1.328	70	.416	475	.173
80	1.009	500	1.346	80	.394	500	.169

$$T_c = \sqrt{\frac{T^{\circ}\text{F} + 460}{530}}$$

$$P_c = \sqrt{\frac{14.73}{P \text{ PSIG} + 14.73}}$$



## **FLOW RATE CORRECTION FACTORS:**

**MULTIPLY FLOW RATE (Q) BY:**

**1) Temperature Correction Factor:**

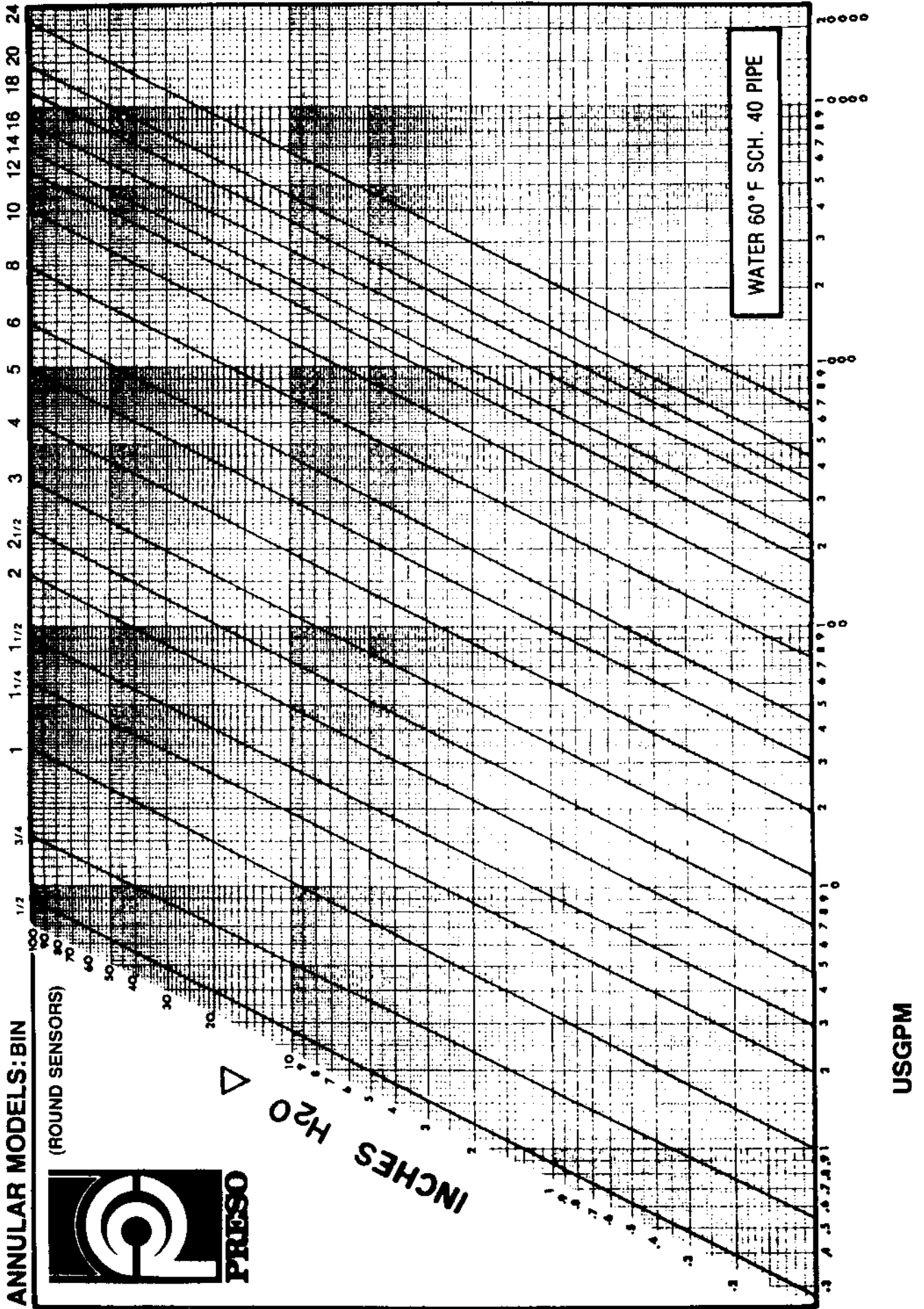
$$T_c = \sqrt{(460 + T_{new}) / (460 + T_{calc})}$$

**2) Pressure Correction Factor:**

$$P_c = \sqrt{(P_{calc} = 14.73) / (P_{new} = 14.73)}$$

# NOMINAL PIPE SIZE — SCHED. 40.

(For other sizes consult factory.)



# NOMINAL PIPE SIZE

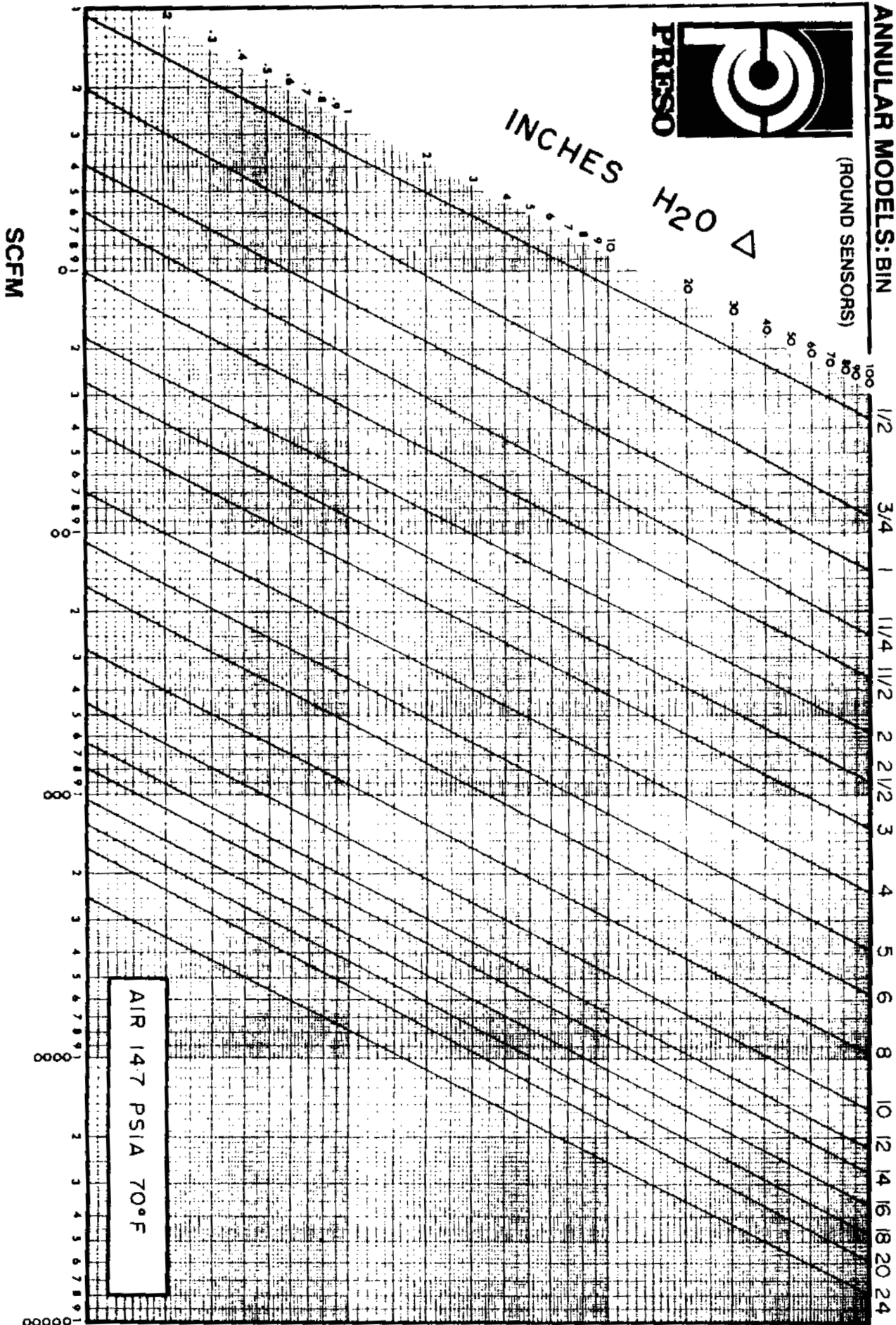
ANNULAR MODELS: BIN

(ROUND SENSORS)

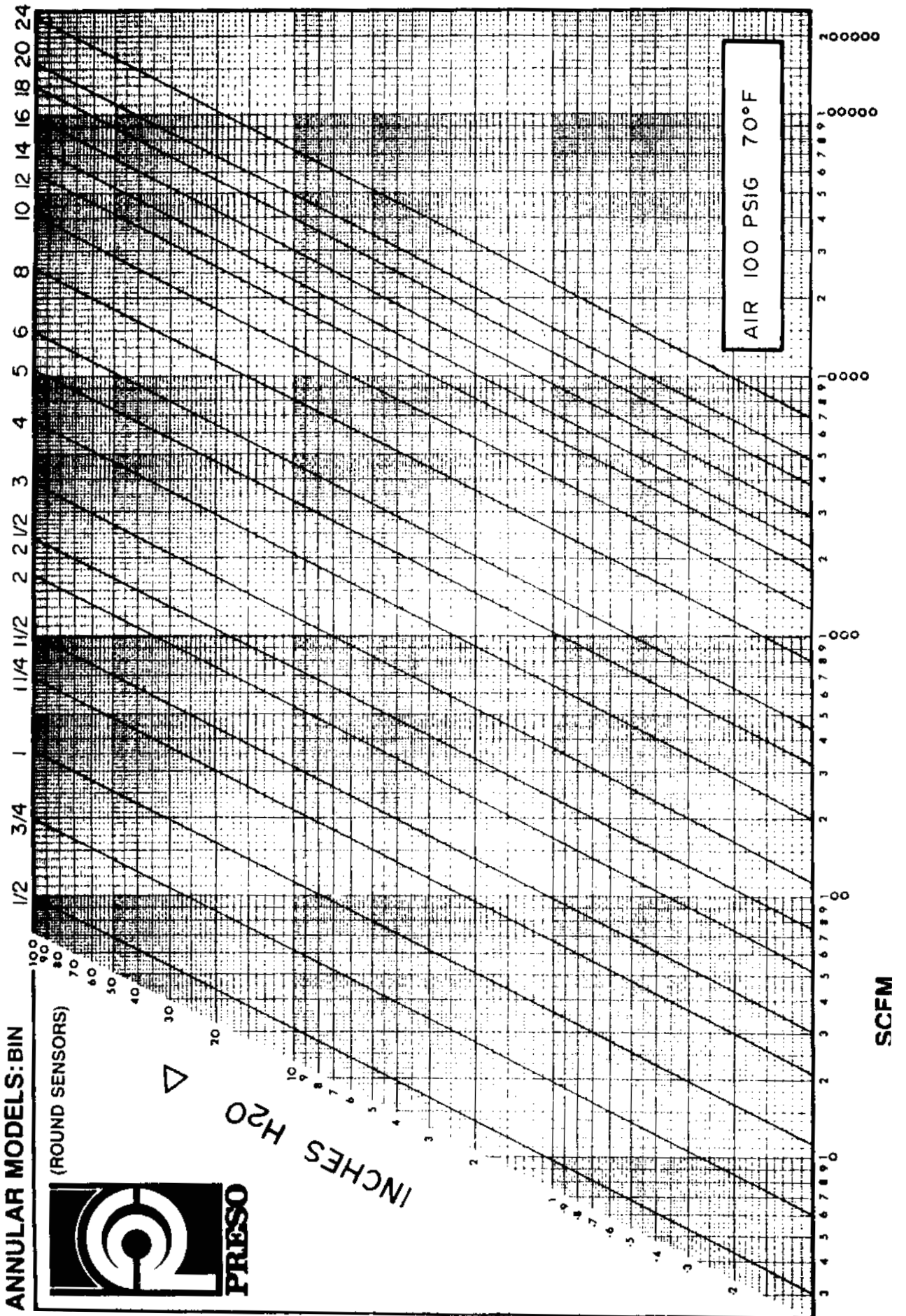


H<sub>2</sub>O Δ

INCHES



# NOMINAL PIPE SIZE

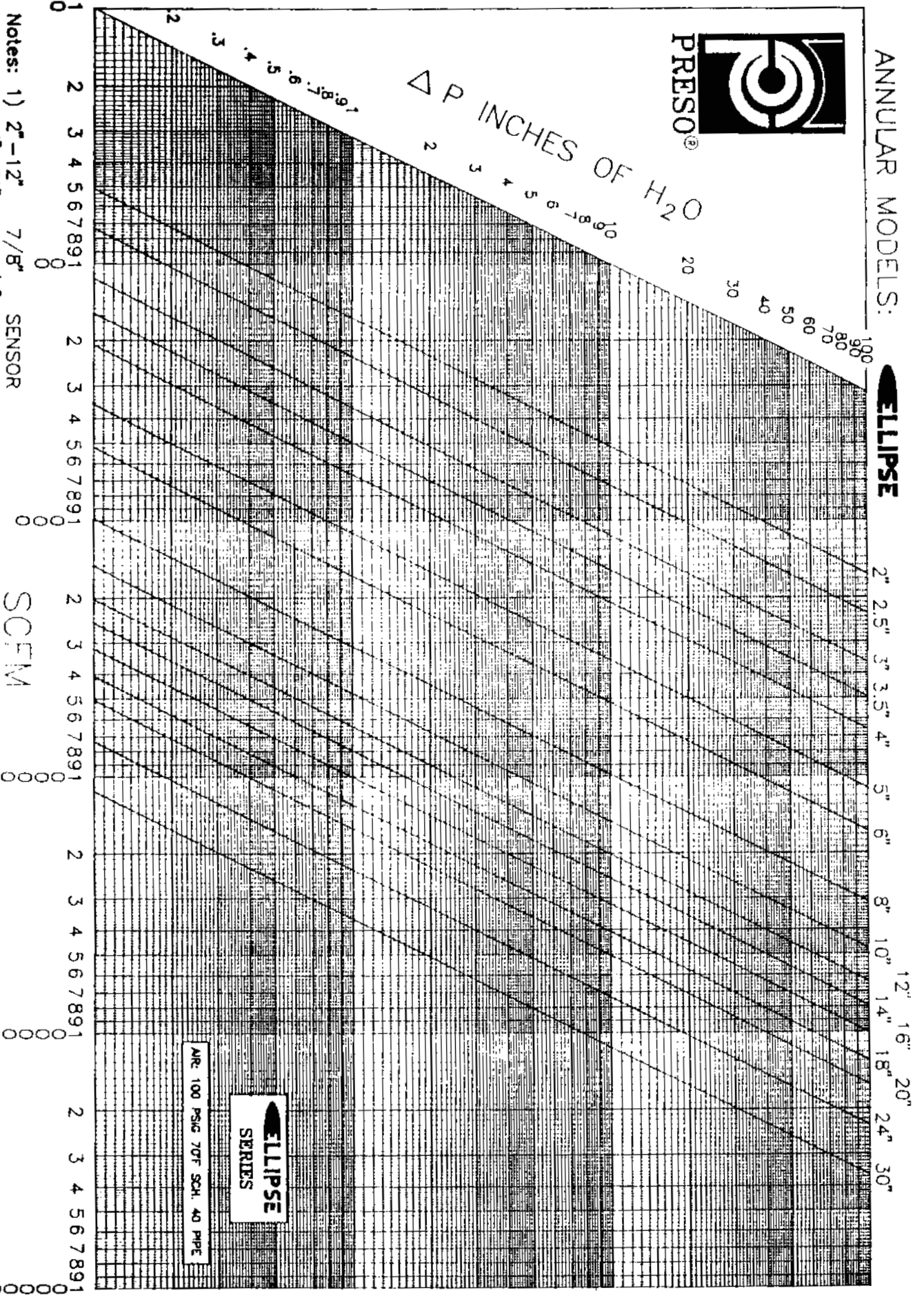




ANNULAR MODELS:



$\Delta P$  INCHES OF H<sub>2</sub>O



- Notes:
- 1) 2"-12" 7/8" SENSOR
  - 14"-30" 1-1/4" SENSOR
  - 2) 2-1/4" SENSORS ARE AVAILABLE AS PER APPLICATION
  - 3) PIPES 12" AND ABOVE ARE SCH. STD.

SCFM



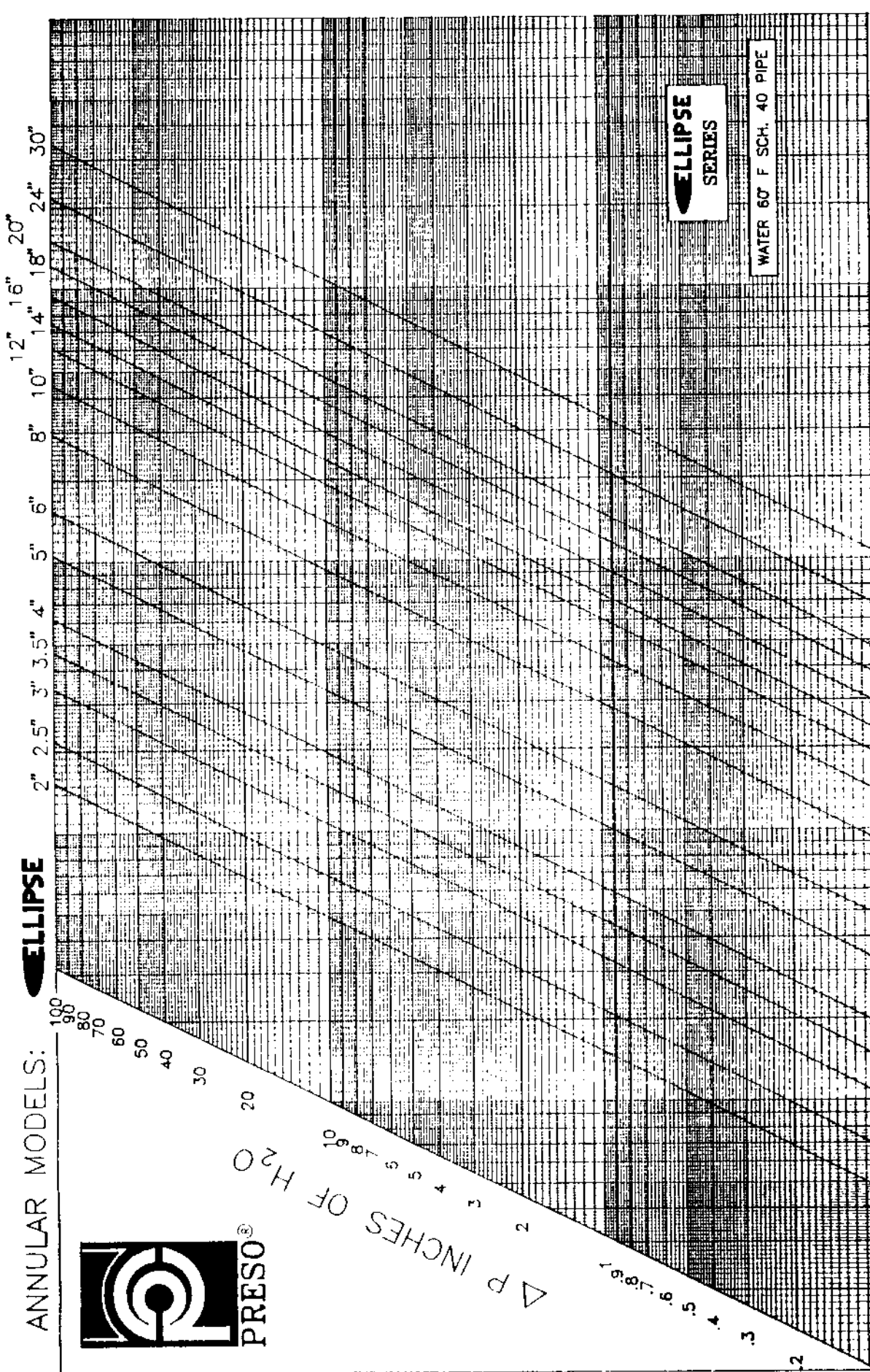
AIR: 100 PSIG 70F SCH. 40 PIPE

DATE: FEB. 1991  
 REVISION 2

**ELLIPSE**



Δ P INCHES OF H<sub>2</sub>O



USGPM

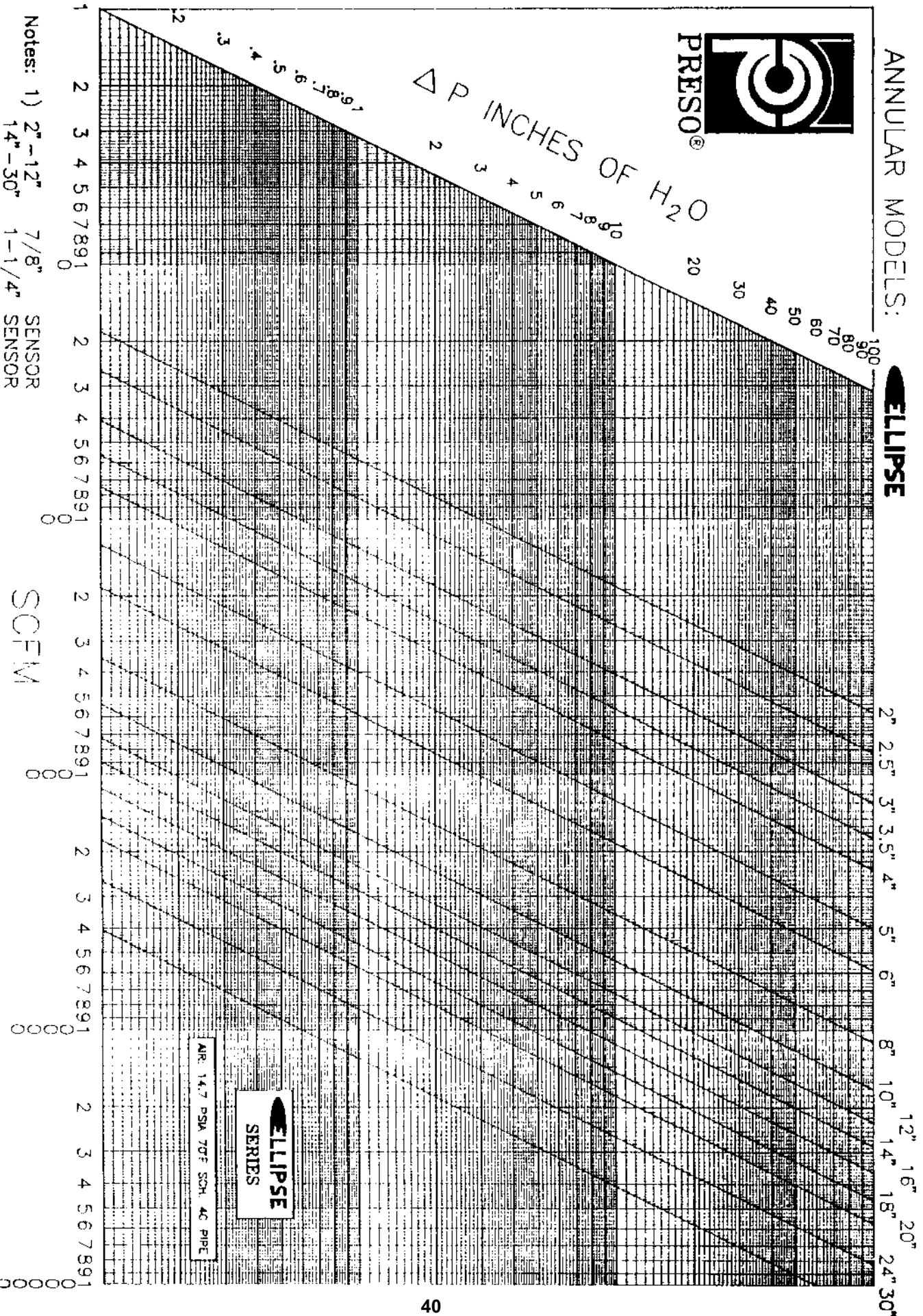
- Notes:
- 1) 2"-12" 7/8" SENSOR
  - 14"-30" 1-1/4" SENSOR
  - 2) 2-1/4" SENSORS ARE AVAILABLE AS PER APPLICATION
  - 3) PIPES 12" AND ABOVE ARE SCH. STD.

DATE: FEB. 1991  
REVISION 2

ANNULAR MODELS:



$\Delta P$  INCHES OF H<sub>2</sub>O



- Notes: 1) 2\"-12\" 7/8\" SENSOR  
 14\"-30\" 1-1/4\" SENSOR  
 2) 2-1/4\" SENSORS ARE AVAILABLE  
 AS PER APPLICATION  
 PIPES 12\" AND ABOVE ARE SCH. STD.

AIR: 14.7 PSIA 70°F SCH. 40 PIPE



DATE: FEB. 1991  
 REVISION 2

	PSI	KPA	Inches H <sub>2</sub> O	mm H <sub>2</sub> O	Inches Hg	mm Hg	Bars	m Bars	Kg/cm <sup>2</sup>	gm/cm <sup>2</sup>
PSI	1	6.8947	27.7620	705.1500	2.0360	51.7150	.0689	68.9470	0.0703	70.3070
KPA	0.1450	1	4.0266	102.2742	0.2953	7.5007	.0100	10.0000	0.0102	10.1972
Inches H <sub>2</sub> O	0.0361	0.2483	1	25.4210	0.0734	1.8650	0.0025	2.4864	0.0025	2.5355
mm H <sub>2</sub> O	0.0014	0.0098	0.0394	1	0.0028	0.0734	0.0001	0.0979	0.00001	0.0982
Inches Hg	0.4912	3.3867	13.6200	345.9400	1	25.4000	0.0339	33.864	0.0345	34.532
mm Hg	0.0193	0.1331	0.5362	13.6200	0.0394	1	0.0013	1.3332	0.0014	1.3595
Bars	14.5040	100.000	402.1800	10215.0000	29.5300	750.0600	1	1000	1.0197	1019.7000
m Bars	0.0145	0.1000	0.4022	10.2150	0.0295	0.7501	0.001	1	0.0010	1.0197
Kg/cm <sup>2</sup>	14.2230	97.9047	394.4100	10018.0	28.9590	735.560	0.9000	980.7000	1	1000
gm/cm <sup>2</sup>	0.0142	0.0979	0.3944	10.0180	0.0290	0.7356	0.0009	0.9807	0.001	1

TEMPERATURE

$$^{\circ}\text{F} = 32 + 9/5 (^{\circ}\text{C})$$

$$^{\circ}\text{C} = ( ^{\circ}\text{F} - 32 ) 5/9$$

EXAMPLE 1 mm Hg = 0.5362 inches H<sub>2</sub>O = 1.3332 mBars

$$97 \text{ mm Hg} = 97 ( 0.5362 ) = 52.0114 \text{ inches H}_2\text{O}$$

$$97 \text{ mmHg} = 97 ( 1.3332 ) = 129.3204 \text{ mBars}$$

Conversion Equivalents

millimetre mm	centimetre cm	metre m	inch in	foot ft	yard yd	Length
1	0.1	0.001	0.0394	0.0033	0.0011	
10	1	0.01	0.3937	0.0328	0.0109	
1000	100	1	39.3701	3.2808	1.0936	
25.4	2.54	0.0254	1	0.0833	0.0278	
304.8	30.48	0.3048	12	1	0.3333	
914.4	91.44	0.9144	36	3	1	

1 kilometre = 1000 metres = 0.62137 miles  
 1 mile = 1609.34 metres = 1.60934 kilometres

square millimetre mm <sup>2</sup>	square centimetre cm <sup>2</sup>	square metre m <sup>2</sup>	square inch in <sup>2</sup>	square foot ft <sup>2</sup>	square yard yd <sup>2</sup>	Area
1	0.01	10 <sup>-6</sup>	1.55 x 10 <sup>-3</sup>	1.076 x 10 <sup>-5</sup>	1.196 x 10 <sup>-6</sup>	
100	1	10 <sup>-4</sup>	0.155	1.076 x 10 <sup>-3</sup>	1.196 x 10 <sup>-4</sup>	
10 <sup>6</sup>	10 000	1	1550	10.764	1.196	
645.16	6.4516	6.452 x 10 <sup>-4</sup>	1	6.944 x 10 <sup>-3</sup>	7.716 x 10 <sup>-4</sup>	
92 903	929.03	0.093	144	1	0.111	
836 127	8361.27	0.836	1296	9	1	

cubic millimetre mm <sup>3</sup>	cubic centimetre cm <sup>3</sup>	cubic metre m <sup>3</sup>	cubic inch in <sup>3</sup>	cubic foot ft <sup>3</sup>	cubic yard yd <sup>3</sup>	Volume
1	0.001	10 <sup>-9</sup>	6.1 x 10 <sup>-5</sup>	3.531 x 10 <sup>-8</sup>	1.308 x 10 <sup>-9</sup>	
1000	1	10 <sup>-6</sup>	0.061	3.531 x 10 <sup>-5</sup>	1.308 x 10 <sup>-6</sup>	
10 <sup>9</sup>	10 <sup>6</sup>	1	61 024	35.31	1.308	
16 387	16.39	1.639 x 10 <sup>-5</sup>	1	5.787 x 10 <sup>-4</sup>	2.143 x 10 <sup>-5</sup>	
2.832 x 10 <sup>7</sup>	2.832 x 10 <sup>4</sup>	0.0283	1728	1	0.0370	
7.646 x 10 <sup>8</sup>	7.646 x 10 <sup>5</sup>	0.7646	46 656	27	1	

cubic metre m <sup>3</sup>	litre l	millilitre ml	U.K. gallon U.K. gal	U.S. gallon U.S. gal	cubic foot ft <sup>3</sup>	Liquid Measure
1	1000	10 <sup>6</sup>	220	264.2	35.3147	
0.001	1	1000	0.22	0.2642	0.0353	
10 <sup>-6</sup>	0.001	1	2.2 x 10 <sup>-4</sup>	2.642 x 10 <sup>-4</sup>	3.53 x 10 <sup>-5</sup>	
0.00455	4.546	4546	1	1.201	0.1605	
0.00378	3.785	3785	0.8327	1	0.1337	
0.0283	28.317	28 317	6.2288	7.4805	1	

1 U.S. Barrel = 42 U.S. gallons (petroleum measure)  
 1 litre = 10<sup>6</sup> mm<sup>3</sup> = 10<sup>3</sup> cm<sup>3</sup> or 1 cubic decimetre (1 dm<sup>3</sup>)  
 1 litre = 1.76 U.K. pints = 2.113 U.S. pints  
 U.K. gallon and U.K. pint also called Imperial gallon and Imperial pint

Conversion Equivalents — continued

metre per second m/s	foot per second ft/s	metre per minute m/min	foot per minute ft/min	kilometre per hour km/h	mile per hour mile/h	Velocity
1	3.281	60	196.85	3.6	2.2369	
0.305	1	18.288	60	1.0973	0.6818	
0.017	0.055	1	3.281	0.06	0.0373	
0.005	0.017	0.305	1	0.0183	0.01136	
0.278	0.911	16.667	54.68	1	0.6214	
0.447	1.467	26.822	88	1.6093	1	

kilogram kg	pound lb	hundredweight cwt	tonne t	U.K. ton	U.S. ton sh ton	Mass
1	2.205	0.0197	0.001	$9.84 \times 10^{-4}$	0.0011	
0.454	1	0.0089	$4.54 \times 10^{-4}$	$4.46 \times 10^{-4}$	$5.0 \times 10^{-4}$	
50.802	112	1	0.0508	0.05	0.056	
1000	2204.6	19.684	1	0.9842	1.1023	
1016	2240	20	1.0161	1	1.12	
907.2	2000	17.857	0.9072	0.8929	1	

kilogram per second kg/s	pound per second lb/s	kilogram per hour kg/h	pound per hour lb/h	U.K. ton/hour ton/h	tonne t/h	Mass Flow Rate
1	2.205	3600	7936.64	3.5431	3.6	
0.454	1	1633	3600	1.607	1.633	
$2.78 \times 10^{-4}$	$6.12 \times 10^{-4}$	1	2.205	$9.84 \times 10^{-4}$	0.001	
$1.26 \times 10^{-4}$	$2.78 \times 10^{-4}$	0.454	1	$4.46 \times 10^{-4}$	$4.54 \times 10^{-4}$	
0.282	0.622	1016	2240	1	1.016	
0.278	0.612	1000	2204.6	0.9842	1	

litre per second l/s	litre per minute l/min	cubic metre per hour m <sup>3</sup> /h	cubic foot per hour ft <sup>3</sup> /h	cubic foot per minute ft <sup>3</sup> /min	U.K. gallon per minute U.K. gal/min	U.S. gallon per minute US gal/min	U.S. barrel per day US barrel/d	Volumetric Rate of Flow
1	60	3.6	127.133	2.1189	13.2	15.85	543.439	
0.017	1	0.06	2.1189	0.0353	0.22	0.264	9.057	
0.278	16.667	1	35.3147	0.5886	3.666	4.403	150.955	
0.008	0.472	0.0283	1	0.0167	0.104	0.125	4.275	
0.472	28.317	1.6990	60	1	6.229	7.480	256.475	
0.076	4.546	0.2728	9.6326	0.1605	1	1.201	41.175	
0.063	3.785	0.2271	8.0209	0.1337	0.833	1	34.286	
0.002	0.110	0.0066	0.2339	0.0039	0.024	0.029	1	

newton N	kilonewton kN	kilogram force* kgf	pound force lbf	Force
1	0.001	0.102	0.225	
1000	1	101.97	224.81	
9.807	0.0098	1	2.205	
4.448	0.0044	0.454	1	

\* The kilogram force is sometimes called the kilopond (kp)

**Commercial Wrought Steel Pipe Data**

Schedule Wall Thickness—Per ASA B36.10-1950

Nominal Pipe Size	Outside Diameter	Thickness	Inside Diameter		Inside Diameter Functions (In Inches)					Transverse Internal Area	
			d	D	d <sup>2</sup>	d <sup>3</sup>	d <sup>4</sup>	d <sup>5</sup>	a	A	
			Inches	Feet					Sq. In.	Sq. Ft.	
Schedule 10	14	0.250	13.5	1.125	182.25	2460.4	33215.	448400.	143.14	0.994	
	16	0.250	15.5	1.291	240.25	3723.9	57720.	894660.	188.69	1.310	
	18	0.250	17.5	1.4583	306.25	5359.4	93789.	1641309.	240.53	1.670	
	20	0.250	19.5	1.625	380.25	7414.9	144590.	2819500.	298.65	2.074	
	24	0.250	23.5	1.958	552.25	12977.	304980.	7167030.	433.74	3.012	
30	0.312	29.376	2.448	862.95	25350.	744288.	21864218.	677.76	4.707		
Schedule 20	8	0.250	8.125	0.6771	66.02	536.38	4359.3	35409.	51.85	0.3601	
	10	0.250	10.25	0.8542	105.06	1076.9	11038.	113141.	82.52	0.5731	
	12	0.250	12.25	1.021	150.06	1838.3	22518.	275855.	117.86	0.8185	
	14	0.312	13.376	1.111	178.92	2393.2	32012.	428185.	140.52	0.9758	
	16	0.312	15.376	1.281	236.42	3635.2	55894.	859442.	185.69	1.290	
	18	0.312	17.376	1.448	301.92	5246.3	91156.	1583978.	237.13	1.647	
	20	0.375	19.250	1.604	370.56	7133.3	137317.	2643352.	291.04	2.021	
24	0.375	23.25	1.937	540.56	12568.	292205.	6793832.	424.56	2.948		
30	0.500	29.00	2.417	841.0	24389.	707281.	20511149.	660.52	4.587		
Schedule 30	8	0.277	8.071	0.6726	65.14	525.75	4243.2	34248.	51.16	0.3553	
	10	0.307	10.136	0.8447	102.74	1041.4	10555.	106987.	80.69	0.5603	
	12	0.330	12.09	1.0075	146.17	1767.2	21366.	258304.	114.80	0.7972	
	14	0.375	13.25	1.1042	175.56	2326.2	30821.	408394.	137.88	0.9575	
	16	0.375	15.25	1.2708	232.56	3546.6	54084.	824801.	182.65	1.268	
	18	0.438	17.124	1.4270	293.23	5021.3	85984.	1472397.	230.30	1.599	
20	0.500	19.00	1.5833	361.00	6859.0	130321.	2476099.	283.53	1.969		
24	0.562	22.876	1.9063	523.31	11971.	273853.	6264703.	411.00	2.854		
30	0.625	28.75	2.3958	826.56	23764.	683201.	19642160.	649.18	4.508		
Schedule 40	1/8	0.405	0.068	0.269	0.0224	0.0724	0.0195	0.005242	0.00141	0.057	0.00040
	1/4	0.540	0.088	0.364	0.0303	0.1325	0.0482	0.01756	0.00639	0.104	0.00072
	3/8	0.675	0.091	0.493	0.0411	0.2430	0.1198	0.05905	0.02912	0.191	0.00133
	1/2	0.840	0.109	0.622	0.0518	0.3869	0.2406	0.1497	0.09310	0.304	0.00211
	3/4	1.050	0.113	0.824	0.0687	0.679	0.5595	0.4610	0.3799	0.533	0.00371
	1	1.315	0.133	1.049	0.0874	1.100	1.154	1.210	1.270	0.864	0.00600
	1 1/4	1.660	0.140	1.380	0.1150	1.904	2.628	3.625	5.005	1.495	0.01040
	1 1/2	1.900	0.145	1.610	0.1342	2.592	4.173	6.718	10.82	2.036	0.01414
	2	2.375	0.154	2.067	0.1722	4.272	8.831	18.250	37.72	3.355	0.02330
	2 1/2	2.875	0.203	2.469	0.2057	6.096	15.051	37.161	91.75	4.788	0.03322
	3	3.500	0.216	3.068	0.2557	9.413	28.878	88.605	271.8	7.393	0.05130
	3 1/2	4.000	0.226	3.548	0.2957	12.59	44.663	158.51	562.2	9.886	0.06870
	4	4.500	0.237	4.026	0.3355	16.21	65.256	262.76	1058.	12.730	0.08840
	5	5.563	0.258	5.047	0.4206	25.47	128.56	648.72	3275.	20.006	0.1390
6	6.625	0.280	6.065	0.5054	36.78	223.10	1352.8	8206.	28.891	0.2006	
8	8.625	0.322	7.981	0.6651	63.70	508.36	4057.7	32380.	50.027	0.3474	
10	10.75	0.365	10.02	0.8350	100.4	1006.0	10080.	101000.	78.855	0.5475	
12	12.75	0.406	11.938	0.9965	142.5	1701.3	20306.	242470.	111.93	0.7773	
14	14.0	0.438	13.124	1.0937	172.24	2260.5	29666.	389340.	135.28	0.9394	
16	16.0	0.500	15.000	1.250	225.0	3375.0	50625.	759375.	176.72	1.2272	
18	18.0	0.562	16.876	1.4063	284.8	4806.3	81111.	1368820.	223.68	1.5533	
20	20.0	0.593	18.814	1.5678	354.0	6659.5	125320.	2357244.	278.00	1.9305	
24	24.0	0.687	22.626	1.8855	511.9	11583.	262040.	5929784.	402.07	2.7921	
Schedule 60	8	0.406	7.813	0.6511	61.04	476.93	3725.9	29113.	47.94	0.3329	
	10	0.500	9.750	0.8125	95.06	926.86	9036.4	88110.	74.66	0.5185	
	12	0.562	11.626	0.9688	135.16	1571.4	18268.	212399.	106.16	0.7372	
	14	0.593	12.814	1.0678	164.20	2104.0	26962.	345480.	128.96	0.8956	
	16	0.656	14.688	1.2240	215.74	3168.8	46544.	683618.	169.44	1.1766	
	18	0.750	16.500	1.3750	272.25	4492.1	74120.	1222982.	213.83	1.4849	
20	0.812	18.376	1.5313	337.68	6205.2	114028.	2095342.	265.21	1.8417		
24	0.968	22.064	1.8387	486.82	10741.	236994.	5229036.	382.35	2.6552		
Schedule 80	1/8	0.405	0.095	0.215	0.0179	0.0462	0.00994	0.002134	0.000459	0.036	0.00025
	1/4	0.540	0.119	0.302	0.0252	0.0912	0.0275	0.008317	0.002513	0.072	0.00050
	3/8	0.675	0.126	0.423	0.0353	0.1789	0.0757	0.03200	0.01354	0.141	0.00098
	1/2	0.840	0.147	0.546	0.0455	0.2981	0.1628	0.08886	0.04852	0.234	0.00163
	3/4	1.050	0.154	0.742	0.0618	0.5506	0.4085	0.3032	0.2249	0.433	0.00300
	1	1.315	0.179	0.957	0.0797	0.9158	0.8765	0.8387	0.8027	0.719	0.00499
1 1/4	1.660	0.191	1.278	0.1065	1.633	2.087	2.6667	3.409	1.283	0.00891	

(continued on the next page)

## Commercial Wrought Steel Pipe Data

Schedule Wall Thickness—Per ASA B36.10-1950

Nominal Pipe Size Inches	Outside Diameter Inches	Thick-ness Inches	Inside Diameter		Inside Diameter Functions (In Inches)				Transverse Internal Area	
			<i>d</i> Inches	<i>D</i> Feet	<i>d</i> <sup>2</sup>	<i>d</i> <sup>3</sup>	<i>d</i> <sup>4</sup>	<i>d</i> <sup>5</sup>	<i>a</i> Sq. In.	<i>A</i> Sq. Ft.
Schedule 80—cont.										
1½	1.900	0.200	1.500	0.1250	2.250	3.375	5.062	7.594	1.767	0.01225
2	2.375	0.218	1.939	0.1616	3.760	7.290	14.136	27.41	2.953	0.02050
2½	2.875	0.276	2.323	0.1936	5.396	12.536	29.117	67.64	4.238	0.02942
3	3.5	0.300	2.900	0.2417	8.410	24.389	70.728	205.1	6.605	0.04587
3½	4.0	0.318	3.364	0.2803	11.32	38.069	128.14	430.8	8.888	0.06170
4	4.5	0.337	3.826	0.3188	14.64	56.006	214.33	819.8	11.497	0.07986
5	5.563	0.375	4.813	0.4011	23.16	111.49	536.38	2583.	18.194	0.1263
6	6.625	0.432	5.761	0.4801	33.19	191.20	1101.6	6346.	26.067	0.1810
8	8.625	0.500	7.625	0.6354	58.14	443.32	3380.3	25775.	45.663	0.3171
10	10.75	0.593	9.564	0.7970	91.47	874.82	8366.8	80020.	71.84	0.4989
12	12.75	0.687	11.376	0.9480	129.41	1472.2	16747.	190523.	101.64	0.7058
14	14.0	0.750	12.500	1.0417	156.25	1953.1	24414.	305176.	122.72	0.8522
16	16.0	0.843	14.314	1.1928	204.89	2932.8	41980.	600904.	160.92	1.1175
18	18.0	0.937	16.126	1.3438	260.05	4193.5	67626.	1090518.	204.24	1.4183
20	20.0	1.031	17.938	1.4948	321.77	5771.9	103536.	1857248.	252.72	1.7550
24	24.0	1.218	21.564	1.7970	465.01	10027.	216234.	4662798.	365.22	2.5362
Schedule 100										
8	8.625	0.593	7.439	0.6199	55.34	411.66	3062.	22781.	43.46	0.3018
10	10.75	0.718	9.314	0.7762	86.75	807.99	7526.	69357.	68.13	0.4732
12	12.75	0.843	11.064	0.9220	122.41	1354.4	14985.	165791.	96.14	0.6677
14	14.0	0.937	12.126	1.0105	147.04	1783.0	21621.	262173.	115.49	0.8020
16	16.0	1.031	13.938	1.1615	194.27	2707.7	37740.	526020.	152.58	1.0596
18	18.0	1.156	15.688	1.3057	246.11	3861.0	60572.	950250.	193.30	1.3423
20	20.0	1.281	17.438	1.4532	304.08	5302.6	92467.	1612438.	238.83	1.6585
24	24.0	1.531	20.938	1.7448	438.40	9179.2	192195.	4024179.	344.32	2.3911
Schedule 120										
4	4.50	0.438	3.624	0.302	13.133	47.595	172.49	625.1	10.315	0.07163
5	5.563	0.500	4.563	0.3802	20.82	95.006	433.5	1978.	16.35	0.1136
6	6.625	0.562	5.501	0.4584	30.26	166.47	915.7	5037.	23.77	0.1650
8	8.625	0.718	7.189	0.5991	51.68	371.54	2671.	19202.	40.59	0.2819
10	10.75	0.843	9.064	0.7553	82.16	744.66	6750.	61179.	64.53	0.4481
12	12.75	1.000	10.750	0.8959	115.56	1242.3	13355.	143563.	90.76	0.6303
14	14.0	1.093	11.814	0.9845	139.57	1648.9	19480.	230137.	109.62	0.7612
16	16.0	1.218	13.564	1.1303	183.98	2495.5	33849.	459133.	144.50	1.0035
18	18.0	1.375	15.250	1.2708	232.56	3546.6	54086.	824804.	182.66	1.2684
20	20.0	1.500	17.000	1.4166	289.00	4913.0	83521.	1419857.	226.98	1.5762
24	24.0	1.812	20.376	1.6980	415.18	8459.7	172375.	3512313.	326.08	2.2645
Schedule 140										
8	8.625	0.812	7.001	0.5834	49.01	343.15	2402.	16819.	38.50	0.2673
10	10.75	1.000	8.750	0.7292	76.56	669.92	5862.	51291.	60.13	0.4176
12	12.75	1.125	10.500	0.8750	110.25	1157.6	12155.	127628.	86.59	0.6013
14	14.0	1.250	11.500	0.9583	132.25	1520.9	17490.	201136.	103.87	0.7213
16	16.0	1.438	13.124	1.0937	172.24	2260.5	29666.	389340.	135.28	0.9394
18	18.0	1.562	14.876	1.2396	221.30	3292.0	48972.	728502.	173.80	1.2070
20	20.0	1.750	16.5	1.3750	272.25	4492.1	74120.	1222981.	213.82	1.4849
24	24.0	2.062	19.876	1.6563	395.06	7852.1	156069.	3102022.	310.28	2.1547
Schedule 160										
½	0.840	0.187	0.466	0.0388	0.2172	0.1012	0.04716	0.02197	0.1706	0.00118
¾	1.050	0.218	0.614	0.0512	0.3770	0.2315	0.1421	0.08726	0.2961	0.00206
1	1.315	0.250	0.815	0.0679	0.6642	0.5413	0.4412	0.3596	0.5217	0.00362
1¼	1.660	0.250	1.160	0.0966	1.346	1.561	1.811	2.100	1.057	0.00734
1½	1.900	0.281	1.338	0.1115	1.790	2.395	3.205	4.288	1.406	0.00976
2	2.375	0.343	1.689	0.1407	2.853	4.818	8.138	13.74	2.241	0.01556
2½	2.875	0.375	2.125	0.1771	4.516	9.596	20.39	43.33	3.546	0.02463
3	3.50	0.438	2.624	0.2187	6.885	18.067	47.41	124.4	5.408	0.03755
4	4.50	0.531	3.438	0.2865	11.82	40.637	139.7	480.3	9.283	0.06447
5	5.563	0.625	4.313	0.3594	18.60	80.230	346.0	1492.	14.61	0.1015
6	6.625	0.718	5.189	0.4324	26.93	139.72	725.0	3762.	21.15	0.1469
8	8.625	0.906	6.813	0.5677	46.42	316.24	2155.	14679.	36.46	0.2532
10	10.75	1.125	8.500	0.7083	72.25	614.12	5220.	44371.	56.75	0.3941
12	12.75	1.312	10.126	0.8438	102.54	1038.3	10514.	106461.	80.53	0.5592
14	14.0	1.406	11.188	0.9323	125.17	1400.4	15668.	175292.	98.31	0.6827
16	16.0	1.593	12.814	1.0678	164.20	2104.0	26961.	345482.	128.96	0.8956
18	18.0	1.781	14.438	1.2032	208.45	3009.7	43454.	627387.	163.72	1.1369
20	20.0	1.968	16.064	1.3387	258.05	4145.3	66590.	1069715.	202.67	1.4074
24	24.0	2.343	19.314	1.6095	373.03	7204.7	139152.	2687582.	292.98	2.0346



## M: Vendor List and Contacts

### M.1 Vendor List and Contacts:

Drill components have been sourced throughout the world with the majority being from within the United States. Below are vendor and applicable manufacturer contact information with respectively sourced equipment.

Price Engineering  
1175 Cottonwood Avenue  
Hartland, WI 53029  
Phone: 262-369-3700  
Fax: 262-369-3711  
<http://www.priceeng.com>

Eric Nyberg  
Aeroquip Product Manager  
262-369-2164  
Joe Moore  
[jmoore@priceeng.com](mailto:jmoore@priceeng.com)  
262-369-2180

-Aeroquip high-pressure hose for conduction of fuel, water, glycol; Lenz high-pressure JIC hose fittings; Hose fitting crimping machine.

-Aeroquip catalog can be found at  
[http://hydraulics.eaton.com/products/fluid\\_conveyance\\_aeroquip.htm](http://hydraulics.eaton.com/products/fluid_conveyance_aeroquip.htm)

McMaster-Carr  
600 N County Line Rd  
Elmhurst, IL 60126-2081  
<http://mcmaster.com>

Sales and Customer Service  
[Chi.sales@mcmaster.com](mailto:Chi.sales@mcmaster.com)  
630-833-0300  
630-834-9427 Fax

-The vast majority of hardware including fasteners; supplies; non-JIC piping and plumbing fittings; electrical wiring and connectors; etc.

-Larger items such as condensate pumps and throttle valves.

Linde Gas LLC  
4802 Pflaum Road  
Madison, WI 53718-6724

Sales and Customer Service  
(608) 223-9080

-Miller Trailblazer welder.

Bradford Supply Company  
P.O. Box 3473  
2000 S. Bunn St.  
Bloomington, IL 61702

Brett Hartrich  
309-828-8313  
800-504-7179  
Fax (309) 827-8924

- Meyers D65-16 AVD-CP high pressure pumps and regulators.
- High pressure pump replacement hardware.

Wiedenbeck Inc  
2451 Kilgust Road  
Monona, WI 53713-4821  
(608) 221-5454

Sales and Customer Service  
608-221-5454  
608- 221-5453 Fax

- Wiedenbeck supplied some tubing.

Physical Sciences Laboratory  
University of Wisconsin-Madison  
3725 Schneider Dr.  
Stoughton, WI 53589-3098

608- 877-2200  
608-877-2201 Fax  
psl@psl.wisc.edu

- PSL engineered and fabricated the Enhanced Hot Water Drill in Stoughton, WI. PSL can be contacted directly for their sourcing of fabrication materials and components.

Wisconsin Foam Products, Inc.  
4601 Tompkins Drive  
Madison, WI 53716  
<http://www.wifoam.com>

Sales and Customer Service  
[info@wifoam.com](mailto:info@wifoam.com)  
800-989-3626  
608-221-4086 Fax

- Difficult to find polymer materials like PE foam sheets and sealed air cellulplank were sourced from Wisconsin Foam Products.

Graybar Electric Co  
1301 West Badger Road  
Madison, WI 53713-2395  
[www.graybar.com](http://www.graybar.com)

Sales and Customer Service  
800-255-0005

- Electrical supplies.

FABCO Equipment Inc  
1111 Applegate Rd  
Madison, WI 53713-3297  
<http://www.fabco.com>

Sales and Customer Service  
608-271-6200  
608-271-1410 Fax

-24" Auger bit and drive unit.

Wisconsin Metal Sales  
200 CADY COURT  
P.O. BOX 149  
REEDSBURG, WI 53959-0149  
<http://www.wimetals.com/>

Sales and Customer Service  
[sales@wimetals.com](mailto:sales@wimetals.com)  
608-524-2393  
608-524-8563 Fax

-Supplementary sheet metal, angle stock, and square tubing

Mid-Atlantic Engine Supply Corp.  
P.O. Box 2270  
Cinnaminson, NJ 08077  
<http://maesco.com>

Sales and Customer Service  
[info@maesco.com](mailto:info@maesco.com)  
800-257-8133  
800-470-4779 Fax

-RACOR fuel filter assembly, fuel filters, and appropriate fitting.

Bens Cleaner Service Inc  
2221 4th Avenue South  
Seattle, WA 98134  
[benscleaner.com](http://benscleaner.com)

Sales and Customer Service  
[customerservice@benscleaner.com](mailto:customerservice@benscleaner.com)  
[sales@benscleaner.com](mailto:sales@benscleaner.com)  
877-922-4262  
206-622-4560 Fax

-Fuel burner replacement parts such as fuel pumps, mounting brackets, igniters, and electrodes.

Motion Industries  
P.O. Box 1477  
Birmingham, AL  
35201-1477 USA  
<https://www.motionindustries.com>

Sales and Customer Service  
877-609-7975

-PolyChain belt 14MGT-1890-37.

Robertson Geologging (USA) Inc.  
10801 Hammerly Blvd. Suite 202  
Houston, TX 77043  
<http://www.geologging.com>

Sales and Customer Service  
[dlacey@geologgingusa.com](mailto:dlacey@geologgingusa.com)  
713-647-7070  
713-647-7073 Fax

-Level wind shaft and follower bushing.

Midwest Pump & Equipment  
2300 S 7th St  
Lincoln, NE 68502

Sales and Customer Service  
800-233-5024

-Liqua Tech 1" flow meter, Pulsar kit

Ferguson Equipment Inc.  
4505 Triangle St  
McFarland, WI 53558-9440  
<http://www.ferguson.com>

Sales and Customer Service  
608-838-3181

-Pipe hardware and such

Marsh Electronics, Inc.  
1563 South 101st Street  
Milwaukee, WI 53214  
<http://www.marshelectronics.com>

Sales and Customer Service  
(800) 236-8327  
(414) 771-2847Fax

-Handheld distance meter -HD150

SNOW IMPLEMENTS  
E5299 West Pioneer Road  
Ironwood, Michigan 49938  
[www.michiweb.com/snowimplements](http://www.michiweb.com/snowimplements)

Sales and Customer Service  
[abrski@skynet.net](mailto:abrski@skynet.net)  
906-932-3502

-Alpina Trans Alp bus sled with six seats and two roll bars.

Midwest Filter Corp  
PO BOX 250  
Highwood, IL 60040  
<http://midwestfilter.com>

Sales and Customer Service  
[Ask-mwf@midwestfilter.com](mailto:Ask-mwf@midwestfilter.com)  
847-680-0566  
847-680-0832 Fax

-PONG 25P2PWE and 5P4P filter bags, filter bag housing, hardware

DGH Corporation  
P.O. Box 5638  
Manchester, NH 03108-5638  
<http://www.dghcorp.com>

Sales and Customer Service  
[information@dghcorp.com](mailto:information@dghcorp.com)  
603-622-0452  
603-622-0487 Fax

-Eight channel RS-485 modules, Five volt power supplies, cable, and mounting hardware.

-RS-485 outputs with RTD, digital, or thermocouple inputs.

R.E. Michel Company  
702 North Tibbs Ave  
PO Box 22346  
Indianapolis, IN 46222  
<http://remichel.com>

Sales and Customer Service  
800-544-0923  
317-264-2554 Fax

-B2YA-8916 SUNTEC oil pump, Delavan fuel spray nozzles, and kaowool.

Unico, Inc,  
3725 Nicholson Rd.  
P. O. Box 0505  
Franksville, WI 53126-0505  
<http://unicous.com>

Sales and Customer Service  
[unicous@unicous.com](mailto:unicous@unicous.com)  
262-886-5678  
262-504-7396 Fax

-Drives and drive controllers

Diebolt & Company  
P.O. Box 744  
Old Lyme, CT. 06371  
<http://dieboltco.com>

Sales and Customer Service  
[sales@dieboltco.com](mailto:sales@dieboltco.com)  
800-DIEBOLT  
888-DIEBOLT Fax

-Heated hose.

First Supply  
6800 Gisholt Drive  
Madison, WI 53713  
<http://1supply.com>

Michael Miller –General Manager  
[mmiller@1supply.com](mailto:mmiller@1supply.com)  
608-222-7799  
608-223-6621 Fax

-B-Line Strut (like Unistrut) hardware.

Brigade Quartermasters, Ltd  
177 Georgia Ave  
Providence, RI 02905  
<http://www.brigadeqm.com>

Ft. McCoy, WI TFX Store  
[tfxmccoy@iragreen.com](mailto:tfxmccoy@iragreen.com)  
608-269-1730  
800-663-7487  
800-738-8522 Fax

-Gloves, glove liners, helmets, socks, sock liners, balaclavas, emergency blankets.

Karst Sports  
Route 1, Box 184  
Shinnston, WV 26431  
<http://www.karstsports.com>

Sales and Customer Service  
[info@karstsports.com](mailto:info@karstsports.com)  
800-734-2851  
304-592-1608 Fax

-Helmets: Black Diamond, Petzel, Edelrid.

TeleChem International, Inc.  
524 East Weddell Drive  
Sunnyvale, CA 94089  
[telecheminternational.com](http://telecheminternational.com)

Sales and Customer Service  
[arrayit@arrayit.com](mailto:arrayit@arrayit.com)  
408-744-1331  
408-744-1711Fax

-Propylene glycol

Powerwerx Inc.  
263 N Berry St  
Brea, CA 92821  
[www.powerwerx.com](http://www.powerwerx.com)

Sales and Customer Service  
[powerwerx.com/contactus.asp](http://powerwerx.com/contactus.asp)  
888-321-0073  
714-674-4949 Fax

-Teflon stranded wire

Yale Cordage  
77 Industrial Park Road  
Saco, ME 04072  
www.yalecordage.com

Sales and Customer Service  
yalecordage.com/contact  
207-282-3396

-Yale Grips

Midland Plastics  
5405 South Westridge Court  
New Berlin, WI 53151  
www.midlandplastics.com

Sales and Customer Service  
midlandplastics.com/contact\_us.htm  
800-938-7000  
262-938-7007 Fax

-Polycarbonate sheet

Anderson Pump & Process  
21365 Gateway Court, Suite 300  
PO BOX 523  
Brookfield, WI 53008-0523  
http://www.aaaco.com

Sales and Customer Service  
sales@aaaco.com  
262-784-3340  
262-784-9749 Fax

-Nord gearbox, XL2B rotary, and Blackmer pumps.  
-Mechanical seals, couplings, and rebuild kits.

Peoria Pump, Inc.  
1308 NE Adams Street  
Peoria, IL 61603-4102

Sales and Customer Service  
309-674-1500

-Grundfos submersible pumps  
-Franklin motors

AI McDermott CO  
2009 Jackson Street  
Oshkosh, WI 54901-2207  
www.aimcdermott.com

Glen Lienhard –Heating Manager  
glienhard@aimcdermott.com  
800-242-0357  
920-231-5041 Fax

-Grundfos and multi-stage  
submersible pumps.

-Unknown motors with numbers  
082321F, 8236F006, and  
082329F.

Kaman Industrial Tech  
2019 Stoughton Road  
Madison, WI 53716  
<http://kamandirect.com>

Marie Hewitt  
608-221-8521

-Additional 1" JIC plumbing fittings.

McMaster-Carr  
600 N County Line Rd  
Elmhurst, IL 60126-2081  
<http://mcmaster.com>

Sales and Customer Service  
[Chi.sales@mcmaster.com](mailto:Chi.sales@mcmaster.com)  
630-833-0300  
630-834-9427 Fax

McMaster-Carr  
600 N County Line Rd  
Elmhurst, IL 60126-2081  
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630-833-0300  
630-834-9427 Fax



REVISIONS				
LTR.	CR	DESCRIPTION	DATE	APPROVED
-	NA	Original version	8/29/02	See below
A	1016	Revised to change event report form from RPSC to IceCube form & removed revision history <ul style="list-style-type: none"> <li>▪ P.3 - Removed revision history; it was redundant with this table.</li> <li>▪ P. 4, TOC- Added Appendix D.</li> <li>▪ 2.10 - Updated to add new Report Form.</li> <li>▪ Added Appendix D.</li> </ul>	2/25/03	Demke
B	IC0020	Updated as follows: <ul style="list-style-type: none"> <li>▪ Included edits from RPSC.</li> <li>▪ Updated Purpose &amp; Scope</li> <li>▪ 1.2 – Added EHS Policy.</li> <li>▪ 1.5.3 – Added IceCube Safety Officer.</li> <li>▪ 1.5.4 – Added Stop Work Authority.</li> <li>▪ 2.11 – Added section on waivers.</li> <li>▪ Chapter 5 – Minor text edits.</li> <li>▪ 5.2.5 – Added objective on Safety Comm. Plan.</li> <li>▪ 5.4.4.2 – Added new paragraph on SP trainings.</li> <li>▪ 5.4.4.3 – Added reference to Appendix E.</li> <li>▪ 5.6 – Added section on Safety Comm. Plan.</li> <li>▪ App. A – Deleted unneeded definitions.</li> <li>▪ App. B – Deleted unused techniques in paragraph 5.</li> <li>▪ App. E – Added training agenda.</li> <li>▪ App. F – Added Safety Communication Plan.</li> </ul>	11/19/04	Demke
C	IC0079	Updated as Follows to reflect on-ice experience at South Pole and transition to construction/deployment operations. Also update to reflect changes in RPS procedures and the necessity for IceCube differences.	08/01/05	Leweling
D	IC0079	Revised as follows: <ul style="list-style-type: none"> <li>• Added Hot Work Program References</li> <li>• Added the 2006/7 Driller/Deployer Training Plan</li> <li>• Revised section 1.5; Added 1.5.7, and Appendix H.</li> <li>• Added 3.12.1.5 and Appendix I</li> </ul>	10/31/06	Zernick
E	NA	Revised as follows: <ul style="list-style-type: none"> <li>• Revised 2010/11 Driller/Deployer Training Plan &amp; Appendix H</li> <li>• Added: Appendices: J,K,&amp; L</li> </ul>	07/01/10	Zernick

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# **IceCube Project Safety Manual**

Antarctic Astronomy & Astrophysics Research Institute

Madison, WI

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## **Introduction**

This IceCube Project Safety Manual is based on the NASA Safety Manual and incorporates much of the referenced documentation (OSHA and other standards) referenced by the NASA Manual. This Manual is intended to be consistent with the Raytheon Polar Services Standard Operating Procedures (SOP) and their referenced documents. In any case where this or the Raytheon Manual requires a more stringent standard, the more stringent standard shall apply except as the IceCube Operating Procedures, Safety Manual, or University of Wisconsin Safety Programs otherwise indicate. In all cases all standards required by the State of Wisconsin and the University of Wisconsin shall be the minimum standards followed.

## **Purpose and Scope**

The IceCube Project Safety Manual defines:

- How project safety and specific safety issues are to be managed, identified, assessed and addressed during the development process and operations.
- How this information is transferred to Antarctic operations.
- Review procedures for safety issues as they arise at the operations site.

This document describes the safety practices that are to be followed by IceCube employees and contractors and contractors during the development, testing and deployment of the project. This manual covers all aspects of IceCube, including, but not limited to, the Enhanced Hot Water Drill, In-Ice Devices, IceTop and the counting house.

The Raytheon Polar Services Safety Manual specifies the standard operating procedures that are to be followed by their personnel deployed at the Antarctic including training, occupational safety & health procedures and corrective action processes.

## **References**

29 CFR 1910.38, 29 CFR 1910.120 – Emergency Response  
29 CFR 1910.95 – Hearing Conservation  
29 CFR 1910.122, .241-244 – Tool Safety  
29 CFR 1910.132, .133, .138, 29 CFR 1926.96, .100, .101, .102, .102 – Personal Protective Equipment  
29 CFR 1910.146 – Confined Space Entry  
29 CFR 1910.147 – Control of hazardous energy (lockout/tagout)  
29 CFR 1910.151, 29 CFR 1926.50 – First Aid  
29 CFR 1910.178 – Forklift Operations  
29 CFR 1910.179 – Overhead and gantry cranes  
29 CFR 1910.180, 29 CFR 1926.550 Mobile Cranes  
29 CFR 1910.184 – Slings  
29 CFR 301-399, 29 CFR 1926, Subpart K – Electrical Safety  
29 CFR 1910.1200 – Hazardous Chemicals  
29 CFR 1910 Subpart L – Fire Protection  
29 CR 1926.500-503 – Fall Protection  
49 CFR 170-178 – Hazardous Materials Regulations (Transportation of)

49 CFR 171 – Hazardous Materials – General Information, Regulations, And Definitions  
49 CFR 172.101 – Hazardous Materials Table, Special Provisions, Hazardous Materials  
Communications, Emergency Response Information, and Training Requirements  
University of Wisconsin Hazard Communication Program  
University of Wisconsin Laboratory Safety Guide  
ANSI Z117.1 – Safety Requirements for Confined Space  
ANSI B30.5-1968 – Mobile and Locomotive Cranes  
Executive Order (EO) 13043 of April 16, 1997 – Increasing Seat Belt Use in the United States  
Executive Order (EO) 12196 of Feb 26, 1980 – Occupational safety and health programs for  
Federal employees and contractors  
NASA Standard 8719.13A – Software Safety  
National Electric Code, MIL-STD 454 – Standard Gen. Requirements for Electronic Equipment  
(General Guidelines for Electronic Equipment - Replaces MIL-STD-454 Document  
Number: MIL MIL-HDBK-454)  
NFPA fire standards, codes, and their appendices.  
NFPA 101 Life Safety Code Handbook.  
NFPA 70 National Electric Code Handbook.  
NIOSH Publication No. 87-113 – A Guide to Safety in Confined Spaces  
OSHA Technical Manual, Section 10, Chapter 3 – Pressure Vessel Guidelines  
International Boiler and Pressure Vessel Code-2004 Edition  
NPD 8710.5 – NASA Policy for Pressure Vessels and Pressurized Systems

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## **CHAPTER 1.       Basic Safety Management**

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### **1.1 General**

1.1.1 This document provides the procedures and guidelines that define the IceCube Safety Program. Safety program responsibility starts at the top with senior management's role of developing policies, providing safety strategies and resources. It is executed by the development and operations teams. Safety is a line management responsibility and function. All employees and contractors are responsible for their own safety, as well as that of others whom their actions may affect. All IceCube employees and contractors and contract employees and contractors are empowered to raise issues of potential safety and request analysis by a qualified individual. Operations employees and contractors are empowered to call for the halt of any process or operation they believe is unsafe and request analysis by a qualified individual. If the activity is unsafe, the qualified individual, in conjunction with the management team and the individual raising the concern, will determine the corrective actions needed. All employees and contractors are also to report any systems designs, operations, processes, or software they feel are unsafe or do not meet safety requirements.

1.1.2 In general, the success or failure of organizations' safety efforts can be measured by the number of incidents involving injury or death to personnel, lost productivity (lost or restricted workdays), environmental damage, or loss of, or damage to, property. However, safety metrics do not measure the success of the IceCube safety efforts. Safety success or failure is measured in human terms of serious injuries to employees and contractors. It is also measured in terms of continuous safety effort improvement, management support, and employee involvement. Safety effort failures can also be measured by increased development time, longer cycle time, operational delays, reduced quality, increased costs, loss of program capability, and loss of technical reputation or stature. Aggressively preventing mishaps is good management and good business practice.

1.1.3 IceCube undertakes many activities involving a high potential of risk. Management of this risk (which involves identifying and eliminating, minimizing, controlling, or accepting the risk) is one of IceCube's most challenging activities and is an integral part of IceCube's safety efforts.

## 1.2 Environmental Safety and Health Policy

### **ENVIRONMENTAL SAFETY AND HEALTH POLICY**

#### **Purpose**

*The purpose of this document is to define the policy of the IceCube Project regarding environmental, safety and health issues, and the principles by which the project will discharge its stewardship responsibilities toward the safety and health of its employees and contractors and the environment, and compliance with the Antarctic Treaty System as implemented by the Antarctic Conservation Act, as amended.*

#### **Policy**

*IceCube is committed to following its policy regarding Environmental, Safety and Health Protection. This policy, as stated below, will be followed by all persons associated with the Project.*

- *IceCube employees and contractors and contractors will participate as good neighbors within the Antarctic community and comply with the requirements of the Antarctic Treaty.*
- *IceCube will work to promote the safety and health of all project participants.*
- *IceCube will operate all research and construction activities in an environmentally responsible manner.*
- *IceCube will consider environmental, safety and health protection in all planning for equipment, facilities and project activities.*
- *IceCube will seek improvements in pollution prevention activities by reducing emissions, eliminating waste and protecting the safety and health of all project participants and the environment.*
- *IceCube will recognize and respond to concerns about potential environmental impacts from project operations.*
- *IceCube will exchange technical and administrative solutions to environmental, safety and health issues with Raytheon Polar Services by removing barriers that inhibit progress and by creating a support forum to facilitate the transfer of information.*

#### **Applicability**

*This policy is applicable to all IceCube Project participants.*

#### **Responsibility**

*All IceCube Project participants are responsible for assuring compliance with this policy*



### **1.3 Essential Components of Policy**

IceCube's safety program is based on the following five essential components:

- 1.3.1 Management commitment and employee involvement.
- 1.3.2 System and worksite hazard analysis.
- 1.3.3 Hazard prevention and control.
- 1.3.4 Safety and health training.
- 1.3.5 Ongoing review, assessment and mitigation of potential safety issues.

### **1.4 Objectives and Principles**

The objectives of IceCube's Safety Program are to affect positively the overall success rate of operations and to prevent injury to personnel, loss of or damage to property, or environmental harm. Requisite program principles include the following:

- 1.4.1 An aggressive and independent safety function for IceCube to ensure that the project is accomplished with proper safety planning.
- 1.4.2 Planning, direction, development of requirements, policies, methodology, procedures, implementation, and evaluation of the safety program to ensure its goals are achieved effectively and efficiently.
- 1.4.3 Compliance with the safety standards issued by the Occupational Safety and Health Administration (OSHA), State of Wisconsin, University of Wisconsin, and Raytheon Polar Services, whichever is more stringent. If no standard applies, IceCube will develop its own supplementary or alternate standards for safety to support its unique operations, materials, facilities, equipment, procedures, and practices.
- 1.4.4 Technical reviews by the developing organization of the safety aspects of all development efforts and operations to ensure that they are being conducted in accordance with sound safety engineering principles.
- 1.4.5 Safety assessments of all systems prior to changes so as to preclude an increase in risk to personnel or equipment. Assessments of both qualitative and quantitative safety risks to people or property along with recommendations to either reduce the risks or accept them. Final risk acceptance is a management responsibility. However, employees and contractors have the right to be informed of the risk acceptance process if it affects their personal safety or health.
- 1.4.6 Investigation of all injuries and illnesses, hazardous conditions, near misses, environmental incidents, and mishaps, and the prompt publication of lessons-learned as part of accident prevention and a continuous improvement effort.

1.4.7 Safety oversight/insight and periodic (weekly, monthly) inspection to ensure compliance with safety policies and assess the effectiveness of safety activities as required by this policy, Federal regulations, State regulations where applicable, and national consensus standards.

1.4.8 Commitment to the quality management principles of ISO 9000.

## 1.5 Authority and Responsibility

1.5.1 The IceCube Project Director has the authority and responsibility to appoint an IceCube Safety Manager who has the authority and responsibility to carry out the policies described herein.

1.5.2 The IceCube Safety Manager has the authority and responsibility to communicate about safety matters to anyone, regardless of organizational reporting channels.

1.5.3 On-site Safety Leads shall be designated for the IceCube Project during drilling and deployment operations at South Pole who shall have the authority to:

- Organize safety inspections.
- Conduct safety trainings.
- Establish safety meetings.
- Report and investigate safety-related events; i.e., Incident Reports
- Procure safety equipment.

1.5.4 **Stop Work Authority** – The on-site IceCube Safety Lead shall have the authority to stop all or portions of IceCube work tasks due to unsafe work conditions.

1.5.5 Line management and line supervision are directly responsibility for the IceCube Safety Program and efforts within their area of authority and responsibility and the work planning necessary to ensure a safe workplace and safe work.

1.5.6 IceCube employees and contractors and contract employees and contractors are directly responsible for their own safety and implementing IceCube Safety Policies, standards, and directives as they apply to the activities the employees and contractors are engaged in.

1.5.7 Detailed Roles and Responsibilities (See Appendix H:

Safety Team: On-Ice Hierarchy (applies to PSL as applicable)

On-Ice Lead/ Safety Manager:

1. Safety Lead- Drilling
  - a. Shift Leads
  - b. Deputy Shift Leads
2. Safety Lead- Deployment
3. Safety Lead- ICL
4. Safety Lead-Other



## **1.6 Risk Assessment (Hazard Analysis)**

The primary purpose of risk assessment is to identify and evaluate risks to support decision-making regarding actions to ensure safety and project success as well as to support decision-making in other areas, such as selection of contract type, development of fee incentives and surveillance plans, and information security. The decision (based on all relevant factors) to accept a hazard with its associated risk is a management responsibility, but will require coordination with appropriate safety officials, effected employees and contractors, and line management. In all cases, when a decision is made to accept a hazard with its associated risk, that decision will be communicated to the next higher management level for review. The probability of a mishap, the severity of the possible consequences and its detectability prior to occurrence shall be major considerations in that decision.

Hazard analysis should use the simplest methods that adequately characterize the probability, severity and detectability of undesired events. Qualitative methods that characterize hazards and failure modes should be used first. Quantitative methods should be used when qualitative methods do not provide an adequate understanding of failure causes, probability of undesired events, or the consequences of hazards or potential failures. Standard operating procedures (SOP's) shall be developed by line management and supervision to ensure that a systematic process is in place for all tasks and processes in a format easily understood by the individual(s) charged with accomplishing that task or process. The SOP's should define the work to be performed, identify the hazards and methods of control, and the methods for performing the work.

## **1.7 Control of Hazardous Conditions**

Systems shall be designed to preclude the occurrence of a hazard or to negate or reduce the effect of a hazard that cannot be eliminated. The level of protection required is a function of the hazard severity, probability and detectability, and may be achieved by a combination of availability, reliability, maintainability (restorability), and redundancy. Protection levels must include consideration for the possibility of operator error. All IceCube employees and contractors or contract employees and contractors are empowered to "Stop Work" if they feel a hazardous condition has not been properly controlled. A pre-job briefing for involved employees and contractors should be conducting before beginning any new unique task or process.

## **1.8 Safety Program Reviews**

1.8.1 During development, safety program reviews shall be integrated with the system and subsystem design reviews so that the safety aspects of the project are reviewed with technical and management reviews. Depending on project need, additional standalone safety reviews may be held to review specific safety issues, or subsystem/system design.

1.8.2 At a minimum, a yearly safety status review will be held with the development team to review issues and events that arose during the previous deployment period. The purpose of this review is to look for new issues and trends that had not been addressed previously or had been addressed inadequately. The safety status review shall occur after each deployment period of IceCube has been completed. Note: This review does not preclude the potential to hold a safety meeting to review a specific issue during a development or deployment activity, task, or period. A post job review should be conducted after completion of new or unique tasks or after

completion of a deployment period to identify any experiences and/or potential improvements required for future activities of job planning.

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## CHAPTER 2. System Safety

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### 2.1 Purpose

This chapter establishes procedures and guidelines for the implementation of system safety processes to ensure the identification and reduction of program safety risks to an acceptable level.

### 2.2 Objective

The principal objective of the system safety activity is to provide for an organized, disciplined approach to the early identification and resolution of hazards impacting personnel, hardware, or project success to a level as low as reasonably achievable (ALARA). The system safety activity will use the 5-step risk management approach noted below. The five steps of the risk management approach are as follows:

2.2.1 **Identify** and document the system safety risks (hazards) early in the project, and continue to update the status of these risks and any newly identified risks through out the project.

2.2.2 **Analyze** the risks (hazards) for probability, severity and detectability. When that is complete, prioritize the risks based upon overall potential risk and when the mitigations need to be implemented into the project.

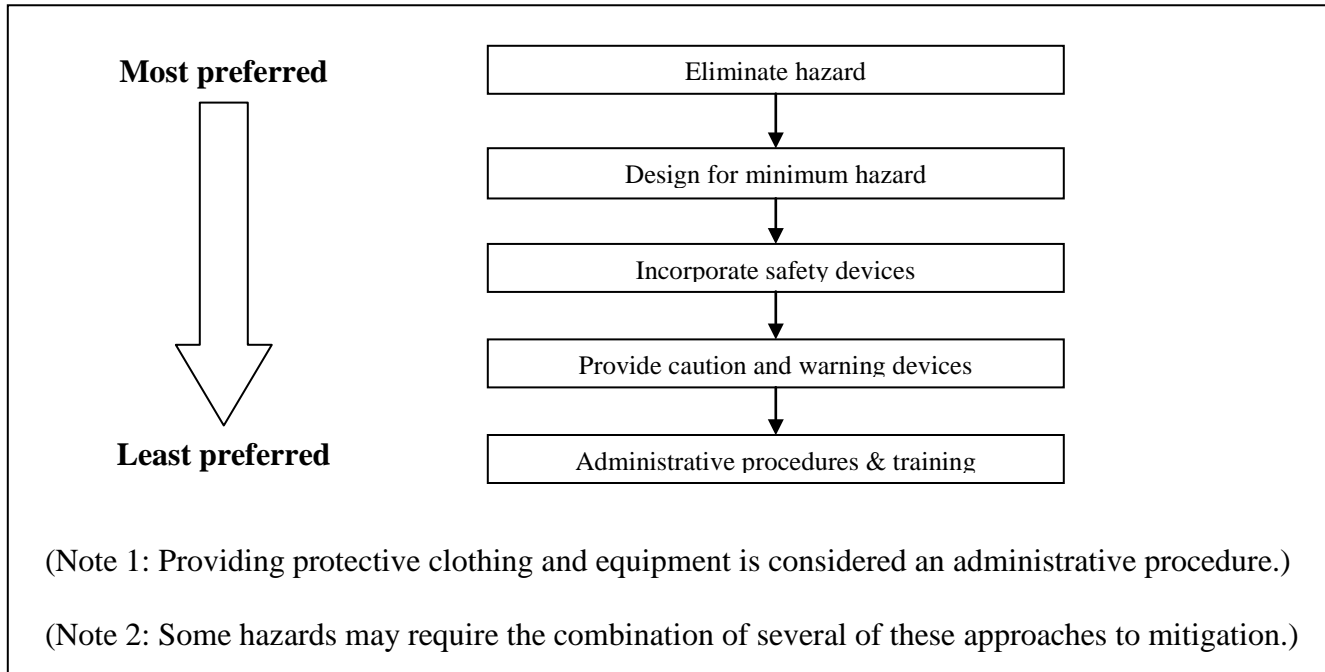
2.2.3 **Plan** what should be done to eliminate or reduce the risks, and provide the planning and decision-making documentation to the appropriate levels of program management for a decision to eliminate, further reduce, or accept the risk. Institute hazard mitigation (corrective) actions.

2.2.4 **Track** the results of the corrective actions, and continue to verify and validate their effectiveness.

2.2.5 **Control** or change the corrective action plans based on the effectiveness of the mitigation actions.

## 2.3 Hazard Reduction Protocol

Hazards will be mitigated according to the following stated order of precedence (see Figure 2.3):



**Figure 2.3 Hazard Reduction Protocol**

## 2.4 Hazard Analysis (HA)

The hazard analysis process is a principal factor in the understanding and management of safety risk. Hazards are identified and resultant risks are assessed by considering:

- Probability of occurrence.
- Severity of consequence.
- Detectability of the issue prior to manifestation of the risk.

Risk may be assessed qualitatively or quantitatively. System safety is an integral part of the overall program risk management decision process.

An analysis expressed numerically may still be considered qualitative, if the numerical assessment is based on the assessor's knowledge, experience and background. An analysis is considered quantitative when the results are based on objective data. For example, the analysis process states that any failure occurring >1 in 100 attempts is a high failure rate. A sample of 1000 units indicates that 20 units failed. This would be a high failure rate (2 in 100 units).

2.4.1 A Failure Modes Effect Analysis (FMEA) will be used as the process for analyzing project hazards. The process is as follows:

2.4.1.1 Hazards and their causes are identified at a system or subsystem level.

2.4.1.2 The severity, probability and detectability are assessed on a numerical scale for each cause of each hazard.

- 2.4.1.3 The scores of these 3 categories are multiplied to generate a Risk Product Number (RPN) (pre-mitigation RPN).
- 2.4.1.4 The level of risk is assigned based on the RPN score.
- 2.4.1.5 The need for mitigation is determined according to the level of risk.
- 2.4.1.6 For hazards requiring mitigation, an appropriate mitigation is planned and the hazard is rescored taking the mitigation into consideration (post-mitigation RPN). This process is repeated until the RPN score has been reduced to an acceptable level.
- 2.4.1.7 The mitigations are prioritized based upon the RPN score and the project impact.
- 2.4.1.8 The hazards and mitigations are tracked until implementation of the mitigation is confirmed.
- 2.4.1.9 Appropriate sections of the hazard analysis are reassessed as changes are made to the materials, hardware, instructions and activities.
- 2.4.1.10 Appendix C contains an example of the FMEA format.

2.4.2 Risk Product Number (RPN). The RPN score is a numerical expression of comparative risk determined by an evaluation of the potential severity of a condition, the probability of its occurrence and its detectability prior to the manifestation of the risk. Scoring is completed as noted below. The RPN number will serve as a means to prioritize corrective actions (mitigations), e.g., the higher the RPN score, the higher the potential risk, the higher the priority to correct the issue. Safety and project management may approve variations to the risk levels with justification.

2.4.2.1 Severity is an assessment of the worst potential consequence, defined by degree of injury or property damage, which could occur. The severity classifications are defined as follows:

<b>Severity Assessment - Hazard Analysis</b>		
<b>Severity Score</b>	<b>Classification</b>	<b>Description</b>
1	Negligible	A condition that would not adversely affect personal safety or health. A condition that subjects facilities or equipment to more than normal wear and tear.
2	Moderate	A condition that may cause minor injury or occupational illness, or minor property damage to facilities, systems or equipment.
3	Critical	A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems or equipment.
4	Catastrophic	A condition that may cause death or permanently disabling injury, facility destruction, or loss of staff or major systems during the project.



2.4.2.2 Probability is the likelihood that an identified hazard will result in a mishap of the severity noted in the severity classification, based on an assessment of such factors as failure rate, location, exposure in terms of cycles or hours of operation, and affected population. The probability classifications are defined as follows:

Probability - Hazard Analysis		
Severity Score	Classification	Description
1	Negligible	The hazard is not likely to occur although it is statistically possible.
2	Remote	Conditions are such that a series of infrequent events would have to occur for the issue to result (i.e., issue could occur once or twice during the life of the project).
3	Occasional	Conditions are such that a coincidence of events would have to occur for the issue to result (i.e., issue could occur a few times during the life of the project).
4	Periodic	Issue will likely occur at a statistically predictable frequency (i.e., issue occurs every two months).
5	Frequent	Issue occurs often or at a statistically significant rate every time an activity is undertaken (i.e., hazard occurs 20% of the time a particular feature is invoked).
6	Continual	Issue occurs every time an activity is undertaken.

2.4.2.3 Detectability is the observability of the hazard prior to inflicting harm. The detectability classifications are defined as follows:

Detectability - Hazard Analysis		
Severity Score	Classification	Description
1	Obvious	The presence of the hazard is obvious to untrained users of the system.
2	Noticeable	The hazard can be detected easily by a trained user of the system or by untrained users of the system with reasonable inspection of displays, monitors, etc.
3	Obscure	The hazard is difficult to detect even for trained users of the system in normal operating situations.
4	Undetectable	The hazard cannot be detected without substantial cross-referencing, testing, or analysis.

2.4.2.4 RPN score is the product of the severity, probability and detectability scores that denotes a relative level of risk for the hazard being evaluated. The risk levels are defined as follows:

Risk Level - Hazard Analysis			
RPN Score	Level Of Risk	Description	Mitigation
≤12	Minor	Negligible potential for harm or risk is small and does not require further reduction.	No mitigation or justification is required.
13-35	Moderate	Reduction or justification is required. If residual risk is still Moderate or reasonable mitigation is unachievable, the risk may be tolerated provided justification is provided	Mitigation to Minor or justification regarding why the residual risk may be tolerated.
≥36	Major	Unacceptable and must be eliminated.	Mitigation required. If reduced to Moderate, justification is required. If reduced to Minor, no justification is required.

2.4.2.5 At the completion of the hazard analysis process, all hazards shall be:

- Mitigated to a Minor risk level, OR,
- Mitigated to a Moderate risk level with justification why the residual risk is to be tolerated.

## **2.5 Safety Activity Phases**

The hazard analysis process begins in the formulation stage and continues, in varying degrees, throughout the project's life cycle. This involvement begins with the early design concepts. The system hazard analysis effort shall be a continuing and iterative process influencing the system in a manner which manages risk as the design progresses, changes and matures.

## **2.6 System Hazard Analysis**

2.6.1 The System Hazard Analysis provides a means to systematically and objectively identify hazards, determine their risk level, and suggest the mechanism for their elimination or control. This iterative process begins in the conceptual phase and extends throughout the life cycle including disposal. The extent and depth of analysis required to meet the following five functions will be determined by system complexity and loss potential. Functions supported by the analysis include the following:

2.6.1.1 Providing the foundation for the development of safety criteria and requirements.

2.6.1.2 Determining whether and how the safety criteria and requirements provided to engineering have been included in the design.

2.6.1.3 Determining whether the safety criteria and requirements created for design and operations have provided an acceptable level of risk for the system.

2.6.1.4 Providing a roadmap (or methodology) for the development of safety goals and criteria.

2.6.1.5 Providing a means for demonstrating that safety goals have been met.

2.6.2 During the hazard identification process, it is essential to remain non-judgmental about the associated probability, severity, detectability and corrective action (mitigation). Once identified, hazards are prioritized by RPN score and program impact (risk assessment). Sufficient analyses are performed to assess the probability of occurrence (usually qualitative for early assessments) for each undesired event identified.

2.6.3 There are several types of analyses that may be used to identify hazards and characterize the severity, probability and detectability of hazards. Some of these analyses are specialized and others which, as designs mature, build on previously accomplished analyses.

2.6.3.1 The first safety analysis is the Preliminary Hazard Analysis (PHA), which shall be performed early in the program or any new task or process. Other primary analyses may include the Subsystem Hazard Analysis (SSHA), Component Level Fault Tree Analysis (FTA), Software Hazard Analysis (SWHA) (see NASA Standard 8719.13A, "Software Safety," for more information), System Hazard Analysis (SHA), Operating and Support Hazard Analysis (O&SHA), Job Hazard Analysis (JHA), Human Factors Engineering Analysis, the Safety Requirements Compliance Matrix, and Integrated Hazard Analysis (IHA), unless otherwise indicated by the PHA. Data from these analyses can be used to offer recommendations to reduce risks.

2.6.3.2 The hazard analyses should use data developed by other types of analyses when available, such as Operations Analysis, Human Factors Engineering Analysis, and Maintainability Analysis. The safety analyst may have to develop specific, limited data to support the hazard analyses if the other analyses are not performed.

## **2.7 System Safety Program Reviews**

2.7.1 The program/project manager, or his designated agent, shall conduct one or more system safety reviews depending on the complexity of the system. These reviews may be in conjunction with other program milestones. The purpose of these reviews is to evaluate the status of hazard analyses, residual risks, hazard controls, verification techniques, technical safety requirements, and program implementation throughout all the phases of the system life cycle. These reviews shall focus on the status/evaluation of management and technical documentation, and the safety residual risks remaining in the program at that stage of development.

2.7.2 Results of such safety reviews shall be communicated with project and line management.

## **2.8 Documentation**

2.8.1 **Traceability** - The system safety task requires creation and maintenance of documentation that provides ready traceability from the baseline safety requirements, criteria, and effort planned in the conceptual phases through the life cycle of the program. All pertinent details of the hazard analysis and review shall be traceable from the initial identification of the hazard through its resolution and any updates, using the continuous risk management approach, until such time in the program as it is no longer applicable.

2.8.2 **HA Summary** – The results of the hazard analysis process shall be recorded in a Hazard Analysis Summary.

2.8.2.1 A Hazard Analysis Summary shall be written for each hazard analysis conducted on a system, subsystem or functional area.

2.8.2.2 Original release and updates to the Hazard Analysis and Hazard Analysis Summary shall be communicated with project and line management.

2.8.2.3 Verify adequate resolution of the hazards and maintain objective evidence of the resolution with or referenced in the Hazard Analysis.

2.8.2.4 The summary shall contain the following information.

Content	Example/Comments																				
Report Title/Document #	Hazard Analysis For IceCube Drill Control Software – HA 04																				
Date of Revision	No specific comments																				
Revision History	See revision history in the beginning of this document																				
Identification of the System, Subsystem or Functional Area, including name, description and any revision/model #'s	Hermes EHWD Control Software version 1.1																				
Purpose of the Hazard Analysis	This analysis was conducted to review potential hazards associated with the software controlling the EHWD, to develop a plan to mitigate those hazards, track those mitigations to closure and document those activities.																				
Summary of Hazards	Statement of the hazards reviewed, functional areas of hazards reviewed or reference to the hazard analysis document.																				
Status of the Hazard Analysis	Open – 18 hazards were reviewed for this software. 4 of the hazards remain open awaiting final implementation of their mitigations. These mitigations are planned to be completed by April 4, 2003.																				
Justifications for not Reducing the Risk on Moderate Risk Issues	The justifications could vary greatly depending on the rationale for not undertaking additional risk reduction.																				
Statistical Summary of Risk Mitigation	<table> <tr> <td>Total Hazards:</td> <td>18</td> </tr> <tr> <td>Major Risk reduced to Moderate:</td> <td>1</td> </tr> <tr> <td>Major to Minor:</td> <td>6</td> </tr> <tr> <td>Moderate to Moderate:</td> <td>1</td> </tr> <tr> <td>Moderate to Minor:</td> <td>5</td> </tr> <tr> <td>Minor to Minor:</td> <td>5</td> </tr> <tr> <td># of Hazards Mitigated to Minor:</td> <td>11</td> </tr> <tr> <td># of Hazards Justified:</td> <td>2</td> </tr> <tr> <td># of Hazards Unmitigated:</td> <td>5</td> </tr> <tr> <td># of Hazards Eliminated:</td> <td>0</td> </tr> </table>	Total Hazards:	18	Major Risk reduced to Moderate:	1	Major to Minor:	6	Moderate to Moderate:	1	Moderate to Minor:	5	Minor to Minor:	5	# of Hazards Mitigated to Minor:	11	# of Hazards Justified:	2	# of Hazards Unmitigated:	5	# of Hazards Eliminated:	0
Total Hazards:	18																				
Major Risk reduced to Moderate:	1																				
Major to Minor:	6																				
Moderate to Moderate:	1																				
Moderate to Minor:	5																				
Minor to Minor:	5																				
# of Hazards Mitigated to Minor:	11																				
# of Hazards Justified:	2																				
# of Hazards Unmitigated:	5																				
# of Hazards Eliminated:	0																				
Reports or other Documents Referenced in the HA or Summary	Attach copies of these documents, if appropriate, otherwise reference the location of the documents.																				
Dates of the Meetings to Review the HA, and Attendees	No specific comments																				
Hazard Analysis table	Completed FMEA form																				
Review and Approval Signatures	<p>The HA Summary should be signed by:</p> <ul style="list-style-type: none"> <li>▪ Author</li> <li>▪ Appropriate Engineer</li> <li>▪ Project Manager</li> <li>▪ Safety Manager</li> </ul>																				

## 2.9 Change Review

Systems are changed during their life to enhance capabilities, provide more efficient operation, and incorporate new technology. With each change, the original safety aspects of the system could be impacted, either increasing or reducing the risk. Any aspect of controlling a hazard could be weakened, new hazards could be created, or conversely, hazards could be eliminated. Even a change that appears inconsequential could have significant impact on the baseline risk of the system. Accordingly, proposed system changes should be subjected to a safety review or analysis as appropriate to assess the safety impact. HA's will be updated, when required, to show any identified risk change. Each change initiator shall ensure that safety personnel, line management, and the impacted employees and contractors assess the potential safety impact of the proposed change and any changes to the baseline risk. Changes proposed to correct a safety problem shall also be analyzed to determine the amount of safety improvement (or detriment) that would actually result from incorporation of the change. There shall be a documented statement of safety impact for every change that is proposed to a project baseline (even if the statement is "No Impact).

## 2.10 Incident Reports

2.10.1 Incident reports are captured per the Report Form - Quality & Safety Issues (Appendix D).

2.10.2 Incident reports include accident (injury reported) and near miss reports (no injury reported).

2.10.3 Completed Report Forms shall be forwarded to the IceCube Project Safety Manager. The purpose of the information is to:

- Investigate issues. Issues may be investigated by IceCube personnel, Raytheon staff, consultants or a combination.
- Determine root cause (whether incidents are due to equipment, training or use error issues).
- Assess safety risk.
- Determine if corrective action is required. Corrective actions can include changes to equipment (hardware or software), training updates and documentation updates.

2.10.4 A report of findings shall be generated for each incident report received. If the investigation report of the incident is received from Raytheon or consultant, and appears to be appropriate and adequate, no additional report is required.

## **2.11 Waivers**

2.11.1 Waivers shall be submitted for approval to the Authority Having Jurisdiction (AHJ) when equipment falls to established standards for safety.

2.11.2 Waivers shall contain the following information:

- Identification of Project and system/subsystem.
- Waiver identification #.
- Name and institution of submitter.
- Date of submission.
- Requirement to be waived including identification of the code, standard or regulation.
- Rationale for waiving requirement.
- Mitigations.
- Project authorization.
- AHJ approval.

2.11.3 For IceCube, the AHJ is the National Science Foundation.

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## **CHAPTER 3. Operational Safety**

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### **3.1 Purpose**

This chapter establishes safety procedures for IceCube's operational safety program including development and polar operations. Many of these procedures correspond with similar safety procedures described in the Raytheon Polar Services Safety Manual (issued before 2004/2005). The procedures included in this chapter are intended to be consistent with, and in some instances supplement, the Raytheon Polar Services Safety Manual and its referenced documents. In any case where this or the Raytheon Manual requires a more stringent standard, the more stringent standard shall apply.

### **3.2 Objectives**

The objective of this chapter is to protect the public, personnel, and property from operations-related safety hazards. This is not inclusive of all regulations and requirements governing operations.

### **3.3 Motor Vehicle Safety**

IceCube shall comply with applicable Federal, State, and local motor vehicle safety regulations, including South Pole Station safety regulations.

3.3.1 Motor Vehicle Operation may be required for the movement of product/materials or transportation of personnel between IceCube project sites.

3.3.1.1 For non-South Pole Operations, operators of motor vehicles shall not drive a motor vehicle for a continuous period of more than 10 hours, including non-employment driving; nor shall the combined duty period exceed 12 hours in any 24-hour period, without at least 8 consecutive hours of rest. Variation in the above policy requires documented approval by the Project Manager and Project Safety Manager

3.3.1.2 If operation of the vehicle involves skills beyond those associated with normal, everyday operation of private motor vehicles, formal initial training, consisting of both classroom and operational testing, shall be conducted to ensure operator proficiency. Refresher training and testing shall be accomplished periodically as determined by the Project Manager or Project Safety Manager.

### 3.3.2 Seat Belts

3.3.2.1 Employees and contractors will use seat belts while on official business as required in Section 1 of Executive Order (EO) 13043 of April 16, 1997, "Increasing Seat Belt Use in the United States." The EO states seat belt use is required by Federal employees and contractors operating or in any vehicle with seat belts while on Federal business. All IceCube employees and contractors shall comply with this requirement while traveling on official business.

3.3.2.3 Passengers are forbidden to be carried in the cargo area of pickup trucks, flatbeds, or special purpose equipment such as fire trucks or escape trucks unless designated occupant positions are provided (see 49 CFR Part 571) and required seat belts are provided.

3.3.2.4 All occupants of motor vehicles (so equipped), including delivery vans and trucks of all sizes, will have their seat belt properly fastened around themselves at all times the vehicle is in motion.

3.3.2.5 All IceCube employees and contractors or contractors who will be operating snow mobiles must complete the Wisconsin Snowmobile Safety "Safety Certification Course" before operating snowmobiles at the South Pole. In addition IceCube has requested that RPS qualify IceCube operators on the specific equipment used at the station.

## 3.4 Personal Protective Equipment

### 3.4.1 General

Personal protective equipment (PPE) shall be issued to IceCube employees and contractors in those situations where engineering controls, management controls, or other corrective actions have not reduced the hazard to an acceptable level or where use of engineering controls, management controls, or other techniques is not feasible.

IceCube will provide employees and contractors and contractors with eye protection, including sunglasses or goggles with 95-99% UV protection for South Pole operations, as required by 29 CFR 1926.102 and 29 CFR 1910.132 -.133. IceCube personnel and contractors may wear contact lenses under their eye protection equipment. Reimbursement for eye protection shall follow established RPS South Pole guidelines.

IceCube will require the use of foot protection as specified in 29 CFR 1910.132, .136 and 29 CFR 1926.96. Reimbursement for foot protection shall follow IceCube and University of Wisconsin guidelines and policy. At the South Pole, foot protection requirements shall ensure that the cold weather is the first priority.

IceCube will provide hand protection for all employees and contractors and contractors as required by 29 CFR 1910.132, and .138. At the South Pole, cold weather protection shall be the first priority.

IceCube will require the use of head protection as required by 29 CFR 1926.100 and 29 CFR 1910.135 in all areas where employees and contractors are exposed to high voltage and falling objects. Hard hats, Class B, shall be used during equipment assembly, exposure to high voltage, and wherever there is the possibility of falling objects weighing in excess of 10 pounds. In all operations, some form of head protection, such as climbing helmets shall be used as necessary. At the South Pole, cold weather protection shall be the first priority.

3.4.2 Examples of PPE. Items which may be purchased and issued by IceCube or Raytheon Polar Services include, but are not limited to, the following:

3.4.2.1 Safety goggles and safety spectacles (plain and prescription).

3.4.2.2 Welding helmets and shields.

3.4.2.3 Safety shoes.

3.4.2.4 Steel sole and/or toe safety boots.

3.4.2.5 Aprons, suits, and gloves (e.g., fire resistant materials, leather, rubber, cotton, and synthetics).

3.4.2.6 Protective head gear (e.g., hard hats and caps, liners, helmets, and hoods).

3.4.2.7 Face shields/face masks.

3.4.2.8 Specialty items of protective nature (e.g., cryogenic handlers suits, SCAPE suits, fire fighter suits, foul weather gear, harnesses, life belts, lifelines, life nets, insulated clothing for "cold test" exposure, supplied air suits, and electrical protective devices).

3.4.2.9 Concentration alarms, toxic gas indicators, explosive gas indicators.

3.4.2.10 Cold Weather Protection (as necessary and recommended by NSF and RPS for the South Pole or as required by the task or process to provide adequate protection).

3.4.3 Personnel are to be trained regarding the PPE required to carry out their particular job tasks.

3.4.4 When appropriate PPE is not available to conduct a job-related task, personnel may request that PPE through the appropriate Safety Officer.

3.4.5 Personnel are not required to conduct job-related tasks without appropriate PPE.



### **3.5 Control of Hazardous Energy (Lockout/Tagout Program)**

IceCube will meet or exceed OSHA minimum performance requirements for the control of hazardous energy as outlined in 29 CFR 1910.147. University of Wisconsin IceCube Deployment and Drilling personnel shall be trained on appropriate lockout/tagout procedures prior to deployment on the IceCube project and/or the South Pole. The IceCube Project shall comply with all aspects of 29 CFR 1910.147 for electrical, pressure, hydraulic, pneumatic, and mechanical systems as a minimum. The basic IceCube philosophy is "NO LOCK, NO WORK". Locks and other equipment for lockout will be supplied by IceCube. Immediate disciplinary action will be taken for any violation of the Lockout/Tagout program.

### **3.6 Pressure and Vacuum Systems Safety**

IceCube will follow NASA's program for ensuring the structural integrity of pressure vessels and pressurized systems (PV/S) and minimizing the associated mishap potential as outlined in NPD 8710.5, "NASA Policy for Pressure Vessels and Pressurized Systems." This NPD assigns responsibilities for the various aspects of the program; references the codes, standards, guides, and Federal regulations that must be followed; and establishes unique NASA requirements in areas such as certification/recertification, documentation, configuration management, and operator training/certification.

Design of all pressure vessels shall meet the minimum requirements of the 2004 International Boiler and Pressure Vessel Code.

All recordkeeping and documentation of pressure vessels shall meet the requirements of the OSHA Technical Manual, Section IV, Chapter 3, Appendix IV: 3.1. Recordkeeping Data for Steel Vessels and Low Pressure Storage Tanks.

(Note: As of July 2005, IceCube has no pressure vessels in operation. However, the pipes and hoses are operation at over 800 PSI. The pipes and hoses are not regulated by the above referenced documents. They are, however, inspected and operated under IceCube SOP's)

### **3.7 Electrical Safety**

This paragraph provides directives for protecting persons and property from electrical hazards. It applies to all IceCube uses of electrical power.

#### **3.7.1 Hazards**

Electrical systems shall be designed in accordance with the National Electric Code, MIL-STD 454, "Standard General Requirements for Electronic Equipment" (General Guidelines for Electronic Equipment - Replaces MIL-STD-454 Document Number: MIL MIL-HDBK-454). Electrical systems shall be operated and maintained to adequately control hazards that are likely to cause death or serious physical harm or severe system damage. All electrical systems shall be reviewed by applicable safety and technical personnel for appropriate location, and for proximity of ignitable or combustible material such as gas, vapor, dust, or fiber.

"Work on energized equipment." Only qualified persons may work on electric circuit parts or equipment that have not been deenergized. Such persons shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools .

### 3.7.2 Requirements

3.7.2.1 All electrical work deemed hazardous by job safety analysis shall be performed by personnel familiar with electrical code requirements and qualified/certified for the class of work. All persons engaged in electrical work shall be instructed in accident prevention and fully informed of the hazards involved. Personnel working with energized equipment should be trained in first-aid procedures that include cardiopulmonary resuscitation or have available personnel trained to provide necessary immediate care.

3.7.2.2 Supervisors shall ensure that no person works alone with high voltage electricity. One person, trained to recognize the electrical hazards, shall be delegated to watch the movements of the other working personnel to warn them if they get dangerously close to live conductors or perform unsafe acts and to assist in the event of an accident.

#### 3.7.2.3 Personnel Protection

- Employees and contractors working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.
- Safety signs and tags. Safety signs, safety symbols, or accident prevention tags shall be used where necessary to warn employees and contractors about electrical hazards which may endanger them.
- Employees and contractors shall wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion.
- When working near exposed energized conductors or circuit parts, each employee shall use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts. If the insulating capability of insulated tools or handling equipment is subject to damage, the insulating material shall be protected.
- Protective shields, protective barriers, or insulating materials shall be used to protect each employee from shock, burns, or other electrically related injuries while that employee is working near exposed energized parts which might be accidentally contacted or where dangerous electric heating or arcing might occur. When normally enclosed live parts are exposed for maintenance or repair, they shall be guarded to protect unqualified persons from contact with the live parts.
- Signs warning of high voltage and prohibiting unauthorized entrance shall be posted at entrances and on the perimeter of the enclosure
- Transformer banks or high-voltage equipment (500+ volts) shall be protected by an enclosure to prevent unauthorized access.
- Metallic enclosures shall be grounded.
- Entrances not under constant observation shall be kept locked.
- An authorized access list of qualified personnel shall be maintained.

3.7.2.4 Where electrostatic discharge (ESD) is a significant hazard to personnel or hardware, conductive floors or other methods will be used.

### **3.8 Hazardous Material Transportation, Storage, and Use**

This paragraph provides direction for protecting persons and property during the transportation, storage, and use of hazardous materials. Every effort shall be made to ensure complete safety and compliance with applicable Federal, State, and local laws and regulations. Hazardous material is defined by law as "a substance or materials in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce" (49 CFR 171.8). The Secretary of Transportation has a list of hazardous materials that is found in 49 CFR 172.101. At a minimum, the Federal regulations (e.g., DOT, EPA, OSHA) for transport of hazardous materials on both Federal property and public roadways shall be met. Hazardous materials are include those that may be highly reactive, poisonous, explosive, flammable, combustible, corrosive, radioactive; produce contamination or pollution of the environment; or cause adverse health effects or unsafe conditions.

A specific hazard communication program for Polar Operations is described in the Raytheon Polar Services SOP EH-A-202. IceCube will follow the University of Wisconsin Hazard Communications Program and Laboratory Safety Guide. IceCube will provide all organizations, conducting work for IceCube or handling IceCube chemicals, with Material Safety Data Sheets (MSDS) upon request. A central file will be maintained for easy reference by IceCube personnel or contractors.

### **3.9 Hazardous Operations**

Hazardous operations involve materials or equipment that, if misused or mishandled, have a high potential to result in loss of life, serious injury to personnel, or damage to systems, equipment, or facilities. Adequate preparation and strict adherence to operating procedures can prevent most of these mishaps. The IceCube program will provide the following actions for hazardous operations.

#### **3.9.1 Hazardous Operating Procedure**

3.9.1.1 IceCube shall identify hazardous operations and identify, assess, analyze, and develop adequate safety controls. Generally, all hazardous operations shall require operating procedures that consist of a detailed plan listing step-by-step functions or tasks to be performed on a system or equipment to ensure safe and efficient operations. The operating procedures shall list special precautions, start and stop time of the operation, and the approving supervisor(s). Certain operations (e.g., rigging, high voltage, etc.) depend on adherence to overall standards and general guidelines and specific training as opposed to operating procedures for each specific operation. In these cases, specific training or certification requirements must be established. Personnel other than certified (or trained) operators shall be excluded from exposure to the operation. Where the risk of injury is high, personnel shall use the buddy system whereby an adjacent or nearby person not directly exposed to the hazard serves as an observer to render assistance.

3.9.1.2 Hazardous procedures shall be marked conspicuously with appropriate warnings or cautions to alert operators that strict adherence to the procedural steps, and safety and health precautions contained therein is required to ensure the safety and health of personnel and equipment.

#### **3.9.2 Personnel Certification.**

Personnel who certify individuals to perform or control hazardous operations, or to use or transport hazardous material, must ensure the individuals possess the necessary knowledge, skill, judgment, and physical ability to do the job in a safe and healthful manner.

### **3.10 Lifting Safety**

IceCube shall attempt to limit the lifting of objects to 35 pounds. Objects over this weight should be a two person lift. The best way to reduce the weight being lifted and to eliminate ergonomic problems is to implement engineering controls to make the job fit the employee and not force the employee to exceed his physical abilities. Engineering controls involve deigning or redesigning work areas, tools, or equipment. Ergonomic review of work stations and ergonomic training is available from the University of Wisconsin Safety Staff. Work stations and design of work tasks should be designed to accommodate the full range of motions needed to complete the job.

### **3.11 Test Operations Safety**

This paragraph provides direction for protecting persons and property during test operations, for both human and unoccupied or robotic tests. Testing also includes hazardous training activities and demonstrations of test hardware or procedures. The requirements stated herein apply to test facilities; test equipment located within, or attached to, test facilities; equipment being tested; test personnel; test conduct; and test documents.

#### **3.11.1 Test Plans**

Test plans shall be developed and evaluated to ensure test performance within safe operating limits. Evaluations will address the test article, test facility, operator involvement, test conditions, potential risk to adjoining facilities and personnel, etc.

#### **3.11.2 Safety Documentation**

Safety documentation establishes the basis for safe test conduct by means of engineering analyses (including hazard analyses calculations). Established test controls will be clearly identified in test drawings, facility drawings, test procedures, etc. The level of safety documentation required will be tailored to the risks involved with the test.

**3.11.3 Test System Requirements.** Personnel responsible for developing test systems must do the following:

3.11.3.1 Design test systems such that test personnel or critical test hardware are not subjected to a test environment wherein a credible single-point failure (e.g., power loss) could result in injury or loss to the critical test hardware.

3.11.3.2 Construct all systems (electrical, mechanical, pneumatic, and/or hydraulic) so that no single failure could cause a critical condition.

3.11.3.3 Ensure that software that may interface with test systems meets the requirements stated in Chapter 2. Software by itself is not hazardous; however, when interfaced with test hardware, software could command a hazardous condition in the hardware.

3.11.3.4 Calibrate and certify safety-critical instrumentation before test operations and as required by test documentation or the test organization's internal procedures.

3.11.3.5 Ensure all personnel involved in tests are informed of potential hazards, safety procedures, and protective measures.

3.11.3.6 Ensure the availability of appropriate emergency medical treatment facilities.

3.11.3.7 Conduct formal reviews of those engineering designs that are complicated or potentially hazardous to facilities.

3.11.3.8 Ensure test reports include anomalies, safety implications, and lessons learned.

#### 3.11.4 Test Readiness Review

Test Readiness Reviews must be conducted for tests involving new or modified hardware and/or procedures. These reviews shall determine the safety, technical, and operational readiness of the test.

#### 3.11.5 Pre-test Meeting

A pre-test meeting must be conducted with all involved personnel to discuss the research facility, design, instrumentation, safety, and operator training and certification. The meeting should also establish the test plan, identify test constraints to ensure facility safety, and determine test article readiness.

3.11.6 All failures noted during the testing operation shall be logged into an appropriate defect tracking system.

### **3.12 Confined Spaces**

3.12.1 A confined space is any space not normally occupied by personnel, has limited or restricted openings for ventilation, access and exit, and may contain chemicals that could produce dangerous air contamination. Entry into confined spaces requires written procedures and authorizations. No entry into “permit required” confined spaces will be made until an assessment of that space has been made and a permit or operating procedures posted. Supervisors have overall responsibility for entry and work in confined spaces and for ensuring that the requirements of the references below are followed.

A specific confined space safety program for Polar Operations is described in the Raytheon Polar Services EH-LMHPs-213, 213A, 213B (dated 12/4/02). IceCube will use the RPS Confined Spaces to document entry of IceCube personnel into Confined Spaces. IceCube personnel will be trained to operate Gas monitors to check for O<sub>2</sub> levels and the presence of any toxic gases such as Carbon Monoxide. Upon verification of the space lockout and sufficient monitoring to ensure the presence of O<sub>2</sub> and no presence of toxic gases, the space will be downgraded from a “permit required confined space” to a “non-permit required confined space as defined in 29 CFR 1910.146 (b) and documented in accordance with 29 CFR 1910.146 (c) (7).

3.12.1.2 OSHA 29 CFR 1910.146, "Permit Required Confined Spaces.", 29 CFR 1926.21 (b)(6) (i) Training.

3.12.1.3 American National Standards Institute (ANSI) Z117.1, "Safety Requirements for Confined Space."

3.12.1.4 NIOSH Publication No. 87-113, "A Guide to Safety in Confined Spaces."

3.12.1.5 See Appendix I: Confined Space Entry Permit Form

### **3.13 Crane & Hoisting Safety**

IceCube shall comply with 29 CFR 1910.179 and 29 CFR 1910.184, regarding the use of overhead/gantry cranes and slings, and 29CFR 1926. 550, for Mobile Cranes, to protect persons and property during lifting operations. A specific lifting safety program for Polar Operations is described in the Raytheon Polar Services SOP EH-A-206. In addition, IceCube will reference the OSHA Crane Safety Handbook in training personnel and in planning any crane operations. A “pre-plan” shall be prepared for any operations requiring the use of two cranes, or a unique “one time” operations, or an operation which requires the involvement of two or more organizations. The RPS supervisor, of the crane operation, is responsible for the “pre-plan”, training, and briefing of involved personnel.

(Note: IceCube does not plan to have any IceCube employees and contractors operate mobile cranes at the South Pole. All operations will be conducted by RPS operators and supervisors.)

### **3.14 Fall Protection**

IceCube will comply with all of the provisions of 29 CFR 1926.500 through .503. IceCube will provide employees and contractors and contractor with all of the necessary equipment to ensure that the tasks and jobs can be accomplished safely. Double lanyards will be used. Single lanyard protection is not acceptable. Lanyards, lifelines, and hooks must have a minimum breaking strength of 5000 pounds. Body belts will not be used. Only locking type snaphooks will be used in personal fall arrest equipment. Fall protection will be used in all jobs over 6' above the surface. Guardrails, a minimum of 39-45" high, may be used to meet the Fall Protection requirements. Training in Fall Protection must be conducted by a "competent person". All IceCube employees and contractors and contractors must certify that they have been trained before using personal fall protection equipment. All IceCube employees and contractors and contractors are responsible for inspecting the fall protection equipment before use. Any damaged equipment must be immediately removed from service. Any equipment with a five year or older manufacturing date shall be inspected and removed from service as necessary or as the manufacturer recommends. Any equipment involved in arresting a fall must be removed from service and inspected. All lanyards involved in arresting a fall must be removed from service.

### **3.15 Hearing Protection**

Sound levels over 85dBA may cause hearing loss. Whenever sound levels exceed 85dBA, IceCube will make every effort to reduce the sound levels through engineering controls. IceCube will follow the requirements of 29 CFR 1910.95 when employees and contractors are exposed to sound levels over 85dBA. If the sound levels can not be reduced through engineering controls, hearing protection will be provided to all IceCube employees and contractors and contractors. IceCube employees and contractors and contractors will be trained in hearing conservation but each employee and contractor is responsible for their personal use of the provided hearing protection. Audiograms will be provided by IceCube for all employees and contractors and contractors deploying to the South Pole as part of their annual South Pole physical.

### **3.16 Forklift Operations**

All IceCube employees and contractors and contractors shall be qualified and certified to operate forklifts in accordance with 29 CFR 1910.178 (l). Forklift operator training, provided by the University of Wisconsin Safety Department, will be utilized for the training as much as possible. IceCube will request specific equipment qualification from RPS for South Pole equipment.

### **3.17 Respiratory Protection**

IceCube will follow the requirements of 29 CFR 1910.134. Appendix G outlines the IceCube written Respiratory Protection Program as recommended by the University of Wisconsin Safety Program. Each IceCube employee and contractor will complete the OSHA Respirator Medical Questionnaire during their annual Polar qualification physical. Based on the pulmonary function test, the examining doctor will indicate the individual's qualification to wear a respirator.

### **3.18 Work Tool Safety**

IceCube will follow the requirements of 29 CFR 1926.300-.307, .404, .702, .951, and 29 CFR 1910.211-.219, .241-244. Each employee and contractor will be responsible for inspecting their tools before use, taking any damaged tools out of service, reporting damaged tools to their supervisor, and maintaining their tools in good working order and a safe condition. All electrical tools with damaged plugs, cords or insulation shall be immediately removed from service and tagged as “out of service”. Eye protection is required whenever an employee is using a pneumatic tool or electrical tool or where flying objects may occur. Hydraulic tools must have an approved fire resistant fluid and not be operated at pressures exceeding the manufacturer’s specifications. All jacks exposed to freezing temperatures must be filled with a non-flammable antifreeze liquid.

### **3.19 Cold Weather Safety**

IceCube, through RPS, will provide adequate cold weather gear. Excessive cold can lead to accidents due to forgetfulness, inability to use hands, and exhaustion associated with hypothermia and frostbite. When exposed to cold, the body tries to conserve heat for the brain and major organs by reducing circulation to the skin, then the body extremities, and finally to organs other than the brain and heart. Eventually an individual can’t move, breathing becomes weakened, and the brain loses reasoning power. The individual becomes semi-conscious, the heart then stops, and death occurs. IceCube requires the use of the buddy system for all outdoor activities at the South Pole. All RPS cold weather safety requirements shall be followed at all times.

### **3.20 First Aid, CPR, and AED’s**

IceCube will follow the guidelines in 29 CFR 1910.151. All IceCube operations are required to have a minimum of two persons available in all areas trained in first aid and CPR. First aid and CPR training classes are provided on a bi-weekly schedule in coordination with the University of Wisconsin Safety Staff. All IceCube employees and contractors are encouraged to take this training. AEDS will be provided in major equipment locations at the South Pole.

### **3.21 Hot Work Program**

In situations where welding, cutting, burning, brazing, grinding, or the use of open flames in areas that may initiate a fire or an explosion arise, IceCube will require a Hot Work permit as a means of control. IceCube shall comply with the RPSC Hot Work Program as referenced below.

#### **REFERENCES:**

- 3.21.1 OSHA 29 CFR 1910.252
- 3.21.2 Raytheon Polar Services Corp. (RPSC) Hot Work Program—EH-M-207



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## **CHAPTER 4. Fire Safety**

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### **4.1 Purpose**

This chapter establishes the overall requirements for the IceCube Fire Safety Program.

### **4.2 Objectives**

The objective of IceCube fire safety policy is to protect human life, property, and the environment from the risk of fire-related hazards. The goals are zero loss of life from fires, a reduction in number of fires to zero, protection for facilities and equipment to preclude major losses, and a reduction in the magnitude of loss for those fires that occur.

### **4.3 General**

IceCube shall implement a comprehensive fire safety program. This program generally provides for the following:

4.3.1 Providing appropriate fire detection and suppression systems for all facilities containing significant hazards or permanently housed personnel in accordance with 29 CFR 1910 Subpart L.

4.3.2 Complying with National Fire Protection Association (NFPA) 101, Life Safety Code.

4.3.3 Ensuring employees and contractors, other than trained professional firefighters, trained volunteers, or emergency response personnel, do not fight fires except in cases where the fire is incipient in nature.

4.3.4 Adhering to the more stringent of fire safety requirements imposed by local, State, or Federal agencies.

### **4.4 Responsibilities**

4.4.1 The IceCube Project Manager is responsible for identifying and reducing fire risks, ensuring fire safety of its operations, and implementing the directives of this chapter. Partners and contractors are responsible for following applicable government laws and requirements for fire protection and life safety in construction and building codes.

4.4.2 IceCube's safety organization shall review and approve all project design criteria and conceptual plans and design documents with life safety and/or fire protection/prevention implications.

### **4.5 Fire Protection Inspections**

Fire hazards will be identified through inspection, discrepancies documented, and abatement plans prepared for corrective action.

4.5.1 Fire inspections will be conducted and documented weekly by line management for each IceCube deployment structure.

4.5.2 The following items shall be checked:

- Fire extinguishers available
- Fire extinguisher accessible
- Fire extinguisher inspected within the last year
- Exits are functional and unobstructed
- Exit signs are visible
- No debris obstructing egress or potentially flammable debris
- No combustible materials near a source of combustion or unattended
- Other potential hazards, such as frayed wires, fuel leak

#### **4.6 Fire Protection Systems**

Extinguishing systems and fire extinguishers shall comply as a minimum with the National Fire Protection Association (NFPA) codes and standards. All fire protection equipment shall be Underwriter Laboratories (UL) listed or Factory Mutual (FM) approved.

#### **4.7 Regulations, Codes, and Standards**

With the goal of protecting life and property, IceCube must comply with the most current requirements of the following documents in the design, construction, and operation of all buildings and structures. When standards are updated and superseded by newer, more stringent requirements, the IceCube Project Manager will perform a risk assessment and determine on a case-by-case basis the need to incorporate the newer requirements and standards into existing facility and equipment operating procedures.

4.7.1 Federal Documents.

4.7.1.1 40 U.S.C. Section 619, "Compliance with Nationally Recognized Codes,"

(Section 6(a) of P.L. 100-678, November 17, 1988), as amended.

4.7.1.2 29 Code of Federal Regulations (CFR) Part 1910 Subpart L, Fire Protection.

4.7.2 Other Standards.

The use of NFPA standards, including their appendices, is mandatory unless the requirements of the local codes are more stringent. Mandatory standards that need to be addressed are as follows:

4.7.2.1 A nationally recognized building code, State of Wisconsin or appropriate local building codes.

4.7.2.2 NFPA fire standards, codes, and their appendices.

4.7.2.3 NFPA 101 Life Safety Code Handbook.

#### 4.7.2.4 NFPA 70 National Electric Code Handbook.

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## **CHAPTER 5.           Communication, Instructional Materials and Training**

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### **5.1 Purpose**

This chapter establishes the procedures for communicating, documenting and training regarding safety issues for the IceCube project. Training conducted with the deployment and operations staff will be documented and maintained in the deployment and operations files.

### **5.2 Objectives**

The objectives of this section are to define the procedures for:

- 5.2.1 Determining safety training needs for the deployment and operations staff.
- 5.2.2 Determining the project specific safety training needs for the Polar deployment personnel.
- 5.2.3 Defining the user documentation and training materials that needs to be developed to ensure adequate safety training for the Polar deployment and operations personnel.
- 5.2.4 How the training is to be delivered to the deployment, operations and drilling personnel.
  - 5.2.4.1 Initial training.
  - 5.2.4.2 Intraseasonal training updates
- 5.2.5 Defining the Safety Communication Plan to ensure that safety issues are discussed and addressed with IceCube and RPSC staff during South Pole operations.

### **5.3 Deployment and Operations Staff Training**

- 5.3.1 The Project Safety Manager shall develop, in conjunction and cooperation with line management, a safety training program for the deployment and operations staff. Line Management shall develop and implement appropriate operational training for each of the tasks and functions planned during each seasons South Pole operations.
- 5.3.2 At a minimum, the safety training shall include training on this manual, hazard analysis training and potential hazards that may occur during the development/testing of the project.
- 5.3.3 The attendance of these trainings shall be documented.

## **5.4 Polar Deployment and Operations Staff Training**

5.4.1 During the deployment and operations planning process, the Project Manager, line management, and Project Safety shall develop a project specific safety training course for IceCube, and train all employees and contractors or visitors to the hazards of the work area. This shall be documented in a Job Site (Hazard) Analysis posted at the work area.

5.4.2 This training shall be focused in two areas, instructions regarding operations (drilling and optical module deployment) and project safety. These two areas may be intertwined during the training, but both need to be covered.

5.4.3 Appropriate, non-project-specific, safety training is addressed through the training noted in 5.4.1 and 5.4.2.

5.4.4 Project operations and safety training will be completed through a direct training. Direct training is where line management train the deployment and operations staff. Upon deployment to the South Pole, line management then train the remaining staff on the safe operation of the IceCube equipment.

5.4.4.1 This training shall be completed prior to the start of IceCube deployment and will be ongoing as work process or scope changes occur.

5.4.4.2 Although much of the safety training will be conducted prior to deployment of staff (at the UW-Madison), additional trainings will need to be completed at the South Pole for site specific issues, safety refreshers, training of previously untrained staff and special safety trainings (i.e., defibrillator).

5.4.4.3 Project operations and safety training shall be updated/repeated prior to commencing IceCube deployment during each drilling season (see Appendix E for 2005/2006 training agenda).

5.4.5 Line management shall interface directly with the IceCube Safety Officer if training needs to be updated during the drilling season (intrasession).

5.4.5.1 The communication from line management shall contain:

- The urgency of the training information.
- Should part or all activities be suspended until the corrective action is implemented.
- Statement of corrective action.
- When does the training need to be completed by.
- Who to contact for additional information.
- Line management shall notify Project Safety and the Project Manager when the training/corrective action is complete.
- IceCube line management and the IceCube Safety Officer will coordinate with RPSC EH&S Station Coordinator on any of the above situations and any training requirements.

## **5.5 Instructions and Training Documentation**

5.5.1 Line management shall determine the user instructions and training documentation that needs to be written for the safe, efficient setup and use of the IceCube project.

5.5.2 Training materials may be parts or all of the user instructions or may be separate documents discussing the major points of an operation.

5.5.3 Warnings and cautions shall be obvious and explicitly stated in the user instructions.

5.5.4 These documents should be ready for use at the time the initial and follow-on training is to be given.

5.5.5 Instructions and safety documentation shall reference the appropriate personal protective equipment that is required to complete a given task.

5.5.6 Copies of IceCube safety trainings shall be maintained at South Pole Station, Raytheon Polar Services Project Office (in Colorado) and IceCube Project Office (in Wisconsin). The original training records shall be maintained by the organization conducting the training with copies sent to the other two organizations.

## **5.6 Safety Communication Plan**

5.6.1 A Safety Communication Plan shall be developed in cooperation with RPSC that describes how safety information is discussed with RPSC and IceCube staff.

5.6.2 The Safety Communication Plan shall include:

- Safety training that will be conducted for RPSC and Ice Cube staff.
- Meetings that will be conducted at South Pole (during operations) to discuss potential safety issues, mitigations and reinforce safe behavior.
- How safety events are to be reported.
- What safety labeling is present in the project.
- How safety is communicated to guests.
- Post-deployment reviews.
- Lines of communication between IceCube line management and staff, safety officers, South Pole Management, and RPSC and IceCube Project Offices.

5.6.3 The Safety Communication Plan is attached as Appendix F.

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## **APPENDIX A: Glossary of Safety and Risk Management Terms**

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**Acceptance Testing.** Tests to determine that a part, component, subsystem, or system is capable of meeting performance requirements over the environmental and operating ranges prescribed in the specification documents.

**Accepted Risk.** A hazard whose risk is not completely mitigated and that has been accepted by top program and safety management.

**Accident Prevention.** Methods and procedures used to eliminate the causes that could lead to a mishap.

**Assessment.** Review or audit process, using predetermined methods, that evaluates hardware, software, procedures, technical and programmatic documents, and the adequacy of their implementation.

**Audit.** Formal review to assess compliance with hardware or software requirements, specifications, baselines, safety standards, procedures, instructions, codes, and contractual and licensing requirements.

**Availability.** Measure of the percentage of time that an item could be used as intended.

**Buddy System.** An arrangement used when risk of injury is high, where personnel work in pairs, with one person in the pair stationed nearby, not directly exposed to the hazard, to serve as an observer to render assistance if needed.

**Catastrophic.** A condition that may cause death or permanently disabling injury, or major system or facility destruction.

**Certification Test.** Test whose objective is to determine and then certify that system specifications are satisfied or personnel skills are present.

**Certified Personnel.** Personnel who have completed required training and whose specified knowledge or proficiency in a skill has been demonstrated and documented.

**Configuration Item.** An item that is designated for configuration management.

**Contributing Root Cause.** A factor, event, or circumstance which led, directly or indirectly, to the dominant root cause, or which contributed to the severity of the mishap.

**Controlled (Risk) Hazard.** The likelihood of occurrence or severity of the associated undesirable event has been reduced to an acceptable level through the imposition of appropriate, readily implementable, verifiable controls, resulting in minimal residual risk.

**Critical.** A condition that may cause severe injury or occupational illness, or major property damage to facilities or systems.

**Critical Lifting Operations.** Lifting and lowering operations involving major programmatic or institutional hardware that is irreplaceable, or will cause serious program delays if damaged, or is hazardous to personnel if dropped or uncontrolled, or will require special budgetary actions to repair damages suffered from lifting malfunctions.

**Critical Single Failure Point (CSFP).** A single item or element, essential to the safe functioning of a system or subsystem, whose failure in a life or program essential application would cause serious problems or be hazardous to personnel.

**Deployment Period.** The period during which Antarctic operations is drilling the holes and placing the detector modules in the holes (occurs during the Antarctic summer months).

**Design Margin.** Percent by which a factor of safety of 1.0 is exceeded or deficient.

**Deviation.** A variance that authorizes departure from a particular safety requirement where the intent of the requirement is being met through alternate means that provide an equivalent level of safety. OSHA refers to this as an alternate or supplemental standard.

**Dominant Root Cause.** Along a chain of events leading to a mishap, the first causal action or failure to act that could have been controlled systemically either by policy/practice/procedure or individual adherence to policy/practice/procedure.

**Eliminated Hazard.** A hazard that has been eliminated by completely removing the hazard causal factors.

**Emergency.** Unintended circumstance bearing clear and present danger to personnel or property which requires an immediate response.

**Exposure.** (1) Vulnerability of a population, property, or other value system to a given activity or hazard; or (2) other measure of the opportunity for failure or mishap events to occur.

**Facility Hazard Analysis (FHA).** The FHA is a preliminary hazard analysis performed during the planning and decision phases of a facility design and acquisition program.

**Factor of Safety (Safety Factor).** Ratio of the design condition to the maximum operating conditions specified during design (see also Safety Margin and Margin of Safety).

**Fail-Operational.** Ability to sustain a failure and retain full operational capability.

**Fail-Safe.** Ability to sustain a failure and retain the capability to safely terminate or control the operation.

**Failure.** Inability of a system, subsystem, component, or part to perform its required function within specified limits.

**Failure Analysis.** A systematic examination of a failed item or system to identify the failure mode and cause.



**Failure Cause.** Physical or chemical process, design defect, quality defect, or other process that initiates a sequence of events leading to failure.

**Failure Effect.** Consequence of a failure mode on the operation, function, or status of an item or system.

**Failure Mode.** Particular way in which a failure can occur, independent of the reason for failure.

**Failure Modes and Effects Analysis (FMEA).** A bottoms up systematic, inductive, methodical analysis performed to identify and document all identifiable failure modes at a prescribed level and to specify the resultant effect of the modes of failure. It is usually performed to identify critical single failure points (CSFPs) in hardware.

**Failure Rate.** Number of failures per unit of time or other measure of opportunity for failures to occur.

**Fault Detection.** Process that discovers or is designed to discover faults.

**Fault Hazard Analysis (FHA).** Analysis performed during design resulting in the identification, evaluation, and control of hazards resulting from piece-part or component faults.

**Failure Tolerance.** Built-in capability of a system to perform as intended in the presence of specified hardware or software failures.

**Fault Tree.** A schematic representation resembling an inverted tree that depicts possible sequential events (failures) that may proceed from discrete credible failures to a single undesired final event (failure). A fault tree is created retrogressively from the final event by deductive logic.

**Fault Tree Analysis (FTA).** An analysis that begins with the definition or identification of an undesired event (failure). The fault tree is a symbolic logic diagram showing the cause-effect relationship between a top undesired event (failure) and one or more contributing causes. It is a type of logic tree that is developed by deductive logic from a top undesired event to all subevents that must occur to cause it.

**Functional Redundancy.** A situation where a dissimilar device provides safety back-up rather than relying on multiple identical devices.

**Hazard.** Existing or potential condition that can result in or contribute to a mishap.

**Hazard Analysis.** Identification and evaluation of existing and potential hazards and the recommended mitigation for the hazard sources found.

**Hazard Analysis Summary.** Safety document that summarizes results of the hazard analyses performed on a system or activity.

**Hazard Control.** Means of reducing the risk of exposure to a hazard.

**Hazard Detectability.** Detectability is the observability of the hazard prior to inflicting harm.

Hazard List. Listing of all identifiable and known hazards.

Hazard Prioritization. Used in risk management, ranking of hazards in order of risk severity by program and safety management for formal action to reduce the level of risk.

Hazard Probability. Likelihood of occurrence, stated in qualitative or quantitative terms, of the aggregate of conditions that result in a specific hazard.

Hazardous Event. Event that contributes to a hazard.

Hazardous Material. Defined by law as "a substance or materials in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce" (49 U.S.C 1802). The Secretary of Transportation has developed a list of materials that are hazardous which may be found in 49 CFR 172.101. Typical hazardous materials are those that may be highly reactive, poisonous, explosive, flammable, combustible, corrosive, radioactive, produce contamination or pollution of the environment, or cause adverse health effects or unsafe conditions.

Hazardous Operation. Any operation involving material or equipment that has a high potential to result in loss of life, serious injury to personnel, or damage to systems, equipment, or facilities.

Human Engineering. Area of engineering that applies scientific knowledge to the design of systems and operations to achieve effective human-system integration.

Human Factors Engineering. Area of engineering dealing with human biomedical and psychosocial characteristics. It includes, but is not limited to, principles and applications in the areas of human engineering, personnel selection, training, life-support, job performance aids, and human performance evaluation.

Imminent Danger. Condition or practice that could be reasonably expected to cause death or serious physical harm immediately or in the near term.

Integrated Hazard Analysis. Comprehensive evaluation of hazards, taking into account all subsystems and elements that are included in the overall system being analyzed, including the system, and operational and environmental envelopes.

Interface Hazard Analysis (IHA). Evaluation of hazards which cross the interfaces between a specified set of components, elements, or subsystems.

Interlock. Hardware or software function that prevents succeeding operations when specific conditions are satisfied.

Margin of Safety. Deviation of the actual (operating) factor of safety from the specified factor of safety. Can be expressed as a magnitude or percentage relative to the specified factor of safety.

Occupational Safety and Health Administration (OSHA). The Federal agency which promulgates and enforces workplace safety regulations and guidance.

Operating and Support Hazard Analysis (O&SHA). An analysis performed to identify hazards and recommend risk reduction alternatives in procedurally controlled activities during all phases of intended use.

**Operating Hazard Analysis (OHA).** An analysis that examines the operator interface during system operation and maintenance actions. Because the operator actions are not defined until late in the system development program, corrective action resulting from this analysis will seldom be a design change. This analysis also determines certification and training requirements and safety inputs to technical manuals, warning signs, and safety placards.

**Preliminary Hazard Analysis (PHA).** A gross study of the initial system concepts. It is used to identify all of the energy sources that constitute inherent hazards. The energy sources are examined for possible accidents in every mode of system operation. The analysis is also used to identify methods of protection against all of the accident possibilities.

**Pressure Vessel.** Any vessel used for the storage or handling of a fluid under positive pressure. A pressure system is an assembly of components under pressure, e.g., vessels, piping, valves, relief devices, pumps, expansion joints, gauges.

**Redundancy.** Use of more than one independent means to accomplish a given function.

**Residual Risk.** Risk that remains from a hazard after all mitigation and controls have been applied.

**Risk.** The combination of (1) the probability (qualitative or quantitative) that a program or project will experience an undesired event such as cost overrun, schedule slippage, safety mishap, or failure to achieve a needed technological breakthrough; and (2) the consequences, impact, or severity of the undesired event were it to occur.

**Risk Management.** An organized, systematic decision-making process that efficiently identifies, analyzes, plans, tracks, controls, communicates, and documents risk to increase the likelihood of achieving program/project goals.

**Risk (Safety) Assessment.** Process of qualitative risk categorization or quantitative risk (safety) estimation, followed by the evaluation of risk significance.

**Safety.** Freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.

**Safety Analysis.** Generic term for a family of analyses, which includes but is not limited to: preliminary hazard analysis, system (subsystem) hazard analysis, operating hazard analysis, software hazard analysis, sneak circuit, and others.

**Safety Assurance.** The attainment of acceptable risk for the safety of personnel, equipment, facilities, and the public during and from the performance of operations.

**Safety Critical.** Term describing any condition, event, operation, process, equipment, or system that could cause or lead to severe injury, or major damage if performed or built improperly, or allowed to remain uncorrected.

**Safety Critical Function.** A system, equipment, or facility function or process that, by not performing as intended, causes a safety critical condition or event.

**Safety Critical Item.** Single failure point or other element or item in a life-essential application that, as determined by the results of failure modes and effects analysis or other safety analysis, is essential to the safe functioning of a system or subsystem.

**Safety Device.** A device that is part of a system, subsystem, or equipment that will reduce or make controllable hazards which cannot be otherwise eliminated through design selection.

**Safety Margin.** Difference between as-built factor of safety and the ratio of actual operating conditions to the maximum operating conditions specified during design.

**Safety Oversight.** Maintaining functional awareness of program activities on a real-time basis to ensure risk acceptability.

**Safety Program.** The implementation of a formal comprehensive set of safety procedures, tasks, and activities to meet safety requirements, goals, and objectives.

**Serious.** When used with "hazard," "violation," or "condition," denotes there is a substantial probability that death or serious physical harm could result.

**Significant Root Cause.** The major anomalous event immediately preceding a mishap in the absence of which the mishap would not have occurred.

**Single Failure Point.** An independent element of a system (hardware, software, or human) the failure of which would result in loss of objectives or hardware.

**Sneak Circuit.** Unintended system design condition in electrical circuits or software source code not caused by a failure, which can inhibit wanted functions or cause unintended functions to occur through a stimulus, path, or a response relationship.

**Software Hazard Analysis.** Identification and verification of adequate software controls and inhibits; and the identification, analysis, and elimination of discrepancies relating to safety critical command and control functions.

**Software Safety Critical.** Software operations that, if not performed, performed out of sequence, or performed incorrectly, could directly or indirectly cause or allow a hazardous condition to exist.

**System Safety.** Application of engineering and management principles, criteria, and techniques to optimize safety and reduce risks within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

**System Safety Manager (SSM).** A designated management person who, qualified by training and/or experience, is responsible to ensure accomplishment of system safety tasks.

**Validation.** (1) An evaluation technique to support or corroborate safety requirements to ensure necessary functions are complete and traceable; (2) the process of evaluating software at the end of the software development process to ensure compliance with software requirements; or (3)

**Design**

validation shall ensure that devices conform to defined user needs and intended uses.

Variance. Documented and approved permission to perform some act or operation contrary to established requirements.

Verification (Software). (1) The process of determining whether the products of a given phase of the software development cycle fulfill the requirements established during the previous phase (see also validation); or (2) formal proof of program correctness; (3) the act of reviewing, inspecting, testing, checking, auditing, or otherwise establishing and documenting whether items, processes, services, or documents conform to specified requirements; or (4) the process of ensuring that the design output meets the design input requirements.

Waiver: A variance that authorizes departure from a specific safety requirement where a certain level of risk has been documented and accepted.

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## APPENDIX B: Safety Analysis Techniques

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The purpose of safety analysis is to provide a means to systematically and objectively identify hazards, determine their risk level, and provide the mechanism for their elimination or control. Safety analysis is an iterative process that begins with the concept and extends throughout the life cycle including disposal.

1. Functions supported by the analysis include the following:
  - a. Providing the foundation for the development of safety criteria and requirements.
  - b. Determining whether and how the safety criteria and requirements provided to engineering have been included in the design.
  - c. Determining whether the safety criteria and requirements created for design and operations have provided an acceptable level of risk for the system.
  - d. Providing part of the means for imposing pre-established safety goals.
  - e. Providing a means for demonstrating that safety goals have been met.

The extent and depth of analysis required to meet these five functions will be determined by system complexity and loss potential.

2. During the hazard identification process, it is essential to remain nonjudgmental about the associated probability, severity, detectability and corrective actions. Once identified, hazards shall then be ranked by severity and program impact (risk assessment). Sufficient analysis must be performed to assess the likelihood of occurrence (usually qualitative for early assessments) for each identified undesired event.

3. There are several types of analyses necessary to identify hazards; some are specialized and others, as designs mature, build on previously accomplished analyses.

4. Analyses such as the ones described below shall be employed to the extent and depth determined by the system safety manager as necessary to fully assess the risk to personnel, equipment, and property.

a. Preliminary Hazard Analysis (PHA). In many ways the PHA is the most important of the safety analyses because it is the foundation on which the rest of the safety analyses and the system safety tasks are built. It documents which generic hazards are associated with the design and operational concept. This provides the initial framework for a master listing (or hazard catalog) of hazards and associated risks that require tracking and resolution during the course of the program design and development. The PHA also may be used to identify safety-critical systems that will require the application of failure modes and effects analysis and further hazard analysis during the design phases.

b. Operating and Support Hazard Analysis (O&SHA). The O&SHA is performed primarily to identify and evaluate the hazards associated with the use of environment, personnel interface, procedures including automated command and control, and supporting facilities/equipment involved in the operation of a system/element. "Operation" for the purposes of this appendix may include, but is not limited to, activities such as testing, installation, maintenance, transportation, contingency operations, and others. This analysis considers the planned system configuration or state at each phase of activity, the facility interfaces, the planned environments (or their ranges), the supporting tools or other equipment specified for use, operational/task sequence, concurrent task effects and limitations, biotechnological factors, regulatory or specified personnel safety and health requirements, and the potential for unplanned events including hazards introduced by human errors (see paragraph g., Human Factor Engineering Analysis). The O&SHA shall identify the safety requirements (i.e., constraints, limitations, conditions) to eliminate hazards or to reduce the associated risk to a level that is acceptable under either regulatory or specified criteria. An O&SHA is also used to validate design safety by verifying that the system will perform as expected if the operator correctly performs each step of approved procedures. The O&SHA should be updated when any system design or operational changes are included to ensure any needed hazard control changes.

c. Integrated Hazard Analysis (IHA). A complex program will require analysis of the widely divergent elements or system designs that must be assembled and operated together. The IHA ensures that hazards, along with their causes and controls, that cross element, system, or operational interfaces are identified, assessed, and resolved to an acceptable level. For purposes of the IHA, integration should be considered an element of a system. This analysis should start with an integrated PHA and progress in parallel with other system or element safety analyses. This analysis is broader in scope in that it looks at an entire program rather than a portion of it. The IHA process should act as a conduit to facilitate notification of affected systems or elements when a hazard, cause, or control crosses an interface.

d. System Hazard Analysis (SHA). An SHA is a top-level hazards analysis to verify system compliance with safety requirements contained in system specifications and other applicable documents. It is used to identify previously unidentified hazards associated with the subsystem interfaces and system functional faults; assess the risk associated with the total system design, including software, and specifically of the subsystem interfaces; and recommend actions necessary to eliminate identified hazards and/or control their associated risk to acceptable levels.

e. Software Safety Analysis (SSA). A PHA identifies the safety-critical characteristics of a system. If the PHA identifies hazards that are functions assigned to an inhibit or software control of the system undergoing analysis, that software must undergo safety analysis. When a system software component has been identified as safety-critical, the software safety analysis process shall begin with the development of safety objectives. The safety objectives shall be derived by examining the properties of each critical function and expressing them in terms of system responses and consequences. These objectives shall be unique to each safety-critical software component. Software safety analysis verifies that the software contains no errors or deficiencies that could contribute to risks to people or property. Software safety analysis consists of four phases: requirements analysis, design analysis, code analysis, and testing. The safety analysis effort shall begin with the requirements analysis phase of software development. This will ensure that all safety-critical requirements are specified and designed into the final software product. This approach to software safety analysis will provide optimum software safety with the least impact to the cost and schedule of the software development effort. The analysis techniques must be structured to allow for revisions and updates as the system matures.

f. Subsystem Hazard Analysis (SSHA). An SSHA is a hazards analysis to verify subsystem compliance with safety requirements contained in subsystem specifications and other applicable documents. It is used to identify previously unidentified hazards associated with the design of subsystems including component failure modes, critical human error inputs, and hazards resulting from functional relationships between components and equipment comprising each subsystem, and to recommend actions necessary to eliminate identified hazards or control their associated risk to acceptable levels.

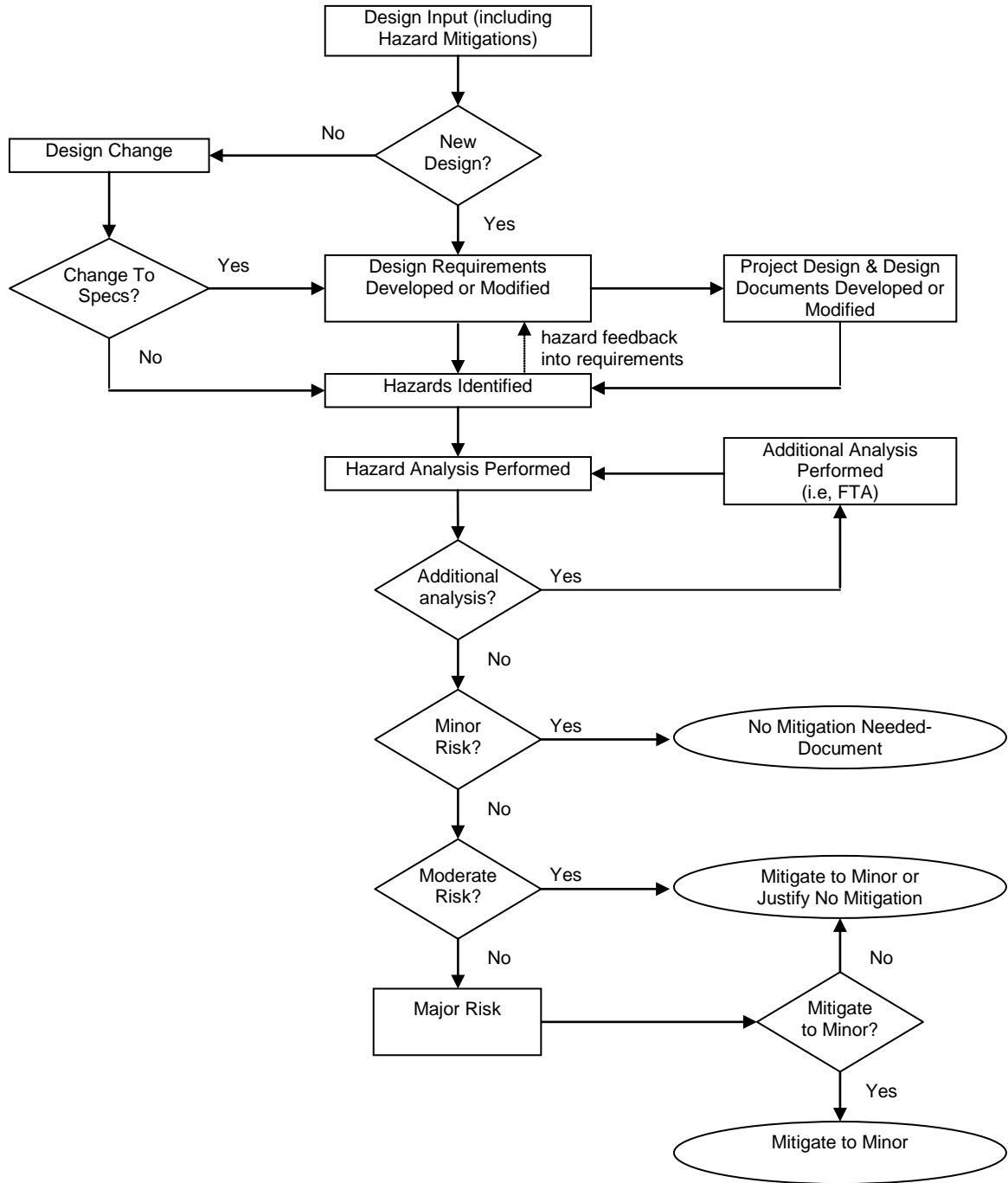
5. The following tools and techniques can be used to help identify the primary causes of an identified hazard:

a. Failure Modes and Effects Analysis (FMEA)/Critical Items List (CIL). The FMEA is usually performed by the assigned reliability office to identify critical items in the hardware or software. Safety personnel can use the FMEA to help verify that all safety-critical hardware or software has been addressed in the hazard analyses. The FMEA is an important technique for evaluating the design and documenting the review process. All credible failure modes and their resultant effects at the component and system levels are identified and documented.

b. Fault Tree Analysis (FTA). The FTA is a technique by which the system safety engineer can rigorously evaluate specific hazardous events. It is a type of logic tree that is developed by deductive logic from a top undesired event to all subevents that must occur to cause it. It is primarily used as a qualitative technique for studying hazardous events in systems, subsystems, components, or operations involving command paths. The FTA can be used to verify that the FMEA has identified all Critical Single Failure Points (CSFP's) consistent with the Top Event hazardous condition. It also can be used for quantitatively evaluating the probability of the top event and all subevent occurrences when sufficient and accurate data are available. Quantitative analyses shall be performed only when it is reasonably certain that the data for part/component failures and human errors for the operational environment exist. The individual failure paths or minimal cut sets shall be generated and evaluated for acceptable risk.



# HAZARD ANALYSIS / RISK REDUCTION PROCESS FLOW



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## APPENDIX C: Example FMEA Form

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The following is an example of an FMEA format that can be used to conduct hazard analysis of the IceCube project. Definitions for each cell can be found below.

### Example FMEA Format

POTENTIAL HAZARD	FAILURE CAUSE	INITIAL RISK				MITIGATION	RESIDUAL RISK				EVIDENCE	REQUIREMENTS	STATUS
		S	P	D	RPN		S	P	D	RPN			
Hazard 1	Cause 1-1 Cause 1-2 Cause 1-3					Mitigation 1-1 Mitigation 1-2 Mitigation 1-3							Eliminated Closed Open
Hazard 2	Cause 2-1 Cause 2-2 Cause 2-3					Mitigation 2-1 Mitigation 2-2 Mitigation 2-3							

### Definitions

Term	Description	Examples/Comments
Hazard	A listing of each hazard that needs to be reviewed for the system/subsystem being reviewed. Hazards are usually listed together in functional or subsystem groupings (i.e., mechanical, fire, electrical, software, etc.) Those groupings may be further broken down into smaller functional areas (i.e., software – motion control, data acquisition, data processing, etc.).	Electrical shock (120 VAC)
Failure Cause	This is a list of the potential causes for the hazard stated. The person generating the hazard analysis should take into account all potential sources of the hazard even if the hazard is not likely to occur (the assessment of risk will determine the likelihood). Sources such as design failure, product malfunction, normal use, use error, unintended use and misuse should be reviewed for each hazard.	Examples for electrical shock (120 VAC): <ul style="list-style-type: none"> <li>Power supply cover does not adequately cover input terminals.</li> <li>Fluid accidentally spilled on power supply.</li> <li>Service person services unit without removing power from power supply.</li> <li>Inadequate grounding.</li> <li>Vibration of system causes wire to rub against edge of cover causing a short.</li> </ul>
Initial Risk	This is the assessment of the hazard prior to mitigation (pre-mitigation assessment) per the information in section 2.4.2. <ul style="list-style-type: none"> <li>Severity – The worst potential consequence.</li> <li>Probability – Likelihood that the identified hazard will result in a mishap of the severity stated.</li> <li>Detectability – Observability of the hazard prior to inflicting harm</li> <li>RPN – Product of the scores of the severity, probability and detectability assessments.</li> </ul>	Note 1: When conducting assessments, the severity, probability and detectability must refer to the same scenario. For example, a life-threatening situation may be very unlikely to occur, whereas the same issue may be much more likely to produce a minor injury. The persons doing the assessments should make sure that the severity, probability and detectability all discuss the same circumstances. Note 2: In some instances, lesser severity issues may cause higher RPN scores. For example, an issue could be life-threatening, but that scenario is not expected to occur (severity = 4, probability = 1); whereas it could produce a minor injury on a frequent basis (severity = 2, probability = 4). If the detectability is the same for both issues, the minor injury would have the higher RPN score.
Mitigation	Descriptions of how each cause of a hazard is to be mitigated. If the hazard is a minor risk $\leq 12$ , "No mitigation required" is adequate. Mitigations may be through design, test lab certifications, verification testing, labels, alarms, status monitors, training, instructions or other appropriate means.	Examples for electrical shock (120 VAC): <ul style="list-style-type: none"> <li>Power supply is certified to UL standards.</li> <li>Deadman switch disconnects input power to the power supply when the cabinet is opened.</li> <li>Grommets used to prevents sharp edges from cutting through the wire insulation.</li> <li>Warning label stating remove power prior to servicing.</li> </ul>
Residual Risk	This is the assessment of the hazard after the mitigation is applied (post-mitigation assessment) per the information in section 2.4.2. A hazard that has been eliminated can receive a	A hazard whose residual risk is $\geq 36$ has been inadequately addressed; additional mitigation is needed.

	RPN score of zero (0).	
Evidence	The column tracks the documentation for the mitigation of the hazard and can include the following: <ul style="list-style-type: none"> <li>▪ Test lab certificate xxxxxx.</li> <li>▪ Verification test zzyyyy, test # 5.</li> <li>▪ Installation instructions.</li> <li>▪ Justification report.</li> <li>▪ Fault tree analysis.</li> <li>▪ Design review documentation.</li> <li>▪ Verification that label was affixed to unit.</li> </ul>	No specific comments
Requirements	The requirement(s) associated with the hazard are indicated here.	It is preferable to refer to the requirement using the document and requirement #'s.
Status	The following terms are to be used to denote the status of each hazard. <ul style="list-style-type: none"> <li>▪ Closed – Mitigation(s) to eliminate or control the hazard have been instituted. This also includes Moderate risk hazards where justification has been written stating why additional mitigation is not required.</li> <li>▪ Open – Hazard exceeds RPN of 12 and mitigations (or justifications) have not been instituted.</li> </ul>	No specific comments

Note: If there is inadequate room on the hazard analysis form to describe the hazards, causes, scoring, mitigations or traceability, the author may wish to write a standalone report that is referenced by the hazard analysis.

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**APPENDIX D: Report Form - Quality & Safety Issues**

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**REPORT FORM**  
Quality & Safety Issues

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Instructions

Please fill out page 1 of this form if:

- *A safety issue arises that could or has resulted in injury to workers or others.*
- An environmental concern has occurred.
- An issue has occurred that significantly affects the performance, reliability, uptime, durability and quality of IceCube systems, subsystems or components.

Complete Sections A - B, and submit the form as noted below.

**SECTION A - REPORTER IDENTIFICATION:** Reporter Completes

Date Of Report:	
Reporter's Name:	Employer:
Reporter's e-mail:	Reporter's Tel:
Date Of Event/Issue Discovered:	Time Of Event:
Device/Material Involved:	Facility Where Issue Occurred:

**SECTION B - ISSUE DESCRIPTION:** Reporter Completes

<b>Description Of Issue:</b> (describe sequence of events that led to issue)	
<b>Other Contributing Circumstances:</b> (e.g., weather, tiredness, etc.)	
<b>Preliminary Root Cause:</b>	
<input type="checkbox"/> Training <input type="checkbox"/> Inattentiveness <input type="checkbox"/> Failure to follow instructions <input type="checkbox"/> Inadequate tools <input type="checkbox"/> Inadequate safety equip. <input type="checkbox"/> Device malfunction <input type="checkbox"/> Lack of procedures <input type="checkbox"/> Hazardous environment <input type="checkbox"/> Maintenance <input type="checkbox"/> Other (explain):	
<b>What Was Done At The Site To Remedy This Issue:</b>	
<b>Is This A Safety Concern?</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No
If yes, explain:	
<b>Was Anyone Hurt?</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No
If yes, explain nature of injury & treatment dispensed:	
<b>Was Any Equipment Damaged?</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No
If yes, explain:	
<b>Could This Issue Result In Decreased Uptime, Productivity or System Reliability?</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No
If yes, explain:	

Submit To: e-mail: hpleweling@icecube.wisc.edu

fax: (608) 263-2309, Hank Leweling

Rev. -,07/31/05, HPL

Page 1 of 2

REPORT #: \_\_\_\_\_

<b>SECTION C - INVESTIGATION SUMMARY: Investigator Completes</b>	
Date Of Investigation:	Investigator's Tel:
Investigator's Name:	Investigator's e-mail:
Summary Of Issue: (describe results of investigation)	
Root Cause:	
Is This A Safety Issue? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Potential Injury Severity (per 9000-0002):	Probability (per 9000-0002):
Detectability (per 9000-0002):	Risk Level (per 9000-0002):
<b>Risk Levels &gt;12 Require Action Or Justification</b>	
<b>SECTION D - REMEDIAL ACTION: Investigator Completes</b>	
Is Remedial Action Needed To Address This Issue? <input type="checkbox"/> Yes <input type="checkbox"/> No	
If yes, explain: Date Completed:	
Has The Reporter Been Informed Of The Investigation Findings? <input type="checkbox"/> Yes <input type="checkbox"/> No	
If yes, explain: Date Completed:	
Has RPSC Been Informed Of The Issue & Findings? <input type="checkbox"/> Yes <input type="checkbox"/> No	
If yes, explain: Date Completed:	
Has NSF Been Informed Of The Issue & Findings? <input type="checkbox"/> Yes <input type="checkbox"/> No	
If yes, explain: Date Completed:	
Investigator's Signature: _____ Date: _____	
Investigator's Title: _____	
Reviewer's Signature: _____ Date: _____	
Reviewer's Title: _____	

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APPENDIX E: **Driller and Deployer Workshop Itinerary**  
**July 26- August 6, 2010**

**Day 1, July 26: Driller Orientation at 222 West Washington**

- 9:00- 9:30am: **Greetings and Introductions.** (30 mins)(Jim Yeck and Alan Elcheikh)  
*Introduction of personnel. Welcome and brief description of the project and its status.  
Everyone then takes it in turns to briefly introduce themselves, talk a little bit about their background, their skills, what they been working on, hobbies, interests, etc  
Show organization chart.*
- 9:30- 10:30am: **IceCube Science Presentation** (60 mins) (Albrecht Karle)  
*Albrecht will give a talk about possible future drilling activities at South Pole related to radio and dark matter projects, as well as possible future IceCube style detector strings.*
- 10:30- 10:45am: Break.
- 10:45-11:45am TBA
- 11:45- 12:00pm: **Ice Cube On Ice Plans** (15 mins) (Tom Hutchings)  
*Present a very broad overview of the drilling plan and the other ICECUBE activities taking place during the season, such as ICL work, IceTop, the various other experiments being deployed into holes, and any future plans, etc*
- 12:00- 12:30pm: **Season's Operational Plan.** (30 mins) (Alan Elcheikh)  
*The goals for the season, shift organisation. How will the work be laid out over the season, the different distinct parts, setup, drilling, tear down. What needs to be done? Changes & upgrades that need to be done on the ice.  
Present an overall plan for the seasons work. What is the current state of the camp and what needs to be done to get the drill camp up and running*
- 12:30- 1:30pm Lunch
- 1:30- 3:30pm: **Driller benefits seminar (120 mins)** (Megan Jeffers)
- 3:30- 3:45pm: Break
- 3:45- 5:00pm: **E-Reimbursements training (75 mins)** (Barbara Witt)  
*For the driller who will not be around for the later course. All others finish up at 3:30pm.*

**Day 2, July 27: Safety, Season's plans, Drill System overview and detailed Drill**

**Explanation**

**(PSL in the morning and move to 222 in the afternoon) Can have PSL all day if need be.**

- 8:30- 8:45am: **PSL Condition of Use and Safety:** (15 mins) (Farshid Feyzi)  
*Introduction to PSL facility. Rules for entering the workshop. Safety protocols. Off limit areas. Use of the library/ break room.*
- 8:45- 9:15am: **South Pole orientation and IceCube/ Raytheon Interaction. (30 mins)**  
(Jay Bollinger)  
*Introduction to RPSC and personnel. RPSC shift structure. What is RPSC's role within IceCube. Station resources -material, equipment, personnel. How do we obtain help when we need it and who are our contact persons. Heavy vehicle support. What is dedicated to us and what do we have to schedule? Who do we ask? Other activities that are planned for the season and how they might affect IceCube*
- 9:15- 10:45am: **Safety Orientation** (90 mins) (Mike Zernick)  
*Orientation and open discussion on roles, responsibilities and safety culture. Policy, rules and regulations for drillers. How to do the job in a safe way. What are the dangerous areas, what are the difficult and dangerous steps in. Give information about the Safe Start web site where people can go to do the course.*
- 10:45- 11:00am: **Break.**
- 11:00- 12:00am: **Explanation of the Enhanced Hot Water Drill.** (60 mins)(Terry Benson)  
*Hand out a list of acronyms, some photos of drill camp and a labeled schematic of the setup before starting the drill talks. Give an introduction to hot water drilling, brief description of the design of the drill system, and an overview of how it works and the idea behind the design. Includes a walkthrough of the test and training site and a walkthrough of the PSL workshop.*  
*Aim to finish at 12:00 then have a walkthrough of the test bed prior to driving to Madison for the rest of the day's sessions.*
- 12:15- 12:30pm *Drive to Madison*
- 12:30- 1:30pm: Lunch
- 1:30- 2:00pm: **Cargo and Deployment (30 mins)** (Terry Hannaford)  
*Cargo orientation. What is the process? How do we organize for cargo to be shipped to Pole? How do we retro cargo? Time frames. Where is the staging area for IceCube cargo? Who do we talk to at Pole to get information on cargo deliveries? What happens before deployment, the PQ process, what to do and in what time frame. Travel arrangements, weight allowance. What happens in CHCH, clothing issue, presentation on what equipment/clothes*

- 2:00- 2:30pm: **Main Generators and PDM** (30 mins)(Jay Bollinger or Gary Freeman, RPSC)  
 Basic overview of generator/ PDM operation. How to sync them. How to top them up with oil. Generator checks: What, where and when to check. What to watch out for when connecting and disconnecting water hoses. Modifications undertaken and what they mean in terms of improving safety. **What needs to be done to the generators prior to starting drilling. What needs to happen to them at the end of the season before shipping to McM?**
- 2:30- 3:00pm: **High Pressure Pump System (HPP).** (30 mins) (Dennis Duling/ Terry Benson)  
*Explain how the main pumps are used in conjunction with the charge pumps. How do we idle? What settings should be set for optimal performance and in what range can we run and at what temperatures without damaging the pumps or the motors. Any other constraint? How to monitor the performance of the pumps, what to check. Describe the accumulators and how to maintain them. Explain the pressure relief system in the building and how to check and maintain it in an operational state. Any heating/ cooling issue we need to be concerned with? Transformer heating? The process for starting a pump that doesn't want to run (Good one for Dennis). The risks of changing the torque limits on the motor controllers. Under what circumstances, if any, can the limits be changed?*  
 -Safety analysis  
 Note: A separate hands on session will be given on the pumps.
- 3:00- 3:15pm: break
- 3:15- 3:45pm: **UNICO Motor Controllers and E-stop/ Reel stop system**(30 mins)  
 (Mark Thoma)  
*Explain what they're used for, where they are located. How should they be operated, how to check them and what values to check. What is the procedure for restarting them?*  
*The emphasis of this talk should be operational rather than technical and focus on the safety aspect. What are people allowed to do to the drives and what must be left to experienced personnel. Describe any modifications done to any of the drives from last season (if any) and how this changes the operation.*  
*Give a brief description of the E-stop system and how to change the system over from local to global mode.*
- 3:45- 4:15pm: **Main Heating System (MHP).** (30 mins) (Terry Benson)  
*Layout of the MHP millvans, hose inlets and outlets, valves and plumbing. How do the heaters work? Design of the system layout. What to monitor. Gauges and values. How accurate are the readings? Can they get stuck and show the wrong value? What to set/change to adjust output temperature. Describe how the heaters are bled.*  
*Explain the y-Strainers and how to flush them. Describe the new flushing method.*



*-Safety analysis: What to pay attention to in the MHP. What are the potential safety hazards and issues, how to handle a runaway heater or a fuel leak. If there are videos ready of the MH's then maybe a quick video would help here.*

*Note: There will be a heater training day.*

4:15- 4:45pm:

**Rod Well System (RWS) (30 mins)** (Dennis Duling/ Jonas Kalin)

*Give a brief overview of the Rodwell system, focusing on the proper methods and techniques for producing a rod well that will last us for the season. Again, if there is a video ready, show some video of the lowering operation, for example.*

**Day 3 , July 28: Safety and Detailed Drill Systems**

**(At 222 all day)**

8:30- 10:30am **Lockout/ Tagout (120 mins)** (Bruce Neumann)

10:30- 10:45am: Break

10:45- 11:45am **Fall Protection and Blood Borne Pathogens (60 mins)** (Bruce Neumann)

11:45- 12:15pm: **Pre Heat System (PHS) and the water tanks and Fuel system (30 mins)**  
(Dennis Duling, Dave Pernic)

*Explain the purpose of the PHS, and how to use it. Describe the water filtration system and how to maintain it.*

*Explain the condensate filtration system and how to check it and change filters.*

*What changes, if any, are being implemented this season.*

*Safety analysis*

**Fuel system** (Dave Pernic/ Dennis Duling)

*Explain the design and layout of the overall fuel system and how we set it up.*

*The big tanks-how to monitor fuel level and how to arrange for replacement tanks.*

*Day Tank: Procedure for fueling - automatic or manual. How do we bleed the system? Day tank, electrical and plumbing.*

*Are there and continuing issues with the fuel system we need to keep an eye on?*

*-Safety analysis of fuel system and how to handle spill issues, potential hazards. (Risk of self ignition when fueling)*

12:15- 1:30pm: Lunch.

1:30- 2:15pm: **DCC - Operations control (45 mins)** (Terry Matt/ Jonas Kalin)

*Go through the role of the DCC and the control software, step by step. Show screen shots of the different screens and explain them to give an overview of how to run the system by computer. What values to monitor from the DCC when idling and when drilling. What types of sensors are there? **How to restart the system if it shuts down.** Show how to plot parameters, the different plotting options and how to use the graphic interface. How to handle an E-stop, fire alarm and other incidents.*

*Give a brief overview of the use of the new remote hand held terminals.*

*Note: This is an introduction, there will be a hands on session later.*

2:15- 3:15pm: **Identifying hose problems and hose replacement** (30 mins) (Dave Pernic)  
*How to identify a faulty hose? What to do if a faulty hose is discovered. How to replace a faulty hose section.*

*-Safety Analysis.*

3:15- 3:30pm Break.

3:30- 4:30pm: **Lessons Learned (60 mins)** ( Mike Zernick)

*Go through the incident reports last year, including all the near misses. Explain how the situation came about. What is being done to rectify the situation in each case.*

**Day 4, July 29: Drilling Procedures**  
**(at 222 West Washington.)**

- 9:00- 10:15am: **Drill Setup Procedure.** (75 mins) (Alan Elcheikh /Dennis Duling)  
*Go through the procedure on how to assemble the weight stack and give an overview. What to think about and some tips. Go through the procedure on how to prepare the drill for drilling, attach the drill and weight stack and explain the necessary settings on the drill before we can start drilling. Show video.*  
**Main Hole drilling** (Alan Elcheikh)  
*Go through the main hole drilling procedure. Explain the events that take place while drilling.*  
  
*The above two sessions will be mainly showing some videos then have the drillers do a review of the relevant chapters in the Operations manual.*
- 10:15- 10:30am: Break
- 10:30- 11:15 am: **Drill Retrieval (45 mins)** (Alan Elcheikh)  
*Retrieval of pump, drill and preparing for deployment. Go through the procedures for retrieving, down hole pump, main drill and disassemble the weight stack, move deployment cable in place and prepare tower and TOS for deployment. Safety analysis*
- 11:15- 12:00pm: **Tower Operations System, Hole to Hole relocation** (45 mins) (Alan Elcheikh)  
*Go through the procedure of tower operations and hole relocation, procedure step by step for the moving of the TOS. Potential risks, freezing hoses, electrical cables. Show overview of the drill sites and in what order we will drill.*  
  
*Again, these two sessions will mainly involve showing some videos then have the drillers review the relevant chapters in the manual*
- 12:00 Lunch and break for Oshkosh.

**Day 5, July 30: Hands on Training (at PSL)**

8:00am- 11:00am     **Pump Theory**     (Dennis Duling)

11:00- 11:15am:     Break

11:15- 5:00pm:     In 4 groups, do the following:

**Pump Hands on Training**     (Dennis Duling/Dave Pernic)

*Describe our different pumps and explain how they work. Explain the need for charge pumps. Disassembling and reassembling pumps. What to check for and how to service them. What settings (limits) to run at and what to think about. UNICO-Pump relationship. Maintenance of pumps. Tips and tricks of starting a HPP. Pump safety.*

**Heater Hands on Training**     (Terry Benson/ Jonas Kalin)

- *Diagnostics and Repair of Honeywell Control.*
- *Troubleshooting and Repair of Fuel System.*
- *Flame Sensor Troubleshooting and Repair.*
- *Ignition System Troubleshooting and Repair.*
- *Setting up Igniters.*
- *Burner Tuning Using Gas Analyzer.*
- *Heater safety.*

**DCC Simulator Hands on Training.** (Matt Newcomb/ Terry Matt)

*Go through the System software in small groups, give everyone the time to play with the program and get familiar with it. If possible hook up real heaters and pumps otherwise use real time data and have a playback mode. Have different scenarios and let people respond to it.*

**UNICO Hands On Training** (Mark Thoma)

*A refresher hands on for drillers who are expected to work on the drives and do's and don't for other drillers.*

**Day 6, August 2: Outreach, Fire and Fork Lift training (PSL)**

9:00- 10:00 **Outreach Talk at Test bed**

10:00- 12:00 Start Fork lift training and any more training in test bed as necessary.

12:00- 1:30pm **Lunch**

1:30- 3:00pm: **Fire training** (Mike Zernick/ Don Siebert)  
*(What fire hazards are there, chemicals, ethanol, fuel, generators. What are the volatile temperature for the different materials? Give some material background information.*  
*Smoke alarms/Fire alarms –location and how do we respond to an alarm.*  
*What to do if we do not have reliable sensors, i.e regular checks -times.*  
*What fire prevention equipment do we have?*  
*Where is it located? How do we use it? When not to use it, never water on electrical fire or CO2 if a person is present.*  
*Go through emergency evacuation procedure.*  
*South Pole station resources: Station fire team, members =trained winter-overs. Response time and how do we interact with station.*

3:00- 4:30pm **Fork Lift Training for drillers**

**Deployment Workshop Itinerary**  
**August 3, 2010**

**Day 7, August 3: Deployment Workshop, PSL**

- 8:00- 8:30am: **Greetings and Introductions** (Tom Hutchings, Tom Ham)  
Introductions of personnel.
- 8:30- 9:30am: **Safety Awareness – Safe Start Refresher** (Mike Zernick)  
Safety Attitude
- 9:30- 9:45am: Break
- 9:45- 10:15am: **Safety Awareness (Continues)**
- 10:15- 10:30am: **DOM Testing and Preparation** (Jim Haugen)  
A brief description of the design of the optical modules. DOM Testing at the Pole along with a general background on testing procedure.
- 10:30- 11:00am: **IceTop** (James Roth)  
Brief explanation of IceTop, what is being planned for the coming season and what help or participation would be helpful from the drill crew.
- 11:00- 11:30pm: **Verification and Commissioning** (TBD)  
String Geometry, DOM separations, and Depth Calculations.
- 11:30- 12:15pm: **Cable Overview** (TBD)  
Information on cable management and responsibilities for cable activities. The installation and operation of the Digital Connectivity Monitor (DCM) will be discussed.
- 12:15- 1:00pm: Lunch in PSL Library
- 1:00- 1:30pm: **Switching from Drilling to Deployment** (Elcheikh or Duling)  
The shift from drilling to deployment and the interaction with deployers in preparing the TOS for deployment. Al will go through the equipment, tools, personnel and procedures necessary for switching from drilling to deployment.  
This discussion will cover what needs to be moved and rewired.
- 1:30- 2:30pm: **Deployment – Seasonal Plan** (Tom Ham)  
Personnel, schedules, equipment and their locations. Necessary preparations that need to be taken before starting deployment. Cable and winch setup and testing.
- 2:30- 2:45pm: Break

2:45- 3:30pm:	<b><u>Deployment Installation</u></b> Discussion of the installation process.	(Gary Hill )
3:30- 4:00pm:	<b><u>Cable Drag Procedure</u></b>	(Tom Ham)
4:00- 4:30pm:	<b><u>Review</u></b>	(Tom Ham)



**Day 8, August 4: Basic Electricity and Hands on Training PSL**

9:30am- 12:30pm: **Basic Electricity**

Terry Matt to give a brief overview of the electrical systems in the drill camp before we start the course

12:30- 1:30pm **Lunch**

8:00- 4:30pm: **Welding training course for experienced drillers,**

Other drillers who aren't doing the welding course will continue to do heater and other general test bed training for the rest of the day, from 1:30 till 4:30pm.

**Day 9, August 5: Rigging Training. (At 222)**

9:00- 12:30pm **Rigging training (P&H Rigging course)** (All Hands)

*This course is scheduled for 8 hours, but may need to be scaled down marginally to fit by 5:00pm.*

**Rigging Fundamentals #800:**

This course is designed for personnel who are required to rig loads for lifting by overhead cranes. Floor crane operations and those personnel working with overhead cranes would benefit from this rigging fundamentals course. Length of course will vary depending on number of personnel and the depth of knowledge of the attendees.

Participants will also receive a 4" x 5" pocket handbook, which highlights good and bad rigging practices, sling capacities and how to calculate unknown loads.

**Course Outline**

- Rigging equipment
- Terminology
- Rigging practices
- Sling
- Inspection
- Use
- Rigging fundamentals

12:30- 1:30pm Lunch

1:30- 5:00pm: **Rigging training.... Continued**

**Day 10, August 6: First Aid and CPR training (at 222 West Washington)**

8:30am- 2:00pm: **CPR, AED/ CR CPR .....**for all drillers and deployers

2:00- 2:15pm: *Break*

2:15- 4:15pm: **E-Reimbursements training (120 mins)**  
(Danielle Erickson/ Stephanie Merucci)

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## **APPENDIX F: Safety Communication Plan**

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### **Purpose & Scope**

This document describes that manner in which safety information regarding the IceCube project is communicated to IceCube & RPSC staff.

### **Safety Communication Plan**

#### **1) Training**

- a) Pre-Deployment Training – Drilling and deployment staff will be trained on operational and safety characteristics of the IceCube drill and deployment equipment. A multi-hour safety training session is planned in both the drilling and deployment sections of the training. Worksite safety information will be discussed during the subsystem trainings as well. The safety training is based on the IceCube Safety Training Guide. This training is to include key drillers, deployers and RPSC staff. Safety Training includes:
  - i) Personal Protective Equipment
  - ii) Fire Safety
  - iii) Chemical Safety (hazard communications)
  - iv) Lockout/Tagout
  - v) Issue Reporting
  - vi) Emergency Stop System
  - vii) Assembly, Operational & Subsystem-Specific Information
  - viii) Preventive Maintenance
- b) First Responder Training – First Responder Training is planned for selected members of the drill/deployment staff prior to deployment. CPR and first aid training is planned.
- c) Lead Training in Christchurch – Supervisor training is planned in Christchurch before the staff leads are deployed to Antarctica. A portion of this training will be Antarctic survivability and the role of the team leads in assuring the safety of their team.
- d) On-Site Training
  - i) On-site training will be conducted by the leads to inform their staffs of operational and safety concerns they need to carry out their tasks. Additional on-site may be needed to address safety-related issues that arise during the course of activities.
  - ii) Task specific safety trainings, such as fire extinguisher and defibrillator training, will be conducted by SPS staff to train IceCube staff.
  - iii) The IceCube safety training (discussed in the Pre-Deployment Training) may need to be repeated for staff not trained prior to deployment (as needed).

#### **2) Staff Meetings At South Pole**

- a) Weekly RPSC-IceCube Safety Meetings – Joint RPSC/IceCube weekly meetings are planned to discuss safety-related issues that occur during operations. These meetings are to be set up by the IceCube Safety Officer and the RPSC Lead Representative for the project.
- b) Shift Change Communications – Shift leads for drilling and deployment shall ensure that the status of the operations is discussed with shift taking over the operation. This communication shall include:
  - i) Status of drilling operations
  - ii) Status of deployment operations

- iii) Potential safety issues that may have arisen during recent shifts
- iv) Recent system malfunctions/known problems (i.e., level wind on supply hose reel not operating properly)
- v) Potential safety issues to watch (i.e., small water leak in MHP2).
- vi) Weather updates.
- vii) General SPS information (flights, visitors, activities, etc.).

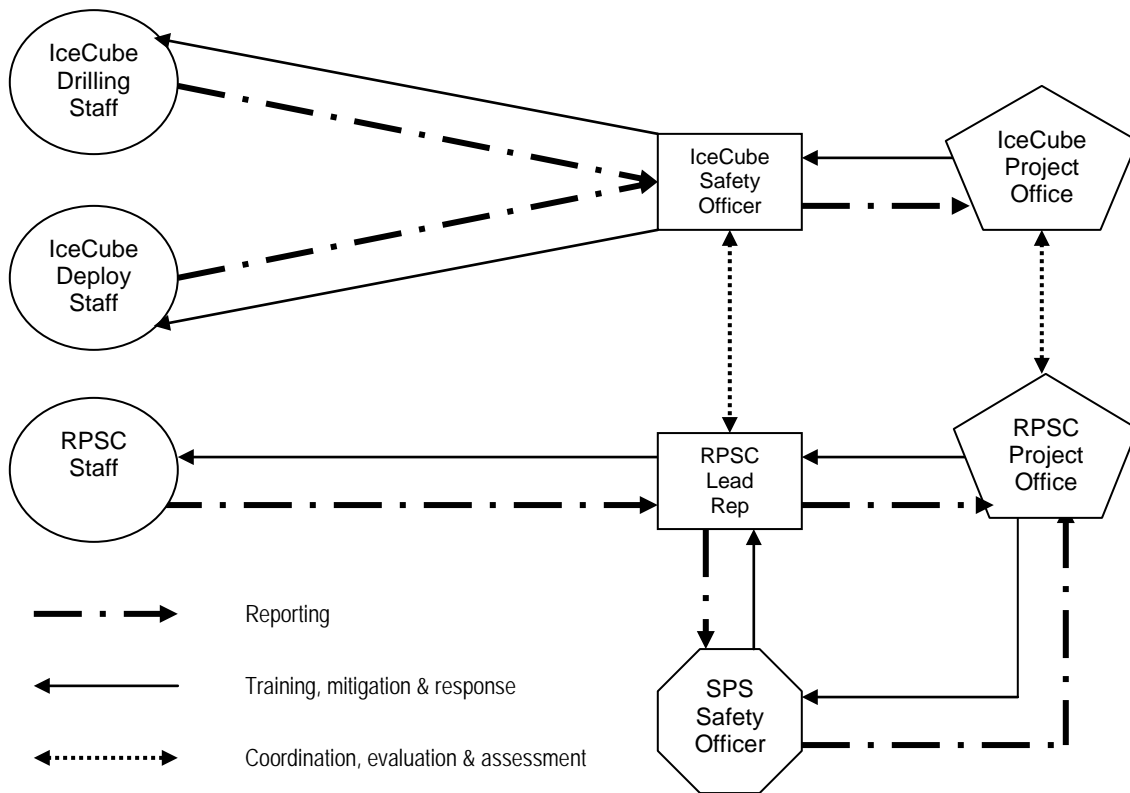
### 3) Issue/Event Reporting

- a) Two reporting mechanisms are used to report safety-related issues with personnel. Although the intent is that RPSC use the RPSC reporting system and the IceCube staff use the IceCube report system, the reporting system used is not as important as that the issue is recorded, reported, evaluated and addressed.
- b) The following persons shall be notified of every safety-related report regardless of which organization the reporting person belongs to or the reporting system used:
  - i) RPSC Lead Representative
  - ii) SP Station Safety Officer
  - iii) IceCube Safety Officer
  - iv) RPSC Safety Manager (Colorado)
  - v) IceCube Project Office (Wisconsin)
- c) RPSC Reporting – RPSC has a well-defined safety reporting system which is described in RPSC procedures EH-A-216 and EH-A-234. This procedure shall be used by RPSC personnel to report accidents, injuries and near misses.
- d) IceCube Reporting – The IceCube issue reporting procedure is described in the IceCube Safety Plan, and is used to report injuries and potential safety events regarding IceCube personnel. This process is also used to report operational (quality) issues. This process will be trained during the pre-deployment training.
- e) Reports shall be reviewed during the weekly safety meetings.

### 4) Labeling – Equipment in the drill/deployment camp has been labeled for direct identification of materials and potential hazards. This labeling includes:

- a) Danger Labels
  - i) Electrical hazard – on e-stop panels (exposure to 480VAC)
  - ii) Moving Machinery – Reels
  - iii) Do Not Operate Without Guards – Drive gears on supply hose reel, HPP pumps, RWS reel, PHS pumps
- b) Caution Labels-Hot Surface – Stinger stacks, brake resistors, drive heat sinks, water output manifolds
- c) Hearing Protection Recommended – HPP
- d) Confined Space – Water Tanks
- e) Authorized Personnel Only – RWS (clearance issues)
- f) No Smoking (entire camp)
- g) Fire Extinguisher Labels
- h) Exit; Not An Exit
- i) Electrical Closet No Storage Permitted
- j) MDS Occupancy Sign – On MHP's, RWS, PHS
- k) Warning, Check Occupancy, Press E-Stop Before Fire Suppression – On MHP's, RWS, PHS
- l) Identification Signs Each MDS
- m) Each heater & motor drive is numbered for identification
- n) Each MDS has an Electrical Reference card that links output devices such as pumps & heaters with their associated operational & protective devices such as circuit breakers, cables & drives

- o) Emergency Stop buttons are red mushroom buttons.
- p) Reel Stop buttons are yellow mushroom buttons.
- 5) **Communication To Guests & Visitors** – Guests or visitors to the IceCube camp will:
  - a) Receive a Visitor’s Job Site Analysis which describes the main operations at the IceCube site and the main job site hazards.
  - b) Be given a guided tour of the IceCube site by a senior member of the IceCube staff.
- 6) **Post-Deployment Reviews** – A review is planned after each deployment season to review operational, safety and communication concerns that arose during the deployment season. These issues shall be assessed, prioritized and investigated (as appropriate). The results of this information shall be integrated into the operational and training plans for the following season.
- 7) **Lines Of Communication** – The following lines of communication shall be established for safety-related issues:



Reporting to SPS Safety Officer is coordinated between the IceCube Safety Officer & RPSC Lead Rep.

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## APPENDIX G: Respiratory Protection Written Program

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## Respiratory Protection Program

### **I. POLICY**

It is the policy of **IceCube** to protect its employees and contractors and contractors from hazardous atmosphere through a comprehensive program of recognition; evaluation; engineering, administrative and work practice controls; and personal protective equipment, including respirators. Hazard elimination and engineering and work practice controls shall be employed to control employee exposure to within allowable exposure limits as much as possible. Respirators and other personal protective equipment shall be provided to affected employees and contractors under this program. The project is committed to full compliance with applicable federal and state regulations pertaining to employee respiratory protection.

### **II. OBJECTIVE**

This document is **IceCube's** Respiratory Protection Program and is designed to protect employees and contractors by establishing accepted practices for respirator use, providing guidelines for training and respirator selection, and explaining proper storage, use and care of respirators. This program also serves to help the project and its employees and contractors comply with Occupational Safety and Health Administration (OSHA) respiratory protection requirements as found in 29 CFR 1910.134.

### **III. SCOPE**

This program applies to all **IceCube** employees and contractors and contractors who need to wear a respirator to perform assigned duties.

(Note: Any IceCube employee or contractor who voluntarily wears a respirator when one is not required (i.e., in certain maintenance and coating operations) is subject to the medical evaluation, cleaning, maintenance, and storage elements of this program, and will be provided with necessary training. Employees and contractors who voluntarily wear filtering face pieces (dust masks) are not subject to the medical evaluation, cleaning, storage, and maintenance provisions of this program.)

### **IV. ASSIGNMENT OF RESPONSIBILITY**

#### **A. Project**

**IceCube** is responsible for providing respirators to employees and contractors when they are necessary for health protection. **IceCube** will provide respirators that are applicable and suitable for the intended purpose at no charge to affected **IceCube** employees and contractors and contractors. Any expense associated with training, medical evaluations and respiratory protection equipment will be borne by **IceCube**.

## **B. Program Administrator**

The Program Administrator for **IceCube** is the IceCube Safety Officer. The Program Administrator is responsible for administering the respiratory protection program. Duties of the program administrator include:

1. Keeping up with knowledge about respiratory protection and maintaining an awareness of current regulatory requirements and good practices.
2. Identifying work areas, process or tasks that require workers to wear respirators.
3. Evaluating hazards.
4. Selecting respiratory protection options.
5. Monitoring respirator use to ensure that respirators are used in accordance with their specifications.
6. Arranging for and/or conducting training.
7. Ensuring proper storage and maintenance of respiratory protection equipment.
8. Conducting qualitative fit testing.
9. Administering the medical surveillance program.
10. Maintaining records required by the program.
11. Evaluating the program.
12. Updating written program, as needed.

## **C. Supervisors and Line Management**

Supervisors and Line Management are responsible for ensuring that the respiratory protection program is implemented in their particular areas. In addition to being knowledgeable about the program requirements for their own protection, supervisors and line management must also ensure that the program is understood and followed by the IceCube employees and contractors and contractors under their charge. Duties of the supervisor and line management include:

1. Ensuring that **IceCube** employees and contractors and contractors under their supervision (including new hires) receive appropriate training, fit testing, and annual medical evaluation.
2. Ensuring the availability of appropriate respirators and accessories.
3. Being aware of tasks requiring the use of respiratory protection.
4. Enforcing the proper use of respiratory protection when necessary.
5. Ensuring that respirators are properly cleaned, maintained, and stored according to this program.
6. Ensuring that respirators fit well and do not cause discomfort.
7. Continually monitoring work areas and operations to identify respiratory hazards.
8. Coordinating with the Program Administrator on how to address respiratory hazards or other concerns regarding this program.

#### **D. IceCube Employees and contractors and Contractors**

Each **IceCube** employee or contractor is responsible for wearing their respirator when and where required and in the manner in which they are trained. They must also:

1. Use the respiratory protection in accordance with the manufacturer's instructions and the training received.
2. Care for and maintain their respirators as instructed, guard them against damage, and store them in a clean, sanitary location.
3. Immediately report any defects in the respiratory protection equipment and whenever there is a respirator malfunction, immediately evacuate to a safe area and report malfunction.
4. Promptly report to the supervisor any symptoms of illness that may be related to respirator usage or exposure to hazardous atmospheres.
5. Report any health concerns related to respirator use or changes in health status to occupational physician.
6. Inform their supervisor or the Program Administrator of any respiratory hazards that they feel are not adequately addressed in the workplace and of any other concerns that they have regarding this program.

#### **V. PROGRAM**

##### **A. Hazard Assessment and Respirator Selection**

The Program Administrator will select respirators to be used in the task, based on the hazards to which workers are exposed and in accordance with the OSHA Respiratory Protection Standard. The Program Administrator will conduct a hazard evaluation for each operation, process, or work area where airborne contaminants may be present in routine operations or during an emergency. The hazard evaluations shall include:

1. Identification and development of a list of hazardous substances used in the workplace by department or work process.
2. Review of work processes to determine where potential exposures to hazardous substances may occur. This review shall be conducted by surveying the workplace, reviewing the process records, and talking with **IceCube** employees and contractors, contractors, supervisors and line management.
3. Exposure monitoring to quantify potential hazardous exposures.

The proper type of respirator for the specific hazard involved will be selected in accordance with the manufacturer's instructions (See Attachment D for more additional information on respirators). Selection of the employees and contractors and appropriate respiratory protection shall be documented by the Program Administrator (See Attachment E).

## **B. Updating the Hazard Assessment**

The Program Administrator must revise and update the hazard assessment as needed (i.e., any time work process changes may potentially affect exposure). If an **IceCube** employee or contractor feels that respiratory protection is needed during a particular activity, s/he is to contact his/her supervisor, line manager, or the Program Administrator. The Program Administrator will evaluate the potential hazard, and arrange for outside assessment if necessary. The Program Administrator will then communicate the results of that assessment to the employees and contractors. If it is determined that respiratory protection is necessary, all other elements of the respiratory protection program will be in effect for those tasks, and the respiratory program will be updated accordingly.

## **C. Training**

The Program Administrator will provide training to respirator users and their supervisors on the contents of the **IceCube** Respiratory Protection Program and their responsibilities under it, and on the OSHA Respiratory Protection Standard. All affected employees and contractors and their supervisors will be trained prior to using a respirator in the workplace. Supervisors will also be trained prior to supervising employees and contractors that must wear respirators.

The training course will cover the following topics:

1. The **IceCube** Respiratory Protection Program;
2. The OSHA Respiratory Protection Standard (29 CFR 1910.134);
3. Respiratory hazards encountered at **IceCube** and their health affects;
4. Proper selection and use of respirators;
5. Limitations of respirators;
6. Respirator donning and user seal (fit) checks;
7. Fit testing;
8. Emergency use procedures;
9. Maintenance and storage; and
10. Medical signs and symptoms limiting the effective use of respirators.

Employees and contractors will be retrained annually or as needed (e.g., work processes change and there is a need to use a different respirator). **IceCube** employees and contractors must demonstrate their understanding of the topics covered in the training through hands-on exercises and a written test. The Program Administrator will document respirator training and the documentation will include the type, model, and size of respirator for which each employee has been trained and fit tested.

#### **D. NIOSH Certification**

All respirators must be certified by the National Institute for Occupational Safety and Health (NIOSH) and shall be used in accordance with the terms of that certification. Also, all filters, cartridges, and canisters must be labeled with the appropriate NIOSH approval label. The label must not be removed or defaced while the respirator is in use.

#### **E. Voluntary Respirator Use**

The Program Administrator shall authorize voluntary use of respiratory protective equipment as requested on a case-by-case basis, depending on specific workplace conditions and the results of medical evaluations.

The Program Administrator will provide all **IceCube** employees and contractors or contractors, who voluntarily choose to wear the above respirators, with a copy of Appendix D of the OSHA Respiratory Protection Standard 1910.134. (Appendix D details the requirements for voluntary use of respirators by employees and contractors.) **IceCube** employees and contractors or contractor who choose to wear a half face piece APR must comply with the procedures for medical evaluation, respirator use, cleaning, and maintenance and Storage portions of this program.

#### **F. Medical Evaluation**

**IceCube** employees and contractors or contractors, who are either required to wear respirators, or who choose to wear a half face piece APR voluntarily, must pass a medical exam provided by **IceCube** before being permitted to wear a respirator on the job. **IceCube** employees and contractors or contractors are not permitted to wear respirators until a physician has determined that they are medically able to do so. Any employee or contractor refusing the medical evaluation will not be allowed to work in an area requiring respirator use.

A licensed physician at Dean Clinic where all project medical services are provided, will provide the medical evaluations. Medical evaluation procedures are as follows:

1. The medical evaluation will be conducted using the questionnaire provided in Appendix C of the OSHA Respiratory Protection Standard 1910.134. The Program Administrator will provide a copy of this questionnaire to all employees and contractors requiring medical evaluations (See Attachment F for a copy of Appendix C of the OSHA Respiratory Protection Standard. Appendix C is the OSHA Respirator Medical Evaluation Questionnaire).
2. To the extent feasible, the project will provide assistance to employees and contractors or contractors who are unable to read the questionnaire. When this is not possible, the employee or contractor will be sent directly to the physician for medical evaluation.

3. All affected employees and contractors or contractors will be given a copy of the medical questionnaire to complete, along with a stamped and addressed envelope for mailing the questionnaire to the project physician. Employees and contractors will be permitted to complete the questionnaire on project time.
4. Follow-up medical exams will be granted to employees and contractors or contractors as required by the Standard, and/or as deemed necessary by the evaluating physician.
5. All employees and contractors or contractors will be granted the opportunity to speak with the physician about their medical evaluation, if they so request.
6. The Program Administrator shall provide the evaluating physician with a copy of this Program, a copy of the OSHA Respiratory Protection Standard, the list of hazardous substances by work area, and the following information about each employee or contractor requiring evaluation:
  - a. his or her work area or job title;
  - b. proposed respirator type and weight;
  - c. length of time required to wear respirator;
  - d. expected physical work load (light, moderate or heavy);
  - e. potential temperature and humidity extremes; and
  - f. any additional protective clothing required.
7. Positive pressure air purifying respirators will be provided to employees and contractors or contractors as required by medical necessity.
8. After an employee or contractor has received clearance to wear his or her respirator, additional medical evaluations will be provided under the following circumstances:
  - a. The employee or contractor reports signs and/or symptoms related to their ability to use the respirator, such as shortness of breath, dizziness, chest pains or wheezing.
  - b. The evaluating physician or supervisor informs the Program Administrator that the employee needs to be reevaluated.
  - c. Information found during the implementation of this program, including observations made during the fit testing and program evaluation, indicates a need for reevaluation.
  - d. A change occurs in workplace conditions that may result in an increased physiological burden on the employee.

(Note: All examinations and questionnaires are to remain confidential between the employee contractor and the physician. The Program Administrator will only retain the

physician's written recommendations regarding each employee's or contractor's ability to wear a respirator.)

### **G. Fit Testing**

Employees and contractors who are required to or who voluntarily wear half-face piece APRs will be fit tested:

1. prior to being allowed to wear any respirator with a tight-fitting face piece;
2. annually; or
3. when there are changes in the employee's physical condition that could affect respiratory fit (e.g., obvious change in body weight, facial scarring, etc.).

Employees and contractors will be fit tested with the make, model, and size of respirator that they will actually wear. Employees and contractors will be provided with several models and sizes of respirators so that they may find an optimal fit. Fit testing of powered air purifying respirators will be conducted in the negative pressure mode.

The Program Administrator will conduct fit tests in accordance with Appendix A of the OSHA Respiratory Protection Standard 1910.134.

### **H. General Respirator Use Procedures**

1. Employees and contractors will use their respirators under conditions specified in this program, and in accordance with the training they receive on the use of each particular model. In addition, the respirator shall not be used in a manner for which it is not certified by NIOSH or by its manufacturer.
2. All employees and contractors shall conduct user seal checks each time they wear their respirators. Employees and contractors shall use either the positive or negative pressure check (depending on which test works best for them) as specified in the OSHA Respiratory Protection Standard.
  - a. **Positive Pressure Test:** This test is performed by closing off the exhalation valve with your hand. Breathe air into the mask. The face fit is satisfactory if some pressure can be built up inside the mask without any air leaking out between the mask and the face of the wearer.
  - b. **Negative Pressure Test:** This test is performed by closing of the inlet openings of the cartridge with the palm of you hand. Some masks may require that the filter holder be removed to seal off the intake valve. Inhale gently so that a vacuum occurs within the face piece. Hold your

breath for ten (10) seconds. If the vacuum remains, and no inward leakage is detected, the respirator is fit properly.

3. All employees and contractors shall be permitted:
  - a. to clean their respirator if it is impeding their ability to work;
  - b. to change filters or cartridges;
  - c. to replace parts; or
  - d. to inspect respirator if it stops functioning as intended.
4. Employees and contractors are not permitted to wear tight-fitting respirators if they have any condition, such as facial scars, facial hair, or missing dentures that would prevent a proper seal. Employees and contractors are not permitted to wear headphones, jewelry, or other items that may interfere with the seal between the face and the face piece.
5. Before and after each use of a respirator, an employee, contractor, or immediate supervisor must make an inspection of tightness or connections and the condition of the face piece, headbands, valves, filter holders and filters. Questionable items must be addressed immediately by the supervisor and/or Program Administrator.

## **I. Air Quality**

For supplied-air respirators, only Grade D breathing air shall be used in the cylinders. Line management will coordinate deliveries of compressed air with the project's vendor and will require the vendor to certify that the air in the cylinders meets the specifications of Grade D breathing air.

Line management will maintain a minimum air supply of one fully charged replacement cylinder for each SAR unit. In addition, cylinders may be recharged as necessary from the breathing air cascade system located near the respirator storage area.

## **J. Change Schedules**

Respirator cartridges shall be replaced as determined by the Program Administrator, supervisor(s), and manufacturers' recommendations.

## **K. Cleaning**

Respirators are to be regularly cleaned and disinfected at the designated respirator cleaning station. Respirators issued for the exclusive use of an employee shall be cleaned as often as necessary. Atmosphere-supplying and emergency use respirators are to be cleaned and disinfected after each use.



The following procedure is to be used when cleaning and disinfecting reusable respirators:

1. Disassemble respirator, removing any filters, canisters, or cartridges.
2. Wash the face piece and all associated parts (except cartridges and elastic headbands) in an approved cleaner-disinfectant solution in warm water (about 120 degrees Fahrenheit). Do not use organic solvents. Use a hand brush to remove dirt.
3. Rinse completely in clean, warm water.
4. Disinfect all facial contact areas by spraying the respirator with an approved disinfectant.
5. Air dry in a clean area.
6. Reassemble the respirator and replace any defective parts. Insert new filters or cartridges and make sure the seal is tight.
7. Place respirator in a clean, dry plastic bag or other airtight container.

Line management will ensure an adequate supply of appropriate cleaning and disinfection materials at the cleaning station. If supplies are low, employees and contractors should notify their supervisor.

#### **L. Maintenance**

Respirators are to be properly maintained at all times in order to ensure that they function properly and protect employees and contractors adequately. Maintenance involves a thorough visual inspection for cleanliness and defects. Worn or deteriorated parts will be replaced prior to use. No components will be replaced or repairs made beyond those recommended by the manufacturer. Repairs to regulators or alarms of atmosphere-supplying respirators will be conducted by the manufacturer.

1. All respirators shall be inspected routinely before and after each use.
2. Respirators kept for emergency use shall be inspected after each use, and at least monthly by the Program Administrator to assure that they are in satisfactory working order
3. The Respirator Inspection Checklist will be used when inspecting respirators.
4. A record shall be kept of inspection dates and findings for respirators maintained for emergency use.
5. Employees and contractors are permitted to leave their work area to perform limited maintenance on their respirator in a designated area that is free of respiratory hazards. Situations when this is permitted include:

- a. washing face and respirator face piece to prevent any eye or skin irritation;
- b. replacing the filter, cartridge or canister;
- c. detection of vapor or gas breakthrough or leakage in the face piece; or
- d. detection of any other damage to the respirator or its components.

## **M. Storage**

After inspection, cleaning, and necessary repairs, respirators shall be stored appropriately to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals.

1. Respirators must be stored in a clean, dry area, and in accordance with the manufacturer's recommendations. Each employee or contractor will clean and inspect their own air-purifying respirator in accordance with the provisions of this program, and will store their respirator in a plastic bag in the designated area. Each employee will have his/her name on the bag and that bag will only be used to store that employee's respirator.
2. Respirators shall be packed or stored so that the face piece and exhalation valve will rest in a near normal position.
3. Respirators shall not be placed in places such as lockers or toolboxes unless they are in carrying cartons.
4. Respirators maintained at stations and work areas for emergency use shall be stored in compartments built specifically for that purpose, be quickly accessible at all times, and be clearly marked.
5. Line Management will store **IceCube's** supply of respirators and respirator components in their original manufacturer's packaging in an area immediately accessible to **IceCube** employees and contractors.

## **N. Respirator Malfunctions and Defects**

1. For any malfunction of an ASR (atmosphere-supplying respirator), such as breakthrough, face piece leakage, or improperly working valve, the respirator wearer should inform his/her supervisor that the respirator no longer functions as intended, and go to the designated safe area to maintain the respirator. The supervisor must ensure that the employee or contractor either receives the needed parts to repair the respirator or is provided with a new respirator.

All workers wearing atmosphere-supplying respirators will work with a buddy. The Program Administrator shall develop and inform employees and contractors of the procedures to be used when a buddy is required to assist a coworker who experiences an ASR malfunction.

2. Respirators that are defective or have defective parts shall be taken out of service immediately. If, during an inspection, an employee discovers a defect in a respirator, he/she is to bring the defect to the attention of his/her supervisor. Supervisors will give all defective respirators to the Program Administrator. The Program Administrator will decide whether to:
  - a. temporarily take the respirator out of service until it can be repaired;
  - b. perform a simple fix on the spot, such as replacing a head strap; or
  - c. dispose of the respirator due to an irreparable problem or defect.

When a respirator is taken out of service for an extended period of time, the respirator will be tagged out of service, and the employee will be given a replacement of a similar make, model, and size. All tagged out respirators will be immediately disposed of.

## **O. Emergency Procedures**

In emergency situations where an atmosphere exists in which the wearer of the respirator could be overcome by a toxic or oxygen-deficient atmosphere, the following procedure should be followed.

1. When the alarm sounds, employees and contractors in the affected area must immediately don their emergency escape respirator, shut down their process equipment, and exit the work area.
2. All other employees and contractors must immediately evacuate the building. **IceCube's** or RPS's Emergency Action Plan describes these procedures (including proper evacuation routes and rally points) in greater detail.
3. Employees and contractors who must remain in a dangerous atmosphere must take the following precautions:
  - a. Employees and contractors must never enter a dangerous atmosphere without first obtaining the proper protective equipment and permission to enter from the Program Administrator or supervisor.
  - b. Employees and contractors must never enter a dangerous atmosphere without at least one additional person present. The additional person must remain in the safe atmosphere.
  - c. Communications (voice, visual or signal line) must be maintained between both individuals or all present.

- d. Respiratory protection in these instances is for escape purposes only. **IceCube** employees and contractors are not trained as emergency responders, and are not authorized to act in such a manner.

## **P. Program Evaluation**

The Program Administrator will conduct periodic evaluations of the workplace to ensure that the provisions of this program are being implemented. The evaluations will include regular consultations with employees and contractors who use respirators and their supervisors, site inspections, air monitoring and a review of records. Items to be considered will include:

1. comfort;
2. ability to breathe without objectionable effort;
3. adequate visibility under all conditions
4. provisions for wearing prescription glasses;
5. ability to perform all tasks without undue interference; and
6. confidence in the face piece fit.

Identified problems will be noted in an inspection log and addressed by the Program Administrator. These findings will be reported to **IceCube** line and project management, and the report will list plans to correct deficiencies in the respirator program and target dates for the implementation of those corrections.

## **Q. Documentation and Recordkeeping**

1. A written copy of this program and the OSHA Respiratory Protection Standard shall be kept in the Program Administrator's office and made available to all employees and contractors who wish to review it.
2. Copies of training and fit test records shall be maintained by the Program Administrator. These records will be updated as new employees and contractors are trained, as existing employees and contractors receive refresher training, and as new fit tests are conducted
3. For employees and contractors covered under the Respiratory Protection Program, the Program Administrator and line management shall maintain copies of the physician's written recommendation regarding each employee's or contractor's ability to wear a respirator. The completed medical questionnaires and evaluating physician's documented findings will remain confidential in the employee's or contractor's medical records at the location of the evaluating physician's practice.

ATTACHMENT G – 1

Respiratory Protection Hazard

**Assessment and Selection Form**

Agency/Institution: \_\_\_\_\_

Worksite: \_\_\_\_\_

General Description of Job Task: \_\_\_\_\_  
\_\_\_\_\_

Job Classification(s) \_\_\_\_\_

Level of physical exertion required to perform job: \_\_\_\_\_  
\_\_\_\_\_

Respiratory hazard(s) present: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

OSHA PEL: \_\_\_\_\_ ACGIH TLV (if applicable): \_\_\_\_\_

Is monitoring data available? \_\_\_\_\_ Yes \_\_\_\_\_ No

If yes, attach to this form.

Contaminant concentrations present in the workplace:

Contaminant(s): \_\_\_\_\_ Concentration: \_\_\_\_\_

Contaminant(s): \_\_\_\_\_ Concentration: \_\_\_\_\_

Contaminant(s): \_\_\_\_\_ Concentration: \_\_\_\_\_

Does data indicate levels that exceed applicable limits? \_\_\_\_\_ Yes \_\_\_\_\_ No

Do data indicate IDLH concentrations? \_\_\_\_\_ Yes \_\_\_\_\_ No

Note: Wherever hazardous exposure(s) cannot be identified or reasonably quantified, the atmosphere must be considered IDLH.

Does data indicate oxygen deficiency (less than 19.5%)? \_\_\_\_\_ Yes \_\_\_\_\_ No

Is the respirator for routine use or emergency use? \_\_\_\_\_

Additional factors (i.e. temperature and humidity levels, etc.): \_\_\_\_\_

Communication requirements: \_\_\_\_\_

Are engineering/ administrative controls feasible? \_\_\_\_\_ Yes \_\_\_\_\_ No

If no, describe reasons: \_\_\_\_\_

Type of respirator selected: \_\_\_\_\_ air purifying \_\_\_\_\_ atmosphere supplying

Style of respirator selected: \_\_\_\_\_ tight-fitting \_\_\_\_\_ lose-fitting

Make: \_\_\_\_\_ Model# \_\_\_\_\_

Type of canister or cartridge to be used: \_\_\_\_\_

Cartridge/canister change schedule if applicable \_\_\_\_\_

Name of Evaluator: \_\_\_\_\_ Date: \_\_\_\_\_

Title: \_\_\_\_\_ Work Phone: \_\_\_\_\_

**ATTACHMENT G – 2**

**Respiratory Hazard Assessment and Certification Form**

Area/Task/Job Description	MSDS Product/Trade Name	Contaminant	Concentration	ppm	mg/m <sup>3</sup>	Recommended Respiratory Protection	Service Life

**I have performed an evaluation of the work areas indicated above, assessed the hazards and selected the appropriate respiratory protection.**

<b>Signature</b>	<b>Name and Title (print)</b>	<b>Date</b>
------------------	-------------------------------	-------------

## **ATTACHMENT G-3**

### **Respirator Protection**

#### **Types of Respirators:**

Respirators are classified into two main classes according to the type of hazardous environment in which the respirator is to be used and the degree of danger to life and health, which that environment presents.

#### **Supplied-Air Respirators:**

This type of respirator supplies uncontaminated breathing air to the user from an external source of air connected by a high-pressure hose to the face piece, hood or helmet. They offer certain advantages over other types of respirators and may be the preferred form of respiratory protection in some applications. Some models are equipped with an air cylinder for emergency escape from an Immediately Dangerous to Life or Health (IDLH) atmosphere. An IDLH atmosphere poses an immediate hazard to life or produces irreversible debilitating effects on health.

Supplied-air respirators are approved for use under the following conditions where the use of air-purifying respirators is precluded:

- In atmospheres where contaminants do not emit a detectable odor or taste or cause irritation at safe concentrations.
- To protect against substances that would generate a high heat reaction with the absorbent in an air-purifying respirator.
- Where chemicals in the atmosphere are absorbed very poorly by the absorbents used in air-purifying respirators, causing very short service life, or where the chemicals are not absorbed at all.
- Where there are two or more contaminants in the atmosphere for which different air-purifying elements are recommended, such as ammonia and benzene, and a combination element is not available.
- When the concentration of a substance is greater than the approved limit for an air-purifying respirator.

#### **Self-Contained Breathing Apparatus (SCBA):**

The Self-Contained Breathing Apparatus (SCBA) is a special type of supplied-air respirator that gives the user an independent air supply from a pressurized tank on the wearer's back. Generally, the air supply lasts for 30 to 60 minutes, but is dependent upon the wearer's size and the type of work performed. SCBAs are used under the following conditions:

- In oxygen-deficient atmospheres where the oxygen level is below 19.5%.
- In poorly ventilated areas and/or in confined spaces such as tanks, tunnels, or vessels. Note: SCBAs are not required if the confined space is well ventilated and the concentration of toxic contaminants is known to be below the upper protection limit recommended for the respirator.



- In atmospheres where the concentration of contaminants is Immediately Dangerous to Life or Health (IDLH).
- In atmospheres where the concentration of toxic contaminants is unknown. Any unknown concentration must be treated as IDLH.
- For firefighting.

## II. Air-Purifying Respirators:

This type of respirator usually consists of a facepiece fitted with appropriate mechanical filters or chemical cartridges or canisters to remove dusts, mists and specific fumes, gases and vapors from the breathing air. The filters and cartridges are color-coded to help the user match the right respirator, filter and/or cartridge to the hazard(s) present in the work area. They are the lightest and the easiest to use type of respiratory protection. The vast majority of work environments fall within their protection limits. Air-purifying respirators include:

- Powered Air-Purifying Respirators (PAPRs) have air blowers to pull air through the cartridges and filters. Some PAPRs are available with hoods or other protective headgear for use in specific types of environments. A PAPR equipped with a hood may be used instead of a tight-fitting face piece by wearers with facial hair, scars, or spectacles. PAPRs are available with chemical cartridges or with High Efficiency Particulate Air-Purifying (HEPA) filters.
- Full-Face piece Air-Purifying Respirators are equipped with a with chemical cartridges and/or filters and a face shield to protect the wearer's face and eyes from liquid splashes or flying particles. Some devices include a speaking diaphragm for easier communication.
- Half-Mask Air-Purifying Respirators cover only the nose and mouth. They often use the same cartridges and filters as full-face piece models. Most manufacturers offer two or three sizes to fit nearly all workers. They usually come with a rubber or silicone face piece and can be worn with prescription or non-prescription glasses or goggles.
- Mouthpiece Respirators are for emergency escape from known concentrations of contaminants. They are lightweight and easily worn around the neck or clipped to a belt. Mouthpiece respirators however are not designed for extended or routine use.
- Disposable Respirators protect the wearer from low (nuisance) concentrations of fumes, mists and/or dust. Some models include an exhalation channel that exhausts air directly for less hot air and moisture buildup in the mask.

### **Respirator Approval:**

The National Institute for Occupational Safety and Health (NIOSH) is responsible for the testing and certification of respiratory protective devices. If approval is given, the items certified are given a TC number, signifying it has been tested and certified. Respiratory protective devices must bear the TC number to be approved for use.

### Selection Process:

1. Identify the airborne contaminant(s):

An important source of information on airborne contaminants is the Material Safety Data Sheet (MSDS) for each product. The MSDS identifies the ingredients in each product that have been determined to be a health hazard and the physical and chemical characteristics of the product such as vapor pressure and flash point.

The physical form of the hazard will also help you determine the type of respiratory protection you will need.

Dusts are tiny suspended particles resulting from a mechanical process such as grinding.

Mists are tiny liquid droplets usually created by spraying operations.

Fumes are small particles formed by a condensing gas or vapor such as in welding.

Vapors are substances that evaporate from a liquid or solid.

Gases are formless fluids that occupy the space in which they are enclosed. Examples include nitrogen and carbon monoxide.

Smoke is a mixture of suspended particles and gases which are the result of combustion.

Smoke can contain toxic contaminants.

2. Determine the concentration level of the contaminant:

Sensitive monitoring instruments will give you a precise reading of the airborne concentration level of the contaminant. If testing indicates that you are exposed to an airborne concentration level at or above the Permissible Exposure Level (PEL) established for that substance, you must use respiratory protection.\* This testing should be done by an industrial hygienist or other qualified staff.

3. Evaluate the conditions of exposure:

There are many variables that can affect your choice of respiratory protection. Always keep these factors in mind:

The nature of the task. How long will you be exposed to each hazard? Is the work strenuous, which makes breathing more difficult?

The characteristics of the work area. Is the work area a confined space and/or poorly ventilated? Will air temperatures be hot or cold? Could more than one contaminant be present?

The type of work process. Does the way chemicals are combined, heated or applied create an additional or new health hazard? An example of this could be a paint spraying or welding operation.

4. Match the hazard, concentration level and the conditions of exposure to the proper type of respirator:

A wide range of supplied-air and air-purifying respirators are available from various manufactures. Contact your supervisor and/or your agency/institution safety coordinator for help in selecting the proper respirator for your specific work area.

\* Note: The OSHA Respiratory Protection Standard (29 CFR 1910.134) requires the employer to prevent occupational diseases caused by breathing contaminated air by the use of engineering control measures such as the enclosure of the operation or the substitution of less toxic materials. When effective engineering controls are not feasible, or while these controls are being instituted, appropriate respirators must be used in accordance with the requirements of the standard.

**ATTACHMENT G-4**

**Sample Record of Respirator Issuance**

<b>IceCube</b> Personnel in Respiratory Protection Program <b>Date:</b>				
Respiratory protection is required for and has been issued to the following personnel:				
Name	Department	Job Description/ Work Procedure	Type of Respirator	Date Issued
		<b>Operator</b>	<b>Half mask APR P100 filter when sanding/ AR continuous flow hood for cleaning</b>	
		<b>Dip tank cleaning</b>	<b>SAR, pressure demand with auxiliary SCBA</b>	
		<b>Spray Booth</b>	<b>SAR, continuous</b>	

**ATTACHMENT G - 5****Respirator Inspection Checklist**

Type of Respirator:	Location:
Respirator Issued to:	Type of Hazard:
<b>Face piece</b>	<input type="checkbox"/> Cracks, tears, or holes <input type="checkbox"/> Face mask distortion <input type="checkbox"/> Cracked or loose lenses/face shield
<b>Head straps</b>	<input type="checkbox"/> Breaks or tears <input type="checkbox"/> Broken buckles
<b>Valves:</b>	<input type="checkbox"/> Residue or dirt <input type="checkbox"/> Cracks or tears in valve material
<b>Filters/Cartridges:</b>	<input type="checkbox"/> Approval designation <input type="checkbox"/> Gaskets <input type="checkbox"/> Cracks or dents in housing <input type="checkbox"/> Proper cartridge for hazard
<b>Air Supply Systems</b>	<input type="checkbox"/> Breathing air quality/grade <input type="checkbox"/> Condition of supply hoses <input type="checkbox"/> Hose connections <input type="checkbox"/> Settings on regulators and valves
<b>Rubber/Elastomer Parts</b>	<input type="checkbox"/> Pliability <input type="checkbox"/> Deterioration

<b>Inspected by:</b>	<b>Date:</b>
<b>Action Taken:</b>	

## ATTACHMENT G – 6

### SCBA Inspection Checklist

SCBA Identification Number: \_\_\_\_\_

<b>1. Is the Face piece in good condition?</b> <i>Look for these Items:</i>			
• Excessive dirt			
• Cracks, tears, holes or distortions from improper storage			
• Inflexibility			
• Cracked or badly scratched lenses in full face pieces			
• Incorrectly mounted full face piece lens or broken or missing mounting clips			
<b>2. Are the headstraps or head harness in good condition?</b> <i>Look for these items:</i>			
• Breaks in the straps			
• Loss of elasticity			
• Broken or malfunctioning buckles and attachments			
• Excessively worn serrations on the head harness which might permit slippage			
<b>3. Is the exhalation valve in good condition?</b> <i>Look for these items:</i>			
• Foreign material under the valve seat			
• Cracks, tears or distortion in the valve material			
• Improper insertion of the valve body in the face piece			
• Cracks, breaks or chips in the valve body, particularly in the sealing surface			
• Missing or defective valve cover			
• Improper installation of the valve in the valve body			
<b>4. Is the breathing tube in good condition?</b> <i>Look for these items:</i>			
• Damaged, worn or missing end connectors			
• Missing or loose hose clamps			
• Deterioration or the hose material			
<b>5. Is the high pressure air supply in good condition?</b> <i>Look for these items:</i>			
• Air supply lines, hoses, attachments and end fittings worn			
• Valves and air flow regulators inoperable			
• Low pressure alarm inoperable			
• Air cylinder less than full			
• Gauges inoperable			
• Air cylinder damaged			
• Air cylinder hydrostatic test out of date			
<b>6. Is the cylinder harness in good condition?</b> <i>Look for these items:</i>			
• Straps or frame showing wear or damage			
• Broken or malfunctioning buckles and attachments			
• Air cylinder attachment devices inoperable			

**If you answered 'no' to any question above, list corrective action taken here:**

<b>Inspected by:</b>	
Date:	

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## APPENDIX H: Safety Program: Roles & Responsibilities

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Goals:

- A. Make IceCube Safety everyone's responsibility both at the Pole and at PSL. Keep everyone's "head" in the "Safety Game." Make us all responsible for each other's "safety" as well as for ourselves.
- B. Organize the Safety function: establish hierarchy/roles and responsibilities
- C. Develop Safety metrics to increase and maintain safety awareness on the part of all.
- D. Prevent all foreseeable injuries

Safety Team:

- A. On-Ice Hierarchy (applies to PSL as applicable)

On-Ice Lead/ Safety Manager: (T. Ha, JY, BM, AK)/ MAZ

1. Safety Lead- Drilling (T.Hu, AE)
  - a. Shift Leads (DD, JC, JF, JK)
  - b. Deputy Shift Leads (DG, TL, DP)
2. Safety Lead- Deployment (TH)
3. Safety Lead- ICL (SC, PW)
4. Safety Lead-Other (JH, KH)- includes: DAQ, Amanda, DOM Test, Cable Guys, etc.

- B. Roles and Responsibilities

1. South Pole IceCube Personnel: ***Everyone*** is accountable for the safe performance of their duties and the safe operations within their areas.
  - Initiate Safety Contacts as required
  - Report any unsafe condition noticed
2. Shift Leads/Deputy Shift Leads:
  - Model for Safe Behavior/ Support of Safety effort
  - Perform weekly scheduled Safety "Walk-Through" Assessments and write report.
  - Write Incident Reports for areas of responsibility as required
  - Conduct weekly Safety Action Meetings in own areas and take minutes.



- Initiate Safety Contacts as required
3. Safety Leads: Drilling, Deployment, ICL, and Other:
- Model for Safe Behavior/ Support of Safety effort
  - Schedule and regularly participate in Safety Assessments in area of responsibility.
  - Develop safety reporting metrics from findings from Safety Assessments
  - Coordination of Incident Report Investigations
  - Implement Corrective Actions from weekly Safety Action Meetings/ Safety Assessments
  - Initiate Safety Contacts as required.
  - “Safety Decision-Maker” in area of responsibility
  - Discuss daily “Safety Awareness Reminder” at Shift start
    - Salient brief Safety topic from issues or metrics for daily safety awareness. Post key metrics in applicable areas
4. On-Ice Lead:
- Model for Safe Behavior/ Support of Safety effort
  - Regular participation in Safety Assessments, Safety Action Meetings as appropriate
  - IceCube “Safety Decision-Maker” on Ice
  - Ensure that weekly Safety Assessments are occurring in all areas.
  - Conduct monthly safety status meetings with safety team
    - Focus upon open safety issues
    - Discuss effectiveness of Corrective Measures
    - Review metrics for Safety Improvement
  - Liaise with RPSC on common matters
5. Safety Manager:
- Model for Safe Behavior/ Support of Safety effort
  - Regular participation in Safety Assessments, Safety Action Meetings as appropriate
  - Support On-Ice Lead, Safety Leads, Deputy Shift leads, and RPSC personnel in all aspects of the safety program
  - Facilitate the implementation of the new Safety Plan
  - Train key people in their roles as appropriate
  - Initiate Safety Contacts as required.
  - Submit completed Incident reports to NSF or other external organizations as required.
  - Liaise with RPSC on common matters.
- C. Simple Documentation
- Training Records
  - Safety “Walk-Through” Assessment Checklists/ Reports

- Minutes from weekly Safety Action Meetings
- Monthly Safety Status Reports

D. Metrics

- Days w/o Lost Time Injury
- Days w/o Reportable Injury
- Days w/o a “Near Miss”
- Behavioral metrics (from Safety Assessments):
  - Frequency in occurrence of negative safety behaviors or circumstances: i.e., no hard hats, chemicals on heaters, blocked aisles, etc.
    - Focus for reduction towards safety improvement
  - Frequency in occurrence of positive safety behaviors or circumstances: i.e., clean areas, fall protection gear being utilized, etc.
    - Focus for emphasis upon the high level of safety already existent at the Pole.
  - The key to the prevention of foreseeable accidents is to get good control of the positive and negative safety behaviors and to make people aware of both.

E. Safety Action Meetings:

- From Assessment Findings, Occurrences, Brainstorming, hazards arise:
  - Weekly Meetings should occur with all persons in an area.
    - People speak openly and honestly about hazards
    - Shift/ Deputy Shift Leads conduct meeting
      - Write down all suggested ideas for hazard mitigation
      - Divide group into 5-person teams
        - » Let each team select a topic
      - Task each team to come up with all possible hazards
      - Task each team to identify possible solutions
    - Review each teams Improvement Plans with the group.
    - Amend accordingly
  - Shift/Deputy Shift Leads work with Safety Leads and entire team to implement changes to processes.
  - Results are discussed at a Monthly Safety Status Meeting

Safety Representative:

In an effort to promote safety throughout the Summer at the Pole, the Safety Rep can assist in the following ways:

- Be a Model for Safe Behavior/ Support of Safety effort.
- Perform weekly scheduled Safety “Walk-Through” Assessments and complete checklist.
- Write Incident Reports for areas as required.
- Promote safety through presence at weekly Safety Action Meetings in Driller and “Other” meetings.
- Initiate Safety Contacts as required.
- Work with Deputy Shift Leads and On-Ice Lead on Safety Concerns. Liaise with RPSC On-Ice Safety Officer as necessary.
- Be available to assist any IceCuber with safety issues or to lend a hand as asked.

This position works with everyone. In this capacity, the position reports to the On-Ice Lead and to the Quality and Safety Manager.

**Safety Plans:**

- Fire extinguisher Weigh-In
- RPSC Rescue Team Walks-Through
- GFCI Receptacle Testing
- CO/Smoke Alarm Installation and Testing
- Emergency rescue drill
- Drill Camp Start-Up Inspections
- Verify and Organize Safety Equipment
- Retrieve and Test AED Machines
- Check IceCube Lab
- Calibrate Air Quality Monitors
- Drill Camp Winterization Checklists

APPENDIX I: Confined Space Entry Permit Form--- Appendix D to §1910.146

Date and Time Issued: \_\_\_\_\_ Date and Time Expires: \_\_\_\_\_
Job site/Space I.D.: \_\_Ice Cube Drill Camp Job Supervisor: Al El-Cheikh\_\_\_\_\_
Equipment to be worked on: \_Hot Water Tank 1\_
Work to be performed: \_\_TIG Welding of Tank Liners

Stand-by personnel: \_\_\_\_\_

1. Atmospheric Checks: Time \_\_\_\_\_
Oxygen \_\_\_\_\_%
Explosive \_\_\_\_\_% L.F.L.
Toxic \_\_\_\_\_PPM

2. Tester's signature: \_\_\_\_\_

3. Source isolation (No Entry): N/A Yes No
Pumps or lines blinded, ( ) ( ) ( )
Disconnected, or blocked ( ) ( ) ( )

4. Ventilation Modification: N/A Yes No
Mechanical ( ) ( ) ( )
Natural Ventilation only ( ) ( ) ( )

5. Atmospheric check after Isolation and Ventilation:
Oxygen \_\_\_\_\_% > 19.5 %
Explosive \_\_\_\_\_% L.F.L < 10 %
Toxic \_\_\_\_\_PPM < 10 PPM H (2) S
Time \_\_\_\_\_

Tester's signature: \_\_\_\_\_

6. Communication procedures: \_1. Signage Posted (2x): "Danger-Confined Space Entry Permit Required- Do Not Enter" 2. All Shift Drillers have been trained in the Confined Space Entry Permit Entry Process. \_\_\_\_\_

7. Rescue procedures: "Buddy System" Two welders in the hole at once plus a spotter on Top to monitor air and process in checking for hazards. Air hazard is largely mitigated through effective area ventilation and through the use of positive pressure air flow welding masks. Evacuation and Emergency procedures are in place. \_\_\_\_\_

8. Entry, standby, and back up persons: Yes No
Successfully completed required training?
Is it current? ( ) ( )

9. Equipment: N/A Yes No
Direct reading gas monitor - tested ( ) ( ) ( )
Safety harnesses and lifelines for entry and standby persons ( ) ( ) ( )

IceCube Project Safety Manual

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Hoisting equipment	( )	( )	( )
Powered communications	( )	( )	( )
SCBA's for entry and standby persons	( )	( )	( )
Protective Clothing	( )	( )	( )
All electric equipment listed Class I, Division I, Group D and Non-sparking tools	( )	( )	( )

10. Periodic atmospheric tests:

Oxygen	_____%	Time _____	Oxygen	_____%	Time _____
Oxygen	_____%	Time _____	Oxygen	_____%	Time _____
Explosive	_____%	Time _____	Explosive	_____%	Time _____
Explosive	_____%	Time _____	Explosive	_____%	Time _____
Toxic	_____%	Time _____	Toxic	_____%	Time _____
Toxic	_____%	Time _____	Toxic	_____%	Time _____

We have reviewed the work authorized by this permit and the information contained here-in. Written instructions and safety procedures have been received and are understood. **Entry cannot be approved if any squares are marked in the "No" column.** This permit is not valid unless all appropriate items are completed.

Permit Prepared By: (IceCube Safety Mgr.) \_\_\_\_\_

Approved By: (Drill Shift Lead) \_\_\_\_\_

Reviewed By (RPSC Safety as necessary): \_\_\_\_\_

\_\_\_\_\_  
(printed name)

\_\_\_\_\_  
(signature)

This permit to be kept at job site. Return job site copy to Safety Office following job completion.

APPENDIX J: SafeStart Training Program

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**Advanced Safety Awareness Training** Did you know that more than 90% of all incidents are partially caused by unintentional at-risk behavior? **SAFESTART™** will help you recognize the state-to-error patterns that contribute to unintentional at-risk behavior so you can minimize your chances for sustaining an injury. It's a simple but effective program that works for anyone in any environment - whether you are on the job, on the road, or at home.

**SAFESTART™** is advanced safety awareness training that teaches you how to avoid behaviors that cause the mistakes and errors you never wanted to make in the first place. The concepts are easy to grasp. That's why **SAFESTART™** is so effective. Employees easily understand and are able to internalize the message so "self-triggers" for safety are put into place. This five-module video/workbook course examines critical errors, while teaching techniques that reduce the risk of injury.

Telling employees to "be careful" is not enough. They need to know what you mean. **SAFESTART™** takes the mystery out of "being careful" by helping you recognize the state to error patterns that significantly increase the risk of what you are doing. Once you recognize these patterns, **SAFESTART™** helps you use the condition or state you are in as a trigger to refocus your attention on the job at hand. It's a simple, effective concept that works on the job, off the job, and on the highway.

**Why  SAFESTART ?**

Obviously, if you don't know about a hazard it will be pretty hard to keep it in mind. But most of us know that sailing right through an intersection when you're supposed to stop could easily cause severe injuries. Yet, out of around 20,000 people were asked, over 90% said they had done just that. They either sailed right through a stop sign or a red light without seeing it, or saw it too late to do anything about it.

Some had close calls, some weren't so lucky. Maybe they were rushing. Maybe they were tired. Maybe they didn't see it because they were looking at a map or dialing a cellular phone. Maybe they didn't see it because they were thinking about something else (driving on auto-pilot) and the stop sign was partially hidden. The point is all of them knew they should stop, and all of them **would** have stopped if they had seen the stop sign in time.



that

## At-Risk Behavior

There are 3 types of at-risk behavior:

- conscious behavior
- habitual behavior
- unintentional behavior



**SAFESTART™** is about unintentional behavior and habitual behavior. Or to be more specific, it's about how to prevent mistakes or errors you never wanted to make in the first place.

Even if people are deliberately willing to increase the risk of a situation, none of them are deliberately trying to get hurt. Something unexpected or unplanned always has to enter the equation. Since you are never trying to make a bad decision or a mistake, it's always unexpected. You may be trying to anticipate errors for other people because you know other people make mistakes, but quite often, your own errors hit you right out of the blue. So unexpectedly at times, that you don't even have time to respond.

Procedures, engineering and ergonomics can minimize or even eliminate mistakes on the job, but off-the-job quite often you're on your own. Perhaps this is why there are twice as many off-the-job injuries as on-the-job injuries. This course is designed to help you **efficiently** minimize the mistakes or errors that can get you hurt, whether it's off-the-job, on-the-job or on-the-highway.

**SAFESTART™** is an advanced safety awareness course that focuses on how to recognize and prevent mistakes before they occur. This [five-module video/workbook course](#) examines critical errors, while teaching techniques that reduce the risk of injury on-the-job, off-the-job and on-the-highway.

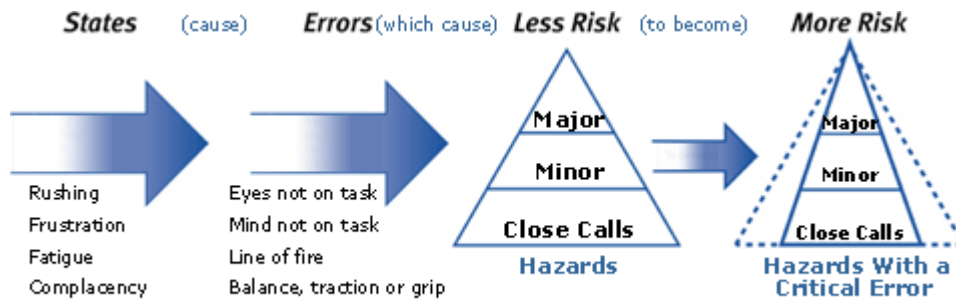
**SAFESTART™** isn't about telling you what to do. It isn't designed to replace sound engineering or good management practices. It isn't intended to replace training on specific workplace hazards.



**SAFESTART™** is an additional way to think about safety. It's about keeping hazards in mind and in sight all of the time. It's about recognizing the patterns of behavior that cause injury.

In a study of up to 10 years of injury/incident reports from over 100 companies, 80-85% of the injuries/incidents involved the same critical behaviors. **SAFESTART™** has also analyzed the states that lead people to make these critical errors - and using the Pareto Principle once again - has identified four states that contributed to almost all of the critical errors.

## Risk Patterns




What differentiates **SAFESTART™** from traditional behavior-based safety processes is linking these states to errors, and teaching people how to recognize these patterns so they don't make a critical error.

More than half a million people in over 1,000 companies worldwide have trained on the **SAFESTART™** concepts. All have been successful in their own ways. Here we detail five companies' accomplishments from their **SAFESTART™** implementations. Although each company's implementation process is unique, one thing remains constant: whether a company is looking to reduce accident rates or is trying to maintain a superb safety record, everyone can benefit from **SAFESTART™**.

## Why SAFESTART™ works

People don't make mistakes that increase or dramatically increase the risk of injury very often. When they do, it's usually because they were in one of four states (rushing, frustration, fatigue or complacency) that significantly contributed to them making the error. Learning how to recognize these state to error patterns so you can "trigger" or "self-trigger" on the state is the first technique. There are three more. While all of this might seem like "common sense", unfortunately common sense isn't always common practice. People need to be able to think about and play with these ideas long enough to really internalize the concepts so they stick. That's why **SAFESTART™** was written in question and answer format - so people could go at their own pace and come to their own conclusions. **SAFESTART™** defines exactly what you need to do and practice to avoid unintentional or accidental contact with hazardous energy. In simpler terms, **SAFESTART™** teaches you how to avoid the mistakes and errors you never wanted to make in the first place.

 **SAFESTART** is an additional way to think about safety

- it's not about telling you what to do
- it's not designed to replace sound engineering or good management practices
- it's not intended to replace training on specific workplace hazards
- **it's about keeping those hazards in mind and in sight** on-the-job, off-the-job and on-the-highway



*These four states...*

- [Rushing](#)
- [Frustration](#)
- [Fatigue](#)
- [Complacency](#)

*can cause or contribute to these critical errors...*

- [Eyes not on Task](#)
- [Mind not on Task](#)
- [Line-of-Fire](#)
- [Balance/Traction/Grip](#)

*...which increase the risk of injury.*

**Rushing:**

When you exceed the pace at which the job is usually done.

**Frustration:**

Caused by relationships inside and outside of the workplace, malfunctioning equipment, inadequate tools, conflicting objectives and pressures.

**Fatigue:**

Too tired to do the job safely, physically or mentally. Too tired to react quickly and prolonged concentration is difficult.

**Complacency:**

Familiar enough with the hazards to become considerably less concerned over time. Contributes significantly to not watching or thinking about what you are doing.

**Eyes not on Task:**

Not looking where you are going and looking at what is coming towards you. Includes moving your eyes before moving your body, being able to see where you are stepping/walking and where your hands are reaching into.

**Mind not on Task:**

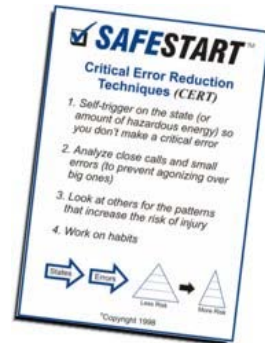
Not concentrating on the job. Being unaware of dangers or deficiencies. Forgetting things, making more errors than normal, going on "auto-pilot", "going away".

**Line-of-Fire:**

Being conscious of where you are or where you are going in relation to the direction of the hazardous energy. Includes protection barriers and P.P.E. if line of fire cannot be predicted accurately.

**Balance/Traction/Grip:**

Doing something that could cause you to lose your balance, traction, or grip. Could include not wearing good footwear/gloves, not having a good grip in the first place, or not seeing or thinking about the hazard.



## SAFESTART MODULES

**SAFESTART™** is an advanced safety awareness course that focuses on how to prevent mistakes or errors you didn't want to make in the first place. This **five-module** video/workbook course examines four states that cause four critical errors. It also explains four techniques you can use to minimize the majority of errors that increase the risk of injury on-the-job, off-the-job and on-the-highway.

**MODULE 1** An introduction and overview to **SAFESTART™**. It covers the concepts of safety, risk and error; critical errors or behaviors; and the states that cause errors.

**MODULE 2** Covers the first two critical errors, eyes not on task and mind not on task, and explains how to avoid them.

**MODULE 3** Covers the last two critical errors, putting yourself in the line of fire and losing your balance, traction or grip. It explains how to avoid line of fire injuries and how to improve your balance, traction and grip.

**MODULE 4** Covers the states that cause these critical errors: rushing, frustration, fatigue and complacency. For each state, specific tips are given to prevent injuries.

**MODULE 5** Covers four techniques that you can use to prevent critical errors and explains how to use these critical error reduction techniques to prevent injuries.

## Implementation Options

**SAFESTART™** consists of five units, and each takes 60-90 minutes to complete. Ideally the sessions would be conducted once a week or once every two weeks. **SAFESTART™** can be followed up with the refresher units, which take about 45 minutes each or with a more involved behavior based safety process that reduces both unintentional and deliberate behaviors.

After 6 years and (literally) hundreds of implementations we have standardized the sessions into 3 options. Choose the implementation option that is right for you. All are conducted by a member of our experienced team, specialists in motivational presentations and behavior based safety.

**Option 1 - Train-The-Trainer Course.** These 3-day workshops are designed to give your in-house trainers a comprehensive overview of **SAFESTART™** and also offer a train-the-trainer component that allows a hands-on opportunity to teach **SAFESTART™**. On day 3 the participants actually lead a unit. After the course, your company rolls out units 1-5 on your own.

**Option 2 - TTT Course, plus Overview.** We do 2-hour overview sessions for all your employees which cover the concepts from unit 1 and unit 2 completely. We then conduct a 3-day Train-The-Trainer course and your company rolls out units 3, 4 & 5 on your own.

**Option 3 - We do all the training in two sessions.** Each session lasts approximately 3 1/2 hours (1/2 day) by combining modules. We only do this to maximize our on-site time, we do not recommend that sessions be combined when using in-house facilitators. These sessions can be done one day to one month apart.

**Note:** Currently, option #2 is the most popular. Probably, because it makes efficient use of the “outside specialist”, and it shortens the training time - only 3 units left to roll out. It also makes it easier for the in-house trainers (as everyone has already been through a unit so they're familiar with the format).

## Testimonials

### **Irwin Research and Development, Inc. releases report on year-long SafeStart Study.**

In July of 2000, with the help of the State of Washington Department of Labor and Industries WISHA Grant Program, Irwin Research and Development, Inc. launched a year-long study into TWL Knowledge Group's **SAFESTART™** program. This in-depth evaluation was designed to determine whether or not the **SAFESTART™** program would increase workers' awareness of at risk habits and behaviors - subsequently decreasing the number of accidents. The study was kick-started with the implementation of a 22-question [survey](#).



The conclusion of the study reveals a good balance of both qualitative and quantitative data.

### [View Research Results](#)

Introduced in November, 1998, this advanced safety awareness program has reduced incidents in some of the harshest environments by as much as 80%. Read what some of our customers are saying about this exceptional program:

Over the last ten years I have investigated several “behavior based” safety programs, all of which had several shortcomings. I have more than ten years of experience in safety management and **SAFESTART™** was the first system that caught my attention and really made something “click” inside my head.

The process, as I like to refer to it, makes common sense common. For a municipality with a peak employment of nearly 1,000 doing jobs that vary greatly (fire, police, electric distribution, water production, wastewater treatment, inspection services, parks and recreation, etc.), we needed something that would be universal and easy to implement. **SAFESTART™** offered that. We needed something that could be easily understood by people with a variety of educational background and cultures. **SAFESTART™** offered that. We needed something that offered a universal message that was simple to recite. **SAFESTART™** offered that. We needed something with a proven track record in actual use. **SAFESTART™** offered that. Finally, we needed something that we could work into our budget (we don't have big budgets like some federal government departments do.) **SAFESTART™** offered that, too.

One of the other behavior-based safety programs may work for other industries, but for a municipality, I think **SAFESTART™** is the answer.

*Patrick Janis  
Risk Manager/Safety Coordinator  
City of College Station*

Before they read a meter or handle a collection, Field Revenue Services employees will do a quick self-evaluation as part of the newly implemented **SAFESTART™** program. Using **SAFESTART™**, personnel will question whether they are: rushing, fatigued, frustrated or complacent. AEP's research supports the programs premise that most near misses and accidents can be traced to these four problem areas of attitude and resulting behavior.

This program is attractive to us because our people often work alone, making peer observations difficult. We hope that the new self-observations will augment our tailgate safety huddles and regular safety meetings to keep safety on top in people's minds.

*Lead Safety Coordinator  
Field Revenue Services  
American Electric Power (AEP)*

One of the difficulties with safety training is, if you tell employees something today, how do you get them to remember it tomorrow, next week or next month. **SAFESTART™** provides tools and concepts, which apply to employee's lives 24 hours a day. Therefore, it has more meaning and value to them and is more likely to be remembered.

I think the value of **SAFESTART™** can best be described by a comment made by one of our employees who had averaged 2 injuries, requiring medical attention, per year for the last four years. During the third session the employee made the comment, "now I understand why I get hurt so much". Since April of 2000 this employee has not had an injury, even a minor one. In fact, the entire department has gone six months without a recordable accident.

**SAFESTART™** helps employees identify unsafe situations and behaviors and gives them the tools to correct bad habits.

*Bill High  
Safety Manager  
Leatherman Tool Group, Inc.*

In terms of the program content, participants felt that the training will help them be more safety conscious not only on-the-job but off-the-job as well. The presentation was found to be easy to follow with helpful videos and, while everyone does not like to read, most felt the workbooks covered the material well.

In 2001 we look forward to continuing to use **SAFESTART™** as a primary safety initiative with our workforce. We hope that positive results will continue and that we can make our workplace and our workforce safer.

*Robert A. Yocum  
Training Coordinator  
ITW Drawform*

## SafeStart Training for IceCube

1. June 18, 2008  
NANA Systems to train 12 Trainers Modules: 1-3 (1-day)
2. W/O:07/21 or W/O: 08/04  
NANA to train 12 Trainers: Modules:4-5 & certify (1-day)
  - 08/04—in time for deployers
3. W/O:07/21 or W/O: 08/04  
NANA Systems to provide up to 5, 90-minute Orientation or Module 1 sessions for all IceCubers
  - Drillers/Deployers/Scientists/222?
    - o 08/05?
4. W/O: 08/04  
Drillers/Deployers get modules: 2-3 trained by I3 trainers. (4 hours)
5. 08/08  
Modular training (1-3) for those IceCubers at 222. (I3 Trainers) 1-Day
6. 10/08  
Modular training (4-5) for those IceCubers at 222. (I3 Trainers) 4 hours
7. 11/08
  - Drillers get modules: 4-5 (2, 90-minute sessions)
  - Modified Modular Training for shorter term IceCubers. (2, 90-minute sessions)
8. 12/08 & 01/08
  - Modified refreshers for all (1-hour sessions) up to five total/month

### NOTES:

- Full season South Pole coverage with Trainers necessary.
- Will need trained trainers up North
- Consideration for all IceCubers: 222 and others
- Possible September Collaboration orientation training for Scientists

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APPENDIX K: Safety Plan: South Pole  
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APPENDIX L: Safety Plan: KRC Campus

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ICECUBE TEST BED:

1. Due to the fact that the Test Bed is no longer a construction site,  
  
Only limited PPE (Physical Protection Equipment) shall be worn:
  - a. Safety Glasses
  - b. Closed-toed shoes
  - c. Safety Shoes are only required when there is danger of foot injury as per below. (See PSL, Wisconsin COMM 32.50 (2).
2. Weekly Safety Walks-Through will occur. Members of the Management Team will walk-through the site to verify the mitigation of existing hazards or to report new ones. These walks-through will be a topic at the on-going Driller Meetings in an effort to keep safety on the forefront.
3. A Hazard's Analysis will be reviewed this summer at the Test Bed Site. These issues will be discussed during meetings and during the summer Driller Training.
4. A safety equipment cabinet has been set up and labeled at the Site. All safety equipment will be reviewed and stored there.
5. Prior to start-up, we will utilize checklists to confirm that all configurations are complete and that all safety precautions have been taken.
6. Once the Test Bed is started-up, the various tests to be performed will be planned, documented and scheduled according to the Test Bed Start-Up Checklist.
7. Nightly Shutdown and Lockup policies are in place for the Test Bed Site.

ICECUBE TOWER SITE:

1. We will follow the similar precautions as at the Tower at the Pole:
  - a. Hard Hats will be worn at all times.
  - b. Safety Glasses will be worn at all times.
  - c. Safety Shoes or Toe Guards are recommended. At a minimum, closed-toed shoes shall be worn at all times. (See PSL, Wisconsin COMM 32.50 (2))
2. Weekly Safety Walks-Through will occur.
3. A Hazards Analysis will take place, using the SP Tower HA as a reference.

### ICECUBE WAREHOUSE:

1. Safety Glasses will be worn by all.
2. DOM Handlers:
  - a. Steel-toed shoes and/or toe guards will be worn.
3. Hard Hats will be worn by those using the electric pallet jack due to the potential for falling objects.

### PSL PROTOCOLS:

All IceCube staff working at PSL, and using PSL tools and resources, must be registered. If you have not done so, or are unsure, please see Kristin Pernic in room 10 (877-2251). The registration process is very simple and includes, name, address, e-mail, emergency contact, etc. It is the responsibility of group leaders (management), who bring **new staff and students** to PSL, to ensure that they are registered. Should you no longer be working at PSL, please inform Kristin Pernic and return any keys issued to you by PSL.

Please also remember that PSL staff and wood shops are available to all qualified users. Bill Cotter is responsible for the assessment of the qualifications of the individual for the use of the piece of equipment requested. All users must check with Bill or Darrell Hamilton prior to using any machines or tools. All other machines and tools in the PSL mechanical and electronics shops are not available for use unless specifically authorized by Bill Cotter or Phil Robl.

If you are working late in the PSL Machine Shop, please inform Bill Cotter or Gary Anderson. Also, when operating Heavy machinery after hours (before 7:00AM and after 4:30PM), please utilize a form of the "Buddy System." Do not work completely alone.

#### 1. PROTECTIVE EYEWEAR

Because the potential exists for airborne/flying objects due to normal shop operations (grinding, etc.), persons walking through the PSL shop en route to the stockroom, outside entrances, DFL, etc. must remain within the main walkway areas outlined on the floor with yellow tape and **MUST** wear eye protection.

All personnel performing ANY type of work in the PSL shop **MUST** wear protective eyewear.

For those who do not have prescription safety glasses, general safety glasses can be found at the entryways to the PSL shop.

#### 2. PROTECTIVE FOOTWEAR

Because the potential exists for objects to fall, persons walking through the PSL shop en route to the stockroom, outside entrances, DFL, etc. must remain within the marked walkway areas outlined on the floor with yellow tape and are strongly encouraged to wear foot protection.



Wisconsin COMM 32.50 (2) requires protective footwear to be worn when working in areas where there is a danger of foot injuries due to falling or rolling objects, or objects piercing the sole, and where such employee's feet are exposed to electrical hazards. Toe guards are available

Always be alert as materials and supplies are being moved around the shop constantly. Aisles should be always kept open to allow safe passage.

### 3. KRC TORNADO / SEVERE WEATHER PROCEDURES

The tornado season in Wisconsin is typically from April to October. The majority of tornadoes occur in the early summer months. The most severe tornadoes occur in April and May. The peak time of day for tornadoes to occur is between 3 PM and 7 PM.

A “Tornado Watch” means weather conditions are favorable for the development of tornadoes in the area. Information on a “Tornado Watch” is given over radio and TV from the Weather Bureau or by emergency governmental agencies of the city and county.

A “Tornado Warning” means a tornado has actually been sighted in the area. The emergency sirens will sound a steady tone for three minutes or longer if there is any danger in the immediate area. The nearest emergency siren is located immediately to the southeast of the Kegonsa Research Campus (KRC), between KRC and Highway 51 / Lake Kegonsa.

KRC also has several severe weather radios, with the main radios located in the PSL tornado shelter (Room 90A), one located in the SRC lobby and another located in the SRC Experiment Preparation Area. When the severe weather radios go into alert/warning, whoever hears the alert/warning should dial “5” from any KRC phone to access the Public Address (PA) system, and announce “Tornado warning. Seek the nearest tornado shelter.” **KRC has two designated tornado shelters**, one at the SRC, the other at PSL. The **Experiment Prep Area in the lower level of the SRC building**, and the **east hallway in the PSL High Bay Lab Area (Room 90A)** are the two designated tornado shelters. Please take time to familiarize yourself with both tornado shelters in order to avoid any questions or confusion in the event of a real warning situation.

Immediately upon hearing the severe weather warning announcement, report to the nearest tornado shelter. Do not seek shelter in the trailers, machine shops, CNTech Annex, warehouse structures, or the Aladdin vault. Stay away from outside walls and glass windows or partitions.

While sheltered, keep listening to the weather radio for the latest tornado advisory information. Remain sheltered until the “All Clear” signal has been given over the radio.

Note: Call Dane County Emergency (911) only to report a tornado sighting.

### 4. KRC FIRE PROCEDURES

For any fire that may occur at KRC:

- A. Pull the nearest fire alarm immediately. If a fire alarm pull station is not immediately accessible, dial 911 to report the fire.
- B. Evacuate the building.

- C. Meet in the designated assembly area which is the northeast area of the PSL parking lot. Be certain to keep the east driveway open for emergency vehicle access.
- D. Call 911 (from a cell phone or different building) to follow up with more details, especially if the alarm was activated and no 911 call has been made. (Note: from KRC phones, you can dial 9-911 or 911.)
- E. Only attempt to fight the fire with a fire extinguisher if you can safely do so and after the alarm has been placed.

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 21:53:45

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	59.00 amps rms	[C5]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	130.00 amps rms	[09]
32	current limit	130.00 amps rms	[E7]
33	motor rms limit	72.00 amps rms	[71]
34	current rate limit	0 amps pk/sec	[18]
35	field current	23.29 amps rms	[23]
36	field boost	200 %	[68]
37	slip frequency	0.667 hertz	[91]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.0471 ohms	[B8]
44	leakage Sigma	Ls 0.00229 henries	[68]
45	Lm squared over Lr	0.02486 henries	[92]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	138.87 ftlb	[2A]
50	motor max torque	327.68 ftlb	[37]

51	motor rtd power	47.07 hp	[AD]	
52	motor max power	111.06 hp	[89]	
53	motor kt	2.562 ftlb/amp	[29]	
54	motor inertia	0.000 ftlbs^2	[94]	
55	machine inertia	0.410 ftlbs^2	[EA]	
56	acc obs bandwidth	40 rad/sec	[03]	
57	system gain id	29.287 1/sec/sec	[D7]	
58	system gain	29.287 1/sec/sec	[C3]	
59	system wn	20.0 rad/sec	[5A]	
60	system order	VELOCITY	[1D]	
61	kv cmd	0.000 upid gain	[D8]	
62	kp cmd	13.658 upid gain	[96]	
63	ki	0.0 upid gain	[97]	
64	kp fbk	13.658 upid gain	[95]	
65	kv fbk	1.183 upid gain	[C8]	
66	kr	1.000 upid gain	[2A]	
67	kp cmd percent	0 %	[D1]	
68	ki load enable	DISABLE	[56]	
69	kp load ratio	0 %	[35]	
70	kv load ratio	0 %	[37]	
71	torque limit	44.00 % max	[0B]	
72	low pass frequency	100.0 hertz	[33]	
73	low pass damping	1.414 gain	[A9]	
74	notch frequency	0.0 hertz	[9F]	
75	notch damping	1.414 gain	[B4]	
76	system gain 1	29.287 1/sec/sec	[72]	
77	system wn 1	20.0 rad/sec	[09]	
78	system order 1	TORQUE	[52]	
79	kv cmd 1	0.000 upid gain	[7E]	
80	kp cmd 1	0.683 upid gain	[7B]	
81	ki 1	0.0 upid gain	[46]	
82	kp fbk 1	0.683 upid gain	[7A]	
83	kv fbk 1	0.000 upid gain	[84]	
84	kr 1	0.000 upid gain	[DA]	
85	kp cmd percent 1	0 %	[80]	
86	ki load enable 1	DISABLE	[05]	
87	kp load ratio 1	0 %	[E4]	
88	kv load ratio 1	0 %	[DD]	
89	torque limit 1	100.00 % max	[88]	
90	low pass frequency 1	100.0 hertz	[E2]	
91	low pass damping 1	1.414 gain	[58]	
92	notch frequency 1	10.0 hertz	[4E]	
93	notch damping 1	1.414 gain	[63]	
94	torque invert	DISABLE	[1A]	
95	base rpm	1780 rpm	[3C]	
96	max vel	540.0 fpm	[7D]	
97	jog vel	175.0 fpm	[7E]	
98	!max motor rpm	1800.0 rpm	[C5]	
99	accel time	3.000 sec	[6E]	
100	decel time	3.000 sec	[4A]	
101	jerk time	0.000 sec	[9D]	
102	settle time	0.200 sec	[B5]	
103	accel time 1	1.000 sec	[FD]	
104	decel time 1	3.000 sec	[F5]	
105	jerk time 1	10.000 sec	[48]	
106	settle time 1	0.200 sec	[60]	
107	fast decel time	0.200 sec	[76]	
108	drive invert	DISABLE	[74]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.028 gain	[0D]	
121	dsv ki	2.816 gain	[60]	
122	dsv kp fbk	0.028 gain	[0C]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm      [2F]
168 dac offset iu      -4    pulses  [6A]
169 dac offset iv       2    pulses  [97]
170 adc offset iu       1    pulses  [A1]
171 adc offset iv       0    pulses  [A0]
172 adc offset fu       0    pulses  [A3]
173 adc offset fv       0    pulses  [A1]
174 adc 1 select        VOLTS      [66]
175 adc 1 set  DISABLED          [19]
176 adc 1 min  -10.00    %       [17]
177 adc 1 max   160.00    %       [0B]
178 adc 1 min volts  5.229 volts [C6]
179 adc 1 max volts  8.598 volts [B7]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value  5.927 volts [BB]
182 !adc 1 value     25.26 %     [3F]
183 adc 2 select        VOLTS      [65]
184 adc 2 set  DISABLED          [18]
185 adc 2 min  -10.00    %       [16]
186 adc 2 max   160.00    %       [0A]
187 adc 2 min volts  5.234 volts [C9]
188 adc 2 max volts  8.618 volts [BD]
189 adc 2 destination-1          [97]
190 !adc 2 raw value  5.834 volts [BD]
191 !adc 2 value     20.18 %     [42]
192 adc 3 select        VOLTS      [64]
193 adc 3 set  DISABLED          [17]
194 adc 3 min  -10.00    %       [15]
195 adc 3 max   160.00    %       [09]
196 adc 3 min volts  5.219 volts [C5]
197 adc 3 max volts  8.598 volts [B5]
198 adc 3 destination-1          [96]
199 !adc 3 raw value  5.805 volts [B5]
200 !adc 3 value     19.76 %     [3E]
201 dac clock level  DRIVE CLOCK [AE]
202 dac 1 select        TORQUE CMD [32]
203 dac 1 ptr   28965          [41]
204 dac 1 item  0              [C5]
205 dac 1 mul   1              [24]
206 dac 1 div   1              [2E]
207 dac 1 abs  DISABLE          [77]
208 !dac 1 output  0.000 volts  [A8]
209 dac 2 select        UPID VEL FBK [D2]
210 dac 2 ptr   26033          [52]
211 dac 2 item  0              [C6]
212 dac 2 mul   32767          [4D]
213 dac 2 div   125829         [25]
214 dac 2 abs  DISABLE          [78]
215 !dac 2 output  0.000 volts  [A9]
216 level 1 password 1111      [7A]
217 level 2 password 0         [0C]
218 level 3 password 0         [0A]
219 lockout time     900.000    sec [D5]
220 !lockout status  LOCKED     [A7]
221 ssi rx mode  DISABLED       [E8]
222 !ssi rx value   0           [56]
223 ssi torque offset0.00 %    [A3]
224 ssi tx mode  DISABLED       [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	35		[D9]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	35		[A6]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	86.45 amps rms			[84]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	716 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	40542026.7212	in		[5C]
275	!feedback pos	40542026.7212	in		[15]
276	!in word 0	000081	\$		[03]
277	!out word 0	000004	\$		[86]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000002	\$		[19]
282	!int word 0	000a00	\$		[6A]

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294965951			[E8]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967294			[9D]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	4			[7A]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	4			[AE]
307	test cycle rpm	1000.0	rpm		[6C]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	600.0	rpm		[65]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque 90	%			[2B]
317	test degrees	180.00	deg		[22]
318	test i field	8.60	amps rms		[DB]
319	test volts 0	volts			[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	240.0	fpm		[B9]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]



```

341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 80.00 % max [59]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos40542026.7212 in [5E]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	IN 7	[87]	
420	motor blower ok req	REQ FORCED ON	[87]	[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT OFF	[94]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS PLC	[78]	
442	out 2	STS PLC	[76]	
443	out 3	STS PLC	[74]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	HIGH PRESS PUMP		[05]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	100.00	% rtd	[94]
483	pend max vel	540.0 fpm		[86]
484	pend index pos	0.0000	in	[ED]
485	pend index vel	3.0 fpm		[18]
486	comp req torq	0.00	% rtd	[E7]
487	comp req vel	240.0 fpm		[7B]
488	comp index pos	4.6800	in	[CF]
489	comp index vel	14.1 fpm		[D9]
490	comp request word0			[52]
491	!comp status word0			[95]
492	comp timeout	0.000 sec		[35]
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000	in	[2F]
496	payout preset	0.0000	in	[E6]
497	!index start pos	0.0000	in	[41]
498	!tension error	0.00 lb		[37]
499	!tgt hose tension	0.00 lb		[42]
500	!hose tension	0.00 lb		[C2]
501	!cable tension	0.00 lb		[79]
502	hose filter gain	0.00000	gain	[3B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	0 %		[76]
505	cable filter gain	0.00000	gain	[F0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000	in/sec/lb	[59]
508	!actual fine control	0.0000	in/sec/lb	[5C]
509	fade filter gain	0.00000	gain	[53]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %		[03]
513	coil min od	0.0000	in	[47]
514	coil max od	0.0000	in	[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	600	volts rms	[97]		
536	hi-spd line low limt	600	volts rms	[A0]		
537	high-low vel cutoff	1400	rpm	[F3]		
538	!Motor Temp. Celsius	25.35	deg	[F8]		
539	!Elec. Closet Temp.	20.31	deg	[D8]		
540	!Pump Room Temp.	19.73	deg	[A4]		
541	Elec Closet Set Pt.	20.00	deg	[B8]		
542	Pump Room Set Pt.	20.00	deg	[5B]		
543	Temp Hysteresis	1.00	deg	[5F]		
544	Mode	Computer Control		[61]		
545	Start	DISABLE		[33]		
546	!Mtr Current Flitered	0.00	amps rms	[AD]		
547	RP Loss Trip	7.50	amps rms	[24]		
548	RP Rise Trip	75.00	amps rms	[01]		
549	1 bit pump	ENABLE		[18]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	13:13:01	Fault				
901	!FH 2 20011002	charge pump pressure		[CD]	\$	
	20/Jan/2010 08:32:12	Fault				
902	!FH 3 18011017	external trip		[61]	\$	18/Jan/2010
	11:05:57	Fault				
903	!FH 4 18011002	charge pump pressure		[C2]	\$	
	18/Jan/2010 09:43:17	Fault				
904	!FH 5 15011002	charge pump pressure		[C3]	\$	
	15/Jan/2010 16:15:56	Fault				
905	!FH 6 15011002	charge pump pressure		[C1]	\$	
	15/Jan/2010 13:36:57	Fault				
906	!FH 7 15011002	charge pump pressure		[BF]	\$	
	15/Jan/2010 13:01:26	Fault				
907	!FH 8 15011002	charge pump pressure		[BD]	\$	
	15/Jan/2010 10:52:23	Fault				
908	!FH 9 14011002	charge pump pressure		[BC]	\$	
	14/Jan/2010 08:56:59	Fault				
909	!FH10 13011002	charge pump pressure		[B4]	\$	
	13/Jan/2010 18:10:54	Fault				
910	!FH11 12011002	charge pump pressure		[BC]	\$	
	12/Jan/2010 11:15:57	Fault				

911	!FH12 12011001	line undervoltage	[C8]	\$	12/Jan/2010
	11:11:57	Fault			
912	!FH13 12011017	external trip	[55]	\$	12/Jan/2010
	11:11:49	Fault			
913	!FH14 12011002	charge pump pressure	[B6]	\$	
	12/Jan/2010 07:17:05	Fault			
914	!FH15 11011017	EXTERNAL TRIP	[D2]	\$	11/Jan/2010
	14:08:42	Fault			
915	!FH16 11011014	IREG SHUTOFF	[2F]	\$	11/Jan/2010
	14:08:42	Fault			
916	!FH17 10011002	charge pump pressure	[B2]	\$	
	10/Jan/2010 15:43:53	Fault			
917	!FH18 10011002	charge pump pressure	[B0]	\$	
	10/Jan/2010 11:59:00	Fault			
918	!FH19 09011002	charge pump pressure	[A6]	\$	
	09/Jan/2010 21:35:22	Fault			
919	!FH20 09011004	DEAD HEAD	[50]	\$	09/Jan/2010 21:34:56
		Fault			
920	!FH21 09011002	charge pump pressure	[B4]	\$	
	09/Jan/2010 21:26:47	Fault			
921	!FH22 09011004	DEAD HEAD	[55]	\$	09/Jan/2010 21:26:18
		Fault			
922	!FH23 09011002	charge pump pressure	[B0]	\$	
	09/Jan/2010 21:15:22	Fault			
923	!FH24 09011004	DEAD HEAD	[51]	\$	09/Jan/2010 21:14:12
		Fault			
924	!FH25 09011002	charge pump pressure	[AC]	\$	
	09/Jan/2010 21:07:42	Fault			
925	!FH26 09011004	DEAD HEAD	[4D]	\$	09/Jan/2010 21:07:12
		Fault			
926	!FH27 09011002	charge pump pressure	[A8]	\$	
	09/Jan/2010 21:06:01	Fault			
927	!FH28 09011004	DEAD HEAD	[49]	\$	09/Jan/2010 21:05:04
		Fault			
928	!FH29 09011004	DEAD HEAD	[47]	\$	09/Jan/2010 21:02:50
		Fault			
929	!FH30 09011002	charge pump pressure	[AB]	\$	
	09/Jan/2010 21:00:21	Fault			
930	!FH31 09011004	DEAD HEAD	[55]	\$	09/Jan/2010 20:56:36
		Fault			
931	!FH32 09011002	charge pump pressure	[B0]	\$	
	09/Jan/2010 20:50:30	Fault			
932	!FH33 09011002	charge pump pressure	[AE]	\$	
	09/Jan/2010 20:47:03	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled

```

\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg tol 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 1 - Enabled  
\$ Charge Pump Pressure 1 - Enabled  
\$ Rapid Pressure Chg 1 - Enabled  
\$ Dead Head 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled  
\$ user fault 12 req 1 - Enabled  
\$ user fault 13 req 1 - Enabled  
\$ user fault 14 req 1 - Enabled  
\$ user fault 15 req 1 - Enabled  
\$ user fault 16 req 1 - Enabled  
\$ user fault 17 req 1 - Enabled  
\$ user fault 18 req 1 - Enabled  
\$ user fault 19 req 1 - Enabled  
\$ user fault 20 req 1 - Enabled  
\$ user fault 21 req 1 - Enabled  
\$ user fault 22 req 1 - Enabled  
\$ user fault 23 req 1 - Enabled  
\$ user fault 24 req 1 - Enabled  
\$ user fault 25 req 1 - Enabled  
\$ user fault 26 req 1 - Enabled  
\$ user fault 27 req 1 - Enabled  
\$ user fault 28 req 1 - Enabled  
\$ user fault 29 req 1 - Enabled

```
$ user fault 30 req1 - Enabled
$ user fault 31 req1 - Enabled

$ Warning Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage0 - Disabled
$ Charge Pump Pressure 0 - Disabled
$ Rapid Pressure Chg 0 - Disabled
$ Dead Head 0 - Disabled
$ user fault 5 req 0 - Disabled
$ user fault 6 req 0 - Disabled
$ user fault 7 req 0 - Disabled
$ user fault 8 req 0 - Disabled
$ user fault 9 req 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
```

\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled



\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:05:40

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	59.00 amps rms	[C5]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	130.00 amps rms	[09]
32	current limit	130.00 amps rms	[E7]
33	motor rms limit	72.00 amps rms	[71]
34	current rate limit	0 amps pk/sec	[18]
35	field current	23.35 amps rms	[26]
36	field boost	200 %	[68]
37	slip frequency	0.667 hertz	[91]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.0466 ohms	[B4]
44	leakage Sigma	Ls 0.00227 henries	[6A]
45	Lm squared over Lr	0.02461 henries	[99]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	137.81 ftlb	[31]
50	motor max torque	325.27 ftlb	[3E]

51	motor rtd power	46.71 hp	[AD]
52	motor max power	110.24 hp	[8A]
53	motor kt	2.544 ftlb/amp	[29]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.407 ftlbs^2	[E4]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	27.401 1/sec/sec	[E5]
58	system gain	27.401 1/sec/sec	[D1]
59	system wn	20.0 rad/sec	[5A]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	14.598 upid gain	[92]
63	ki	0.0 upid gain	[97]
64	kp fbk	14.598 upid gain	[91]
65	kv fbk	1.264 upid gain	[C8]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	44.00 % max	[0B]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	27.401 1/sec/sec	[80]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.730 upid gain	[82]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.730 upid gain	[81]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1780 rpm	[3C]
96	max vel	540.0 fpm	[7D]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	1800.0 rpm	[C5]
99	accel time	3.000 sec	[6E]
100	decel time	3.000 sec	[4A]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	3.000 sec	[F5]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	DISABLE	[74]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.027 gain	[0E]	
121	dsv ki	2.791 gain	[5E]	
122	dsv kp fbk	0.027 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm      [2F]
168 dac offset iu      20    pulses  [69]
169 dac offset iv     -34    pulses  [35]
170 adc offset iu      24    pulses  [6C]
171 adc offset iv     -17    pulses  [3B]
172 adc offset fu     -25    pulses  [3F]
173 adc offset fv     -20    pulses  [42]
174 adc 1 select      VOLTS      [66]
175 adc 1 set    DISABLED      [19]
176 adc 1 min   -10.00    %      [17]
177 adc 1 max   160.00    %      [0B]
178 adc 1 min volts  5.239 volts [C5]
179 adc 1 max volts  8.598 volts [B7]
180 adc 1 destination-1      [A1]
181 !adc 1 raw value 6.181 volts [C2]
182 !adc 1 value    37.95 %      [36]
183 adc 2 select      VOLTS      [65]
184 adc 2 set    DISABLED      [18]
185 adc 2 min    0.00    %      [74]
186 adc 2 max    0.00    %      [71]
187 adc 2 min volts  0.000 volts [D7]
188 adc 2 max volts  0.000 volts [D4]
189 adc 2 destination-1      [97]
190 !adc 2 raw value 0.024 volts [CB]
191 !adc 2 value    0.00    %      [7D]
192 adc 3 select      VOLTS      [64]
193 adc 3 set    DISABLED      [17]
194 adc 3 min    0.00    %      [73]
195 adc 3 max    0.00    %      [70]
196 adc 3 min volts  0.000 volts [D6]
197 adc 3 max volts  0.000 volts [D3]
198 adc 3 destination-1      [96]
199 !adc 3 raw value 0.009 volts [BE]
200 !adc 3 value    0.00    %      [85]
201 dac clock level  DRIVE CLOCK [AE]
202 dac 1 select      TORQUE CMD [32]
203 dac 1 ptr    28965          [41]
204 dac 1 item 0              [C5]
205 dac 1 mul    1              [24]
206 dac 1 div    1              [2E]
207 dac 1 abs    DISABLE      [77]
208 !dac 1 output  0.000 volts  [A8]
209 dac 2 select      UPID VEL FBK [D2]
210 dac 2 ptr    26033          [52]
211 dac 2 item 0              [C6]
212 dac 2 mul    32767          [4D]
213 dac 2 div    125829         [25]
214 dac 2 abs    DISABLE      [78]
215 !dac 2 output  0.000 volts  [A9]
216 level 1 password 1111      [7A]
217 level 2 password 0         [0C]
218 level 3 password 0         [0A]
219 lockout time    900.000    sec [D5]
220 !lockout status LOCKED      [A7]
221 ssi rx mode DISABLED      [E8]
222 !ssi rx value  0            [56]
223 ssi torque offset0.00    %  [A3]
224 ssi tx mode DISABLED      [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	36		[D8]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	36		[A5]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	86.45 amps rms			[84]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	730 volts		[E5]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	19.95 amps rms			[3E]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	34760315.1226	in		[57]
275	!feedback pos	34760315.1226	in		[10]
276	!in word 0	000081	\$		[03]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000002	\$		[19]
282	!int word 0	000800	\$		[93]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967294		[9D]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	4		[7A]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	4		[AE]
307	test cycle rpm	1000.0	rpm	[6C]
308	test id min rpm	0.0	rpm	[DB]
309	test jog rpm	600.0	rpm	[65]
310	test max rpm	900.0	rpm	[64]
311	test min rpm	-900.0	rpm	[38]
312	test period	0.000	sec	[B1]
313	test ramp	DISABLE		[B8]
314	test position	10.000	rev	[7A]
315	test time	1.000	sec	[81]
316	test torque	90	%	[2B]
317	test degrees	180.00	deg	[22]
318	test i field	8.60	amps rms	[DB]
319	test volts	0	volts	[B6]
320	test length	24.0001	in	[B0]
321	test accel time	4.000	sec	[69]
322	test freq ramp time	6.000	sec	[E0]
323	test adc	1		[02]
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0	fpm	[0E]
330	vel preset 1	0.0	fpm	[21]
331	vel preset 2	291.0	fpm	[B3]
332	vel preset 3	0.0	fpm	[1D]
333	vel preset 4	0.0	fpm	[1B]
334	vel preset 5	0.0	fpm	[19]
335	vel preset 6	0.0	fpm	[17]
336	vel preset 7	0.0	fpm	[15]
337	vel preset 8	0.0	fpm	[13]
338	vel offset	0.0	fpm	[76]
339	vel gain	100.00	%	[EA]
340	vel tolerance	0.0	fpm	[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 80.00 % max [59]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos34760315.1226 in [59]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	IN 7	[87]	
420	motor blower ok req	REQ FORCED ON	[87]	[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT OFF	[94]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	HIGH PRESS PUMP		[05]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	100.00	% rtd	[94]
483	pend max vel	540.0 fpm		[86]
484	pend index pos	0.0000	in	[ED]
485	pend index vel	3.0 fpm		[18]
486	comp req torq	0.00	% rtd	[E7]
487	comp req vel	240.0 fpm		[7B]
488	comp index pos	0.0000	in	[E1]
489	comp index vel	0.0 fpm		[0F]
490	comp request word0			[52]
491	!comp status word0			[95]
492	comp timeout	0.000 sec		[35]
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000	in	[2F]
496	payout preset	0.0000	in	[E6]
497	!index start pos	0.0000	in	[41]
498	!tension error	0.00 lb		[37]
499	!tgt hose tension	0.00 lb		[42]
500	!hose tension	0.00 lb		[C2]
501	!cable tension	0.00 lb		[79]
502	hose filter gain	0.97000	gain	[2B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	25 %		[3F]
505	cable filter gain	0.97000	gain	[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000	in/sec/lb	[59]
508	!actual fine control	0.0000	in/sec/lb	[5C]
509	fade filter gain	0.97000	gain	[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %		[03]
513	coil min od	0.0000	in	[47]
514	coil max od	0.0000	in	[44]

515	coil diameter	0.0000	in	[31]	
516	!coil circumference	0.0000	in	[FF]	
517	coil usage	0.0	ft	[F2]	
518	coil source	MOTOR SOCKET		[63]	
519	material source	MOTOR SOCKET		[BA]	
520	coil od limit	DISABLE		[6F]	
521	coil od rate	0.0000	in	[E0]	
522	coil update distance	2.0002	in	[8C]	
523	level direction	NONE		[10]	
524	!level drum velocity	0.0	rpm	units:10	[ED]
525	level follow gain	0.000	gain	[20]	
526	!level follow vel	0.0	fpm	[12]	
527	!level follow req vel	0.0	fpm	[A9]	
528	level follow vel off	0.0	fpm	[D6]	
529	level circumference	3.6000	in	[A2]	
530	level dwell count	0		[72]	
531	!level circ count	0		[C7]	
532	!index pos	0.0000	in	[99]	
533	!drive control mode	NONE		[E7]	
534	pend disable time	0.000	sec	[A4]	
535	lo-spd line low limt	600	volts rms	[97]	
536	hi-spd line low limt	600	volts rms	[A0]	
537	high-low vel cutoff	1400	rpm	[F3]	
538	!Motor Temp. Celsius	38.23	deg	[F7]	
539	!Elec. Closet Temp.	0.00	deg	[0E]	
540	!Pump Room Temp.	0.00	deg	[E8]	
541	Elec Closet Set Pt.	20.00	deg	[B8]	
542	Pump Room Set Pt.	20.00	deg	[5B]	
543	Temp Hysteresis	3.00	deg	[5D]	
544	Mode	Computer Control		[61]	
545	Start	DISABLE		[33]	
546	!Mtr Current Filtered	0.00	amps rms	[AD]	
547	RP Loss Trip	7.50	amps rms	[24]	
548	RP Rise Trip	75.00	amps rms	[01]	
549	1 bit pump	ENABLE		[18]	
900	!FH 1 20011002	charge pump pressure		[CF]	\$
	20/Jan/2010 17:02:36	Fault			
901	!FH 2 20011002	charge pump pressure		[CD]	\$
	20/Jan/2010 15:32:38	Fault			
902	!FH 3 20011002	charge pump pressure		[CB]	\$
	20/Jan/2010 13:38:51	Fault			
903	!FH 4 20011017	EXTERNAL TRIP		[E6]	\$ 20/Jan/2010
	13:16:06	Fault			
904	!FH 5 20011014	IREG SHUTOFF		[43]	\$ 20/Jan/2010
	13:16:06	Fault			
905	!FH 6 20011002	charge pump pressure		[C5]	\$
	20/Jan/2010 10:03:59	Fault			
906	!FH 7 18011017	external trip		[59]	\$ 18/Jan/2010
	11:08:58	Fault			
907	!FH 8 18011002	charge pump pressure		[BA]	\$
	18/Jan/2010 09:46:20	Fault			
908	!FH 9 15011002	charge pump pressure		[BB]	\$
	15/Jan/2010 09:35:07	Fault			
909	!FH10 14011002	charge pump pressure		[B3]	\$
	14/Jan/2010 08:59:56	Fault			
910	!FH11 13011002	charge pump pressure		[BB]	\$
	13/Jan/2010 16:10:33	Fault			

```

911 !FH12 12011002 charge pump pressure [BA] $
12/Jan/2010 11:18:53 Fault
912 !FH13 12011001 line undervoltage [C6] $ 12/Jan/2010
11:14:50 Fault
913 !FH14 12011017 external trip [53] $ 12/Jan/2010
11:14:43 Fault
914 !FH15 12011002 charge pump pressure [B4] $
12/Jan/2010 07:19:59 Fault
915 !FH16 11011017 EXTERNAL TRIP [D0] $ 11/Jan/2010
14:11:35 Fault
916 !FH17 11011014 IREG SHUTOFF [2D] $ 11/Jan/2010
14:11:35 Fault
917 !FH18 09011002 charge pump pressure [A8] $
09/Jan/2010 21:48:51 Fault
918 !FH19 09011004 DEAD HEAD [49] $ 09/Jan/2010 21:48:31
Fault

```

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor resolv 1 loss 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg tol 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

```

\$ computer timeout 0 - Disabled  
\$ Line Undervoltage1 - Enabled  
\$ Charge Pump Pressure 1 - Enabled  
\$ Rapid Pressure Chg 1 - Enabled  
\$ Dead Head 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled  
  
\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled

\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

```
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END



\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 21:59:47

DATA\_START

```
UNITS 2      [29]
0  unit system ENGLISH          [14]
1  position units  REV          [ED]
2  velocity units  MINUTES      [BA]
3  hertz units DISABLE          [2C]
4  clock frequency 50  hertz    [0F]
5  drive multiple  1           [C7]
6  upid multiple   10          [FE]
7  ac multiple 2           [1A]
8  ac fast multiple 1         [4C]
9  vector source  MOTOR SOCKET [DC]
10 upid motor source MOTOR SOCKET [44]
11 upid load source LOAD SOCKET [45]
12 load vector control  DISABLE [08]
13 transducerless  ENABLE      [D6]
14 motor fbk size  2048 pulses/rev [29]
15 motor resolution 3.6000 in/rev [4E]
16 motor fbk invert DISABLE    [3C]
17 motor input teeth1          [7F]
18 motor output teeth 1        [FD]
19 motor encoder bits  BITS 0  [E4]
20 motor encoder turns  1      [B3]
21 load fbk size  0  pulses/rev [5A]
22 load resolution 10.0001 in/rev [B8]
23 load fbk invert  DISABLE    [CF]
24 load input teeth 1          [12]
25 load output teeth1          [90]
26 load encoder bits BITS 0    [77]
27 load encoder turns  1      [3D]
28 motor rated voltage 460 volts [24]
29 motor rated current 59.00 amps rms [C5]
30 motor rated frequency 60 hertz [8A]
31 maximum current 130.00 amps rms [09]
32 current limit 130.00 amps rms [E7]
33 motor rms limit 72.00 amps rms [71]
34 current rate limit 0  amps pk/sec [18]
35 field current 23.76 amps rms [21]
36 field boost 200 % [68]
37 slip frequency 0.667 hertz [91]
38 motor poles 4 [C0]
39 synchronous motor DISABLE [57]
40 vector offset 0.00 deg [47]
41 vector ffwd 0.00000 sec [8B]
42 torque ffwd 0.00 deg [18]
43 stator resistance Rs 0.0465 ohms [B5]
44 leakage Sigma Ls 0.00226 henries [6B]
45 Lm squared over Lr 0.02433 henries [9A]
46 current filter 2.00 hertz [D3]
47 voltage filter 2.00 hertz [E3]
48 power filter 2.00 hertz [A7]
49 motor rtd torque 138.16 ftlb [32]
50 motor max torque 327.00 ftlb [45]
```

51	motor rtd power	46.82 hp	[AB]
52	motor max power	110.83 hp	[85]
53	motor kt	2.558 ftlb/amp	[24]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.409 ftlbs^2	[E2]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	32.537 1/sec/sec	[DF]
58	system gain	32.537 1/sec/sec	[CB]
59	system wn	20.0 rad/sec	[5A]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	12.294 upid gain	[9B]
63	ki	0.0 upid gain	[97]
64	kp fbk	12.294 upid gain	[9A]
65	kv fbk	1.065 upid gain	[C9]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	43.00 % max	[0C]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	32.537 1/sec/sec	[7A]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.615 upid gain	[80]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.615 upid gain	[7F]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1780 rpm	[3C]
96	max vel	540.0 fpm	[7D]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	1800.0 rpm	[C5]
99	accel time	3.000 sec	[6E]
100	decel time	3.000 sec	[4A]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	3.000 sec	[F5]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	DISABLE	[74]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.027 gain	[0E]	
121	dsv ki	2.779 gain	[58]	
122	dsv kp fbk	0.027 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

```

167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -2    pulses      [6C]
169 dac offset iv      -14   pulses      [37]
170 adc offset iu       19   pulses      [68]
171 adc offset iv      -32   pulses      [3E]
172 adc offset fu       0    pulses      [A3]
173 adc offset fv      -12   pulses      [41]
174 adc 1 select        VOLTS          [66]
175 adc 1 set   DISABLED          [19]
176 adc 1 min   -10.00    %        [17]
177 adc 1 max   160.00    %        [0B]
178 adc 1 min volts  5.250 volts    [CC]
179 adc 1 max volts  8.588 volts    [B8]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value 5.878 volts    [B6]
182 !adc 1 value    22.03 %        [47]
183 adc 2 select        VOLTS          [65]
184 adc 2 set   DISABLED          [18]
185 adc 2 min   0.00    %        [74]
186 adc 2 max   0.00    %        [71]
187 adc 2 min volts  0.000 volts    [D7]
188 adc 2 max volts  0.000 volts    [D4]
189 adc 2 destination-1          [97]
190 !adc 2 raw value 0.034 volts    [CA]
191 !adc 2 value    0.00    %        [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set   DISABLED          [17]
194 adc 3 min   0.00    %        [73]
195 adc 3 max   0.00    %        [70]
196 adc 3 min volts  0.000 volts    [D6]
197 adc 3 max volts  0.000 volts    [D3]
198 adc 3 destination-1          [96]
199 !adc 3 raw value 0.009 volts    [BE]
200 !adc 3 value    0.00    %        [85]
201 dac clock level  DRIVE CLOCK    [AE]
202 dac 1 select        TORQUE CMD    [32]
203 dac 1 ptr   28965          [41]
204 dac 1 item  0              [C5]
205 dac 1 mul   1              [24]
206 dac 1 div   1              [2E]
207 dac 1 abs   DISABLE        [77]
208 !dac 1 output 0.000 volts    [A8]
209 dac 2 select        UPID VEL FBK  [D2]
210 dac 2 ptr   26033          [52]
211 dac 2 item  0              [C6]
212 dac 2 mul   32767          [4D]
213 dac 2 div   125829         [25]
214 dac 2 abs   DISABLE        [78]
215 !dac 2 output 0.000 volts    [A9]
216 level 1 password 1111        [7A]
217 level 2 password 0           [0C]
218 level 3 password 0           [0A]
219 lockout time    900.000    sec    [D5]
220 !lockout status LOCKED        [A7]
221 ssi rx mode DISABLED          [E8]
222 !ssi rx value   0            [56]
223 ssi torque offset0.00 %      [A3]
224 ssi tx mode DISABLED          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	37		[D7]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	37		[A4]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	86.45 amps rms			[84]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	674 volts		[DE]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	33310488.9490	in		[4B]
275	!feedback pos	33310488.9490	in		[04]
276	!in word 0	000081	\$		[03]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000002	\$		[19]
282	!int word 0	000a00	\$		[6A]

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294965951			[E8]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967294			[9D]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	4			[7A]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	4			[AE]
307	test cycle rpm	1000.0	rpm		[6C]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	600.0	rpm		[65]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque 90	%			[2B]
317	test degrees	180.00	deg		[22]
318	test i field	8.60	amps rms		[DB]
319	test volts 0	volts			[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	217.5	fpm		[B0]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 80.00 % max [59]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos33310488.9490 in [4D]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	IN 7	[87]	
420	motor blower ok req	REQ FORCED ON	[87]	[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT OFF	[94]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	



457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	HIGH PRESS PUMP		[05]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	100.00	% rtd	[94]
483	pend max vel	540.0 fpm		[86]
484	pend index pos	0.0000	in	[ED]
485	pend index vel	3.0 fpm		[18]
486	comp req torq	0.00	% rtd	[E7]
487	comp req vel	382.5 fpm		[6F]
488	comp index pos	0.0000	in	[E1]
489	comp index vel	0.0 fpm		[0F]
490	comp request word0			[52]
491	!comp status word0			[95]
492	comp timeout	0.000 sec		[35]
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000	in	[2F]
496	payout preset	0.0000	in	[E6]
497	!index start pos	0.0000	in	[41]
498	!tension error	0.00 lb		[37]
499	!tgt hose tension	0.00 lb		[42]
500	!hose tension	0.00 lb		[C2]
501	!cable tension	0.00 lb		[79]
502	hose filter gain	0.97000	gain	[2B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	25 %		[3F]
505	cable filter gain	0.97000	gain	[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000	in/sec/lb	[59]
508	!actual fine control	0.0000	in/sec/lb	[5C]
509	fade filter gain	0.97000	gain	[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %		[03]
513	coil min od	0.0000	in	[47]
514	coil max od	0.0000	in	[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	600	volts rms	[97]		
536	hi-spd line low limt	600	volts rms	[A0]		
537	high-low vel cutoff	1400	rpm	[F3]		
538	!Motor Temp. Celsius	22.01	deg	[02]		
539	!Elec. Closet Temp.	0.00	deg	[0E]		
540	!Pump Room Temp.	0.00	deg	[E8]		
541	Elec Closet Set Pt.	20.00	deg	[B8]		
542	Pump Room Set Pt.	20.00	deg	[5B]		
543	Temp Hysteresis	3.00	deg	[5D]		
544	Mode	Computer Control		[61]		
545	Start	DISABLE		[33]		
546	!Mtr Current Filtered	0.00	amps rms	[AD]		
547	RP Loss Trip	7.50	amps rms	[24]		
548	RP Rise Trip	75.00	amps rms	[01]		
549	1 bit pump	ENABLE		[18]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	13:11:45	Fault				
901	!FH 2 20011002	charge pump pressure		[CD]	\$	
	20/Jan/2010 08:30:55	Fault				
902	!FH 3 18011017	external trip		[61]	\$	18/Jan/2010
	11:04:41	Fault				
903	!FH 4 18011002	charge pump pressure		[C2]	\$	
	18/Jan/2010 09:42:27	Fault				
904	!FH 5 15011002	charge pump pressure		[C3]	\$	
	15/Jan/2010 09:30:51	Fault				
905	!FH 6 14011002	charge pump pressure		[C2]	\$	
	14/Jan/2010 08:55:47	Fault				
906	!FH 7 13011002	charge pump pressure		[C1]	\$	
	13/Jan/2010 16:05:42	Fault				
907	!FH 8 12011002	charge pump pressure		[C0]	\$	
	12/Jan/2010 11:14:44	Fault				
908	!FH 9 12011001	line undervoltage		[CC]	\$	12/Jan/2010
	11:10:40	Fault				
909	!FH10 12011002	charge pump pressure		[B5]	\$	
	12/Jan/2010 11:10:38	Fault				
910	!FH11 12011017	EXTERNAL TRIP		[D9]	\$	12/Jan/2010
	11:10:35	Fault				

911 !FH12 12011002 charge pump pressure [BA] \$  
 12/Jan/2010 10:52:46 Fault  
 912 !FH13 12011002 charge pump pressure [B8] \$  
 12/Jan/2010 08:51:34 Fault  
 913 !FH14 12011002 charge pump pressure [B6] \$  
 12/Jan/2010 08:32:18 Fault  
 914 !FH15 12011002 charge pump pressure [B4] \$  
 12/Jan/2010 08:07:05 Fault  
 915 !FH16 11011017 EXTERNAL TRIP [D0] \$ 11/Jan/2010  
 14:07:28 Fault  
 916 !FH17 09011002 charge pump pressure [AA] \$  
 09/Jan/2010 21:45:52 Fault  
 917 !FH18 09011004 DEAD HEAD [4B] \$ 09/Jan/2010 21:45:24  
 Fault

\$ Fault Masks:  
 \$ bus overvoltage 1 - Enabled  
 \$ AMB thermal switch 1 - Enabled  
 \$ fast overcurrent 1 - Enabled  
 \$ HS thermal switch1 - Enabled  
 \$ gate driver dsat 1 - Enabled  
 \$ ireg shutoff 1 - Enabled  
 \$ low voltage supply 1 - Enabled  
 \$ external trip 1 - Enabled  
 \$ dynamic brake limit 1 - Enabled  
 \$ watchdog timer 1 - Enabled  
 \$ motor resolv 1 loss 0 - Disabled  
 \$ load pg loss a 1 - Enabled  
 \$ motor marker 1 - Enabled  
 \$ load marker 1 - Enabled  
 \$ overrun 1 - Enabled  
 \$ motor rms limit 1 - Enabled  
 \$ circuit breaker 1 - Enabled  
 \$ pos error 0 - Disabled  
 \$ bus undervoltage 1 - Enabled  
 \$ motor fbk loss 0 - Disabled  
 \$ load fbk loss 1 - Enabled  
 \$ motor runaway 0 - Disabled  
 \$ load runaway 1 - Enabled  
 \$ non volatile mem 1 - Enabled  
 \$ rtc takeover 1 - Enabled  
 \$ fbk circuit breaker 1 - Enabled  
 \$ ssi receive 1 - Enabled  
 \$ inverter rms 1 - Enabled  
 \$ sync receive 1 - Enabled  
 \$ armature curr error 1 - Enabled  
 \$ field current loss 1 - Enabled  
 \$ overspeed trip 1 - Enabled  
 \$ sync data error 1 - Enabled  
 \$ bus reg toll 1 - Enabled  
 \$ unknown fbk module 1 - Enabled  
 \$ torque reg error 1 - Enabled  
 \$ communication error 1 - Enabled  
 \$ ehalt fault 1 - Enabled  
 \$ motor thermal switch 1 - Enabled  
 \$ motor blower off 1 - Enabled  
 \$ computer timeout 0 - Disabled  
 \$ Line Undervoltage 1 - Enabled

\$ Charge Pump Pressure 1 - Enabled  
\$ Rapid Pressure Chg 1 - Enabled  
\$ Dead Head 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled

\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled

\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled

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$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 21:56:33

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	59.00 amps rms	[C5]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	130.00 amps rms	[09]
32	current limit	130.00 amps rms	[E7]
33	motor rms limit	72.00 amps rms	[71]
34	current rate limit	0 amps pk/sec	[18]
35	field current	21.76 amps rms	[23]
36	field boost	200 %	[68]
37	slip frequency	0.667 hertz	[91]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.0484 ohms	[B4]
44	leakage Sigma	Ls 0.00232 henries	[6E]
45	Lm squared over Lr	0.02665 henries	[93]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	140.77 ftlb	[32]
50	motor max torque	328.98 ftlb	[33]



51	motor rtd power	47.71 hp	[AC]	
52	motor max power	111.50 hp	[8A]	
53	motor kt	2.567 ftlb/amp	[24]	
54	motor inertia	0.000 ftlbs^2	[94]	
55	machine inertia	0.412 ftlbs^2	[E8]	
56	acc obs bandwidth	40 rad/sec	[03]	
57	system gain id	31.747 1/sec/sec	[DD]	
58	system gain	31.747 1/sec/sec	[C9]	
59	system wn	20.0 rad/sec	[5A]	
60	system order	VELOCITY	[1D]	
61	kv cmd	0.000 upid gain	[D8]	
62	kp cmd	12.600 upid gain	[A4]	
63	ki	0.0 upid gain	[97]	
64	kp fbk	12.600 upid gain	[A3]	
65	kv fbk	1.091 upid gain	[CA]	
66	kr	1.000 upid gain	[2A]	
67	kp cmd percent	0 %	[D1]	
68	ki load enable	DISABLE	[56]	
69	kp load ratio	0 %	[35]	
70	kv load ratio	0 %	[37]	
71	torque limit	44.00 % max	[0B]	
72	low pass frequency	100.0 hertz	[33]	
73	low pass damping	1.414 gain	[A9]	
74	notch frequency	0.0 hertz	[9F]	
75	notch damping	1.414 gain	[B4]	
76	system gain 1	31.747 1/sec/sec	[78]	
77	system wn 1	20.0 rad/sec	[09]	
78	system order 1	TORQUE	[52]	
79	kv cmd 1	0.000 upid gain	[7E]	
80	kp cmd 1	0.630 upid gain	[83]	
81	ki 1	0.0 upid gain	[46]	
82	kp fbk 1	0.630 upid gain	[82]	
83	kv fbk 1	0.000 upid gain	[84]	
84	kr 1	0.000 upid gain	[DA]	
85	kp cmd percent 1	0 %	[80]	
86	ki load enable 1	DISABLE	[05]	
87	kp load ratio 1	0 %	[E4]	
88	kv load ratio 1	0 %	[DD]	
89	torque limit 1	100.00 % max	[88]	
90	low pass frequency 1	100.0 hertz	[E2]	
91	low pass damping 1	1.414 gain	[58]	
92	notch frequency 1	10.0 hertz	[4E]	
93	notch damping 1	1.414 gain	[63]	
94	torque invert	DISABLE	[1A]	
95	base rpm	1780 rpm	[3C]	
96	max vel	540.0 fpm	[7D]	
97	jog vel	175.0 fpm	[7E]	
98	!max motor rpm	1800.0 rpm	[C5]	
99	accel time	3.000 sec	[6E]	
100	decel time	3.000 sec	[4A]	
101	jerk time	0.000 sec	[9D]	
102	settle time	0.200 sec	[B5]	
103	accel time 1	1.000 sec	[FD]	
104	decel time 1	3.000 sec	[F5]	
105	jerk time 1	10.000 sec	[48]	
106	settle time 1	0.200 sec	[60]	
107	fast decel time	0.200 sec	[76]	
108	drive invert	DISABLE	[74]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.028 gain	[0D]	
121	dsv ki	2.853 gain	[5F]	
122	dsv kp fbk	0.028 gain	[0C]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu    -109 pulses        [04]
169 dac offset iv     13 pulses        [65]
170 adc offset iu    -29 pulses        [3A]
171 adc offset iv     33 pulses        [6A]
172 adc offset fu     -2 pulses        [74]
173 adc offset fv     69 pulses        [62]
174 adc 1 select      VOLTS            [66]
175 adc 1 set         DISABLED          [19]
176 adc 1 min        -10.00 %           [17]
177 adc 1 max         160.00 %          [0B]
178 adc 1 min volts   5.288 volts       [C1]
179 adc 1 max volts   8.666 volts       [BB]
180 adc 1 destination-1                [A1]
181 !adc 1 raw value  6.015 volts       [C6]
182 !adc 1 value      26.61 %          [3F]
183 adc 2 select      VOLTS            [65]
184 adc 2 set         DISABLED          [18]
185 adc 2 min         0.00 %            [74]
186 adc 2 max         0.00 %            [71]
187 adc 2 min volts   0.000 volts       [D7]
188 adc 2 max volts   0.000 volts       [D4]
189 adc 2 destination-1                [97]
190 !adc 2 raw value  0.029 volts       [C6]
191 !adc 2 value      0.00 %            [7D]
192 adc 3 select      VOLTS            [64]
193 adc 3 set         DISABLED          [17]
194 adc 3 min         0.00 %            [73]
195 adc 3 max         0.00 %            [70]
196 adc 3 min volts   0.000 volts       [D6]
197 adc 3 max volts   0.000 volts       [D3]
198 adc 3 destination-1                [96]
199 !adc 3 raw value  0.019 volts       [BD]
200 !adc 3 value      0.00 %            [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select      TORQUE CMD        [32]
203 dac 1 ptr         28965             [41]
204 dac 1 item        0                 [C5]
205 dac 1 mul         1                 [24]
206 dac 1 div         1                 [2E]
207 dac 1 abs         DISABLE           [77]
208 !dac 1 output     0.000 volts       [A8]
209 dac 2 select      UPID VEL FBK      [D2]
210 dac 2 ptr         26033            [52]
211 dac 2 item        0                 [C6]
212 dac 2 mul         32767            [4D]
213 dac 2 div         125829           [25]
214 dac 2 abs         DISABLE           [78]
215 !dac 2 output     0.000 volts       [A9]
216 level 1 password  1111             [7A]
217 level 2 password  0                 [0C]
218 level 3 password  0                 [0A]
219 lockout time      900.000 sec       [D5]
220 !lockout status   LOCKED           [A7]
221 ssi rx mode        DISABLED         [E8]
222 !ssi rx value     0                 [56]
223 ssi torque offset 0.00 %           [A3]
224 ssi tx mode        DISABLED         [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	38		[D6]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	38		[A3]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	86.45 amps rms			[84]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	671 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.25 amps rms			[7F]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	37458900.9585	in		[40]
275	!feedback pos	37458900.9585	in		[F9]
276	!in word 0	000081	\$		[03]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000002	\$		[19]
282	!int word 0	000800	\$		[93]

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294965951			[E8]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967294			[9D]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	4			[7A]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	4			[AE]
307	test cycle rpm	1000.0	rpm		[6C]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	600.0	rpm		[65]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque 90	%			[2B]
317	test degrees	180.00	deg		[22]
318	test i field	8.60	amps rms		[DB]
319	test volts 0	volts			[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	217.5	fpm		[B0]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 80.00 % max [59]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos37458900.9585 in [42]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	IN 7	[87]	
420	motor blower ok req	REQ FORCED ON	[87]	[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT OFF	[94]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	HIGH PRESS PUMP		[05]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	100.00	% rtd	[94]
483	pend max vel	540.0 fpm		[86]
484	pend index pos	0.0000	in	[ED]
485	pend index vel	3.0 fpm		[18]
486	comp req torq	0.00	% rtd	[E7]
487	comp req vel	382.5 fpm		[6F]
488	comp index pos	4.2300	in	[D8]
489	comp index vel	14.1 fpm		[D9]
490	comp request word0			[52]
491	!comp status word0			[95]
492	comp timeout	0.000 sec		[35]
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000	in	[2F]
496	payout preset	0.0000	in	[E6]
497	!index start pos	0.0000	in	[41]
498	!tension error	0.00 lb		[37]
499	!tgt hose tension	0.00 lb		[42]
500	!hose tension	0.00 lb		[C2]
501	!cable tension	0.00 lb		[79]
502	hose filter gain	0.00000	gain	[3B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	0 %		[76]
505	cable filter gain	0.00000	gain	[F0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000	in/sec/lb	[59]
508	!actual fine control	0.0000	in/sec/lb	[5C]
509	fade filter gain	0.00000	gain	[53]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %		[03]
513	coil min od	0.0000	in	[47]
514	coil max od	0.0000	in	[44]



515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	600	volts rms	[97]		
536	hi-spd line low limt	600	volts rms	[A0]		
537	high-low vel cutoff	1400	rpm	[F3]		
538	!Motor Temp. Celsius	26.64	deg	[F5]		
539	!Elec. Closet Temp.	0.00	deg	[0E]		
540	!Pump Room Temp.	0.00	deg	[E8]		
541	Elec Closet Set Pt.	20.00	deg	[B8]		
542	Pump Room Set Pt.	20.00	deg	[5B]		
543	Temp Hysteresis	3.00	deg	[5D]		
544	Mode	Computer Control		[61]		
545	Start	DISABLE		[33]		
546	!Mtr Current Filtered	0.00	amps rms	[AD]		
547	RP Loss Trip	7.50	amps rms	[24]		
548	RP Rise Trip	75.00	amps rms	[01]		
549	1 bit pump	ENABLE		[18]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	13:16:01	Fault				
901	!FH 2 20011002	charge pump pressure		[CD]	\$	
	20/Jan/2010 09:12:53	Fault				
902	!FH 3 18011017	EXTERNAL TRIP		[E1]	\$	18/Jan/2010
	17:05:44	Fault				
903	!FH 4 18011014	IREG SHUTOFF		[3E]	\$	18/Jan/2010
	17:05:44	Fault				
904	!FH 5 18011002	charge pump pressure		[C0]	\$	
	18/Jan/2010 16:52:41	Fault				
905	!FH 6 18011002	charge pump pressure		[BE]	\$	
	18/Jan/2010 13:21:46	Fault				
906	!FH 7 18011002	charge pump pressure		[BC]	\$	
	18/Jan/2010 11:33:07	Fault				
907	!FH 8 18011017	EXTERNAL TRIP		[D7]	\$	18/Jan/2010
	11:08:57	Fault				
908	!FH 9 18011014	IREG SHUTOFF		[34]	\$	18/Jan/2010
	11:08:57	Fault				
909	!FH10 15011002	charge pump pressure		[B2]	\$	
	15/Jan/2010 09:49:32	Fault				
910	!FH11 13011002	charge pump pressure		[BB]	\$	
	13/Jan/2010 21:15:31	Fault				

911 !FH12 13011002 charge pump pressure [B9] \$  
 13/Jan/2010 16:23:42 Fault  
 912 !FH13 12011002 charge pump pressure [B8] \$  
 12/Jan/2010 11:18:59 Fault  
 913 !FH14 12011001 line undervoltage [C4] \$ 12/Jan/2010  
 11:14:56 Fault  
 914 !FH15 12011017 external trip [51] \$ 12/Jan/2010  
 11:14:51 Fault  
 915 !FH16 12011002 charge pump pressure [B2] \$  
 12/Jan/2010 07:30:44 Fault  
 916 !FH17 11011017 EXTERNAL TRIP [CE] \$ 11/Jan/2010  
 14:11:44 Fault  
 917 !FH18 10011003 RAPID PRESSURE CHG [99] \$  
 10/Jan/2010 22:27:08 Fault  
 918 !FH19 10011002 charge pump pressure [AE] \$  
 10/Jan/2010 21:00:07 Fault  
 919 !FH20 09011002 charge pump pressure [AD] \$  
 09/Jan/2010 21:54:50 Fault  
 920 !FH21 09011004 DEAD HEAD [57] \$ 09/Jan/2010 21:50:40  
 Fault

\$ Fault Masks:  
 \$ bus overvoltage 1 - Enabled  
 \$ AMB thermal switch 1 - Enabled  
 \$ fast overcurrent 1 - Enabled  
 \$ HS thermal switch1 - Enabled  
 \$ gate driver dsat 1 - Enabled  
 \$ ireg shutoff 1 - Enabled  
 \$ low voltage supply 1 - Enabled  
 \$ external trip 1 - Enabled  
 \$ dynamic brake limit 1 - Enabled  
 \$ watchdog timer 1 - Enabled  
 \$ motor resolv 1 loss 0 - Disabled  
 \$ load pg loss a 1 - Enabled  
 \$ motor marker 1 - Enabled  
 \$ load marker 1 - Enabled  
 \$ overrun 1 - Enabled  
 \$ motor rms limit 1 - Enabled  
 \$ circuit breaker 1 - Enabled  
 \$ pos error 0 - Disabled  
 \$ bus undervoltage 1 - Enabled  
 \$ motor fbk loss 0 - Disabled  
 \$ load fbk loss 1 - Enabled  
 \$ motor runaway 0 - Disabled  
 \$ load runaway 1 - Enabled  
 \$ non volatile mem 1 - Enabled  
 \$ rtc takeover 1 - Enabled  
 \$ fbk circuit breaker 1 - Enabled  
 \$ ssi receive 1 - Enabled  
 \$ inverter rms 1 - Enabled  
 \$ sync receive 1 - Enabled  
 \$ armature curr error 1 - Enabled  
 \$ field current loss 1 - Enabled  
 \$ overspeed trip 1 - Enabled  
 \$ sync data error 1 - Enabled  
 \$ bus reg toll 1 - Enabled  
 \$ unknown fbk module 1 - Enabled  
 \$ torque reg error 1 - Enabled

\$ communication error 1 - Enabled  
\$ ehalt fault1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage1 - Enabled  
\$ Charge Pump Pressure 1 - Enabled  
\$ Rapid Pressure Chg 1 - Enabled  
\$ Dead Head 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled

\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled  
  
\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled

\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Charge Pump Pressure 0 - Disabled  
\$ Rapid Pressure Chg 0 - Disabled  
\$ Dead Head 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled

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$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 01:43:34

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	10.50 amps rms	[CD]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	10.50 amps rms	[74]
34	current rate limit	0 amps pk/sec	[18]
35	field current	5.23 amps rms	[59]
36	field boost	200 %	[68]
37	slip frequency	1.167 hertz	[95]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.6165 ohms	[B2]
44	leakage Sigma	Ls 0.01318 henries	[68]
45	Lm squared over Lr	0.00000 henries	[A6]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	0.00 ftlb	[A5]
50	motor max torque	0.00 ftlb	[B1]

51	motor rtd power	0.00	hp	[EF]	
52	motor max power	0.00	hp	[F2]	
53	motor kt	0.000	ftlb/amp	[38]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.000	ftlbs^2	[EF]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	118.048	1/sec/sec	[AD]	
58	system gain	118.048	1/sec/sec	[99]	
59	system wn	5.0	rad/sec	[87]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.212	upid gain	[D8]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.212	upid gain	[D7]	
65	kv fbk	0.073	upid gain	[CB]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	118.048	1/sec/sec	[48]	
77	system wn 1	20.0	rad/sec	[09]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.169	upid gain	[7C]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.169	upid gain	[7B]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		ENABLE	[67]	
95	base rpm	3540	rpm	[40]	
96	max vel	1500.0	fpm	[50]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	5000.0	rpm	[C9]	
99	accel time	5.000	sec	[6C]	
100	decel time	5.000	sec	[48]	
101	jerk time	0.000	sec	[9D]	
102	settle time	5.000	sec	[B2]	
103	accel time 1	5.000	sec	[F9]	
104	decel time 1	5.000	sec	[F3]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	5.000	sec	[5D]	
107	fast decel time	1.000	sec	[77]	
108	drive invert		ENABLE	[C1]	



109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.162 gain	[0E]	
121	dsv ki	16.208 gain	[30]	
122	dsv kp fbk	0.162 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -65  pulses      [33]
169 dac offset iv      -18  pulses      [33]
170 adc offset iu      -63  pulses      [3C]
171 adc offset iv       0   pulses      [A0]
172 adc offset fu       0   pulses      [A3]
173 adc offset fv      -34  pulses      [3D]
174 adc 1 select        VOLTS          [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00  %                      [75]
177 adc 1 max  0.00  %                      [72]
178 adc 1 min volts  0.000 volts           [D8]
179 adc 1 max volts  0.000 volts           [D5]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value 0.004 volts           [CE]
182 !adc 1 value     0.00  %              [7E]
183 adc 2 select        VOLTS          [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00  %                      [74]
186 adc 2 max  0.00  %                      [71]
187 adc 2 min volts  0.000 volts           [D7]
188 adc 2 max volts  0.000 volts           [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value 0.004 volts           [CD]
191 !adc 2 value     0.00  %              [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00  %                      [73]
195 adc 3 max  0.00  %                      [70]
196 adc 3 min volts  0.000 volts           [D6]
197 adc 3 max volts  0.000 volts           [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value 0.000 volts           [C7]
200 !adc 3 value     0.00  %              [85]
201 dac clock level  DRIVE CLOCK          [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr  28965                      [41]
204 dac 1 item 0                      [C5]
205 dac 1 mul  1                          [24]
206 dac 1 div  1                          [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output     0.000 volts         [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr  26033                      [52]
211 dac 2 item 0                      [C6]
212 dac 2 mul  32767                      [4D]
213 dac 2 div  349525                    [24]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output     0.000 volts         [A9]
216 level 1 password 1111                [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time      900.000      sec     [D5]
220 !lockout status  LOCKED              [A7]
221 ssi rx mode DISABLED                  [E8]
222 !ssi rx value     0                    [56]
223 ssi torque offset0.00  %             [A3]
224 ssi tx mode DISABLED                  [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	41		[DC]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	41		[A9]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	662 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.03 amps rms			[83]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	74480849.3256	in		[43]
275	!feedback pos	74480849.3256	in		[FC]
276	!in word 0	000001	\$		[0B]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000000	\$		[1B]
282	!int word 0	000000	\$		[9B]

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294965951			[E8]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	0			[7E]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	0			[B2]
307	test cycle rpm	900.0 rpm			[94]
308	test id min rpm	177.0 rpm			[6C]
309	test jog rpm	20.0 rpm			[99]
310	test max rpm	900.0 rpm			[64]
311	test min rpm	-900.0 rpm			[38]
312	test period	0.000 sec		[B1]	
313	test ramp	DISABLE			[B8]
314	test position	10.000 rev			[7A]
315	test time	1.000 sec		[81]	
316	test torque	30 %		[31]	
317	test degrees	180.00 deg			[22]
318	test i field	0.00 amps rms			[E9]
319	test volts	0 volts		[B6]	
320	test length	24.0001 in			[B0]
321	test accel time	4.000 sec			[69]
322	test freq ramp time	20.000 sec			[B4]
323	test adc	1		[02]	
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0 fpm			[0E]
330	vel preset 1	0.0 fpm			[21]
331	vel preset 2	750.0 fpm			[B3]
332	vel preset 3	0.0 fpm			[1D]
333	vel preset 4	0.0 fpm			[1B]
334	vel preset 5	0.0 fpm			[19]
335	vel preset 6	0.0 fpm			[17]
336	vel preset 7	0.0 fpm			[15]
337	vel preset 8	0.0 fpm			[13]
338	vel offset	0.0 fpm		[76]	
339	vel gain	100.00 %			[EA]
340	vel tolerance	0.0 fpm			[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 40.00 % max [5D]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 1110.0 fpm [46]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 3700 rpm [4B]
377 rpm rev shutoff -3700 rpm [11]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos74480849.3256 in [45]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT OFF	[94]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	BOOSTER PUMP		[B4]
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	0.00 % rtd	[F5]	
483	pend max vel	0.0 fpm	[EF]	
484	pend index pos	0.0000 in		[ED]
485	pend index vel	0.0 fpm	[1B]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	810.0 fpm	[78]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word0		[95]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	25 %	[3F]	
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	line low limit	600	volts rms	[9D]		
536	Mode	Computer Control		[60]		
537	Start	DISABLE		[32]		
538	1 bit pump	ENABLE		[1A]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	12:39:13	Fault				
901	!FH 2 18011017	EXTERNAL TRIP		[E3]	\$	18/Jan/2010
	10:32:10	Fault				
902	!FH 3 12011001	line undervoltage		[D8]	\$	12/Jan/2010
	10:38:12	Fault				
903	!FH 4 12011017	external trip		[65]	\$	12/Jan/2010
	10:38:09	Fault				
904	!FH 5 11011017	EXTERNAL TRIP		[E4]	\$	11/Jan/2010
	13:35:03	Fault				
905	!FH 6 30120917	external trip		[57]	\$	30/Dec/2009
	12:45:24	Fault				
906	!FH 7 30120901	line undervoltage		[C6]	\$	30/Dec/2009
	12:44:03	Fault				
907	!FH 8 30120917	external trip		[53]	\$	30/Dec/2009
	12:35:41	Fault				
908	!FH 9 30120917	external trip		[51]	\$	30/Dec/2009
	12:35:41	Fault				
909	!FH10 30120917	external trip		[48]	\$	30/Dec/2009
	12:35:41	Fault				
910	!FH11 30120917	external trip		[4F]	\$	30/Dec/2009
	12:35:41	Fault				
911	!FH12 30120917	external trip		[4D]	\$	30/Dec/2009
	12:35:39	Fault				
912	!FH13 30120917	external trip		[4B]	\$	30/Dec/2009
	12:35:27	Fault				
913	!FH14 30120917	external trip		[49]	\$	30/Dec/2009
	12:28:40	Fault				
914	!FH15 30120917	external trip		[47]	\$	30/Dec/2009
	12:28:40	Fault				
915	!FH16 30120917	external trip		[45]	\$	30/Dec/2009
	12:28:39	Fault				
916	!FH17 30120917	external trip		[43]	\$	30/Dec/2009
	12:28:39	Fault				



917	!FH18 30120917	external trip	[41]	\$	30/Dec/2009
	12:28:39	Fault			
918	!FH19 30120917	external trip	[3F]	\$	30/Dec/2009
	12:28:39	Fault			
919	!FH20 30120917	external trip	[46]	\$	30/Dec/2009
	12:28:38	Fault			
920	!FH21 30120917	external trip	[4D]	\$	30/Dec/2009
	12:27:53	Fault			
921	!FH22 30120917	external trip	[4B]	\$	30/Dec/2009
	12:27:25	Fault			
922	!FH23 30120917	external trip	[49]	\$	30/Dec/2009
	12:27:25	Fault			
923	!FH24 30120917	external trip	[47]	\$	30/Dec/2009
	12:27:25	Fault			
924	!FH25 30120917	external trip	[45]	\$	30/Dec/2009
	12:27:25	Fault			
925	!FH26 30120917	external trip	[43]	\$	30/Dec/2009
	12:27:24	Fault			
926	!FH27 30120917	external trip	[41]	\$	30/Dec/2009
	12:27:21	Fault			
927	!FH28 30120917	external trip	[3F]	\$	30/Dec/2009
	12:27:21	Fault			
928	!FH29 30120917	external trip	[3D]	\$	30/Dec/2009
	12:27:21	Fault			
929	!FH30 30120917	external trip	[44]	\$	30/Dec/2009
	12:27:21	Fault			
930	!FH31 30120917	external trip	[4B]	\$	30/Dec/2009
	12:27:20	Fault			
931	!FH32 30120917	external trip	[49]	\$	30/Dec/2009
	12:27:20	Fault			
932	!FH33 30120917	external trip	[47]	\$	30/Dec/2009
	12:27:20	Fault			
933	!FH34 30120917	external trip	[45]	\$	30/Dec/2009
	12:27:20	Fault			
934	!FH35 30120917	external trip	[43]	\$	30/Dec/2009
	12:27:20	Fault			
935	!FH36 30120917	external trip	[41]	\$	30/Dec/2009
	12:27:19	Fault			
936	!FH37 30120917	external trip	[3F]	\$	30/Dec/2009
	12:27:19	Fault			
937	!FH38 30120917	external trip	[3D]	\$	30/Dec/2009
	12:27:19	Fault			
938	!FH39 30120917	external trip	[3B]	\$	30/Dec/2009
	12:27:19	Fault			
939	!FH40 30120917	external trip	[42]	\$	30/Dec/2009
	12:27:19	Fault			
940	!FH41 30120917	external trip	[49]	\$	30/Dec/2009
	12:27:19	Fault			
941	!FH42 30120917	external trip	[47]	\$	30/Dec/2009
	12:27:18	Fault			
942	!FH43 30120917	external trip	[45]	\$	30/Dec/2009
	12:27:17	Fault			
943	!FH44 30120917	external trip	[43]	\$	30/Dec/2009
	12:24:43	Fault			
944	!FH45 30120917	external trip	[41]	\$	30/Dec/2009
	12:24:42	Fault			
945	!FH46 30120917	external trip	[3F]	\$	30/Dec/2009
	12:24:42	Fault			

946	!FH47 30120917	external trip	[3D]	\$	30/Dec/2009
	12:24:42	Fault			
947	!FH48 30120917	external trip	[3B]	\$	30/Dec/2009
	12:24:42	Fault			
948	!FH49 30120917	external trip	[39]	\$	30/Dec/2009
	12:24:41	Fault			
949	!FH50 30120917	external trip	[40]	\$	30/Dec/2009
	12:24:41	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout 1 - Enabled
$ Line Undervoltage 1 - Enabled
$ user fault 2 req 1 - Enabled
$ user fault 3 req 1 - Enabled
$ user fault 4 req 1 - Enabled
$ user fault 5 req 1 - Enabled
$ user fault 6 req 1 - Enabled
$ user fault 7 req 1 - Enabled

```

\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled

\$ sync data error 0 - Disabled  
\$ bus reg tol0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled

\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 01:40:56

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH		[14]	
1	position units	REV		[ED]	
2	velocity units	MINUTES		[BA]	
3	hertz units	DISABLE		[2C]	
4	clock frequency	50	hertz	[0F]	
5	drive multiple	1		[C7]	
6	upid multiple	20		[FD]	
7	ac multiple1		[1B]		
8	ac fast multiple	1		[4C]	
9	vector source	MOTOR SOCKET		[DC]	
10	upid motor source	MOTOR SOCKET		[44]	
11	upid load source	LOAD SOCKET		[45]	
12	load vector control	DISABLE		[08]	
13	transducerless	ENABLE		[D6]	
14	motor fbk size	2048	pulses/rev	[29]	
15	motor resolution	3.6000	in/rev	[4E]	
16	motor fbk invert	DISABLE		[3C]	
17	motor input teeth1		[7F]		
18	motor output teeth	1		[FD]	
19	motor encoder bits	BITS 0		[E4]	
20	motor encoder turns	1		[B3]	
21	load fbk size	0	pulses/rev	[5A]	
22	load resolution	10.0001	in/rev	[B8]	
23	load fbk invert	DISABLE		[CF]	
24	load input teeth 1		[12]		
25	load output teeth1		[90]		
26	load encoder bits	BITS 0		[77]	
27	load encoder turns	1		[3D]	
28	motor rated voltage	480	volts	[22]	
29	motor rated current	4.10	amps rms	[FE]	
30	motor rated frequency	60	hertz	[8A]	
31	maximum current	9.60	amps rms	[5E]	
32	current limit	9.60	amps rms	[3C]	
33	motor rms limit	3.40	amps rms	[A3]	
34	current rate limit	0	amps pk/sec	[18]	
35	field current	2.09	amps rms	[58]	
36	field boost 200	%	[68]		
37	slip frequency	2.500	hertz	[9D]	
38	motor poles 2		[C2]		
39	synchronous motor	DISABLE		[57]	
40	vector offset	0.00	deg	[47]	
41	vector fwd	0.00000	sec	[8B]	
42	torque fwd	0.00	deg	[18]	
43	stator resistance	Rs	5.2124	ohms	[B6]
44	leakage Sigma	Ls	0.02674	henries	[62]
45	Lm squared over	Lr	0.25004	henries	[9B]
46	current filter	2.00	hertz	[D3]	
47	voltage filter	2.00	hertz	[E3]	
48	power filter	2.00	hertz	[A7]	
49	motor rtd torque	4.07	ftlb	[9A]	
50	motor max torque	10.82	ftlb	[76]	

51	motor rtd power	2.67	hp	[E0]	
52	motor max power	7.11	hp	[E9]	
53	motor kt	1.155	ftlb/amp	[2C]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.001	ftlbs^2	[EE]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	202.529	1/sec/sec	[AF]	
58	system gain	202.529	1/sec/sec	[9B]	
59	system wn	4.0	rad/sec	[88]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.079	upid gain	[CD]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.079	upid gain	[CC]	
65	kv fbk	0.034	upid gain	[CE]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	202.529	1/sec/sec	[4A]	
77	system wn 1	20.0	rad/sec	[09]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.099	upid gain	[7A]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.099	upid gain	[79]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		ENABLE	[67]	
95	base rpm	3450	rpm	[40]	
96	max vel	1500.0	fpm	[50]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	5000.0	rpm	[C9]	
99	accel time	1.000	sec	[70]	
100	decel time	1.000	sec	[4C]	
101	jerk time	0.000	sec	[9D]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	2.000	sec	[FC]	
104	decel time 1	2.000	sec	[F6]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	0.200	sec	[60]	
107	fast decel time	0.200	sec	[76]	
108	drive invert		ENABLE	[C1]	



109	!motor vel 539.1 fpm	[3D]	
110	inv thermal warning 80.0 %	[E6]	
111	motor rms warning80.0 %	[9C]	
112	modulation selectDIGITAL	[65]	
113	switch frequency 6000 hertz	[C7]	
114	thermal protection STANDARD	[78]	
115	dsv synchronized DISABLE	[BB]	
116	dsv wn 200.0 rad/sec	[58]	
117	dsv vphz wn10.0 rad/sec	[A0]	
118	dsv kv percent 85.00 %	[BA]	
119	dsv kp cmd percent 100 %	[D5]	
120	dsv kp cmd 0.328 gain	[0A]	
121	dsv ki 32.883 gain	[29]	
122	dsv kp fbk 0.328 gain	[09]	
123	dsv deadtime percent 25 %	[F6]	
124	dsv v boost 0 %	[BD]	
125	dsv bus correction DISABLE	[38]	
126	acr i loop 5.000 acr gain	[B9]	
127	acr v ffwd 1.000 acr gain	[C2]	
128	acr field i loop 40.000 acr gain	[64]	
129	acr field v ffwd 1.000 acr gain	[9C]	
130	dbm const switch freq ENABLE	[9E]	
131	dbm pulses 4	[1B]	
132	dbm min vel 5.0 hertz	[7F]	
133	dbm volts per hertz 8.0	[67]	
134	dbm clamp voltage0 volts	[61]	
135	dbm block modulation 30 % clamp	[CB]	
136	dbm run current limit 0.00 amps rms	[4E]	
137	dbm run limit gain 0.000 gain	[05]	
138	damping kp 0.00006 gain	[69]	
139	damping max 1000.00 ftlb	[F9]	
140	damping min freq 20.0 hertz	[3F]	
141	damping max freq 90.0 hertz	[35]	
142	vbus reg filter 300.00 hertz	[2A]	
143	vbus filter 0.80 hertz	[E2]	
144	vbus notch frequency 0.0 hertz	[91]	
145	vbus notch damping 1.414 gain	[A6]	
146	vbus kp 3.000 gain	[ED]	
147	vbus ki 3.000 gain	[F3]	
148	vbus window shift-1.22 volts	[58]	
149	vbus dac limit 10.00 volts	[C7]	
150	db watts 0 watts	[C1]	
151	db resistance 0.000 ohms	[80]	
152	db time constant 25 secs	[07]	
153	!db percent used 0 %	[1C]	
154	flux control CLOSED LOOP	[45]	
155	flux cutoff min 10.0 rad/sec	[0E]	
156	flux cutoff max 20.0 rad/sec	[0A]	
157	flux kp 1.000 gain	[EE]	
158	flux id obs bandwidth 50 rad/sec	[4A]	
159	torq est filter 0.01000 sec	[D2]	
160	torq reg select DISABLED	[40]	
161	torq reg wn 0.0 rad/sec	[E3]	
162	torq reg kp cmd pct 0 %	[0B]	
163	torq reg kp cmd 0.000 gain	[39]	
164	torq reg ki 0.00 gain	[C3]	
165	torq reg kp fbk 0.000 gain	[38]	
166	coulomb torque 0.00 ftlb	[1F]	

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167 friction deadzone 100.0 rpm          [2F]
168 dac offset iu      1      pulses      [9A]
169 dac offset iv     -73     pulses      [32]
170 adc offset iu     -12     pulses      [42]
171 adc offset iv     -77     pulses      [35]
172 adc offset fu     -17     pulses      [3E]
173 adc offset fv      16     pulses      [6A]
174 adc 1 select      VOLTS          [66]
175 adc 1 set        DISABLED        [19]
176 adc 1 min      0.00 %           [75]
177 adc 1 max      0.00 %           [72]
178 adc 1 min volts 0.000 volts      [D8]
179 adc 1 max volts 0.000 volts      [D5]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value -0.035      volts  [9D]
182 !adc 1 value    0.00 %           [7E]
183 adc 2 select      VOLTS          [65]
184 adc 2 set        DISABLED        [18]
185 adc 2 min      0.00 %           [74]
186 adc 2 max      0.00 %           [71]
187 adc 2 min volts 0.000 volts      [D7]
188 adc 2 max volts 0.000 volts      [D4]
189 adc 2 destination-1          [97]
190 !adc 2 raw value 0.000 volts      [D1]
191 !adc 2 value    0.00 %           [7D]
192 adc 3 select      VOLTS          [64]
193 adc 3 set        DISABLED        [17]
194 adc 3 min      0.00 %           [73]
195 adc 3 max      0.00 %           [70]
196 adc 3 min volts 0.000 volts      [D6]
197 adc 3 max volts 0.000 volts      [D3]
198 adc 3 destination-1          [96]
199 !adc 3 raw value 0.009 volts      [BE]
200 !adc 3 value    0.00 %           [85]
201 dac clock level  DRIVE CLOCK      [AE]
202 dac 1 select      TORQUE CMD      [32]
203 dac 1 ptr      28965            [41]
204 dac 1 item      0              [C5]
205 dac 1 mul       1              [24]
206 dac 1 div       1              [2E]
207 dac 1 abs       DISABLE        [77]
208 !dac 1 output   0.790 volts      [98]
209 dac 2 select      UPID VEL FBK    [D2]
210 dac 2 ptr      26033            [52]
211 dac 2 item      0              [C6]
212 dac 2 mul      32767            [4D]
213 dac 2 div      174763          [24]
214 dac 2 abs       DISABLE        [78]
215 !dac 2 output   3.610 volts      [9F]
216 level 1 password 1111          [7A]
217 level 2 password 0              [0C]
218 level 3 password 0              [0A]
219 lockout time     900.000      sec   [D5]
220 !lockout status  LOCKED          [A7]
221 ssi rx mode      DISABLED        [E8]
222 !ssi rx value    0              [56]
223 ssi torque offset 0.00 %        [A3]
224 ssi tx mode      DISABLED        [E3]

```

225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	44		[D9]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	44		[A6]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	1802.2 rpm		[FC]	
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	7.87 % max	[C1]		
258	!bus voltage	655 volts		[DF]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	1.62 amps rms			[7D]
264	!torque est command	-0.85 ftlb		[6B]	
265	!torque est feedback	-0.93 ftlb		[25]	
266	!load power	-0.27 hp	[5B]		
267	!motor power	-0.30 hp		[CF]	
268	!motor current	2.48 amps rms			[CF]
269	!motor voltage	-216 volts rms			[5E]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.59 hp		[B8]	
272	!command vel	540.0 fpm		[97]	
273	!feedback vel	542.5 fpm		[49]	
274	!command pos	21000418.1021	in		[6B]
275	!feedback pos	21000370.8425	in		[18]
276	!in word 0	000001	\$		[0B]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000085	\$		[0E]
282	!int word 0	008c95	\$		[52]

283	!int word 1	000000	\$	[99]
284	!int word 2	001a00	\$	[65]
285	!int word 3	000021	\$	[92]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	1500.0 rpm		[45]
309	test jog rpm	900.0 rpm		[62]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	10.000 rev		[7A]
315	test time	1.000 sec	[81]	
316	test torque	100 %	[03]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in		[B0]
321	test accel time	4.000 sec		[69]
322	test freq ramp time	6.000 sec		[E0]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	540.0 fpm		[B8]
331	vel preset 2	1035.0 fpm		[86]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	0.0 fpm		[47]

```

341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source DISABLED [6F]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd DISABLE [FF]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select VEL SELECT [AB]
367 vel ovrd vel 0.0 fpm [D9]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 4000 rpm [51]
377 rpm rev shutoff -4000 rpm [17]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel540.2 fpm [96]
385 !motor socket pos21002347.1675 in [5B]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state AUTO RUN [F2]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF		[16]
412	decelerate req	REQ FORCED OFF		[10]
413	speed adjust req	REQ FORCED OFF		[61]
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF		[A7]
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT ON	[BE]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT ON	[2F]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT ON	[EF]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT OFF	[8A]	
430	!at req vel sts	OUT ON	[48]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED			[74]
458	sout 12	STS DISABLED			[72]
459	sout 13	STS DISABLED			[70]
460	sout 14	STS DISABLED			[77]
461	sout 15	STS DISABLED			[75]
462	sout 16	STS DISABLED			[73]
463	sout 17	STS DISABLED			[71]
464	sout 18	STS DISABLED			[6F]
465	sout 19	STS DISABLED			[6D]
466	sout 20	STS DISABLED			[74]
467	sout 21	STS DISABLED			[72]
468	sout 22	STS DISABLED			[70]
469	sout 23	STS DISABLED			[6E]
470	sout 24	STS DISABLED			[75]
471	sout 25	STS DISABLED			[73]
472	sout 26	STS DISABLED			[71]
473	sout 27	STS DISABLED			[6F]
474	sout 28	STS DISABLED			[6D]
475	sout 29	STS DISABLED			[6B]
476	sout 30	STS DISABLED			[72]
477	sout 31	STS DISABLED			[70]
478	drive type	TANK TRANSFR PUMP			[64]
479	allow pend reverse	DISABLE			[39]
480	torque mode enable	DISABLE			[57]
481	torq override enable	DISABLE			[75]
482	pend max torq	0.00 % rtd		[F5]	
483	pend max vel	0.0 fpm		[EF]	
484	pend index pos	0.0000 in			[ED]
485	pend index vel	0.0 fpm		[1B]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	540.0 fpm		[78]	
488	comp index pos	0.0000 in			[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word1			[51]	
491	!comp status word469			[22]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000 in			[2F]
496	payout preset	0.0000 in			[E6]
497	!index start pos	0.0000 in			[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000 gain			[2B]
503	!smooth hose tension	0.00 lb			[05]
504	hose load 25	%		[3F]	
505	cable filter gain	0.97000 gain			[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000 in/sec/lb			[59]
508	!actual fine control	0.0000 in/sec/lb			[5C]
509	fade filter gain	0.97000 gain			[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0 %		[03]	
513	coil min od	0.0000 in			[47]
514	coil max od	0.0000 in			[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	VELOCITY MODE		[63]		
534	pend disable time	0.000	sec	[A4]		
535	line low limit	600	volts rms	[9D]		
536	Mode	Computer Control		[60]		
537	Start	DISABLE		[32]		
538	1 bit pump	ENABLE		[1A]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	13:02:17	Fault				
901	!FH 2 18011017	external trip		[63]	\$	18/Jan/2010
	16:52:00	Fault				
902	!FH 3 18011017	external trip		[61]	\$	18/Jan/2010
	10:55:14	Fault				
903	!FH 4 12011017	external trip		[65]	\$	12/Jan/2010
	11:01:11	Fault				
904	!FH 5 11011017	external trip		[64]	\$	11/Jan/2010
	13:58:04	Fault				
905	!FH 6 30120917	external trip		[57]	\$	30/Dec/2009
	12:31:24	Fault				
906	!FH 7 28120917	external trip		[4E]	\$	28/Dec/2009
	19:25:45	Fault				
907	!FH 8 22120917	external trip		[52]	\$	22/Dec/2009
	08:58:41	Fault				
908	!FH 9 15120917	external trip		[4E]	\$	15/Dec/2009
	15:24:42	Fault				
909	!FH10 12120917	external trip		[48]	\$	12/Dec/2009
	14:37:43	Fault				
910	!FH11 11120907	BUS UNDERVOLTAGE		[F9]	\$	11/Dec/2009
	00:40:42	Fault				
911	!FH12 03120917	external trip		[4D]	\$	03/Dec/2009
	11:53:41	Fault				
912	!FH13 30110917	external trip		[4C]	\$	30/Nov/2009
	09:41:09	Fault				
913	!FH14 27110917	EXTERNAL TRIP		[C4]	\$	27/Nov/2009
	20:07:46	Fault				
914	!FH15 27110917	EXTERNAL TRIP		[C2]	\$	27/Nov/2009
	19:22:41	Fault				
915	!FH16 27110917	external trip		[40]	\$	27/Nov/2009
	08:43:54	Fault				
916	!FH17 27110917	external trip		[3E]	\$	27/Nov/2009
	05:56:47	Fault				



```
$ Fault Masks:
$ bus overvoltage 1 - Enabled
$   AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout 1 - Enabled
$ Line Undervoltage1 - Enabled
$ user fault 2 req 1 - Enabled
$ user fault 3 req 1 - Enabled
$ user fault 4 req 1 - Enabled
$ user fault 5 req 1 - Enabled
$ user fault 6 req 1 - Enabled
$ user fault 7 req 1 - Enabled
$ user fault 8 req 1 - Enabled
$ user fault 9 req 1 - Enabled
$ user fault 10 req1 - Enabled
$ user fault 11 req1 - Enabled
$ user fault 12 req1 - Enabled
$ user fault 13 req1 - Enabled
$ user fault 14 req1 - Enabled
$ user fault 15 req1 - Enabled
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\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled

\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 01:38:18

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	20	[FD]
7	ac multiple	1	[1B]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	480 volts	[22]
29	motor rated current	4.10 amps rms	[FE]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	9.60 amps rms	[5E]
32	current limit	9.60 amps rms	[3C]
33	motor rms limit	3.40 amps rms	[A3]
34	current rate limit	0 amps pk/sec	[18]
35	field current	2.06 amps rms	[5B]
36	field boost	200 %	[68]
37	slip frequency	2.500 hertz	[9D]
38	motor poles	2	[C2]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector fwd	0.00000 sec	[8B]
42	torque fwd	0.00 deg	[18]
43	stator resistance	Rs 5.1439 ohms	[AE]
44	leakage Sigma	Ls 0.02679 henries	[5D]
45	Lm squared over Lr	0.25535 henries	[92]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	4.12 ftlb	[9E]
50	motor max torque	10.91 ftlb	[76]

51	motor rtd power	2.71 hp	[E5]
52	motor max power	7.17 hp	[E3]
53	motor kt	1.165 ftlb/amp	[2B]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.000 ftlbs^2	[EF]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	456.575 1/sec/sec	[A3]
58	system gain	456.575 1/sec/sec	[8F]
59	system wn	20.0 rad/sec	[5A]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.876 upid gain	[C8]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.876 upid gain	[C7]
65	kv fbk	0.076 upid gain	[C8]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	456.575 1/sec/sec	[3E]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.044 upid gain	[84]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.044 upid gain	[83]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	ENABLE	[67]
95	base rpm	3450 rpm	[40]
96	max vel	1500.0 fpm	[50]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	5000.0 rpm	[C9]
99	accel time	1.000 sec	[70]
100	decel time	1.000 sec	[4C]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	2.000 sec	[FC]
104	decel time 1	2.000 sec	[F6]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.329 gain	[09]	
121	dsv ki	32.945 gain	[2A]	
122	dsv kp fbk	0.329 gain	[08]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu    -29 pulses          [33]
169 dac offset iv     8 pulses          [91]
170 adc offset iu    -1 pulses          [74]
171 adc offset iv    32 pulses          [6B]
172 adc offset fu    -1 pulses          [75]
173 adc offset fv    48 pulses          [65]
174 adc 1 select     VOLTS              [66]
175 adc 1 set        DISABLED           [19]
176 adc 1 min 0.00 % [75]
177 adc 1 max 0.00 % [72]
178 adc 1 min volts 0.000 volts         [D8]
179 adc 1 max volts 0.000 volts         [D5]
180 adc 1 destination-1                 [A1]
181 !adc 1 raw value 0.004 volts        [CE]
182 !adc 1 value 0.00 % [7E]
183 adc 2 select     VOLTS              [65]
184 adc 2 set        DISABLED           [18]
185 adc 2 min 0.00 % [74]
186 adc 2 max 0.00 % [71]
187 adc 2 min volts 0.000 volts         [D7]
188 adc 2 max volts 0.000 volts         [D4]
189 adc 2 destination-1                 [97]
190 !adc 2 raw value -0.005 volts       [9F]
191 !adc 2 value 0.00 % [7D]
192 adc 3 select     VOLTS              [64]
193 adc 3 set        DISABLED           [17]
194 adc 3 min 0.00 % [73]
195 adc 3 max 0.00 % [70]
196 adc 3 min volts 0.000 volts         [D6]
197 adc 3 max volts 0.000 volts         [D3]
198 adc 3 destination-1                 [96]
199 !adc 3 raw value 0.000 volts        [C7]
200 !adc 3 value 0.00 % [85]
201 dac clock level DRIVE CLOCK        [AE]
202 dac 1 select     TORQUE CMD         [32]
203 dac 1 ptr 28965 [41]
204 dac 1 item 0 [C5]
205 dac 1 mul 1 [24]
206 dac 1 div 1 [2E]
207 dac 1 abs DISABLE [77]
208 !dac 1 output 0.000 volts [A8]
209 dac 2 select     UPID VEL FBK      [D2]
210 dac 2 ptr 26033 [52]
211 dac 2 item 0 [C6]
212 dac 2 mul 32767 [4D]
213 dac 2 div 174763 [24]
214 dac 2 abs DISABLE [78]
215 !dac 2 output 0.000 volts [A9]
216 level 1 password 1111 [7A]
217 level 2 password 0 [0C]
218 level 3 password 0 [0A]
219 lockout time 120.000 sec [DB]
220 !lockout status LOCKED [A7]
221 ssi rx mode DISABLED [E8]
222 !ssi rx value 0 [56]
223 ssi torque offset0.00 % [A3]
224 ssi tx mode DISABLED [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	43		[DA]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	43		[A7]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec			[24]
255	!motor rpm	-1.0 rpm	[6B]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	8.65 % max	[C4]		
258	!bus voltage	653 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.20 amps rms			[84]
264	!torque est command	-2.06 ftlb		[70]	
265	!torque est feedback	-2.20 ftlb		[2D]	
266	!load power	-1.15 hp	[5D]		
267	!motor power	-1.09 hp		[C8]	
268	!motor current	2.81 amps rms			[D2]
269	!motor voltage	-355 volts rms			[5A]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	1.45 hp		[BC]	
272	!command vel	804.0 fpm			[94]
273	!feedback vel	803.6 fpm			[48]
274	!command pos	51668903.7296	in		[41]
275	!feedback pos	51668921.9322	in		[02]
276	!in word 0	000001	\$		[0B]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000085	\$		[0E]
282	!int word 0	008c95	\$		[52]

283	!int word 1	000000	\$	[99]
284	!int word 2	001a00	\$	[65]
285	!int word 3	000021	\$	[92]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	1500.0 rpm		[45]
309	test jog rpm	900.0 rpm		[62]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	10.000 rev		[7A]
315	test time	1.000 sec	[81]	
316	test torque	100 %	[03]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in	[B0]	
321	test accel time	4.000 sec	[69]	
322	test freq ramp time	6.000 sec		[E0]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	804.0 fpm		[B5]
331	vel preset 2	1035.0 fpm		[86]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	0.0 fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source DISABLED [6F]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd DISABLE [FF]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select VEL SELECT [AB]
367 vel ovrd vel 0.0 fpm [D9]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 4000 rpm [51]
377 rpm rev shutoff -4000 rpm [17]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel1804.3 fpm [92]
385 !motor socket pos51671977.1620 in [4D]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state AUTO RUN [F2]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF		[16]
412	decelerate req	REQ FORCED OFF		[10]
413	speed adjust req	REQ FORCED OFF		[61]
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF		[A7]
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT ON	[BE]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT ON	[2F]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT ON	[EF]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT OFF	[8A]	
430	!at req vel sts	OUT ON	[48]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED			[74]
458	sout 12	STS DISABLED			[72]
459	sout 13	STS DISABLED			[70]
460	sout 14	STS DISABLED			[77]
461	sout 15	STS DISABLED			[75]
462	sout 16	STS DISABLED			[73]
463	sout 17	STS DISABLED			[71]
464	sout 18	STS DISABLED			[6F]
465	sout 19	STS DISABLED			[6D]
466	sout 20	STS DISABLED			[74]
467	sout 21	STS DISABLED			[72]
468	sout 22	STS DISABLED			[70]
469	sout 23	STS DISABLED			[6E]
470	sout 24	STS DISABLED			[75]
471	sout 25	STS DISABLED			[73]
472	sout 26	STS DISABLED			[71]
473	sout 27	STS DISABLED			[6F]
474	sout 28	STS DISABLED			[6D]
475	sout 29	STS DISABLED			[6B]
476	sout 30	STS DISABLED			[72]
477	sout 31	STS DISABLED			[70]
478	drive type	TANK TRANSFR PUMP			[64]
479	allow pend reverse	DISABLE			[39]
480	torque mode enable	DISABLE			[57]
481	torq override enable	DISABLE			[75]
482	pend max torq	0.00 % rtd		[F5]	
483	pend max vel	0.0 fpm		[EF]	
484	pend index pos	0.0000 in			[ED]
485	pend index vel	0.0 fpm		[1B]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	804.0 fpm		[75]	
488	comp index pos	0.0000 in			[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word1			[51]	
491	!comp status word469			[22]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000 in			[2F]
496	payout preset	0.0000 in			[E6]
497	!index start pos	0.0000 in			[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000 gain			[2B]
503	!smooth hose tension	0.00 lb			[05]
504	hose load 25	%		[3F]	
505	cable filter gain	0.97000 gain			[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000 in/sec/lb			[59]
508	!actual fine control	0.0000 in/sec/lb			[5C]
509	fade filter gain	0.97000 gain			[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0 %		[03]	
513	coil min od	0.0000 in			[47]
514	coil max od	0.0000 in			[44]

```

515 coil diameter      0.0000      in      [31]
516 !coil circumference  0.0000      in      [FF]
517 coil usage 0.0 ft      [F2]
518 coil source MOTOR SOCKET      [63]
519 material source MOTOR SOCKET      [BA]
520 coil od limit DISABLE      [6F]
521 coil od rate      0.0000      in      [E0]
522 coil update distance  2.0002      in      [8C]
523 level direction NONE      [10]
524 !level drum velocity  0.0 rpm units:10 [ED]
525 level follow gain0.000 gain [20]
526 !level follow vel0.0 fpm [12]
527 !level follow req vel 0.0 fpm [A9]
528 level follow vel off 0.0 fpm [D6]
529 level circumference  3.6000      in      [A2]
530 level dwell count0 [72]
531 !level circ count0 [C7]
532 !index pos 0.0000      in      [99]
533 !drive control mode VELOCITY MODE [63]
534 pend disable time0.000 sec [A4]
535 line low limit 600 volts rms [9D]
536 Mode Computer Control [60]
537 Start DISABLE [32]
538 1 bit pump ENABLE [1A]
900 !FH 1 20011017 external trip [6C] $ 20/Jan/2010
    13:19:18 Fault
901 !FH 2 18011017 external trip [63] $ 18/Jan/2010
    17:09:03 Fault
902 !FH 3 18011017 external trip [61] $ 18/Jan/2010
    11:12:16 Fault
903 !FH 4 12011017 external trip [65] $ 12/Jan/2010
    11:18:15 Fault
904 !FH 5 11011017 EXTERNAL TRIP [E4] $ 11/Jan/2010
    14:15:10 Fault
905 !FH 6 30120917 external trip [57] $ 30/Dec/2009
    13:05:26 Fault
906 !FH 7 30120917 external trip [55] $ 30/Dec/2009
    13:05:26 Fault
907 !FH 8 30120917 external trip [53] $ 30/Dec/2009
    13:05:26 Fault
908 !FH 9 30120917 external trip [51] $ 30/Dec/2009
    13:05:26 Fault
909 !FH10 30120917 external trip [48] $ 30/Dec/2009
    13:05:25 Fault
910 !FH11 30120917 external trip [4F] $ 30/Dec/2009
    13:05:25 Fault
911 !FH12 30120917 external trip [4D] $ 30/Dec/2009
    13:05:25 Fault
912 !FH13 30120917 external trip [4B] $ 30/Dec/2009
    13:05:25 Fault
913 !FH14 30120917 external trip [49] $ 30/Dec/2009
    13:05:25 Fault
914 !FH15 30120917 external trip [47] $ 30/Dec/2009
    13:05:24 Fault
915 !FH16 30120917 external trip [45] $ 30/Dec/2009
    13:05:24 Fault
916 !FH17 30120917 external trip [43] $ 30/Dec/2009
    13:05:24 Fault

```

917	!FH18 30120917	external trip	[41]	\$	30/Dec/2009
	13:05:24	Fault			
918	!FH19 30120917	external trip	[3F]	\$	30/Dec/2009
	13:05:24	Fault			
919	!FH20 30120917	external trip	[46]	\$	30/Dec/2009
	13:05:23	Fault			
920	!FH21 30120917	external trip	[4D]	\$	30/Dec/2009
	13:05:23	Fault			
921	!FH22 30120917	external trip	[4B]	\$	30/Dec/2009
	13:05:22	Fault			
922	!FH23 30120917	external trip	[49]	\$	30/Dec/2009
	12:48:31	Fault			
923	!FH24 28120917	external trip	[40]	\$	28/Dec/2009
	19:42:53	Fault			
924	!FH25 22120917	external trip	[44]	\$	22/Dec/2009
	09:15:51	Fault			
925	!FH26 18120917	external trip	[3D]	\$	18/Dec/2009
	16:44:10	Fault			
926	!FH27 15120917	external trip	[3E]	\$	15/Dec/2009
	15:41:53	Fault			
927	!FH28 12120917	external trip	[3F]	\$	12/Dec/2009
	14:54:54	Fault			
928	!FH29 11120907	BUS UNDERVOLTAGE	[E7]	\$	11/Dec/2009
	00:57:52	Fault			
929	!FH30 03120917	external trip	[44]	\$	03/Dec/2009
	12:10:53	Fault			
930	!FH31 30110917	external trip	[4C]	\$	30/Nov/2009
	09:58:22	Fault			
931	!FH32 27110917	EXTERNAL TRIP	[C4]	\$	27/Nov/2009
	20:24:59	Fault			
932	!FH33 27110917	EXTERNAL TRIP	[C2]	\$	27/Nov/2009
	19:39:54	Fault			
933	!FH34 27110917	external trip	[40]	\$	27/Nov/2009
	09:01:07	Fault			
934	!FH35 27110917	external trip	[3E]	\$	27/Nov/2009
	06:14:00	Fault			
935	!FH36 26110917	EXTERNAL TRIP	[BD]	\$	26/Nov/2009
	16:28:17	Fault			
936	!FH37 26110917	EXTERNAL TRIP	[BB]	\$	26/Nov/2009
	16:25:54	Fault			
937	!FH38 26110917	EXTERNAL TRIP	[B9]	\$	26/Nov/2009
	16:25:22	Fault			
938	!FH39 26110917	EXTERNAL TRIP	[B7]	\$	26/Nov/2009
	16:19:34	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled

```

\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg tol 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage 1 - Enabled  
\$ user fault 2 req 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled  
\$ user fault 12 req 1 - Enabled  
\$ user fault 13 req 1 - Enabled  
\$ user fault 14 req 1 - Enabled  
\$ user fault 15 req 1 - Enabled  
\$ user fault 16 req 1 - Enabled  
\$ user fault 17 req 1 - Enabled  
\$ user fault 18 req 1 - Enabled  
\$ user fault 19 req 1 - Enabled  
\$ user fault 20 req 1 - Enabled  
\$ user fault 21 req 1 - Enabled  
\$ user fault 22 req 1 - Enabled  
\$ user fault 23 req 1 - Enabled  
\$ user fault 24 req 1 - Enabled  
\$ user fault 25 req 1 - Enabled  
\$ user fault 26 req 1 - Enabled  
\$ user fault 27 req 1 - Enabled  
\$ user fault 28 req 1 - Enabled  
\$ user fault 29 req 1 - Enabled



```
$ user fault 30 req1 - Enabled
$ user fault 31 req1 - Enabled

$ Warning Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage0 - Disabled
$ user fault 2 req 0 - Disabled
$ user fault 3 req 0 - Disabled
$ user fault 4 req 0 - Disabled
$ user fault 5 req 0 - Disabled
$ user fault 6 req 0 - Disabled
$ user fault 7 req 0 - Disabled
$ user fault 8 req 0 - Disabled
$ user fault 9 req 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
```

\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled

\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 01:46:27

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth 1	[7F]	
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth 1	[12]	
25	load output teeth 1	[90]	
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	10.20 amps rms	[D0]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	10.50 amps rms	[74]
34	current rate limit	0 amps pk/sec	[18]
35	field current	3.54 amps rms	[57]
36	field boost 200	% [68]	
37	slip frequency	1.833 hertz	[95]
38	motor poles 2	[C2]	
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg [18]	
43	stator resistance	Rs 1.0682 ohms	[B3]
44	leakage Sigma	Ls 0.01626 henries	[66]
45	Lm squared over Lr	0.16480 henries	[93]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	12.34 ftlb	[6B]
50	motor max torque	35.85 ftlb	[6C]

51	motor rtd power	8.20	hp	[E5]	
52	motor max power	23.82	hp	[B3]	
53	motor kt	1.291	ftlb/amp	[2B]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.012	ftlbs^2	[EC]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	53.084	1/sec/sec	[DF]	
58	system gain	53.084	1/sec/sec	[CB]	
59	system wn	5.0	rad/sec	[87]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.471	upid gain	[D1]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.471	upid gain	[D0]	
65	kv fbk	0.163	upid gain	[CB]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	53.084	1/sec/sec	[7A]	
77	system wn 1	20.0	rad/sec	[09]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.377	upid gain	[7B]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.377	upid gain	[7A]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		ENABLE	[67]	
95	base rpm	3490	rpm	[3C]	
96	max vel	1500.0	fpm	[50]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	5000.0	rpm	[C9]	
99	accel time	1.000	sec	[70]	
100	decel time	1.000	sec	[4C]	
101	jerk time	0.000	sec	[9D]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	1.000	sec	[FD]	
104	decel time 1	1.000	sec	[F7]	
105	jerk time 1	0.000	sec	[48]	
106	settle time 1	0.200	sec	[60]	
107	fast decel time	0.200	sec	[76]	
108	drive invert		DISABLE	[74]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.199 gain	[04]	
121	dsv ki	19.995 gain	[20]	
122	dsv kp fbk	0.199 gain	[03]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -94 pulses        [31]
169 dac offset iv      -93 pulses        [30]
170 adc offset iu      -79 pulses        [35]
171 adc offset iv      -87 pulses        [34]
172 adc offset fu       25 pulses        [6C]
173 adc offset fv       64 pulses        [67]
174 adc 1 select        VOLTS           [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00 %           [75]
177 adc 1 max  0.00 %           [72]
178 adc 1 min volts  0.000 volts        [D8]
179 adc 1 max volts  0.000 volts        [D5]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value 0.009 volts        [C9]
182 !adc 1 value    0.00 %           [7E]
183 adc 2 select        VOLTS           [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00 %           [74]
186 adc 2 max  0.00 %           [71]
187 adc 2 min volts  0.000 volts        [D7]
188 adc 2 max volts  0.000 volts        [D4]
189 adc 2 destination-1          [97]
190 !adc 2 raw value -0.005 volts        [9F]
191 !adc 2 value    0.00 %           [7D]
192 adc 3 select        VOLTS           [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00 %           [73]
195 adc 3 max  0.00 %           [70]
196 adc 3 min volts  0.000 volts        [D6]
197 adc 3 max volts  0.000 volts        [D3]
198 adc 3 destination-1          [96]
199 !adc 3 raw value 0.000 volts        [C7]
200 !adc 3 value    0.00 %           [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select        TORQUE CMD       [32]
203 dac 1 ptr  28965           [41]
204 dac 1 item 0              [C5]
205 dac 1 mul  1              [24]
206 dac 1 div  1              [2E]
207 dac 1 abs  DISABLE        [77]
208 !dac 1 output  0.000 volts        [A8]
209 dac 2 select        UPID VEL FBK     [D2]
210 dac 2 ptr  26033           [52]
211 dac 2 item 0              [C6]
212 dac 2 mul  32767           [4D]
213 dac 2 div  349525          [24]
214 dac 2 abs  DISABLE        [78]
215 !dac 2 output  0.000 volts        [A9]
216 level 1 password 1111        [7A]
217 level 2 password 0          [0C]
218 level 3 password 0          [0A]
219 lockout time  900.000 sec        [D5]
220 !lockout status  LOCKED         [A7]
221 ssi rx mode  DISABLED          [E8]
222 !ssi rx value  0              [56]
223 ssi torque offset0.00 %        [A3]
224 ssi tx mode  DISABLED          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	42		[DB]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	42		[A8]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	662 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	4.34 amps rms			[7B]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	137798213.2357	in		[15]
275	!feedback pos	137798213.2357	in		[CE]
276	!in word 0	000001	\$		[0B]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000000	\$		[1B]
282	!int word 0	000000	\$		[9B]



283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	177.0 rpm		[6C]
309	test jog rpm	20.0 rpm		[99]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	10.000 rev		[7A]
315	test time	1.000 sec	[81]	
316	test torque	30 %	[31]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in		[B0]
321	test accel time	4.000 sec		[69]
322	test freq ramp time	20.000 sec		[B4]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	0.0 fpm		[21]
331	vel preset 2	780.0 fpm		[B0]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	30.0 fpm		[14]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 90.00 % max [58]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 3800 rpm [4A]
377 rpm rev shutoff -3800 rpm [10]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos137798213.2357 in [17]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ FORCED ON		[1D]
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT OFF	[13]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	TURBINE PUMP		[B9]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	0.00 % rtd	[F5]	
483	pend max vel	0.0 fpm	[EF]	
484	pend index pos	0.0000 in		[ED]
485	pend index vel	0.0 fpm	[1B]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	720.0 fpm	[78]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word128		[2A]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	25 %	[3F]	
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	line low limit	575	volts rms	[92]		
536	Mode	Computer Control		[60]		
537	Start	DISABLE		[32]		
538	1 bit pump	ENABLE		[1A]		
900	!FH 1 20011017	EXTERNAL TRIP		[EC]	\$	20/Jan/2010
	13:19:31	Fault				
901	!FH 2 18011017	EXTERNAL TRIP		[E3]	\$	18/Jan/2010
	17:09:15	Fault				
902	!FH 3 18011017	EXTERNAL TRIP		[E1]	\$	18/Jan/2010
	11:12:28	Fault				
903	!FH 4 12011001	line undervoltage		[D6]	\$	12/Jan/2010
	11:18:25	Fault				
904	!FH 5 12011017	EXTERNAL TRIP		[E3]	\$	12/Jan/2010
	11:18:25	Fault				
905	!FH 6 11011017	EXTERNAL TRIP		[E2]	\$	11/Jan/2010
	14:15:18	Fault				
906	!FH 7 30120917	external trip		[55]	\$	30/Dec/2009
	13:26:56	Fault				
907	!FH 8 30120917	external trip		[53]	\$	30/Dec/2009
	13:26:56	Fault				
908	!FH 9 30120917	external trip		[51]	\$	30/Dec/2009
	13:26:55	Fault				
909	!FH10 30120917	external trip		[48]	\$	30/Dec/2009
	13:26:55	Fault				
910	!FH11 30120917	external trip		[4F]	\$	30/Dec/2009
	13:25:34	Fault				
911	!FH12 30120901	line undervoltage		[BE]	\$	30/Dec/2009
	13:24:18	Fault				
912	!FH13 30120917	EXTERNAL TRIP		[CB]	\$	30/Dec/2009
	13:18:29	Fault				
913	!FH14 30120917	EXTERNAL TRIP		[C9]	\$	30/Dec/2009
	13:18:29	Fault				
914	!FH15 30120917	EXTERNAL TRIP		[C7]	\$	30/Dec/2009
	13:18:29	Fault				
915	!FH16 30120917	EXTERNAL TRIP		[C5]	\$	30/Dec/2009
	13:18:29	Fault				
916	!FH17 30120917	EXTERNAL TRIP		[C3]	\$	30/Dec/2009
	13:18:29	Fault				

917	!FH18 30120917	EXTERNAL TRIP	[C1]	\$	30/Dec/2009
	13:18:28	Fault			
918	!FH19 30120917	EXTERNAL TRIP	[BF]	\$	30/Dec/2009
	13:18:28	Fault			
919	!FH20 30120917	EXTERNAL TRIP	[C6]	\$	30/Dec/2009
	13:18:17	Fault			
920	!FH21 30120917	EXTERNAL TRIP	[CD]	\$	30/Dec/2009
	13:18:17	Fault			
921	!FH22 30120917	EXTERNAL TRIP	[CB]	\$	30/Dec/2009
	13:18:17	Fault			
922	!FH23 30120917	EXTERNAL TRIP	[C9]	\$	30/Dec/2009
	13:18:17	Fault			
923	!FH24 30120917	EXTERNAL TRIP	[C7]	\$	30/Dec/2009
	13:18:16	Fault			
924	!FH25 30120917	EXTERNAL TRIP	[C5]	\$	30/Dec/2009
	13:18:16	Fault			
925	!FH26 30120917	EXTERNAL TRIP	[C3]	\$	30/Dec/2009
	13:06:03	Fault			
926	!FH27 30120917	EXTERNAL TRIP	[C1]	\$	30/Dec/2009
	13:06:03	Fault			
927	!FH28 30120917	EXTERNAL TRIP	[BF]	\$	30/Dec/2009
	13:06:03	Fault			
928	!FH29 30120917	EXTERNAL TRIP	[BD]	\$	30/Dec/2009
	13:06:03	Fault			
929	!FH30 30120917	EXTERNAL TRIP	[C4]	\$	30/Dec/2009
	13:06:02	Fault			
930	!FH31 30120917	EXTERNAL TRIP	[CB]	\$	30/Dec/2009
	13:06:01	Fault			
931	!FH32 30120917	EXTERNAL TRIP	[C9]	\$	30/Dec/2009
	13:01:12	Fault			
932	!FH33 30120917	EXTERNAL TRIP	[C7]	\$	30/Dec/2009
	13:01:11	Fault			
933	!FH34 30120917	EXTERNAL TRIP	[C5]	\$	30/Dec/2009
	13:01:11	Fault			
934	!FH35 30120917	EXTERNAL TRIP	[C3]	\$	30/Dec/2009
	13:01:11	Fault			
935	!FH36 30120917	EXTERNAL TRIP	[C1]	\$	30/Dec/2009
	13:00:27	Fault			
936	!FH37 30120917	EXTERNAL TRIP	[BF]	\$	30/Dec/2009
	13:00:27	Fault			
937	!FH38 30120917	EXTERNAL TRIP	[BD]	\$	30/Dec/2009
	13:00:27	Fault			
938	!FH39 30120917	EXTERNAL TRIP	[BB]	\$	30/Dec/2009
	13:00:26	Fault			
939	!FH40 30120917	EXTERNAL TRIP	[C2]	\$	30/Dec/2009
	13:00:26	Fault			
940	!FH41 30120917	EXTERNAL TRIP	[C9]	\$	30/Dec/2009
	13:00:26	Fault			
941	!FH42 30120917	EXTERNAL TRIP	[C7]	\$	30/Dec/2009
	12:48:36	Fault			
942	!FH43 28120917	EXTERNAL TRIP	[BE]	\$	28/Dec/2009
	19:42:58	Fault			
943	!FH44 22120901	line undervoltage	[B3]	\$	22/Dec/2009
	09:15:55	Fault			
944	!FH45 22120917	external trip	[40]	\$	22/Dec/2009
	09:15:53	Fault			
945	!FH46 19120901	LINE UNDERVOLTAGE	[A9]	\$	19/Dec/2009
	16:32:44	Fault			

946	!FH47 15120901	line undervoltage	[AB]	\$	15/Dec/2009
	15:41:54	Fault			
947	!FH48 15120917	EXTERNAL TRIP	[B8]	\$	15/Dec/2009
	15:41:53	Fault			
948	!FH49 15120914	IREG SHUTOFF	[15]	\$	15/Dec/2009
	15:41:53	Fault			
949	!FH50 12120917	EXTERNAL TRIP	[C0]	\$	12/Dec/2009
	14:54:54	Fault			

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$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch 1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout 1 - Enabled
$ Line Undervoltage 1 - Enabled
$ user fault 2 req 1 - Enabled
$ user fault 3 req 1 - Enabled
$ user fault 4 req 1 - Enabled
$ user fault 5 req 1 - Enabled
$ user fault 6 req 1 - Enabled
$ user fault 7 req 1 - Enabled

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\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled



\$ sync data error 0 - Disabled  
\$ bus reg tol0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled

\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:17:58

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	14.20 amps rms	[CC]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	17.00 amps rms	[72]
34	current rate limit	0 amps pk/sec	[18]
35	field current	7.59 amps rms	[4E]
36	field boost	200 %	[68]
37	slip frequency	2.500 hertz	[9D]
38	motor poles	2	[C2]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 1.2007 ohms	[BA]
44	leakage Sigma	Ls 0.01026 henries	[6C]
45	Lm squared over Lr	0.07319 henries	[92]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	14.75 ftlb	[64]
50	motor max torque	33.13 ftlb	[77]

51	motor rtd power	9.90	hp	[DD]	
52	motor max power	22.24	hp	[B8]	
53	motor kt	1.229	ftlb/amp	[2A]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.007	ftlbs^2	[E8]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	186.792	1/sec/sec	[A2]	
58	system gain	186.792	1/sec/sec	[8E]	
59	system wn	4.0	rad/sec	[88]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.134	upid gain	[D5]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.134	upid gain	[D4]	
65	kv fbk	0.046	upid gain	[CB]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	186.792	1/sec/sec	[3D]	
77	system wn 1	4.5	rad/sec	[32]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.024	upid gain	[86]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.024	upid gain	[85]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		DISABLE	[1A]	
95	base rpm	3525	rpm	[3D]	
96	max vel	1500.0	fpm	[50]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	5000.0	rpm	[C9]	
99	accel time	10.000	sec	[40]	
100	decel time	10.000	sec	[1C]	
101	jerk time	0.000	sec	[9D]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	1.000	sec	[FD]	
104	decel time 1	1.000	sec	[F7]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	0.200	sec	[60]	
107	fast decel time	0.200	sec	[76]	
108	drive invert		ENABLE	[C1]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	4000 hertz	[C9]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.126 gain	[0E]	
121	dsv ki	12.617 gain	[30]	
122	dsv kp fbk	0.126 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -90  pulses      [35]
169 dac offset iv      -60  pulses      [36]
170 adc offset iu      -87  pulses      [36]
171 adc offset iv      -62  pulses      [3B]
172 adc offset fu       16  pulses      [6C]
173 adc offset fv       64  pulses      [67]
174 adc 1 select        VOLTS          [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00  %                    [75]
177 adc 1 max  0.00  %                    [72]
178 adc 1 min volts  0.000 volts          [D8]
179 adc 1 max volts  0.000 volts          [D5]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value 0.019 volts          [C8]
182 !adc 1 value     0.00  %              [7E]
183 adc 2 select        VOLTS          [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00  %                    [74]
186 adc 2 max  0.00  %                    [71]
187 adc 2 min volts  0.000 volts          [D7]
188 adc 2 max volts  0.000 volts          [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value 0.004 volts          [CD]
191 !adc 2 value     0.00  %              [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00  %                    [73]
195 adc 3 max  0.00  %                    [70]
196 adc 3 min volts  0.000 volts          [D6]
197 adc 3 max volts  0.000 volts          [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value 0.004 volts          [C3]
200 !adc 3 value     0.00  %              [85]
201 dac clock level  DRIVE CLOCK          [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr  28965                    [41]
204 dac 1 item 0                    [C5]
205 dac 1 mul  1                    [24]
206 dac 1 div  1                    [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output     0.000 volts          [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr  26033                    [52]
211 dac 2 item 0                    [C6]
212 dac 2 mul  32767                    [4D]
213 dac 2 div  349525                    [24]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output     0.000 volts          [A9]
216 level 1 password 1111                    [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time      300.000  sec          [DB]
220 !lockout status  LEVEL 3              [8E]
221 ssi rx mode DISABLED                    [E8]
222 !ssi rx value     0                    [56]
223 ssi torque offset0.00  %              [A3]
224 ssi tx mode DISABLED                    [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	54		[D8]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	662 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.03 amps rms			[83]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000001 \$			[0B]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000200 \$			[99]



283	!int word 1	000000	\$	[99]
284	!int word 2	001000	\$	[96]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4227857087		[EC]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	1200.0	rpm	[6A]
308	test id min rpm	0.0	rpm	[DB]
309	test jog rpm	200.0	rpm	[69]
310	test max rpm	900.0	rpm	[64]
311	test min rpm	-900.0	rpm	[38]
312	test period	0.000	sec	[B1]
313	test ramp	DISABLE		[B8]
314	test position	10.000	rev	[7A]
315	test time	1.000	sec	[81]
316	test torque	20	%	[32]
317	test degrees	180.00	deg	[22]
318	test i field	0.00	amps rms	[E9]
319	test volts	0	volts	[B6]
320	test length	24.0001	in	[B0]
321	test accel time	4.000	sec	[69]
322	test freq ramp time	6.000	sec	[E0]
323	test adc	1		[02]
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL	1	[3F]
328	vel slv select	ADC	1	[C1]
329	min cruise vel	0.0	fpm	[0E]
330	vel preset 1	0.0	fpm	[21]
331	vel preset 2	1035.0	fpm	[86]
332	vel preset 3	0.0	fpm	[1D]
333	vel preset 4	0.0	fpm	[1B]
334	vel preset 5	0.0	fpm	[19]
335	vel preset 6	0.0	fpm	[17]
336	vel preset 7	0.0	fpm	[15]
337	vel preset 8	0.0	fpm	[13]
338	vel offset	0.0	fpm	[76]
339	vel gain	100.00	%	[EA]
340	vel tolerance	0.0	fpm	[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source DISABLED [6F]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd DISABLE [FF]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select VEL SELECT [AB]
367 vel ovrd vel 0.0 fpm [D9]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt800 volts [04]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 4000 rpm [51]
377 rpm rev shutoff -4000 rpm [17]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip DISABLE [11]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

```

399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF		[16]
412	decelerate req	REQ FORCED OFF		[10]
413	speed adjust req	REQ FORCED OFF		[61]
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF		[A7]
418	inj brake req	REQ FORCED OFF		[B2]
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	RODRIGUEZ PUMP		[17]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	80.00 % rtd	[BD]	
483	pend max vel	1057.5 fpm	[4D]	
484	pend index pos	100.0001 in	[8B]	
485	pend index vel	39.6 fpm	[D9]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	795.0 fpm	[6C]	
488	comp index pos	0.0000 in	[E1]	
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word128		[2A]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0	[24]	
494	!comp handshake ctr p	0	[72]	
495	payout distance	0.0000 in	[2F]	
496	payout preset	0.0000 in	[E6]	
497	!index start pos	0.0000 in	[41]	
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain	[2B]	
503	!smooth hose tension	0.00 lb	[05]	
504	hose load	25 %	[3F]	
505	cable filter gain	0.97000 gain	[E0]	
506	!smooth cable tension	0.00 lb	[BA]	
507	fine control gain	0.0000 in/sec/lb	[59]	
508	!actual fine control	0.0000 in/sec/lb	[5C]	
509	fade filter gain	0.97000 gain	[43]	
510	hose tension offset	0.00 lb	[3B]	
511	cable tension offset	0.00 lb	[F2]	
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in	[47]	
514	coil max od	0.0000 in	[44]	

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	line low limit	600	volts rms	[9D]		
536	Mode	Computer Control		[60]		
537	Start	DISABLE		[32]		
538	1 bit pump	ENABLE		[1A]		
900	!FH 1 20011001	line undervoltage		[DD]	\$	20/Jan/2010
	16:54:16	Fault				
901	!FH 2 12011007	BUS UNDERVOLTAGE		[12]	\$	12/Jan/2010
	10:54:25	Fault				
902	!FH 3 29120905	FAST OVERCURRENT		[ED]	\$	29/Dec/2009
	02:28:21	Fault				
903	!FH 4 27120901	line undervoltage		[C6]	\$	27/Dec/2009
	17:04:38	Fault				
904	!FH 5 27120901	line undervoltage		[C4]	\$	27/Dec/2009
	15:42:35	Fault				
905	!FH 6 27120914	IREG SHUTOFF		[30]	\$	27/Dec/2009
	15:42:17	Fault				
906	!FH 7 27120908	GATE DRIVER DSAT		[18]	\$	27/Dec/2009
	15:42:17	Fault				
907	!FH 8 27120905	FAST OVERCURRENT		[E5]	\$	27/Dec/2009
	15:39:54	Fault				
908	!FH 9 27120908	GATE DRIVER DSAT		[14]	\$	27/Dec/2009
	15:38:18	Fault				
909	!FH10 27120908	GATE DRIVER DSAT		[0B]	\$	27/Dec/2009
	15:36:21	Fault				
910	!FH11 27120908	GATE DRIVER DSAT		[12]	\$	27/Dec/2009
	15:30:50	Fault				
911	!FH12 27120901	line undervoltage		[B8]	\$	27/Dec/2009
	13:36:15	Fault				
912	!FH13 27120908	GATE DRIVER DSAT		[0E]	\$	27/Dec/2009
	13:36:02	Fault				
913	!FH14 27120908	GATE DRIVER DSAT		[0C]	\$	27/Dec/2009
	13:35:30	Fault				
914	!FH15 27120901	line undervoltage		[B2]	\$	27/Dec/2009
	13:23:06	Fault				
915	!FH16 27120908	GATE DRIVER DSAT		[08]	\$	27/Dec/2009
	13:22:53	Fault				
916	!FH17 27120908	GATE DRIVER DSAT		[06]	\$	27/Dec/2009
	13:22:28	Fault				

917	!FH18 27120908	GATE DRIVER DSAT	[04]	\$	27/Dec/2009
	13:21:46	Fault			
918	!FH19 27120914	IREG SHUTOFF	[18]	\$	27/Dec/2009
	13:15:35	Fault			
919	!FH20 27120908	GATE DRIVER DSAT	[09]	\$	27/Dec/2009
	13:15:35	Fault			
920	!FH21 27120908	GATE DRIVER DSAT	[10]	\$	27/Dec/2009
	13:14:17	Fault			
921	!FH22 27120908	GATE DRIVER DSAT	[0E]	\$	27/Dec/2009
	13:12:40	Fault			
922	!FH23 26120908	GATE DRIVER DSAT	[0D]	\$	26/Dec/2009
	22:38:19	Fault			
923	!FH24 26120908	GATE DRIVER DSAT	[0B]	\$	26/Dec/2009
	22:35:38	Fault			
924	!FH25 26120908	GATE DRIVER DSAT	[09]	\$	26/Dec/2009
	14:14:57	Fault			
925	!FH26 23120908	GATE DRIVER DSAT	[0A]	\$	23/Dec/2009
	16:10:41	Fault			
926	!FH27 23120908	GATE DRIVER DSAT	[08]	\$	23/Dec/2009
	15:22:05	Fault			
927	!FH28 22120901	line undervoltage	[AF]	\$	22/Dec/2009
	08:51:59	Fault			
928	!FH29 21120920	OVERSPEED TRIP	[79]	\$	21/Dec/2009
	16:19:33	Fault			
929	!FH30 21120920	OVERSPEED TRIP	[80]	\$	21/Dec/2009
	16:18:46	Fault			
930	!FH31 21120905	FAST OVERCURRENT	[E3]	\$	21/Dec/2009
	16:17:54	Fault			
931	!FH32 21120905	FAST OVERCURRENT	[E1]	\$	21/Dec/2009
	16:13:40	Fault			
932	!FH33 21120908	GATE DRIVER DSAT	[10]	\$	21/Dec/2009
	15:23:53	Fault			
933	!FH34 21120908	GATE DRIVER DSAT	[0E]	\$	21/Dec/2009
	14:56:38	Fault			
934	!FH35 15120907	BUS UNDERVOLTAGE	[E9]	\$	15/Dec/2009
	15:17:56	Fault			
935	!FH36 03120901	LINE UNDERVOLTAGE	[B2]	\$	03/Dec/2009
	11:47:00	Fault			
936	!FH37 02120908	GATE DRIVER DSAT	[09]	\$	02/Dec/2009
	14:57:30	Fault			
937	!FH38 30110907	BUS UNDERVOLTAGE	[E7]	\$	30/Nov/2009
	09:34:27	Fault			
938	!FH39 27110907	BUS UNDERVOLTAGE	[DF]	\$	27/Nov/2009
	08:37:13	Fault			
939	!FH40 26110901	line undervoltage	[AF]	\$	26/Nov/2009
	17:11:50	Fault			
940	!FH41 26110901	line undervoltage	[B6]	\$	26/Nov/2009
	17:10:13	Fault			
941	!FH42 24110901	line undervoltage	[B6]	\$	24/Nov/2009
	22:39:01	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled

```

\$ low voltage supply 1 - Enabled  
\$ external trip 1 - Enabled  
\$ dynamic brake limit 1 - Enabled  
\$ watchdog timer 1 - Enabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 1 - Enabled  
\$ motor marker 1 - Enabled  
\$ load marker1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 0 - Disabled  
\$ ehalt fault1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ user fault 2 req 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled

\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled



\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled

\$ sync data error 0 - Disabled  
\$ bus reg tol0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:22:24

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH		[14]	
1	position units	REV		[ED]	
2	velocity units	MINUTES		[BA]	
3	hertz units	DISABLE		[2C]	
4	clock frequency	50	hertz	[0F]	
5	drive multiple	1		[C7]	
6	upid multiple	20		[FD]	
7	ac multiple	1		[1B]	
8	ac fast multiple	1		[4C]	
9	vector source	MOTOR SOCKET		[DC]	
10	upid motor source	MOTOR SOCKET		[44]	
11	upid load source	LOAD SOCKET		[45]	
12	load vector control	DISABLE		[08]	
13	transducerless	DISABLE		[89]	
14	motor fbk size	2048	pulses/rev	[29]	
15	motor resolution	3.6000	in/rev	[4E]	
16	motor fbk invert	DISABLE		[3C]	
17	motor input teeth	1		[7F]	
18	motor output teeth	1		[FD]	
19	motor encoder bits	BITS 14		[AF]	
20	motor encoder turns	1		[B3]	
21	load fbk size	0	pulses/rev	[5A]	
22	load resolution	10.0001	in/rev	[B8]	
23	load fbk invert	DISABLE		[CF]	
24	load input teeth	1		[12]	
25	load output teeth	1		[90]	
26	load encoder bits	BITS 0		[77]	
27	load encoder turns	1		[3D]	
28	motor rated voltage	640	volts	[24]	
29	motor rated current	3.30	amps rms	[FD]	
30	motor rated frequency	60	hertz	[8A]	
31	maximum current	9.60	amps rms	[5E]	
32	current limit	9.60	amps rms	[3C]	
33	motor rms limit	3.30	amps rms	[A4]	
34	current rate limit	0	amps pk/sec	[18]	
35	field current	0.00	amps rms	[63]	
36	field boost	200	%	[68]	
37	slip frequency	0.000	hertz	[A4]	
38	motor poles	4		[C0]	
39	synchronous motor	ENABLE		[A4]	
40	vector offset	0.70	deg	[40]	
41	vector ffwd	0.00000	sec	[8B]	
42	torque ffwd	0.00	deg	[18]	
43	stator resistance	Rs	2.7157 ohms	[AE]	
44	leakage Sigma	Ls	0.04686 henries	[5D]	
45	Lm squared over Lr	0.18137	henries	[92]	
46	current filter	2.00	hertz	[D3]	
47	voltage filter	2.00	hertz	[E3]	
48	power filter	2.00	hertz	[A7]	
49	motor rtd torque	8.74	ftlb	[92]	
50	motor max torque	25.43	ftlb	[73]	

51	motor rtd power	2.91 hp	[E3]
52	motor max power	8.47 hp	[DF]
53	motor kt	2.646 ftlb/amp	[26]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.000 ftlbs^2	[EF]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	172.643 1/sec/sec	[AC]
58	system gain	172.643 1/sec/sec	[98]
59	system wn	10.0 rad/sec	[5B]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.579 upid gain	[C8]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.579 upid gain	[C7]
65	kv fbk	0.100 upid gain	[D4]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	172.643 1/sec/sec	[47]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.116 upid gain	[84]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.116 upid gain	[83]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1750 rpm	[3F]
96	max vel	1500.0 fpm	[50]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	5000.0 rpm	[C9]
99	accel time	1.000 sec	[70]
100	decel time	1.000 sec	[4C]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	1.000 sec	[F7]
105	jerk time 1	0.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	DISABLE	[74]

109	!motor vel	0.0	fpm	[AF]	
110	inv thermal warning	80.0	%		[E6]
111	motor rms warning	80.0	%	[9C]	
112	modulation select	DIGITAL			[65]
113	switch frequency	6000	hertz	[C7]	
114	thermal protection	STANDARD			[78]
115	dsv synchronized	DISABLE			[BB]
116	dsv wn	200.0	rad/sec	[58]	
117	dsv vphz wn	10.0	rad/sec	[A0]	
118	dsv kv percent	85.00	%	[BA]	
119	dsv kp cmd percent	100	%		[D5]
120	dsv kp cmd	0.576	gain	[05]	
121	dsv ki	57.626	gain	[27]	
122	dsv kp fbk	0.576	gain	[04]	
123	dsv deadtime percent	25	%		[F6]
124	dsv v boost	0	%	[BD]	
125	dsv bus correction	DISABLE			[38]
126	acr i loop	5.000	acr gain	[B9]	
127	acr v ffwd	1.000	acr gain	[C2]	
128	acr field i loop	40.000	acr gain		[64]
129	acr field v ffwd	1.000	acr gain	[9C]	
130	dbm const switch freq	ENABLE			[9E]
131	dbm pulses	4		[1B]	
132	dbm min vel	5.0	hertz	[7F]	
133	dbm volts per hertz	8.0			[67]
134	dbm clamp voltage	0	volts	[61]	
135	dbm block modulation	30	% clamp		[CB]
136	dbm run current limit	0.00	amps rms		[4E]
137	dbm run limit gain	0.000	gain	[05]	
138	damping kp	0.00006	gain	[69]	
139	damping max	1000.00	ftlb	[F9]	
140	damping min freq	20.0	hertz	[3F]	
141	damping max freq	90.0	hertz	[35]	
142	vbus reg filter	300.00	hertz		[2A]
143	vbus filter	0.80	hertz	[E2]	
144	vbus notch frequency	0.0	hertz		[91]
145	vbus notch damping	1.414	gain		[A6]
146	vbus kp	3.000	gain	[ED]	
147	vbus ki	3.000	gain	[F3]	
148	vbus window shift	-1.22	volts	[58]	
149	vbus dac limit	10.00	volts	[C7]	
150	db watts	0	watts	[C1]	
151	db resistance	0.000	ohms	[80]	
152	db time constant	25	secs	[07]	
153	!db percent used	0	%	[1C]	
154	flux control	OPEN LOOP			[CD]
155	flux cutoff min	10.0	rad/sec		[0E]
156	flux cutoff max	20.0	rad/sec		[0A]
157	flux kp	1.000	gain	[EE]	
158	flux id obs bandwidth	50	rad/sec		[4A]
159	torq est filter	0.01000	sec		[D2]
160	torq reg select	DISABLED			[40]
161	torq reg wn	0.0	rad/sec	[E3]	
162	torq reg kp cmd pct	0	%		[0B]
163	torq reg kp cmd	0.000	gain	[39]	
164	torq reg ki	0.00	gain	[C3]	
165	torq reg kp fbk	0.000	gain	[38]	
166	coulomb torque	0.00	ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -16  pulses      [37]
169 dac offset iv       25  pulses      [62]
170 adc offset iu      -25  pulses      [3E]
171 adc offset iv       -9  pulses      [6A]
172 adc offset fu      -15  pulses      [40]
173 adc offset fv       79  pulses      [61]
174 adc 1 select        VOLTS          [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00  %           [75]
177 adc 1 max  0.00  %           [72]
178 adc 1 min volts  0.000 volts      [D8]
179 adc 1 max volts  0.000 volts      [D5]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value -0.005      volts  [A0]
182 !adc 1 value     0.00  %           [7E]
183 adc 2 select        VOLTS          [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00  %           [74]
186 adc 2 max  0.00  %           [71]
187 adc 2 min volts  0.000 volts      [D7]
188 adc 2 max volts  0.000 volts      [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value 0.004 volts      [CD]
191 !adc 2 value     0.00  %           [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00  %           [73]
195 adc 3 max  0.00  %           [70]
196 adc 3 min volts  0.000 volts      [D6]
197 adc 3 max volts  0.000 volts      [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value -0.005      volts  [95]
200 !adc 3 value     0.00  %           [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select        TORQUE CMD      [32]
203 dac 1 ptr   28965                    [41]
204 dac 1 item  0                    [C5]
205 dac 1 mul   1                    [24]
206 dac 1 div   1                    [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output  0.000 volts          [A8]
209 dac 2 select        UPID VEL FBK    [D2]
210 dac 2 ptr   26033                    [52]
211 dac 2 item  0                    [C6]
212 dac 2 mul   32767                    [4D]
213 dac 2 div   174763                    [24]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output  0.000 volts          [A9]
216 level 1 password 1111                    [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time     900.000      sec     [D5]
220 !lockout status  LEVEL 3              [8E]
221 ssi rx mode DISABLE                    [E8]
222 !ssi rx value    0                    [56]
223 ssi torque offset0.00  %           [A3]
224 ssi tx mode DISABLE                    [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	53		[D9]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	662 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.4640 in			[C1]
275	!feedback pos	0.4640 in			[7A]
276	!in word 0	000001 \$			[0B]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000800 \$			[93]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4294967295		[00]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294967295		[E5]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	0.0 rpm		[DB]
309	test jog rpm	900.0 rpm		[62]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	10.000 rev		[7A]
315	test time	1.000 sec	[81]	
316	test torque	20 %	[32]	
317	test degrees	180.00 deg		[22]
318	test i field	0.30 amps rms		[E6]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in		[B0]
321	test accel time	4.000 sec		[69]
322	test freq ramp time	15.000 sec		[B0]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	0.0 fpm		[21]
331	vel preset 2	18.0 fpm		[E6]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	0.0 fpm		[47]



341	torque offset enable	AUTO PERMISSIVE			[0D]
342	torque offset	0.00 % max	[AA]		
343	torque offset rate	0.000 sec	[FD]		
344	offset rate select	BOTH	[18]		
345	preset upr torq lmt	100.00 % max	[30]		
346	preset lwr torq lmt	-100.00 % max	[04]		
347	upr torq lmt rate	0.000 sec	[96]		
348	lwr torq lmt rate	0.000 sec	[97]		
349	torque slave source	DISABLED		[6F]	
350	torque slave data	0.00 % max	[5D]		
351	track enable	DISABLE	[AA]		
352	track source	MOTOR SOCKET		[F9]	
353	track ref pos	0.0000 in	[5F]		
354	!track position	0.0000 in	[77]		
355	track preset pos	0.0000 in	[07]		
356	droop ref select	DISABLED		[DC]	
357	droop ref torque	100.0 %	[DF]		
358	droop maximum	0.0 fpm	[20]		
359	droop start torque	0.0 %	[4D]		
360	droop filter tc	10.000 sec	[1F]		
361	!droop vel actual	0.0 fpm	[22]		
362	offset vel err tol	0.0 fpm	[A1]		
363	offset filter tc	2.000 sec	[E8]		
364	torq slave vel ovrd	DISABLE		[FF]	
365	vel ovrd torq thrsh	0.00 % max	[9B]		
366	vel ovrd select	VEL SELECT		[AB]	
367	vel ovrd vel	0.0 fpm	[D9]		
368	bus reg	DISABLE	[96]		
369	bus reg min vel	50 rpm	[0A]		
370	bus reg tol vel	0 rpm	[3C]		
371	bus reg tol time	0 secs	[74]		
372	bus reg kp	2.000 gain	[05]		
373	bus reg kd	0.000 gain	[12]		
374	bus reg upper lmt	758 volts	[F8]		
375	bus reg torq lmt	20 %	[B2]		
376	rpm fwd shutoff	3600 rpm	[4C]		
377	rpm rev shutoff	-3600 rpm	[12]		
378	ssi data req vel	0.0 fpm	[88]		
379	drive stop mode	COAST	[F1]		
380	inj brake pct	0 %	[16]		
381	inj brake time	0.000 sec	[D9]		
382	magnet flux	0.8464 Wb	[EE]		
383	ext trip	ENABLE	[5E]		
384	!motor socket vel	0.0 fpm	[01]		
385	!motor socket pos	0.4640 in		[C3]	
386	!load socket vel	0.0 fpm	[90]		
387	!load socket pos	0.0000 in		[60]	
388	!follow socket vel	0.0 fpm		[9B]	
389	!follow socket pos	0.0000 in		[6B]	
390	!main state	MAIN USER STATE		[0B]	
391	!application state	MOTOR OFF WAIT		[5F]	
392	motor on req	REQ PLC		[B8]	
393	motor on enable req	REQ FORCED ON		[9F]	
394	fault reset req	REQ PLC		[85]	
395	warning reset req	REQ PLC		[AA]	
396	jog fwd req	REQ PLC	[41]		
397	jog rev req	REQ PLC	[34]		
398	fast stop req	REQ FORCED ON		[BB]	

399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	MOTOR ON STS	[0B]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	ROD WELL WINCH		[62]
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	50.00 % rtd	[C0]	
483	pend max vel	510.0 fpm	[89]	
484	pend index pos	3.6000 in		[E4]
485	pend index vel	60.0 fpm	[E5]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	0.0 fpm	[E1]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word192		[29]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	25 %	[3F]	
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	line low limit	650	volts rms	[98]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	15:10:58	Fault				
901	!FH 2 18011017	external trip		[63]	\$	18/Jan/2010
	11:11:50	Fault				
902	!FH 3 16011017	external trip		[63]	\$	16/Jan/2010
	23:04:30	Fault				
903	!FH 4 12011017	external trip		[65]	\$	12/Jan/2010
	11:22:03	Fault				
904	!FH 5 11011017	external trip		[64]	\$	11/Jan/2010
	14:14:50	Fault				
905	!FH 6 01011017	external trip		[63]	\$	01/Jan/2010
	19:10:17	Fault				
906	!FH 7 01011017	external trip		[61]	\$	01/Jan/2010
	19:10:11	Fault				
907	!FH 8 01011017	external trip		[5F]	\$	01/Jan/2010
	19:10:01	Fault				
908	!FH 9 30120917	external trip		[51]	\$	30/Dec/2009
	12:48:18	Fault				
909	!FH10 28120917	external trip		[41]	\$	28/Dec/2009
	22:05:39	Fault				
910	!FH11 28120917	external trip		[48]	\$	28/Dec/2009
	22:05:38	Fault				
911	!FH12 28120917	external trip		[46]	\$	28/Dec/2009
	22:05:37	Fault				
912	!FH13 28120917	external trip		[44]	\$	28/Dec/2009
	22:05:36	Fault				
913	!FH14 28120917	external trip		[42]	\$	28/Dec/2009
	22:05:35	Fault				
914	!FH15 28120917	external trip		[40]	\$	28/Dec/2009
	22:05:30	Fault				
915	!FH16 28120917	external trip		[3E]	\$	28/Dec/2009
	22:05:14	Fault				
916	!FH17 28120917	external trip		[3C]	\$	28/Dec/2009
	22:05:12	Fault				
917	!FH18 28120917	external trip		[3A]	\$	28/Dec/2009
	22:05:09	Fault				

918	!FH19 22120917	external trip	[3E]	\$	22/Dec/2009
	09:17:29	Fault			
919	!FH20 22120917	external trip	[45]	\$	22/Dec/2009
	09:15:41	Fault			
920	!FH21 19120917	external trip	[46]	\$	19/Dec/2009
	21:02:10	Fault			
921	!FH22 15120917	external trip	[48]	\$	15/Dec/2009
	16:26:03	Fault			
922	!FH23 12120917	EXTERNAL TRIP	[C9]	\$	12/Dec/2009
	14:54:52	Fault			
923	!FH24 08120917	external trip	[42]	\$	08/Dec/2009
	22:56:16	Fault			
924	!FH25 03120917	external trip	[45]	\$	03/Dec/2009
	12:18:49	Fault			
925	!FH26 03120917	external trip	[43]	\$	03/Dec/2009
	12:10:58	Fault			
926	!FH27 30110917	external trip	[42]	\$	30/Nov/2009
	15:30:16	Fault			
927	!FH28 30110917	external trip	[40]	\$	30/Nov/2009
	15:29:58	Fault			
928	!FH29 30110917	external trip	[3E]	\$	30/Nov/2009
	15:29:52	Fault			
929	!FH30 30110917	external trip	[45]	\$	30/Nov/2009
	15:29:50	Fault			
930	!FH31 30110917	external trip	[4C]	\$	30/Nov/2009
	10:14:51	Fault			
931	!FH32 27110917	external trip	[44]	\$	27/Nov/2009
	09:01:40	Fault			
932	!FH33 26110917	external trip	[43]	\$	26/Nov/2009
	10:19:49	Fault			
933	!FH34 26110917	external trip	[41]	\$	26/Nov/2009
	10:17:49	Fault			
934	!FH35 26110917	external trip	[3F]	\$	26/Nov/2009
	10:17:43	Fault			
935	!FH36 26110917	external trip	[3D]	\$	26/Nov/2009
	10:16:26	Fault			
936	!FH37 26110917	external trip	[3B]	\$	26/Nov/2009
	10:16:22	Fault			
937	!FH38 26110917	external trip	[39]	\$	26/Nov/2009
	10:16:16	Fault			
938	!FH39 26110917	external trip	[37]	\$	26/Nov/2009
	10:16:10	Fault			
939	!FH40 26110917	EXTERNAL TRIP	[BE]	\$	26/Nov/2009
	10:15:37	Fault			
940	!FH41 26110917	EXTERNAL TRIP	[C5]	\$	26/Nov/2009
	10:14:52	Fault			
941	!FH42 26110917	EXTERNAL TRIP	[C3]	\$	26/Nov/2009
	10:14:49	Fault			
942	!FH43 26110917	EXTERNAL TRIP	[C1]	\$	26/Nov/2009
	10:14:46	Fault			
943	!FH44 26110917	EXTERNAL TRIP	[BF]	\$	26/Nov/2009
	10:14:12	Fault			
944	!FH45 26110917	EXTERNAL TRIP	[BD]	\$	26/Nov/2009
	10:14:05	Fault			
945	!FH46 26110917	EXTERNAL TRIP	[BB]	\$	26/Nov/2009
	10:13:11	Fault			
946	!FH47 26110917	EXTERNAL TRIP	[B9]	\$	26/Nov/2009
	10:12:54	Fault			

947	!FH48 26110917	EXTERNAL TRIP	[B7]	\$	26/Nov/2009
	10:11:27	Fault			
948	!FH49 26110917	EXTERNAL TRIP	[B5]	\$	26/Nov/2009
	10:11:23	Fault			
949	!FH50 26110917	EXTERNAL TRIP	[BC]	\$	26/Nov/2009
	10:08:04	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor resolv 1 loss 1 - Enabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 1 - Enabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 1 - Enabled
$ load fbk loss 1 - Enabled
$ motor runaway 1 - Enabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout 1 - Enabled
$ Line Undervoltage 1 - Enabled
$ user fault 2 req 1 - Enabled
$ user fault 3 req 1 - Enabled
$ user fault 4 req 1 - Enabled
$ user fault 5 req 1 - Enabled
$ user fault 6 req 1 - Enabled
$ user fault 7 req 1 - Enabled
$ user fault 8 req 1 - Enabled
$ user fault 9 req 1 - Enabled

```

\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:

\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled

\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled



\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:15:16

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth 1	[7F]	
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth 1	[12]	
25	load output teeth 1	[90]	
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	10.20 amps rms	[D0]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	10.50 amps rms	[74]
34	current rate limit	0 amps pk/sec	[18]
35	field current	3.52 amps rms	[59]
36	field boost 200	% [68]	
37	slip frequency	1.833 hertz	[95]
38	motor poles 2	[C2]	
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg [18]	
43	stator resistance	Rs 1.0688 ohms	[AD]
44	leakage Sigma	Ls 0.01577 henries	[61]
45	Lm squared over Lr	0.16597 henries	[8A]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	12.37 ftlb	[68]
50	motor max torque	35.89 ftlb	[68]

51	motor rtd power	8.22	hp	[E3]
52	motor max power	23.85	hp	[B0]
53	motor kt	1.293	ftlb/amp	[29]
54	motor inertia	0.000	ftlbs^2	[94]
55	machine inertia	0.012	ftlbs^2	[EC]
56	acc obs bandwidth	40	rad/sec	[03]
57	system gain id	54.440	1/sec/sec	[E2]
58	system gain	54.440	1/sec/sec	[CE]
59	system wn	5.0	rad/sec	[87]
60	system order		VELOCITY	[1D]
61	kv cmd	0.000	upid gain	[D8]
62	kp cmd	0.459	upid gain	[CB]
63	ki	0.0	upid gain	[97]
64	kp fbk	0.459	upid gain	[CA]
65	kv fbk	0.159	upid gain	[C6]
66	kr	1.000	upid gain	[2A]
67	kp cmd percent	0	%	[D1]
68	ki load enable		DISABLE	[56]
69	kp load ratio	0	%	[35]
70	kv load ratio	0	%	[37]
71	torque limit	100.00	% max	[E2]
72	low pass frequency	100.0	hertz	[33]
73	low pass damping	1.414	gain	[A9]
74	notch frequency	0.0	hertz	[9F]
75	notch damping	1.414	gain	[B4]
76	system gain 1	54.440	1/sec/sec	[7D]
77	system wn 1	20.0	rad/sec	[09]
78	system order 1		TORQUE	[52]
79	kv cmd 1	0.000	upid gain	[7E]
80	kp cmd 1	0.367	upid gain	[7C]
81	ki 1	0.0	upid gain	[46]
82	kp fbk 1	0.367	upid gain	[7B]
83	kv fbk 1	0.000	upid gain	[84]
84	kr 1	0.000	upid gain	[DA]
85	kp cmd percent 1	0	%	[80]
86	ki load enable 1		DISABLE	[05]
87	kp load ratio 1	0	%	[E4]
88	kv load ratio 1	0	%	[DD]
89	torque limit 1	100.00	% max	[88]
90	low pass frequency 1	100.0	hertz	[E2]
91	low pass damping 1	1.414	gain	[58]
92	notch frequency 1	10.0	hertz	[4E]
93	notch damping 1	1.414	gain	[63]
94	torque invert		ENABLE	[67]
95	base rpm	3490	rpm	[3C]
96	max vel	1500.0	fpm	[50]
97	jog vel	175.0	fpm	[7E]
98	!max motor rpm	5000.0	rpm	[C9]
99	accel time	1.000	sec	[70]
100	decel time	1.000	sec	[4C]
101	jerk time	0.000	sec	[9D]
102	settle time	0.200	sec	[B5]
103	accel time 1	1.000	sec	[FD]
104	decel time 1	1.000	sec	[F7]
105	jerk time 1	10.000	sec	[48]
106	settle time 1	0.200	sec	[60]
107	fast decel time	0.200	sec	[76]
108	drive invert		DISABLE	[74]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.193 gain	[0A]	
121	dsv ki	19.393 gain	[28]	
122	dsv kp fbk	0.193 gain	[09]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -92  pulses      [33]
169 dac offset iv      -83  pulses      [31]
170 adc offset iu      -77  pulses      [37]
171 adc offset iv      -80  pulses      [3B]
172 adc offset fu       24  pulses      [6D]
173 adc offset fv       64  pulses      [67]
174 adc 1 select        VOLTS          [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00  %                    [75]
177 adc 1 max  0.00  %                    [72]
178 adc 1 min volts  0.000 volts          [D8]
179 adc 1 max volts  0.000 volts          [D5]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value 0.004 volts          [CE]
182 !adc 1 value     0.00  %              [7E]
183 adc 2 select        VOLTS          [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00  %                    [74]
186 adc 2 max  0.00  %                    [71]
187 adc 2 min volts  0.000 volts          [D7]
188 adc 2 max volts  0.000 volts          [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value 0.000 volts          [D1]
191 !adc 2 value     0.00  %              [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00  %                    [73]
195 adc 3 max  0.00  %                    [70]
196 adc 3 min volts  0.000 volts          [D6]
197 adc 3 max volts  0.000 volts          [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value -0.005      volts    [95]
200 !adc 3 value     0.00  %              [85]
201 dac clock level  DRIVE CLOCK          [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr  28965                    [41]
204 dac 1 item 0                    [C5]
205 dac 1 mul  1                    [24]
206 dac 1 div  1                    [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output     0.000 volts          [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr  26033                    [52]
211 dac 2 item 0                    [C6]
212 dac 2 mul  32767                    [4D]
213 dac 2 div  349525                    [24]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output     0.000 volts          [A9]
216 level 1 password 1111                    [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time      900.000      sec     [D5]
220 !lockout status  LOCKED              [A7]
221 ssi rx mode DISABLED                    [E8]
222 !ssi rx value     0                    [56]
223 ssi torque offset0.00  %              [A3]
224 ssi tx mode DISABLED                    [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	51		[DB]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	51		[A8]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	663 volts		[E0]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	4.50 amps rms			[7D]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	121945844.9237	in		[14]
275	!feedback pos	121945844.9237	in		[CD]
276	!in word 0	000001	\$		[0B]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000000	\$		[1B]
282	!int word 0	000200	\$		[99]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	177.0 rpm		[6C]
309	test jog rpm	20.0 rpm		[99]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	10.000 rev		[7A]
315	test time	1.000 sec	[81]	
316	test torque	30 %	[31]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in		[B0]
321	test accel time	4.000 sec		[69]
322	test freq ramp time	20.000 sec		[B4]
323	test adc	1	[02]	
324	!display count	3		[A7]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	0.0 fpm		[21]
331	vel preset 2	540.0 fpm		[B6]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	30.0 fpm		[14]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 90.00 % max [58]
346 preset lwr torq lmt -5.00 % max [60]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 3800 rpm [4A]
377 rpm rev shutoff -3800 rpm [10]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip DISABLE [11]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos121945844.9237 in [16]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ FORCED ON		[21]
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ FORCED ON		[1D]
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT OFF	[13]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	TURBINE PUMP		[B9]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	0.00 % rtd	[F5]	
483	pend max vel	0.0 fpm	[EF]	
484	pend index pos	0.0000 in		[ED]
485	pend index vel	0.0 fpm	[1B]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	810.0 fpm	[78]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word192		[29]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	hose load	25 %	[3F]	
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	line low limit	600	volts rms	[9D]		
536	Mode	Computer Control		[60]		
537	Start	DISABLE		[32]		
538	1 bit pump	ENABLE		[1A]		
900	!FH 1	14011000	BUS OVERVOLTAGE	[5B]	\$	14/Jan/2010
		09:08:48	Fault			
901	!FH 2	12011001	line undervoltage	[DA]	\$	12/Jan/2010
		11:18:19	Fault			
902	!FH 3	12011007	BUS UNDERVOLTAGE	[10]	\$	12/Jan/2010
		11:18:18	Fault			
903	!FH 4	06011001	LINE UNDERVOLTAGE	[D3]	\$	06/Jan/2010
		23:59:43	Fault			
904	!FH 5	06011001	LINE UNDERVOLTAGE	[D1]	\$	06/Jan/2010
		23:28:47	Fault			
905	!FH 6	06011001	LINE UNDERVOLTAGE	[CF]	\$	06/Jan/2010
		14:52:12	Fault			
906	!FH 7	04011001	LINE UNDERVOLTAGE	[CF]	\$	04/Jan/2010
		19:31:39	Fault			
907	!FH 8	04011001	LINE UNDERVOLTAGE	[CD]	\$	04/Jan/2010
		16:55:37	Fault			
908	!FH 9	29120900	BUS OVERVOLTAGE	[3B]	\$	29/Dec/2009
		06:35:38	Fault			
909	!FH10	29120901	LINE UNDERVOLTAGE	[B1]	\$	29/Dec/2009
		06:33:22	Fault			
910	!FH11	29120901	LINE UNDERVOLTAGE	[B8]	\$	29/Dec/2009
		04:45:56	Fault			
911	!FH12	27120901	LINE UNDERVOLTAGE	[B8]	\$	27/Dec/2009
		14:23:56	Fault			
912	!FH13	27120901	LINE UNDERVOLTAGE	[B6]	\$	27/Dec/2009
		06:52:21	Fault			
913	!FH14	22120901	LINE UNDERVOLTAGE	[B9]	\$	22/Dec/2009
		15:10:52	Fault			
914	!FH15	22120901	line undervoltage	[B7]	\$	22/Dec/2009
		09:15:55	Fault			
915	!FH16	22120901	LINE UNDERVOLTAGE	[B5]	\$	22/Dec/2009
		09:00:32	Fault			
916	!FH17	21120901	LINE UNDERVOLTAGE	[B4]	\$	21/Dec/2009
		08:25:27	Fault			

917	!FH18 19120901	LINE UNDERVOLTAGE	[AB]	\$	19/Dec/2009
	16:33:22	Fault			
918	!FH19 19120901	LINE UNDERVOLTAGE	[A9]	\$	19/Dec/2009
	16:29:33	Fault			
919	!FH20 18120901	LINE UNDERVOLTAGE	[B1]	\$	18/Dec/2009
	02:34:23	Fault			
920	!FH21 16120901	LINE UNDERVOLTAGE	[BA]	\$	16/Dec/2009
	09:41:36	Fault			
921	!FH22 16120901	LINE UNDERVOLTAGE	[B8]	\$	16/Dec/2009
	09:38:31	Fault			
922	!FH23 16120901	LINE UNDERVOLTAGE	[B6]	\$	16/Dec/2009
	09:32:29	Fault			
923	!FH24 16120901	LINE UNDERVOLTAGE	[B4]	\$	16/Dec/2009
	09:13:36	Fault			
924	!FH25 16120901	LINE UNDERVOLTAGE	[B2]	\$	16/Dec/2009
	08:41:35	Fault			
925	!FH26 16120901	LINE UNDERVOLTAGE	[B0]	\$	16/Dec/2009
	08:31:53	Fault			
926	!FH27 15120901	line undervoltage	[AF]	\$	15/Dec/2009
	15:41:57	Fault			
927	!FH28 15120907	BUS UNDERVOLTAGE	[E5]	\$	15/Dec/2009
	15:41:56	Fault			
928	!FH29 12120901	LINE UNDERVOLTAGE	[AE]	\$	12/Dec/2009
	23:38:30	Fault			
929	!FH30 11120901	LINE UNDERVOLTAGE	[B6]	\$	11/Dec/2009
	00:54:00	Fault			
930	!FH31 08120901	LINE UNDERVOLTAGE	[B7]	\$	08/Dec/2009
	19:39:14	Fault			
931	!FH32 05120901	LINE UNDERVOLTAGE	[B8]	\$	05/Dec/2009
	19:23:13	Fault			
932	!FH33 03120901	LINE UNDERVOLTAGE	[B8]	\$	03/Dec/2009
	12:11:02	Fault			
933	!FH34 03120901	LINE UNDERVOLTAGE	[B6]	\$	03/Dec/2009
	05:46:39	Fault			
934	!FH35 30110901	line undervoltage	[B5]	\$	30/Nov/2009
	09:58:33	Fault			
935	!FH36 30110907	BUS UNDERVOLTAGE	[EB]	\$	30/Nov/2009
	09:58:32	Fault			
936	!FH37 27110901	line undervoltage	[AB]	\$	27/Nov/2009
	09:01:18	Fault			
937	!FH38 27110907	BUS UNDERVOLTAGE	[E1]	\$	27/Nov/2009
	09:01:17	Fault			
938	!FH39 24110917	EXTERNAL TRIP	[B9]	\$	24/Nov/2009
	23:49:56	Fault			

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$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled

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\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg tol 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage 1 - Enabled  
\$ user fault 2 req 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled  
\$ user fault 12 req 1 - Enabled  
\$ user fault 13 req 1 - Enabled  
\$ user fault 14 req 1 - Enabled  
\$ user fault 15 req 1 - Enabled  
\$ user fault 16 req 1 - Enabled  
\$ user fault 17 req 1 - Enabled  
\$ user fault 18 req 1 - Enabled  
\$ user fault 19 req 1 - Enabled  
\$ user fault 20 req 1 - Enabled  
\$ user fault 21 req 1 - Enabled  
\$ user fault 22 req 1 - Enabled  
\$ user fault 23 req 1 - Enabled  
\$ user fault 24 req 1 - Enabled  
\$ user fault 25 req 1 - Enabled  
\$ user fault 26 req 1 - Enabled  
\$ user fault 27 req 1 - Enabled  
\$ user fault 28 req 1 - Enabled  
\$ user fault 29 req 1 - Enabled

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$ user fault 30 req1 - Enabled
$ user fault 31 req1 - Enabled

$ Warning Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage0 - Disabled
$ user fault 2 req 0 - Disabled
$ user fault 3 req 0 - Disabled
$ user fault 4 req 0 - Disabled
$ user fault 5 req 0 - Disabled
$ user fault 6 req 0 - Disabled
$ user fault 7 req 0 - Disabled
$ user fault 8 req 0 - Disabled
$ user fault 9 req 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
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\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled

\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

DATA\_END

\$END



\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/18 21:33:35

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth 1	[7F]	
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth 1	[12]	
25	load output teeth 1	[90]	
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	10.20 amps rms	[D0]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	10.50 amps rms	[74]
34	current rate limit	0 amps pk/sec	[18]
35	field current	3.54 amps rms	[57]
36	field boost 200	% [68]	
37	slip frequency	1.833 hertz	[95]
38	motor poles 2	[C2]	
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg [18]	
43	stator resistance	Rs 1.0682 ohms	[B3]
44	leakage Sigma	Ls 0.01626 henries	[66]
45	Lm squared over Lr	0.16480 henries	[93]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	12.34 ftlb	[6B]
50	motor max torque	35.85 ftlb	[6C]

51	motor rtd power	8.20	hp	[E5]	
52	motor max power	23.82	hp	[B3]	
53	motor kt	1.291	ftlb/amp	[2B]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.012	ftlbs^2	[EC]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	58.024	1/sec/sec	[E0]	
58	system gain	58.024	1/sec/sec	[CC]	
59	system wn	5.0	rad/sec	[87]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.431	upid gain	[D5]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.431	upid gain	[D4]	
65	kv fbk	0.149	upid gain	[C7]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	58.024	1/sec/sec	[7B]	
77	system wn 1	20.0	rad/sec	[09]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.345	upid gain	[80]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.345	upid gain	[7F]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		ENABLE	[67]	
95	base rpm	3490	rpm	[3C]	
96	max vel	1500.0	fpm	[50]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	5000.0	rpm	[C9]	
99	accel time	4.000	sec	[6D]	
100	decel time	4.000	sec	[49]	
101	jerk time	0.000	sec	[9D]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	1.000	sec	[FD]	
104	decel time 1	1.000	sec	[F7]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	0.200	sec	[60]	
107	fast decel time	0.200	sec	[76]	
108	drive invert		DISABLE	[74]	

109	!motor vel	0.0	fpm	[AF]	
110	inv thermal warning	80.0	%		[E6]
111	motor rms warning	80.0	%	[9C]	
112	modulation select	DIGITAL			[65]
113	switch frequency	6000	hertz	[C7]	
114	thermal protection	STANDARD			[78]
115	dsv synchronized	DISABLE			[BB]
116	dsv wn	200.0	rad/sec	[58]	
117	dsv vphz wn	10.0	rad/sec	[A0]	
118	dsv kv percent	85.00	%	[BA]	
119	dsv kp cmd percent	100	%		[D5]
120	dsv kp cmd	0.199	gain	[04]	
121	dsv ki	19.995	gain	[20]	
122	dsv kp fbk	0.199	gain	[03]	
123	dsv deadtime percent	25	%		[F6]
124	dsv v boost	0	%	[BD]	
125	dsv bus correction	DISABLE			[38]
126	acr i loop	5.000	acr gain	[B9]	
127	acr v ffwd	1.000	acr gain	[C2]	
128	acr field i loop	40.000	acr gain		[64]
129	acr field v ffwd	1.000	acr gain	[9C]	
130	dbm const switch freq	ENABLE			[9E]
131	dbm pulses	4		[1B]	
132	dbm min vel	5.0	hertz	[7F]	
133	dbm volts per hertz	8.0			[67]
134	dbm clamp voltage	0	volts	[61]	
135	dbm block modulation	30	% clamp		[CB]
136	dbm run current limit	0.00	amps rms		[4E]
137	dbm run limit gain	0.000	gain	[05]	
138	damping kp	0.00006	gain	[69]	
139	damping max	1000.00	ftlb	[F9]	
140	damping min freq	20.0	hertz	[3F]	
141	damping max freq	90.0	hertz	[35]	
142	vbus reg filter	300.00	hertz		[2A]
143	vbus filter	0.80	hertz	[E2]	
144	vbus notch frequency	0.0	hertz	[91]	
145	vbus notch damping	1.414	gain	[A6]	
146	vbus kp	3.000	gain	[ED]	
147	vbus ki	3.000	gain	[F3]	
148	vbus window shift	-1.22	volts	[58]	
149	vbus dac limit	10.00	volts	[C7]	
150	db watts	0	watts	[C1]	
151	db resistance	0.000	ohms	[80]	
152	db time constant	25	secs	[07]	
153	!db percent used	0	%	[1C]	
154	flux control	CLOSED LOOP			[45]
155	flux cutoff min	10.0	rad/sec	[0E]	
156	flux cutoff max	20.0	rad/sec	[0A]	
157	flux kp	1.000	gain	[EE]	
158	flux id obs bandwidth	50	rad/sec		[4A]
159	torq est filter	0.01000	sec	[D2]	
160	torq reg select	DISABLED			[40]
161	torq reg wn	0.0	rad/sec	[E3]	
162	torq reg kp cmd pct	0	%		[0B]
163	torq reg kp cmd	0.000	gain	[39]	
164	torq reg ki	0.00	gain	[C3]	
165	torq reg kp fbk	0.000	gain	[38]	
166	coulomb torque	0.00	ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -94 pulses        [31]
169 dac offset iv      -93 pulses        [30]
170 adc offset iu      -79 pulses        [35]
171 adc offset iv      -87 pulses        [34]
172 adc offset fu       25 pulses        [6C]
173 adc offset fv       64 pulses        [67]
174 adc 1 select        VOLTS            [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00 %           [75]
177 adc 1 max  0.00 %           [72]
178 adc 1 min volts  0.000 volts        [D8]
179 adc 1 max volts  0.000 volts        [D5]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value -0.005 volts        [A0]
182 !adc 1 value  0.00 %           [7E]
183 adc 2 select        VOLTS            [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00 %           [74]
186 adc 2 max  0.00 %           [71]
187 adc 2 min volts  0.000 volts        [D7]
188 adc 2 max volts  0.000 volts        [D4]
189 adc 2 destination-1          [97]
190 !adc 2 raw value 0.000 volts        [D1]
191 !adc 2 value  0.00 %           [7D]
192 adc 3 select        VOLTS            [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00 %           [73]
195 adc 3 max  0.00 %           [70]
196 adc 3 min volts  0.000 volts        [D6]
197 adc 3 max volts  0.000 volts        [D3]
198 adc 3 destination-1          [96]
199 !adc 3 raw value 0.000 volts        [C7]
200 !adc 3 value  0.00 %           [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr  28965             [41]
204 dac 1 item 0                [C5]
205 dac 1 mul  1                 [24]
206 dac 1 div  1                 [2E]
207 dac 1 abs  DISABLE          [77]
208 !dac 1 output  0.000 volts        [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr  26033             [52]
211 dac 2 item 0                [C6]
212 dac 2 mul  32767             [4D]
213 dac 2 div  349525            [24]
214 dac 2 abs  DISABLE          [78]
215 !dac 2 output  0.000 volts        [A9]
216 level 1 password 1111         [7A]
217 level 2 password 0           [0C]
218 level 3 password 0           [0A]
219 lockout time  300.000 sec        [DB]
220 !lockout status  LOCKED        [A7]
221 ssi rx mode  DISABLED          [E8]
222 !ssi rx value  0                [56]
223 ssi torque offset0.00 %        [A3]
224 ssi tx mode  DISABLED          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	52		[DA]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	52		[A7]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	675 volts		[DD]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.08 amps rms			[7E]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	109181649.1602	in		[1F]
275	!feedback pos	109181649.1602	in		[D8]
276	!in word 0	000001	\$		[0B]
277	!out word 0	000000	\$		[8A]
278	!sin word 0	000000	\$		[97]
279	!sin word 1	000000	\$		[95]
280	!sout word 0	000000	\$		[1D]
281	!sout word 1	000000	\$		[1B]
282	!int word 0	000000	\$		[9B]

283	!int word 1	000000	\$	[99]
284	!int word 2	001000	\$	[96]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	177.0 rpm		[6C]
309	test jog rpm	20.0 rpm		[99]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	10.000 rev		[7A]
315	test time	1.000 sec	[81]	
316	test torque	30 %	[31]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in		[B0]
321	test accel time	4.000 sec		[69]
322	test freq ramp time	20.000 sec		[B4]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	0.0 fpm		[21]
331	vel preset 2	840.0 fpm		[B3]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	30.0 fpm		[14]

341	torque offset enable	AUTO PERMISSIVE		[0D]
342	torque offset	0.00 % max	[AA]	
343	torque offset rate	0.000 sec	[FD]	
344	offset rate select	BOTH	[18]	
345	preset upr torq lmt	90.00 % max	[58]	
346	preset lwr torq lmt	-5.00 % max	[60]	
347	upr torq lmt rate	0.000 sec	[96]	
348	lwr torq lmt rate	0.000 sec	[97]	
349	torque slave source	TORQUE DATA		[8D]
350	torque slave data	0.00 % max	[5D]	
351	track enable	DISABLE	[AA]	
352	track source	MOTOR SOCKET		[F9]
353	track ref pos	0.0000 in	[5F]	
354	!track position	0.0000 in	[77]	
355	track preset pos	0.0000 in	[07]	
356	droop ref select	DISABLED	[DC]	
357	droop ref torque	100.0 %	[DF]	
358	droop maximum	0.0 fpm	[20]	
359	droop start torque	0.0 %	[4D]	
360	droop filter tc	10.000 sec	[1F]	
361	!droop vel actual	0.0 fpm	[22]	
362	offset vel err tol	0.0 fpm	[A1]	
363	offset filter tc	2.000 sec	[E8]	
364	torq slave vel ovr	ENABLE		[4C]
365	vel ovr torq thrsh	0.00 % max	[9B]	
366	vel ovr select	OVERIDE VEL	[5D]	
367	vel ovr vel	540.0 fpm	[70]	
368	bus reg	ENABLE	[E3]	
369	bus reg min vel	50 rpm	[0A]	
370	bus reg tol vel	50 rpm	[07]	
371	bus reg tol time	5 secs	[6F]	
372	bus reg kp	2.000 gain	[05]	
373	bus reg kd	0.000 gain	[12]	
374	bus reg upper lmt	800 volts	[04]	
375	bus reg torq lmt	20 %	[B2]	
376	rpm fwd shutoff	3800 rpm	[4A]	
377	rpm rev shutoff	-3800 rpm	[10]	
378	ssi data req vel	0.0 fpm	[88]	
379	drive stop mode	COAST	[F1]	
380	inj brake pct	0 %	[16]	
381	inj brake time	0.000 sec	[D9]	
382	magnet flux	0.0000 Wb	[04]	
383	ext trip	DISABLE	[11]	
384	!motor socket vel	0.0 fpm	[01]	
385	!motor socket pos	109181649.1602 in		[21]
386	!load socket vel	0.0 fpm	[90]	
387	!load socket pos	0.0000 in	[60]	
388	!follow socket vel	0.0 fpm	[9B]	
389	!follow socket pos	0.0000 in		[6B]
390	!main state	MAIN USER STATE	[0B]	
391	!application state	MOTOR OFF WAIT		[5F]
392	motor on req	REQ PLC	[B8]	
393	motor on enable req	REQ FORCED ON		[9F]
394	fault reset req	REQ PLC	[85]	
395	warning reset req	REQ PLC	[AA]	
396	jog fwd req	REQ PLC	[41]	
397	jog rev req	REQ PLC	[34]	
398	fast stop req	REQ FORCED ON		[BB]

399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ FORCED ON	[1D]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT OFF	[13]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	



457	sout 11	STS DISABLED			[74]
458	sout 12	STS DISABLED			[72]
459	sout 13	STS DISABLED			[70]
460	sout 14	STS DISABLED			[77]
461	sout 15	STS DISABLED			[75]
462	sout 16	STS PLC		[CC]	
463	sout 17	STS PLC		[CA]	
464	sout 18	STS PLC		[C8]	
465	sout 19	STS PLC		[C6]	
466	sout 20	STS PLC		[CD]	
467	sout 21	STS PLC		[CB]	
468	sout 22	STS PLC		[C9]	
469	sout 23	STS PLC		[C7]	
470	sout 24	STS PLC		[CE]	
471	sout 25	STS PLC		[CC]	
472	sout 26	STS PLC		[CA]	
473	sout 27	STS PLC		[C8]	
474	sout 28	STS PLC		[C6]	
475	sout 29	STS PLC		[C4]	
476	sout 30	STS PLC		[CB]	
477	sout 31	STS PLC		[C9]	
478	drive type	TURBINE PUMP			[B9]
479	allow pend reverse	DISABLE			[39]
480	torque mode enable	DISABLE			[57]
481	torq override enable	DISABLE			[75]
482	pend max torq	0.00 % rtd		[F5]	
483	pend max vel	0.0 fpm		[EF]	
484	pend index pos	0.0000 in			[ED]
485	pend index vel	0.0 fpm		[1B]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	900.0 fpm		[78]	
488	comp index pos	0.0000 in			[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word0			[52]	
491	!comp status word192			[29]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000 in			[2F]
496	payout preset	0.0000 in			[E6]
497	!index start pos	0.0000 in			[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000 gain			[2B]
503	!smooth hose tension	0.00 lb			[05]
504	hose load	25 %		[3F]	
505	cable filter gain	0.97000 gain			[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000 in/sec/lb			[59]
508	!actual fine control	0.0000 in/sec/lb			[5C]
509	fade filter gain	0.97000 gain			[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0 %		[03]	
513	coil min od	0.0000 in			[47]
514	coil max od	0.0000 in			[44]

```

515 coil diameter      0.0000      in      [31]
516 !coil circumference  0.0000      in      [FF]
517 coil usage 0.0 ft      [F2]
518 coil source MOTOR SOCKET      [63]
519 material source MOTOR SOCKET      [BA]
520 coil od limit DISABLE      [6F]
521 coil od rate      0.0000      in      [E0]
522 coil update distance  2.0002      in      [8C]
523 level direction NONE      [10]
524 !level drum velocity  0.0 rpm units:10 [ED]
525 level follow gain0.000 gain [20]
526 !level follow vel0.0 fpm [12]
527 !level follow req vel 0.0 fpm [A9]
528 level follow vel off 0.0 fpm [D6]
529 level circumference  3.6000      in      [A2]
530 level dwell count0 [72]
531 !level circ count0 [C7]
532 !index pos 0.0000      in      [99]
533 !drive control mode NONE [E7]
534 pend disable time0.000 sec [A4]
535 line low limit 600 volts rms [9D]
536 Mode Computer Control [60]
537 Start DISABLE [32]
538 1 bit pump ENABLE [FA]
900 !FH 1 12011001 line undervoltage [DC] $ 12/Jan/2010
11:18:07 Fault
901 !FH 2 12011007 BUS UNDERVOLTAGE [12] $ 12/Jan/2010
11:18:06 Fault
902 !FH 3 27120901 line undervoltage [C8] $ 27/Dec/2009
20:57:05 Fault
903 !FH 4 27120900 BUS OVERVOLTAGE [47] $ 27/Dec/2009
20:54:31 Fault
904 !FH 5 22120901 line undervoltage [C9] $ 22/Dec/2009
09:15:36 Fault
905 !FH 6 22120907 BUS UNDERVOLTAGE [FF] $ 22/Dec/2009
09:15:36 Fault
906 !FH 7 15120901 line undervoltage [C3] $ 15/Dec/2009
15:41:35 Fault
907 !FH 8 15120907 BUS UNDERVOLTAGE [F9] $ 15/Dec/2009
15:41:35 Fault
908 !FH 9 07120914 IREG SHUTOFF [2C] $ 07/Dec/2009
08:42:50 Fault
909 !FH10 07120900 BUS OVERVOLTAGE [36] $ 07/Dec/2009
08:42:50 Fault
910 !FH11 03120901 LINE UNDERVOLTAGE [C0] $ 03/Dec/2009
12:10:37 Fault
911 !FH12 30110901 line undervoltage [BF] $ 30/Nov/2009
09:58:06 Fault
912 !FH13 30110907 bus undervoltage [15] $ 30/Nov/2009
09:58:05 Fault
913 !FH14 27110901 line undervoltage [B5] $ 27/Nov/2009
09:00:50 Fault
914 !FH15 27110907 BUS UNDERVOLTAGE [EB] $ 27/Nov/2009
09:00:49 Fault
915 !FH16 27110900 BUS OVERVOLTAGE [32] $ 27/Nov/2009
01:36:55 Fault

```

\$ Fault Masks:

\$ bus overvoltage 1 - Enabled  
\$ AMB thermal switch 1 - Enabled  
\$ fast overcurrent 1 - Enabled  
\$ HS thermal switch 1 - Enabled  
\$ gate driver dsat 1 - Enabled  
\$ ireg shutoff 1 - Enabled  
\$ low voltage supply 1 - Enabled  
\$ external trip 1 - Enabled  
\$ dynamic brake limit 1 - Enabled  
\$ watchdog timer 1 - Enabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 1 - Enabled  
\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage 1 - Enabled  
\$ user fault 2 req 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled  
\$ user fault 12 req 1 - Enabled  
\$ user fault 13 req 1 - Enabled  
\$ user fault 14 req 1 - Enabled  
\$ user fault 15 req 1 - Enabled  
\$ user fault 16 req 1 - Enabled  
\$ user fault 17 req 1 - Enabled

\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled

\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled

\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 00:47:15

DATA\_START

UNITS 2 [29]

0	unit system	METRIC		[5A]
1	position units	REV		[ED]
2	velocity units	MINUTES		[BA]
3	hertz units	DISABLE		[2C]
4	clock frequency	50	hertz	[0F]
5	drive multiple	1		[C7]
6	upid multiple	10		[FE]
7	ac multiple	2	[1A]	
8	ac fast multiple	1		[4C]
9	vector source	MOTOR SOCKET		[DC]
10	upid motor source	MOTOR SOCKET		[44]
11	upid load source	LOAD SOCKET		[45]
12	load vector control	DISABLE		[08]
13	transducerless	DISABLE		[89]
14	motor fbk size	2048	pulses/rev	[29]
15	motor resolution	3.6000	in/rev	[4E]
16	motor fbk invert	DISABLE		[3C]
17	motor input teeth	1		[7F]
18	motor output teeth	1		[FD]
19	motor encoder bits	BITS 0		[E4]
20	motor encoder turns	1		[B3]
21	load fbk size	2048	pulses/rev	[BC]
22	load resolution	3.6000	in/rev	[E1]
23	load fbk invert	DISABLE		[CF]
24	load input teeth	1		[12]
25	load output teeth	1		[90]
26	load encoder bits	BITS 0		[77]
27	load encoder turns	1		[3D]
28	motor rated voltage	460	volts	[24]
29	motor rated current	3.40	amps rms	[FC]
30	motor rated frequency	60	hertz	[8A]
31	maximum current	9.60	amps rms	[5E]
32	current limit	9.60	amps rms	[3C]
33	motor rms limit	3.74	amps rms	[9C]
34	current rate limit	0	amps pk/sec	[18]
35	field current	2.08	amps rms	[59]
36	field boost	200	%	[68]
37	slip frequency	0.734	hertz	[96]
38	motor poles	4		[C0]
39	synchronous motor	DISABLE		[57]
40	vector offset	0.00	deg	[47]
41	vector ffwd	0.00000	sec	[8B]
42	torque ffwd	0.00	deg	[18]
43	stator resistance	Rs	1.7246	ohms [B0]
44	leakage Sigma	Ls	0.03745	henries [62]
45	Lm squared over	Lr	0.28621	henries [93]
46	current filter	2.00	hertz	[D3]
47	voltage filter	2.00	hertz	[E3]
48	power filter	2.00	hertz	[A7]
49	motor rtd torque	7.06	ftlb	[98]
50	motor max torque	24.68	ftlb	[6D]

51	motor rtd power	2.35	hp	[E5]	
52	motor max power	8.22	hp	[E6]	
53	motor kt	2.632	ftlb/amp	[2B]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.012	ftlbs^2	[EC]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	79.783	1/sec/sec	[D1]	[D1]
58	system gain	79.783	1/sec/sec	[BD]	
59	system wn	5.0	rad/sec	[87]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.313	upid gain	[D6]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.313	upid gain	[D5]	
65	kv fbk	0.109	upid gain	[CB]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	79.783	1/sec/sec	[6C]	[6C]
77	system wn 1	20.0	rad/sec	[09]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.251	upid gain	[84]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.251	upid gain	[83]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		DISABLE	[1A]	
95	base rpm	1750	rpm	[3F]	
96	max vel	525.0	fpm	[7A]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	1750.0	rpm	[C1]	
99	accel time	1.000	sec	[70]	
100	decel time	3.000	sec	[4A]	
101	jerk time	0.000	sec	[9D]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	1.000	sec	[FD]	
104	decel time 1	1.000	sec	[F7]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	1.000	sec	[61]	
107	fast decel time	1.000	sec	[77]	
108	drive invert		DISABLE	[74]	



109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.460 gain	[0D]	
121	dsv ki	46.054 gain	[2E]	
122	dsv kp fbk	0.460 gain	[0C]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	OPEN LOOP	[CD]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

167	friction deadzone	100.0 rpm	[2F]	
168	dac offset iu	-19 pulses	[34]	
169	dac offset iv	-16 pulses	[35]	
170	adc offset iu	-26 pulses	[3D]	
171	adc offset iv	-5 pulses	[6E]	
172	adc offset fu	15 pulses	[6D]	
173	adc offset fv	-16 pulses	[3D]	
174	adc 1 select	VOLTS	[66]	
175	adc 1 set	DISABLED	[19]	
176	adc 1 min	0.00 %	[75]	
177	adc 1 max	0.00 %	[72]	
178	adc 1 min volts	0.004 volts	[D4]	
179	adc 1 max volts	9.599 volts	[B5]	
180	adc 1 destination-1		[A1]	
181	!adc 1 raw value	0.009 volts	[C9]	
182	!adc 1 value	0.00 %	[7E]	
183	adc 2 select	VOLTS	[65]	
184	adc 2 set	DISABLED	[18]	
185	adc 2 min	0.00 %	[74]	
186	adc 2 max	0.00 %	[71]	
187	adc 2 min volts	0.000 volts	[D7]	
188	adc 2 max volts	0.000 volts	[D4]	
189	adc 2 destination-1		[97]	
190	!adc 2 raw value	0.000 volts	[D1]	
191	!adc 2 value	0.00 %	[7D]	
192	adc 3 select	VOLTS	[64]	
193	adc 3 set	DISABLED	[17]	
194	adc 3 min	0.00 %	[73]	
195	adc 3 max	0.00 %	[70]	
196	adc 3 min volts	0.000 volts	[D6]	
197	adc 3 max volts	0.000 volts	[D3]	
198	adc 3 destination-1		[96]	
199	!adc 3 raw value	0.000 volts	[C7]	
200	!adc 3 value	0.00 %	[85]	
201	dac clock level	DRIVE CLOCK	[AE]	
202	dac 1 select	TORQUE CMD	[32]	
203	dac 1 ptr	28965	[41]	
204	dac 1 item	0	[C5]	
205	dac 1 mul	1	[24]	
206	dac 1 div	1	[2E]	
207	dac 1 abs	DISABLE	[77]	
208	!dac 1 output	0.000 volts	[A8]	
209	dac 2 select	UPID VEL FBK	[D2]	
210	dac 2 ptr	26033	[52]	
211	dac 2 item	0	[C6]	
212	dac 2 mul	32767	[4D]	
213	dac 2 div	122334	[31]	
214	dac 2 abs	DISABLE	[78]	
215	!dac 2 output	0.000 volts	[A9]	
216	level 1 password	1111	[7A]	
217	level 2 password	0	[0C]	
218	level 3 password	0	[0A]	
219	lockout time	900.000 sec	[D5]	
220	!lockout status	LEVEL 3	[8E]	
221	ssi rx mode	DISABLED	[E8]	
222	!ssi rx value	0	[56]	
223	ssi torque offset	0.00 %	[A3]	
224	ssi tx mode	DISABLED	[E3]	

225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	12		[DE]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	663 volts		[E0]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.01 amps rms			[85]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000040 \$			[08]
277	!out word 0	000006 \$			[84]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000000 \$			[9B]

283	!int word 1	000000	\$	[99]	
284	!int word 2	000000	\$	[97]	
285	!int word 3	000000	\$	[95]	
286	hardware mask	-2097153		[81]	
287	hardware warning mask	0		[D2]	
288	hardware event mask	0		[A5]	
289	!hardware faults	131072		[E4]	
290	!hardware warnings	0		[10]	
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	-1347		[02]	
294	software warning mask	0		[B7]	
295	software event mask	0		[8A]	
296	!software faults	0		[C7]	
297	!software warnings	0		[EC]	
298	!software latch	0		[48]	
299	!software unmasked	0		[FB]	
300	user mask	-1		[57]	
301	user warning mask	0		[6E]	
302	user event mask	0		[41]	
303	!user faults	8		[76]	
304	!user warnings	0		[A3]	
305	!user latch	0		[FF]	
306	!user unmasked	8		[AA]	
307	test cycle rpm	900.0 rpm		[94]	
308	test id min rpm	0.0 rpm		[DB]	
309	test jog rpm	900.0 rpm		[62]	
310	test max rpm	900.0 rpm		[64]	
311	test min rpm	-900.0 rpm			[38]
312	test period	0.000 sec		[B1]	
313	test ramp	DISABLE		[B8]	
314	test position	10.000 rev			[7A]
315	test time	1.000 sec		[81]	
316	test torque	80 %		[2C]	
317	test degrees	180.00 deg			[22]
318	test i field	0.00 amps rms			[E9]
319	test volts	0 volts		[B6]	
320	test length	24.0001 in		[B0]	
321	test accel time	4.000 sec		[69]	
322	test freq ramp time	6.000 sec			[E0]
323	test adc	1		[02]	
324	!display count	0		[AA]	
325	!display flag	0		[38]	
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1		[C1]	
329	min cruise vel	0.0 fpm		[0E]	
330	vel preset 1	0.0 fpm		[21]	
331	vel preset 2	0.0 fpm		[1F]	
332	vel preset 3	0.0 fpm		[1D]	
333	vel preset 4	0.0 fpm		[1B]	
334	vel preset 5	0.0 fpm		[19]	
335	vel preset 6	0.0 fpm		[17]	
336	vel preset 7	0.0 fpm		[15]	
337	vel preset 8	0.0 fpm		[13]	
338	vel offset	0.0 fpm		[76]	
339	vel gain	100.00 %		[EA]	
340	vel tolerance	0.0 fpm		[47]	

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 525.0 fpm [6D]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 10 rpm [0B]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 1750 rpm [48]
377 rpm rev shutoff -1750 rpm [0E]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos -0.0005 in [2E]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

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399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	STS DISABLED	[21]		
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED	[19]		
445	out 5	STS DISABLED	[17]		
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

457	sout 11	STS DISABLED		[74]	
458	sout 12	STS DISABLED		[72]	
459	sout 13	STS DISABLED		[70]	
460	sout 14	STS DISABLED		[77]	
461	sout 15	STS DISABLED		[75]	
462	sout 16	STS PLC		[CC]	
463	sout 17	STS PLC		[CA]	
464	sout 18	STS PLC		[C8]	
465	sout 19	STS PLC		[C6]	
466	sout 20	STS PLC		[CD]	
467	sout 21	STS PLC		[CB]	
468	sout 22	STS PLC		[C9]	
469	sout 23	STS PLC		[C7]	
470	sout 24	STS PLC		[CE]	
471	sout 25	STS PLC		[CC]	
472	sout 26	STS PLC		[CA]	
473	sout 27	STS PLC		[C8]	
474	sout 28	STS PLC		[C6]	
475	sout 29	STS PLC		[C4]	
476	sout 30	STS PLC		[CB]	
477	sout 31	STS PLC		[C9]	
478	drive type	DRILL CABLE LEVEL		[AE]	
479	allow pend reverse	ENABLE			[86]
480	torque mode enable	DISABLE			[57]
481	torq override enable	ENABLE			[C2]
482	pend max torq	0.00 % rtd		[F5]	
483	pend max vel	525.0 fpm		[83]	
484	pend index pos	830.0002 in			[80]
485	pend index vel	540.0 fpm		[B2]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	0.0 fpm		[E1]	
488	comp index pos	0.0000 in			[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word0			[52]	
491	!comp status word0			[95]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000 in			[2F]
496	payout preset	0.0000 in			[E6]
497	!index start pos	0.0000 in			[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000 gain			[2B]
503	!smooth hose tension	0.00 lb			[05]
504	target hose load %	25 %			[53]
505	cable filter gain	0.97000 gain			[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000 in/sec/lb			[59]
508	!actual fine control	0.0000 in/sec/lb			[5C]
509	fade filter gain	0.97000 gain			[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0 %		[03]	
513	coil min od	0.0000 in			[47]
514	coil max od	0.0000 in			[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	SAME		[1A]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.434	gain	[15]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	310		[0E]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	-0.0005	in	[2B]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011003	soft limit error		[6E]	\$	20/Jan/2010
	19:41:12	Fault				
901	!FH 2 20011017	external trip		[6A]	\$	20/Jan/2010
	19:41:12	Fault				
902	!FH 3 20011003	soft limit error		[6A]	\$	20/Jan/2010
	19:39:25	Fault				
903	!FH 4 20011017	external trip		[66]	\$	20/Jan/2010
	19:39:25	Fault				
904	!FH 5 18011017	external trip		[5D]	\$	18/Jan/2010
	20:20:23	Fault				
905	!FH 6 18011003	soft limit error		[5D]	\$	18/Jan/2010
	19:18:51	Fault				
906	!FH 7 18011003	soft limit error		[5B]	\$	18/Jan/2010
	19:18:51	Fault				
907	!FH 8 18011003	soft limit error		[59]	\$	18/Jan/2010
	19:18:48	Fault				
908	!FH 9 18011003	soft limit error		[57]	\$	18/Jan/2010
	19:18:47	Fault				
909	!FH10 18011003	soft limit error		[4E]	\$	18/Jan/2010
	18:02:38	Fault				
910	!FH11 18011003	soft limit error		[55]	\$	18/Jan/2010
	18:02:38	Fault				
911	!FH12 18011003	soft limit error		[53]	\$	18/Jan/2010
	18:02:35	Fault				
912	!FH13 18011003	soft limit error		[51]	\$	18/Jan/2010
	12:48:44	Fault				



913	!FH14 18011003	soft limit error	[4F]	\$	18/Jan/2010
	12:48:44	Fault			
914	!FH15 18011003	soft limit error	[4D]	\$	18/Jan/2010
	12:48:41	Fault			
915	!FH16 18011003	soft limit error	[4B]	\$	18/Jan/2010
	12:48:40	Fault			
916	!FH17 18011017	external trip	[47]	\$	18/Jan/2010
	12:46:01	Fault			
917	!FH18 18011003	soft limit error	[47]	\$	18/Jan/2010
	12:25:01	Fault			
918	!FH19 18011003	soft limit error	[45]	\$	18/Jan/2010
	12:25:01	Fault			
919	!FH20 18011003	soft limit error	[4C]	\$	18/Jan/2010
	12:25:00	Fault			
920	!FH21 18011003	soft limit error	[53]	\$	18/Jan/2010
	12:24:59	Fault			
921	!FH22 18011003	soft limit error	[51]	\$	18/Jan/2010
	12:24:51	Fault			
922	!FH23 18011003	soft limit error	[4F]	\$	18/Jan/2010
	12:00:12	Fault			
923	!FH24 18011017	EXTERNAL TRIP	[CB]	\$	18/Jan/2010
	11:58:50	Fault			
924	!FH25 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	11:47:07	Fault			
925	!FH26 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:47:07	Fault			
926	!FH27 18011017	EXTERNAL TRIP	[C5]	\$	18/Jan/2010
	11:47:06	Fault			
927	!FH28 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:47:06	Fault			
928	!FH29 18011017	EXTERNAL TRIP	[C1]	\$	18/Jan/2010
	11:47:06	Fault			
929	!FH30 18011017	EXTERNAL TRIP	[C8]	\$	18/Jan/2010
	11:47:05	Fault			
930	!FH31 18011017	EXTERNAL TRIP	[CF]	\$	18/Jan/2010
	11:47:05	Fault			
931	!FH32 18011003	soft limit error	[4F]	\$	18/Jan/2010
	11:46:17	Fault			
932	!FH33 18011017	EXTERNAL TRIP	[CB]	\$	18/Jan/2010
	11:46:17	Fault			
933	!FH34 18011003	soft limit error	[4B]	\$	18/Jan/2010
	11:46:16	Fault			
934	!FH35 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:46:16	Fault			
935	!FH36 18011003	soft limit error	[47]	\$	18/Jan/2010
	11:46:16	Fault			
936	!FH37 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:46:16	Fault			
937	!FH38 18011003	soft limit error	[43]	\$	18/Jan/2010
	11:46:16	Fault			
938	!FH39 18011017	EXTERNAL TRIP	[BF]	\$	18/Jan/2010
	11:46:16	Fault			
939	!FH40 18011003	soft limit error	[48]	\$	18/Jan/2010
	11:46:15	Fault			
940	!FH41 18011017	EXTERNAL TRIP	[CD]	\$	18/Jan/2010
	11:45:06	Fault			
941	!FH42 18011003	soft limit error	[4D]	\$	18/Jan/2010
	11:45:05	Fault			

942	!FH43 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	11:45:05	Fault			
943	!FH44 18011003	soft limit error	[49]	\$	18/Jan/2010
	11:45:04	Fault			
944	!FH45 18011017	EXTERNAL TRIP	[C5]	\$	18/Jan/2010
	11:45:04	Fault			
945	!FH46 18011003	soft limit error	[45]	\$	18/Jan/2010
	11:45:04	Fault			
946	!FH47 18011017	EXTERNAL TRIP	[C1]	\$	18/Jan/2010
	11:45:04	Fault			
947	!FH48 18011003	soft limit error	[41]	\$	18/Jan/2010
	11:45:03	Fault			
948	!FH49 18011017	EXTERNAL TRIP	[BD]	\$	18/Jan/2010
	11:28:18	Fault			
949	!FH50 18011003	soft limit error	[46]	\$	18/Jan/2010
	11:28:17	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 0 - Disabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg tol 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

```

\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ Soft Limit Error 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled

\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

```
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 00:42:42

DATA\_START

UNITS 2 [29]

0	unit system	METRIC	[5A]	
1	position units	FEET METER	[19]	
2	velocity units	MINUTES	[BA]	
3	hertz units	DISABLE	[2C]	
4	clock frequency	50 hertz	[0F]	
5	drive multiple	1	[C7]	
6	upid multiple	10	[FE]	
7	ac multiple	2	[1A]	
8	ac fast multiple	1	[4C]	
9	vector source	MOTOR SOCKET		[DC]
10	upid motor source	MOTOR SOCKET		[44]
11	upid load source	LOAD SOCKET	[45]	
12	load vector control	DISABLE		[08]
13	transducerless	DISABLE	[89]	
14	motor fbk size	2048 pulses/rev	[29]	
15	motor resolution	121.7097 in/rev		[DC]
16	motor fbk invert	DISABLE	[3C]	
17	motor input teeth	1	[7F]	
18	motor output teeth	220	[9A]	
19	motor encoder bits	BITS 0		[E4]
20	motor encoder turns	1	[B3]	
21	load fbk size	2048 pulses/rev	[BC]	
22	load resolution	113.0972 in/rev		[73]
23	load fbk invert	ENABLE	[1C]	
24	load input teeth	1	[12]	
25	load output teeth	1	[90]	
26	load encoder bits	BITS 0		[77]
27	load encoder turns	1	[3D]	
28	motor rated voltage	460 volts	[24]	
29	motor rated current	27.00 amps rms		[CA]
30	motor rated frequency	60 hertz	[8A]	
31	maximum current	80.00 amps rms	[35]	
32	current limit	80.00 amps rms	[13]	
33	motor rms limit	29.70 amps rms	[68]	
34	current rate limit	0 amps pk/sec		[18]
35	field current	15.00 amps rms	[2D]	
36	field boost	200 %	[68]	
37	slip frequency	0.390 hertz	[98]	
38	motor poles	4	[C0]	
39	synchronous motor	DISABLE		[57]
40	vector offset	0.00 deg	[47]	
41	vector fwd	0.00000 sec	[8B]	
42	torque fwd	0.00 deg	[18]	
43	stator resistance	Rs 0.1433 ohms		[B9]
44	leakage Sigma	Ls 0.00565 henries		[65]
45	Lm squared over Lr	0.03814 henries		[96]
46	current filter	2.00 hertz	[D3]	
47	voltage filter	2.00 hertz	[E3]	
48	power filter	2.00 hertz	[A7]	
49	motor rtd torque	56.79 ftlb	[5A]	
50	motor max torque	198.26 ftlb	[37]	

51	motor rtd power	19.36 hp	[AC]
52	motor max power	67.57 hp	[A9]
53	motor kt	2.529 ftlb/amp	[26]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.229 ftlbs^2	[E2]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	34.061 1/sec/sec	[E5]
58	system gain	34.061 1/sec/sec	[D1]
59	system wn	5.0 rad/sec	[87]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.734 upid gain	[CF]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.734 upid gain	[CE]
65	kv fbk	0.254 upid gain	[CA]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	34.061 1/sec/sec	[80]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.587 upid gain	[78]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.587 upid gain	[77]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1790 rpm	[3B]
96	max vel	82.0 fpm	[AC]
97	jog vel	4.9 fpm	[DE]
98	!max motor rpm	1779.1 rpm	[B5]
99	accel time	2.000 sec	[6F]
100	decel time	2.000 sec	[4B]
101	jerk time	1.000 sec	[9C]
102	settle time	0.200 sec	[B5]
103	accel time 1	10.000 sec	[CD]
104	decel time 1	10.000 sec	[C7]
105	jerk time 1	1.000 sec	[47]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]



109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.069 gain	[08]	
121	dsv ki	6.948 gain	[56]	
122	dsv kp fbk	0.069 gain	[07]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	7000 watts	[2A]	
151	db resistance	16.700 ohms	[42]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	OPEN LOOP	[CD]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	ESTIMATED	[D8]	
161	torq reg wn	500.0 rad/sec	[7E]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	12.87 gain	[81]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -11 pulses        [3C]
169 dac offset iv      -10 pulses        [3B]
170 adc offset iu      -34 pulses        [3E]
171 adc offset iv      17 pulses         [68]
172 adc offset fu      -46 pulses        [3C]
173 adc offset fv      -1 pulses         [73]
174 adc 1 select       VOLTS             [66]
175 adc 1 set          DISABLED          [19]
176 adc 1 min          0.00 %            [75]
177 adc 1 max          0.00 %            [72]
178 adc 1 min volts    0.009 volts       [CF]
179 adc 1 max volts    9.609 volts       [BD]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value   0.043 volts       [CB]
182 !adc 1 value       0.00 %            [7E]
183 adc 2 select       VOLTS             [65]
184 adc 2 set          DISABLED          [18]
185 adc 2 min          0.00 %            [74]
186 adc 2 max          0.00 %            [71]
187 adc 2 min volts    0.000 volts       [D7]
188 adc 2 max volts    0.000 volts       [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value   0.009 volts       [C8]
191 !adc 2 value       0.00 %            [7D]
192 adc 3 select       VOLTS             [64]
193 adc 3 set          DISABLED          [17]
194 adc 3 min          0.00 %            [73]
195 adc 3 max          0.00 %            [70]
196 adc 3 min volts    0.000 volts       [D6]
197 adc 3 max volts    0.000 volts       [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value   -0.005 volts      [95]
200 !adc 3 value       0.00 %            [85]
201 dac clock level    DRIVE CLOCK       [AE]
202 dac 1 select       TORQUE CMD        [32]
203 dac 1 ptr          28965             [41]
204 dac 1 item          0                 [C5]
205 dac 1 mul           1                 [24]
206 dac 1 div           1                 [2E]
207 dac 1 abs          DISABLE           [77]
208 !dac 1 output      0.000 volts       [A8]
209 dac 2 select       UPID VEL FBK      [D2]
210 dac 2 ptr          26033             [52]
211 dac 2 item          0                 [C6]
212 dac 2 mul           32767            [4D]
213 dac 2 div           124368           [28]
214 dac 2 abs          DISABLE           [78]
215 !dac 2 output      0.000 volts       [A9]
216 level 1 password    1111             [7A]
217 level 2 password    0                 [0C]
218 level 3 password    0                 [0A]
219 lockout time        900.000 sec       [D5]
220 !lockout status    LEVEL 3           [8E]
221 ssi rx mode        DISABLED          [E8]
222 !ssi rx value       0                 [56]
223 ssi torque offset   0.00 %           [A3]
224 ssi tx mode        CMD VEL           [40]

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225	!ssi tx value	0		[51]	
226	ssi position lock	ENABLE		[E5]	
227	ssi tx clock	ENABLE		[0A]	
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0		[24]	
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU		[B3]	
232	console baud rate	38400 BAUD		[66]	
233	console parity	NONE	[3F]		
234	console address	100	[B0]		
235	console checksum	BCC	[0B]		
236	console units	METRIC		[2E]	
237	console pos units	IN MM	[2E]		
238	console vel units	SECONDS		[7A]	
239	porta protocol	OPTOMUX		[21]	
240	porta baud rate	19200 BAUD		[37]	
241	porta parity	NONE	[0D]		
242	porta stop bits	STOP 1		[A6]	
243	porta address	0	[DE]		
244	porta checksum	BCC	[D8]		
245	porta units	ENGLISH	[B5]		
246	porta pos units	FEET METER		[8B]	
247	porta vel units	MINUTES		[31]	
248	optomux bits dev	BITS 32		[31]	
249	optomux num devices	1		[74]	
250	optomux output 0	0	[CF]		
251	optomux output 1	65535	[F5]		
252	optomux retries	3	[CD]		
253	optomux timeout	1.000 sec	[CC]		
254	optomux wd time	5.000 sec	[24]		
255	!motor rpm	0.0 rpm	[99]		
256	!max current	53.20 amps rms		[91]	
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	665 volts	[DE]		
259	!max bus voltage	1011 volts	[55]		
260	!armature voltage	0 volts	[3F]		
261	!max voltage	0 volts	[59]		
262	!field voltage	0 volts	[9A]		
263	!motor thermal rms	0.00 amps rms		[86]	
264	!torque est command	0.00 ftlb	[A5]		
265	!torque est feedback	0.00 ftlb	[5E]		
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp	[FF]		
268	!motor current	0.00 amps rms		[DD]	
269	!motor voltage	0 volts rms	[F4]		
270	!maximum voltage	460 volts rms		[C5]	
271	!inverter power	-0.01 hp	[98]		
272	!command vel	0.0 fpm	[00]		
273	!feedback vel	0.0 fpm	[B9]		
274	!command pos	0.0006 in		[C9]	
275	!feedback pos	0.0006 in		[82]	
276	!in word 0	000cd0 \$		[A5]	
277	!out word 0	000000 \$		[8A]	
278	!sin word 0	000000 \$		[97]	
279	!sin word 1	000000 \$		[95]	
280	!sout word 0	000000 \$		[1D]	
281	!sout word 1	000000 \$		[1B]	
282	!int word 0	000200 \$		[99]	

283	!int word 1	000008	\$		[91]
284	!int word 2	000000	\$		[97]
285	!int word 3	000400	\$		[91]
286	hardware mask	4294967295			[00]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294967293			[E7]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967271			[A2]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	64			[44]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	64			[78]
307	test cycle rpm	1750.0	rpm		[60]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	900.0	rpm		[62]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque	80	%		[2C]
317	test degrees	180.00	deg		[22]
318	test i field	0.00	amps rms		[E9]
319	test volts	0	volts		[B6]
320	test length	24.0000	in		[B1]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	0.0	fpm		[1F]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 80.00 % max [59]
346 preset lwr torq lmt -80.00 % max [2D]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 82.0 fpm [9F]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 2 secs [72]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.1337 in [C3]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 318.0030 in [F1]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

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399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	MOTOR ON STS		[0B]	
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS DISABLED		[1B]	
444	out 4	STS DISABLED		[19]	
445	out 5	STS DISABLED		[17]	
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

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457  sout 11      STS DISABLED                [74]
458  sout 12      STS DISABLED                [72]
459  sout 13      STS DISABLED                [70]
460  sout 14      STS DISABLED                [77]
461  sout 15      STS DISABLED                [75]
462  sout 16      STS PLC                    [CC]
463  sout 17      STS PLC                    [CA]
464  sout 18      STS PLC                    [C8]
465  sout 19      STS PLC                    [C6]
466  sout 20      STS PLC                    [CD]
467  sout 21      STS PLC                    [CB]
468  sout 22      STS PLC                    [C9]
469  sout 23      STS PLC                    [C7]
470  sout 24      STS PLC                    [CE]
471  sout 25      STS PLC                    [CC]
472  sout 26      STS PLC                    [CA]
473  sout 27      STS PLC                    [C8]
474  sout 28      STS PLC                    [C6]
475  sout 29      STS PLC                    [C4]
476  sout 30      STS PLC                    [CB]
477  sout 31      STS PLC                    [C9]
478  drive type NONE                        [04]
479  allow pend reverse    ENABLE                [86]
480  torque mode enable   DISABLE              [57]
481  torq override enable  ENABLE                [C2]
482  pend max torq      80.00 % rtd          [BD]
483  pend max vel       23.0 mpm    units:3    [13]
484  pend index pos     36.0000    in          [B4]
485  pend index vel     3.9 fpm             [0F]
486  comp req torq      0.00 % rtd          [E7]
487  comp req vel       0.0 fpm            [E1]
488  comp index pos     0.0000    in          [E1]
489  comp index vel     0.0 fpm            [0F]
490  comp request word0                                [52]
491  !comp status word0                                [95]
492  comp timeout      0.000 sec          [35]
493  comp handshake ctr  0                [24]
494  !comp handshake ctr p 0                [72]
495  payout distance    0.0000    in          [2F]
496  payout preset     0.0000    in          [E6]
497  !index start pos  0.0000    in          [41]
498  !tension error     0.00 lb           [37]
499  !tgt hose tension 0.00 lb           [42]
500  !hose tension     0.00 lb           [C2]
501  !cable tension    0.00 lb           [79]
502  hose filter gain   0.97000    gain      [2B]
503  !smooth hose tension 0.00 lb       [05]
504  cable filter gain  0.97000    gain      [E1]
505  !smooth cable tension 0.00 lb       [BB]
506  fine control gain  0.0550    in/sec/lb   [50]
507  !actual fine control 0.0000    in/sec/lb   [5D]
508  fade filter gain   0.97000    gain      [44]
509  hose tension offset 0.00 lb         [33]
510  cable tension offset 0.00 lb         [F3]
511  !hose load fbk     0 %              [04]
512  coil min od 790.00 mm    units:1     [97]
513  coil max od 2480.00 mm   units:1     [66]
514  coil diameter     2088.00 mm    units:1     [4F]

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515 !coil circumference 3091.43 mm units:1 [1B]
516 !coil usage 0.0 m units:1 [A1]
517 coil source MOTOR SOCKET [64]
518 material source LOAD SOCKET [2C]
519 coil od limit DISABLE [67]
520 coil od rate 1.8110 in [D6]
521 coil update distance 118.1102 in [23]
522 level direction NONE [11]
523 !level drum velocity 0.0 rpm units:10 [EE]
524 level follow gain 0.000 gain [21]
525 !level follow vel 0.0 fpm [13]
526 !level follow req vel 0.0 fpm [AA]
527 level follow vel off 0.0 fpm [D7]
528 level circumference 3.6000 in [A3]
529 level dwell count 0 [6A]
530 !level circ count 0 [C8]
531 !index pos 0.0000 in [9A]
532 !drive control mode NONE [E8]
533 pend disable time 0.000 sec [A5]
534 lo-spd line low limt 575 volts rms [8D]
535 hi-spd line low limt 575 volts rms [96]
536 high-low vel cutoff 0 rpm [89]
537 payout at drum -6.2 m units:1 [F7]
538 payout at tower 470.8332 in [DB]
539 drum payout offset 0.0 m units:1 [78]
540 tower payout offset 0.0000 in [AB]
541 Hose Max Load 0.00 lb [38]
542 Hose Min Load 0.00 lb [39]
543 Cable Max Load 0.00 lb [EE]
544 Cable Min Load 0.00 lb [EF]
545 Reel Mode Drill/Deployment [C1]
546 !Deploy Payout -2579.3045 m units:7 [F5]
547 !Dep PLRV -2579.3045 m units:7 [86]
548 Dep reset DISABLE [E2]
549 Load Cell Cal. DISABLE [BF]
550 Ld cell torque limit 8.00 % max [79]
551 ld cell pend. vel. 0.5 mpm units:7 [9D]
552 !Tower PLRV 3.8819 m units:7 [55]
553 Drill payout reset ENABLE [93]
554 !raw tower payout 11.9592 m units:7 [3D]
555 !Drum PLRV -0.0005 m units:7 [B6]
556 !raw drum payout -0.0005 m units:7 [CD]
557 max torque 0.00 ftlb units:0 [29]
900 !FH 1 20011006 drive identity error [C2] $
20/Jan/2010 19:41:44 Fault
901 !FH 2 20011017 external trip [6A] $ 20/Jan/2010
19:41:44 Fault
902 !FH 3 20011006 drive identity error [BE] $
20/Jan/2010 19:41:41 Fault
903 !FH 4 20011005 turn on lw unico [A4] $ 20/Jan/2010
19:41:41 Fault
904 !FH 5 20011017 external trip [64] $ 20/Jan/2010
19:41:41 Fault
905 !FH 6 20011005 turn on lw unico [A0] $ 20/Jan/2010
19:41:08 Fault
906 !FH 7 20011006 drive identity error [B6] $
20/Jan/2010 19:40:00 Fault

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907	!FH 8 20011017	external trip	[5E]	\$	20/Jan/2010
	19:40:00	Fault			
908	!FH 9 20011006	drive identity error	[B2]	\$	
	20/Jan/2010 19:39:56	Fault			
909	!FH10 20011017	external trip	[53]	\$	20/Jan/2010
	19:39:56	Fault			
910	!FH11 18011005	turn on lw unico	[91]	\$	18/Jan/2010
	20:21:37	Fault			
911	!FH12 18011009	turn on hose unico!	[9E]	\$	
	18/Jan/2010 20:21:24	Fault			
912	!FH13 18011017	EXTERNAL TRIP	[CF]	\$	18/Jan/2010
	20:20:53	Fault			
913	!FH14 18011017	EXTERNAL TRIP	[CD]	\$	18/Jan/2010
	12:46:30	Fault			
914	!FH15 18011005	turn on lw unico	[89]	\$	18/Jan/2010
	12:01:39	Fault			
915	!FH16 18011006	drive identity error	[9F]	\$	
	18/Jan/2010 12:00:47	Fault			
916	!FH17 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:59:19	Fault			
917	!FH18 18011000	MOTOR MARKER	[1C]	\$	18/Jan/2010
	11:49:41	Fault			
918	!FH19 18011017	external trip	[43]	\$	18/Jan/2010
	11:47:35	Fault			
919	!FH20 18011006	drive identity error	[A0]	\$	
	18/Jan/2010 11:46:50	Fault			
920	!FH21 18011000	motor marker	[C8]	\$	18/Jan/2010
	11:45:33	Fault			
921	!FH22 18011017	external trip	[4F]	\$	18/Jan/2010
	11:28:46	Fault			
922	!FH23 18011006	drive identity error	[A3]	\$	
	18/Jan/2010 11:28:10	Fault			
923	!FH24 18011017	external trip	[4B]	\$	18/Jan/2010
	11:28:10	Fault			
924	!FH25 18011006	drive identity error	[9F]	\$	
	18/Jan/2010 11:28:09	Fault			
925	!FH26 18011017	external trip	[47]	\$	18/Jan/2010
	11:28:09	Fault			
926	!FH27 18011006	drive identity error	[9B]	\$	
	18/Jan/2010 11:28:09	Fault			
927	!FH28 18011017	external trip	[43]	\$	18/Jan/2010
	11:28:09	Fault			
928	!FH29 18011006	drive identity error	[97]	\$	
	18/Jan/2010 11:28:09	Fault			
929	!FH30 18011017	external trip	[48]	\$	18/Jan/2010
	11:28:09	Fault			
930	!FH31 18011006	drive identity error	[A5]	\$	
	18/Jan/2010 11:28:08	Fault			
931	!FH32 18011017	external trip	[4D]	\$	18/Jan/2010
	11:28:08	Fault			
932	!FH33 18011006	drive identity error	[A1]	\$	
	18/Jan/2010 11:27:05	Fault			
933	!FH34 18011017	external trip	[49]	\$	18/Jan/2010
	11:27:05	Fault			
934	!FH35 18011006	drive identity error	[9D]	\$	
	18/Jan/2010 11:26:48	Fault			
935	!FH36 18011017	external trip	[45]	\$	18/Jan/2010
	11:26:48	Fault			

936	!FH37 18011006	drive identity error	[99]	\$	
	18/Jan/2010 11:25:26	Fault			
937	!FH38 18011017	EXTERNAL TRIP	[C1]	\$	18/Jan/2010
	11:25:26	Fault			
938	!FH39 18011006	drive identity error	[95]	\$	
	18/Jan/2010 11:25:11	Fault			
939	!FH40 18011017	EXTERNAL TRIP	[C6]	\$	18/Jan/2010
	11:25:11	Fault			
940	!FH41 18011006	drive identity error	[A3]	\$	
	18/Jan/2010 11:25:08	Fault			
941	!FH42 18011017	EXTERNAL TRIP	[CB]	\$	18/Jan/2010
	11:25:08	Fault			
942	!FH43 18011006	drive identity error	[9F]	\$	
	18/Jan/2010 11:25:08	Fault			
943	!FH44 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:25:08	Fault			
944	!FH45 18011006	drive identity error	[9B]	\$	
	18/Jan/2010 11:24:47	Fault			
945	!FH46 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:24:47	Fault			
946	!FH47 18011006	drive identity error	[97]	\$	
	18/Jan/2010 11:24:46	Fault			
947	!FH48 18011017	EXTERNAL TRIP	[BF]	\$	18/Jan/2010
	11:24:46	Fault			
948	!FH49 18011006	drive identity error	[93]	\$	
	18/Jan/2010 11:24:46	Fault			
949	!FH50 18011017	EXTERNAL TRIP	[C4]	\$	18/Jan/2010
	11:24:46	Fault			

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$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage suppply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 1 - Enabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 1 - Enabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 1 - Enabled
$ load fbk loss 1 - Enabled
$ motor runaway 1 - Enabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled

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\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage 1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ Hose Tension Error 0 - Disabled  
\$ Cable Tension Error 0 - Disabled  
\$ Turn On LW Unico 1 - Enabled  
\$ Drive Identity Error 1 - Enabled  
\$ Deployment Velocity 1 - Enabled  
\$ READY HOSE REEL!!! 1 - Enabled  
\$ Turn On Hose Unico! 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled

\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Hose Tension Error 0 - Disabled  
\$ Cable Tension Error 0 - Disabled  
\$ Turn On LW Unico 0 - Disabled  
\$ Drive Identity Error 0 - Disabled  
\$ Deployment Velocity 0 - Disabled  
\$ READY HOSE REEL!!! 0 - Disabled  
\$ Turn On Hose Unico! 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled

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$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled

$ Event Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss 0 - Disabled
$ load pg loss 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage 0 - Disabled
$ Load Cell Error 0 - Disabled
$ Hose Tension Error 0 - Disabled
$ Cable Tension Error 0 - Disabled
$ Turn On LW Unico 0 - Disabled
$ Drive Identity Error 0 - Disabled
$ Deployment Velocity 0 - Disabled
$ READY HOSE REEL!!! 0 - Disabled
$ Turn On Hose Unico! 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
```

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$ user fault 14 req0 - Disabled
$ user fault 15 req0 - Disabled
$ user fault 16 req0 - Disabled
$ user fault 17 req0 - Disabled
$ user fault 18 req0 - Disabled
$ user fault 19 req0 - Disabled
$ user fault 20 req0 - Disabled
$ user fault 21 req0 - Disabled
$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
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DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 00:53:32

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH		[14]	
1	position units	REV		[ED]	
2	velocity units	MINUTES			[BA]
3	hertz units	DISABLE		[2C]	
4	clock frequency	50	hertz	[0F]	
5	drive multiple	1		[C7]	
6	upid multiple	10		[FE]	
7	ac multiple	2		[1A]	
8	ac fast multiple	1		[4C]	
9	vector source	MOTOR SOCKET			[DC]
10	upid motor source	MOTOR SOCKET			[44]
11	upid load source	LOAD SOCKET		[45]	
12	load vector control	DISABLE			[08]
13	transducerless	ENABLE		[D6]	
14	motor fbk size	2048	pulses/rev	[29]	
15	motor resolution	3.6000	in/rev		[4E]
16	motor fbk invert	DISABLE		[3C]	
17	motor input teeth	1		[7F]	
18	motor output teeth	1		[FD]	
19	motor encoder bits	BITS 0			[E4]
20	motor encoder turns	1		[B3]	
21	load fbk size	2048	pulses/rev	[BC]	
22	load resolution	3.6000	in/rev		[E1]
23	load fbk invert	DISABLE		[CF]	
24	load input teeth	1		[12]	
25	load output teeth	1		[90]	
26	load encoder bits	BITS 0			[77]
27	load encoder turns	1		[3D]	
28	motor rated voltage	480	volts	[22]	
29	motor rated current	3.00	amps rms		[00]
30	motor rated frequency	60	hertz	[8A]	
31	maximum current	9.60	amps rms	[5E]	
32	current limit	9.60	amps rms	[3C]	
33	motor rms limit	3.40	amps rms	[A3]	
34	current rate limit	0	amps pk/sec		[18]
35	field current	2.39	amps rms	[55]	
36	field boost	200	%	[68]	
37	slip frequency	3.265	hertz	[94]	
38	motor poles	4		[C0]	
39	synchronous motor	DISABLE			[57]
40	vector offset	0.00	deg	[47]	
41	vector ffwd	0.00000	sec	[8B]	
42	torque ffwd	0.00	deg	[18]	
43	stator resistance	Rs 3.0331	ohms		[BA]
44	leakage Sigma	Ls 0.04110	henries		[6F]
45	Lm squared over Lr	0.44300	henries		[9B]
46	current filter	2.00	hertz	[D3]	
47	voltage filter	2.00	hertz	[E3]	
48	power filter	2.00	hertz	[A7]	
49	motor rtd torque	8.48	ftlb	[91]	
50	motor max torque	43.52	ftlb	[73]	

51	motor rtd power	2.83 hp	[E2]
52	motor max power	14.50 hp	[B8]
53	motor kt	4.692 ftlb/amp	[23]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.030 ftlbs^2	[EC]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	76.300 1/sec/sec	[E3]
58	system gain	76.300 1/sec/sec	[CF]
59	system wn	5.0 rad/sec	[87]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.328 upid gain	[D0]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.328 upid gain	[CF]
65	kv fbk	0.113 upid gain	[D0]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	25.00 % max	[0C]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	76.300 1/sec/sec	[7E]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.262 upid gain	[82]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.262 upid gain	[81]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	50.00 % max	[B4]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1750 rpm	[3F]
96	max vel	1500.0 fpm	[50]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	5000.0 rpm	[C9]
99	accel time	1.000 sec	[70]
100	decel time	1.000 sec	[4C]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	2.000 sec	[FC]
104	decel time 1	2.000 sec	[F6]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]



109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.505 gain	[0D]	
121	dsv ki	50.543 gain	[30]	
122	dsv kp fbk	0.505 gain	[0C]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone 100.0 rpm          [2F]
168 dac offset iu      26    pulses      [63]
169 dac offset iv     -73    pulses      [32]
170 adc offset iu      32    pulses      [6D]
171 adc offset iv     -78    pulses      [34]
172 adc offset fu      17    pulses      [6B]
173 adc offset fv       5    pulses      [9C]
174 adc 1 select        VOLTS          [66]
175 adc 1 set  DISABLED          [19]
176 adc 1 min  0.00 %           [75]
177 adc 1 max  0.00 %           [72]
178 adc 1 min volts  0.004 volts    [D4]
179 adc 1 max volts  9.570 volts    [C0]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value 0.014 volts    [CD]
182 !adc 1 value    0.00 %         [7E]
183 adc 2 select        VOLTS          [65]
184 adc 2 set  DISABLED          [18]
185 adc 2 min  0.00 %           [74]
186 adc 2 max  0.00 %           [71]
187 adc 2 min volts  0.000 volts    [D7]
188 adc 2 max volts  0.000 volts    [D4]
189 adc 2 destination-1          [97]
190 !adc 2 raw value 0.004 volts    [CD]
191 !adc 2 value    0.00 %         [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set  DISABLED          [17]
194 adc 3 min  0.00 %           [73]
195 adc 3 max  0.00 %           [70]
196 adc 3 min volts  0.000 volts    [D6]
197 adc 3 max volts  0.000 volts    [D3]
198 adc 3 destination-1          [96]
199 !adc 3 raw value 0.000 volts    [C7]
200 !adc 3 value    0.00 %         [85]
201 dac clock level  DRIVE CLOCK    [AE]
202 dac 1 select        TORQUE CMD    [32]
203 dac 1 ptr  28965            [41]
204 dac 1 item 0              [C5]
205 dac 1 mul   1              [24]
206 dac 1 div   1              [2E]
207 dac 1 abs  DISABLE          [77]
208 !dac 1 output  0.000 volts      [A8]
209 dac 2 select        UPID VEL FBK  [D2]
210 dac 2 ptr  26033            [52]
211 dac 2 item 0              [C6]
212 dac 2 mul   32767           [4D]
213 dac 2 div   349525          [24]
214 dac 2 abs  DISABLE          [78]
215 !dac 2 output  0.000 volts      [A9]
216 level 1 password 1111         [7A]
217 level 2 password 0           [0C]
218 level 3 password 0           [0A]
219 lockout time      900.000      sec  [D5]
220 !lockout status  LEVEL 3       [8E]
221 ssi rx mode  DISABLED          [E8]
222 !ssi rx value    0             [56]
223 ssi torque offset 0.00 %       [A3]
224 ssi tx mode  DISABLED          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	15		[DB]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	661 volts		[E2]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.03 amps rms			[83]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000040 \$			[08]
277	!out word 0	000006 \$			[84]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000200 \$			[99]

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294965949			[E1]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	8			[76]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	8			[AA]
307	test cycle rpm	900.0 rpm			[94]
308	test id min rpm	900.0 rpm			[72]
309	test jog rpm	900.0 rpm			[62]
310	test max rpm	900.0 rpm			[64]
311	test min rpm	-900.0 rpm			[38]
312	test period	0.000 sec		[B1]	
313	test ramp	DISABLE			[B8]
314	test position	10.000 rev			[7A]
315	test time	1.000 sec		[81]	
316	test torque	50 %		[2F]	
317	test degrees	180.00 deg			[22]
318	test i field	0.00 amps rms			[E9]
319	test volts	0 volts		[B6]	
320	test length	24.0001 in			[B0]
321	test accel time	4.000 sec			[69]
322	test freq ramp time	6.000 sec			[E0]
323	test adc	1		[02]	
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0 fpm			[0E]
330	vel preset 1	0.0 fpm			[21]
331	vel preset 2	150.0 fpm			[B9]
332	vel preset 3	0.0 fpm			[1D]
333	vel preset 4	0.0 fpm			[1B]
334	vel preset 5	0.0 fpm			[19]
335	vel preset 6	0.0 fpm			[17]
336	vel preset 7	0.0 fpm			[15]
337	vel preset 8	0.0 fpm			[13]
338	vel offset	0.0 fpm		[76]	
339	vel gain	100.00 %			[EA]
340	vel tolerance	0.0 fpm			[47]

```

341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 30 rpm [09]
371 bus reg tol time 3 secs [71]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos -7.1996 in [13]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

```

399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	STS DISABLED	[21]		
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED	[19]		
445	out 5	STS DISABLED	[17]		
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	DRILL HOSE LEVEL		[D6]
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	ENABLE		[A4]
481	torq override enable	ENABLE		[C2]
482	pend max torq	25.00 % rtd	[BE]	
483	pend max vel	540.0 fpm	[86]	
484	pend index pos	830.0002 in		[80]
485	pend index vel	540.0 fpm	[B2]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	0.0 fpm	[E1]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word0		[95]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	target hose load %	0 %		[8A]
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	OPPOSITE		[CD]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.839	gain	[0C]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	672		[03]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0007	in	[56]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011003	soft limit error		[6E]	\$	20/Jan/2010
	19:40:52	Fault				
901	!FH 2 20011017	external trip		[6A]	\$	20/Jan/2010
	19:40:52	Fault				
902	!FH 3 20011003	soft limit error		[6A]	\$	20/Jan/2010
	19:38:59	Fault				
903	!FH 4 20011017	external trip		[66]	\$	20/Jan/2010
	19:38:59	Fault				
904	!FH 5 18011003	soft limit error		[5F]	\$	18/Jan/2010
	12:24:24	Fault				
905	!FH 6 18011017	external trip		[5B]	\$	18/Jan/2010
	12:24:24	Fault				
906	!FH 7 18011003	soft limit error		[5B]	\$	18/Jan/2010
	11:59:10	Fault				
907	!FH 8 18011017	EXTERNAL TRIP		[D7]	\$	18/Jan/2010
	11:58:30	Fault				
908	!FH 9 18011017	EXTERNAL TRIP		[D5]	\$	18/Jan/2010
	11:28:34	Fault				
909	!FH10 18011003	soft limit error		[4E]	\$	18/Jan/2010
	11:24:37	Fault				
910	!FH11 18011017	EXTERNAL TRIP		[D3]	\$	18/Jan/2010
	11:24:37	Fault				
911	!FH12 18011003	soft limit error		[53]	\$	18/Jan/2010
	11:24:36	Fault				
912	!FH13 18011017	EXTERNAL TRIP		[CF]	\$	18/Jan/2010
	11:24:36	Fault				



913	!FH14 18011003	soft limit error	[4F]	\$	18/Jan/2010
	11:24:35	Fault			
914	!FH15 18011017	EXTERNAL TRIP	[CB]	\$	18/Jan/2010
	11:24:35	Fault			
915	!FH16 18011003	soft limit error	[4B]	\$	18/Jan/2010
	11:24:35	Fault			
916	!FH17 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:24:35	Fault			
917	!FH18 18011003	soft limit error	[47]	\$	18/Jan/2010
	11:24:34	Fault			
918	!FH19 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:24:34	Fault			
919	!FH20 18011003	soft limit error	[4C]	\$	18/Jan/2010
	11:24:34	Fault			
920	!FH21 18011017	EXTERNAL TRIP	[D1]	\$	18/Jan/2010
	11:24:34	Fault			
921	!FH22 18011003	soft limit error	[51]	\$	18/Jan/2010
	11:24:27	Fault			
922	!FH23 18011017	EXTERNAL TRIP	[CD]	\$	18/Jan/2010
	11:24:27	Fault			
923	!FH24 18011003	soft limit error	[4D]	\$	18/Jan/2010
	11:24:26	Fault			
924	!FH25 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	11:24:26	Fault			
925	!FH26 18011003	soft limit error	[49]	\$	18/Jan/2010
	11:24:25	Fault			
926	!FH27 18011017	EXTERNAL TRIP	[C5]	\$	18/Jan/2010
	11:24:25	Fault			
927	!FH28 18011003	soft limit error	[45]	\$	18/Jan/2010
	11:24:24	Fault			
928	!FH29 18011017	EXTERNAL TRIP	[C1]	\$	18/Jan/2010
	11:24:24	Fault			
929	!FH30 18011003	soft limit error	[4A]	\$	18/Jan/2010
	11:24:12	Fault			
930	!FH31 18011017	EXTERNAL TRIP	[CF]	\$	18/Jan/2010
	11:24:12	Fault			
931	!FH32 18011003	soft limit error	[4F]	\$	18/Jan/2010
	11:24:11	Fault			
932	!FH33 18011017	EXTERNAL TRIP	[CB]	\$	18/Jan/2010
	11:24:11	Fault			
933	!FH34 18011003	soft limit error	[4B]	\$	18/Jan/2010
	11:24:11	Fault			
934	!FH35 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:24:11	Fault			
935	!FH36 18011003	soft limit error	[47]	\$	18/Jan/2010
	11:24:10	Fault			
936	!FH37 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:24:10	Fault			
937	!FH38 18011003	soft limit error	[43]	\$	18/Jan/2010
	11:24:09	Fault			
938	!FH39 18011017	EXTERNAL TRIP	[BF]	\$	18/Jan/2010
	11:24:09	Fault			
939	!FH40 18011003	soft limit error	[48]	\$	18/Jan/2010
	11:24:08	Fault			
940	!FH41 18011017	EXTERNAL TRIP	[CD]	\$	18/Jan/2010
	11:24:08	Fault			
941	!FH42 18011003	soft limit error	[4D]	\$	18/Jan/2010
	11:23:04	Fault			

942	!FH43 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	11:22:02	Fault			
943	!FH44 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:22:01	Fault			
944	!FH45 18011017	EXTERNAL TRIP	[C5]	\$	18/Jan/2010
	11:21:59	Fault			
945	!FH46 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:21:58	Fault			
946	!FH47 18011017	EXTERNAL TRIP	[C1]	\$	18/Jan/2010
	11:21:54	Fault			
947	!FH48 18011017	EXTERNAL TRIP	[BF]	\$	18/Jan/2010
	11:21:53	Fault			
948	!FH49 18011017	EXTERNAL TRIP	[BD]	\$	18/Jan/2010
	11:21:52	Fault			
949	!FH50 18011017	EXTERNAL TRIP	[C4]	\$	18/Jan/2010
	11:21:51	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 0 - Disabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg tol 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

```

\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ Soft Limit Error 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled

\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

```
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 00:49:58

DATA\_START

UNITS 2 [29]

0	unit system	METRIC	[5A]	
1	position units	FEET METER	[19]	
2	velocity units	MINUTES	[BA]	
3	hertz units	DISABLE	[2C]	
4	clock frequency	50 hertz	[0F]	
5	drive multiple	1	[C7]	
6	upid multiple	10	[FE]	
7	ac multiple	2	[1A]	
8	ac fast multiple	1	[4C]	
9	vector source	MOTOR SOCKET		[DC]
10	upid motor source	MOTOR SOCKET		[44]
11	upid load source	LOAD SOCKET	[45]	
12	load vector control	DISABLE		[08]
13	transducerless	DISABLE	[89]	
14	motor fbk size	2048 pulses/rev	[29]	
15	motor resolution	288.1907 in/rev		[D4]
16	motor fbk invert	DISABLE	[3C]	
17	motor input teeth	1	[7F]	
18	motor output teeth	1182	[62]	
19	motor encoder bits	BITS 0		[E4]
20	motor encoder turns	1	[B3]	
21	load fbk size	2048 pulses/rev	[BC]	
22	load resolution	42.0906 in/rev		[A5]
23	load fbk invert	ENABLE	[1C]	
24	load input teeth	1	[12]	
25	load output teeth	1	[90]	
26	load encoder bits	BITS 0		[77]
27	load encoder turns	1	[3D]	
28	motor rated voltage	460 volts	[24]	
29	motor rated current	27.00 amps rms		[CA]
30	motor rated frequency	60 hertz	[8A]	
31	maximum current	80.00 amps rms	[35]	
32	current limit	80.00 amps rms	[13]	
33	motor rms limit	29.70 amps rms	[68]	
34	current rate limit	0 amps pk/sec		[18]
35	field current	15.00 amps rms	[2D]	
36	field boost	200 %	[68]	
37	slip frequency	0.390 hertz	[98]	
38	motor poles	4	[C0]	
39	synchronous motor	DISABLE		[57]
40	vector offset	0.00 deg	[47]	
41	vector ffwd	0.00000 sec	[8B]	
42	torque ffwd	0.00 deg	[18]	
43	stator resistance	Rs 0.1433 ohms		[B9]
44	leakage Sigma	Ls 0.00565 henries		[65]
45	Lm squared over Lr	0.03814 henries		[96]
46	current filter	2.00 hertz	[D3]	
47	voltage filter	2.00 hertz	[E3]	
48	power filter	2.00 hertz	[A7]	
49	motor rtd torque	56.79 ftlb	[5A]	
50	motor max torque	198.26 ftlb	[37]	

51	motor rtd power	19.36 hp	[AC]	
52	motor max power	67.57 hp	[A9]	
53	motor kt	2.529 ftlb/amp	[26]	
54	motor inertia	0.000 ftlbs^2	[94]	
55	machine inertia	0.273 ftlbs^2	[E3]	
56	acc obs bandwidth	40 rad/sec	[03]	
57	system gain id	29.067 1/sec/sec	[DB]	
58	system gain	29.067 1/sec/sec	[C7]	
59	system wn	5.0 rad/sec	[87]	
60	system order	VELOCITY	[1D]	
61	kv cmd	0.000 upid gain	[D8]	
62	kp cmd	0.860 upid gain	[CF]	
63	ki	0.0 upid gain	[97]	
64	kp fbk	0.860 upid gain	[CE]	
65	kv fbk	0.298 upid gain	[C2]	
66	kr	1.000 upid gain	[2A]	
67	kp cmd percent	0 %	[D1]	
68	ki load enable	DISABLE	[56]	
69	kp load ratio	0 %	[35]	
70	kv load ratio	0 %	[37]	
71	torque limit	100.00 % max	[E2]	
72	low pass frequency	100.0 hertz	[33]	
73	low pass damping	1.414 gain	[A9]	
74	notch frequency	0.0 hertz	[9F]	
75	notch damping	1.414 gain	[B4]	
76	system gain 1	29.067 1/sec/sec	[76]	
77	system wn 1	20.0 rad/sec	[09]	
78	system order 1	TORQUE	[52]	
79	kv cmd 1	0.000 upid gain	[7E]	
80	kp cmd 1	0.688 upid gain	[76]	
81	ki 1	0.0 upid gain	[46]	
82	kp fbk 1	0.688 upid gain	[75]	
83	kv fbk 1	0.000 upid gain	[84]	
84	kr 1	0.000 upid gain	[DA]	
85	kp cmd percent 1	0 %	[80]	
86	ki load enable 1	DISABLE	[05]	
87	kp load ratio 1	0 %	[E4]	
88	kv load ratio 1	0 %	[DD]	
89	torque limit 1	100.00 % max	[88]	
90	low pass frequency 1	100.0 hertz	[E2]	
91	low pass damping 1	1.414 gain	[58]	
92	notch frequency 1	10.0 hertz	[4E]	
93	notch damping 1	1.414 gain	[63]	
94	torque invert	DISABLE	[1A]	
95	base rpm	1790 rpm	[3B]	
96	max vel	65.0 fpm	[AB]	
97	jog vel	4.9 fpm	[DE]	
98	!max motor rpm	3196.8 rpm	[B3]	
99	accel time	1.000 sec	[70]	
100	decel time	1.000 sec	[4C]	
101	jerk time	0.000 sec	[9D]	
102	settle time	0.200 sec	[B5]	
103	accel time 1	1.000 sec	[FD]	
104	decel time 1	1.000 sec	[F7]	
105	jerk time 1	0.000 sec	[48]	
106	settle time 1	0.200 sec	[60]	
107	fast decel time	0.200 sec	[76]	
108	drive invert	DISABLE	[74]	



109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.069 gain	[08]	
121	dsv ki	6.948 gain	[56]	
122	dsv kp fbk	0.069 gain	[07]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	7000 watts	[2A]	
151	db resistance	16.700 ohms	[42]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	OPEN LOOP	[CD]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	ESTIMATED	[D8]	
161	torq reg wn	500.0 rad/sec	[7E]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	12.87 gain	[81]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

167	friction deadzone	100.0 rpm	[2F]	
168	dac offset iu	-11 pulses	[3C]	
169	dac offset iv	-10 pulses	[3B]	
170	adc offset iu	-34 pulses	[3E]	
171	adc offset iv	17 pulses	[68]	
172	adc offset fu	-46 pulses	[3C]	
173	adc offset fv	-1 pulses	[73]	
174	adc 1 select	VOLTS	[66]	
175	adc 1 set	DISABLED	[19]	
176	adc 1 min	0.00 %	[75]	
177	adc 1 max	0.00 %	[72]	
178	adc 1 min volts	0.000 volts	[D8]	
179	adc 1 max volts	0.000 volts	[D5]	
180	adc 1 destination-1		[A1]	
181	!adc 1 raw value	-0.005 volts	[A0]	
182	!adc 1 value	0.00 %	[7E]	
183	adc 2 select	TENSION	[DD]	
184	adc 2 set	DISABLED	[18]	
185	adc 2 min	0.00 %	[74]	
186	adc 2 max	5000.00 %	[DC]	
187	adc 2 min volts	2.087 volts	[C6]	
188	adc 2 max volts	6.797 volts	[B7]	
189	adc 2 destination-1		[97]	
190	!adc 2 raw value	0.000 volts	[D1]	
191	!adc 2 value	-2215.71 %	[AE]	
192	adc 3 select	TENSION	[DC]	
193	adc 3 set	DISABLED	[17]	
194	adc 3 min	0.00 %	[73]	
195	adc 3 max	10000.00 %	[AF]	
196	adc 3 min volts	1.983 volts	[C1]	
197	adc 3 max volts	8.568 volts	[B8]	
198	adc 3 destination-1		[96]	
199	!adc 3 raw value	0.000 volts	[C7]	
200	!adc 3 value	-3011.40 %	[BF]	
201	dac clock level	DRIVE CLOCK	[AE]	
202	dac 1 select	TORQUE CMD	[32]	
203	dac 1 ptr	28965	[41]	
204	dac 1 item	0	[C5]	
205	dac 1 mul	1	[24]	
206	dac 1 div	1	[2E]	
207	dac 1 abs	DISABLE	[77]	
208	!dac 1 output	0.000 volts	[A8]	
209	dac 2 select	UPID VEL FBK	[D2]	
210	dac 2 ptr	26033	[52]	
211	dac 2 item	0	[C6]	
212	dac 2 mul	32767	[4D]	
213	dac 2 div	223473	[2B]	
214	dac 2 abs	DISABLE	[78]	
215	!dac 2 output	0.000 volts	[A9]	
216	level 1 password	1111	[7A]	
217	level 2 password	0	[0C]	
218	level 3 password	0	[0A]	
219	lockout time	900.000 sec	[D5]	
220	!lockout status	LEVEL 3	[8E]	
221	ssi rx mode	VEL	[39]	
222	!ssi rx value	0	[56]	
223	ssi torque offset	0.00 %	[A3]	
224	ssi tx mode	DISABLED	[E3]	

225	!ssi tx value	0		[51]	
226	ssi position lock	ENABLE		[E5]	
227	ssi tx clock	DISABLE		[BD]	
228	rtc source	SSI	[4E]		
229	ssi rx error limit	1		[23]	
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU		[B3]	
232	console baud rate	38400 BAUD		[66]	
233	console parity	NONE	[3F]		
234	console address	16	[DA]		
235	console checksum	BCC	[0B]		
236	console units	METRIC		[2E]	
237	console pos units	IN MM	[2E]		
238	console vel units	SECONDS		[7A]	
239	porta protocol	OPTOMUX		[21]	
240	porta baud rate	19200 BAUD		[37]	
241	porta parity	NONE	[0D]		
242	porta stop bits	STOP 1		[A6]	
243	porta address	0	[DE]		
244	porta checksum	BCC	[D8]		
245	porta units	ENGLISH	[B5]		
246	porta pos units	FEET METER		[8B]	
247	porta vel units	MINUTES		[31]	
248	optomux bits dev	BITS 32		[31]	
249	optomux num devices	1		[74]	
250	optomux output 0	0	[CF]		
251	optomux output 1	65535	[F5]		
252	optomux retries	3	[CD]		
253	optomux timeout	1.000 sec	[CC]		
254	optomux wd time	5.000 sec	[24]		
255	!motor rpm	0.0 rpm	[99]		
256	!max current	53.20 amps rms		[91]	
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	665 volts	[DE]		
259	!max bus voltage	1011 volts	[55]		
260	!armature voltage	0 volts	[3F]		
261	!max voltage	0 volts	[59]		
262	!field voltage	0 volts	[9A]		
263	!motor thermal rms	0.08 amps rms		[7E]	
264	!torque est command	0.00 ftlb	[A5]		
265	!torque est feedback	0.00 ftlb	[5E]		
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp	[FF]		
268	!motor current	0.00 amps rms		[DD]	
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms		[C5]	
271	!inverter power	0.00 hp	[C6]		
272	!command vel	0.0 fpm	[00]		
273	!feedback vel	0.0 fpm	[B9]		
274	!command pos	-0.0005 in		[9D]	
275	!feedback pos	-0.0005 in		[56]	
276	!in word 0	0008c0 \$		[D1]	
277	!out word 0	00000c \$		[57]	
278	!sin word 0	000000 \$		[97]	
279	!sin word 1	000000 \$		[95]	
280	!sout word 0	000000 \$		[1D]	
281	!sout word 1	000000 \$		[1B]	
282	!int word 0	000000 \$		[9B]	

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000400	\$		[91]
286	hardware mask	4294934399			[01]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294967293			[E7]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	64			[44]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	64			[78]
307	test cycle rpm	1770.0	rpm		[5E]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	900.0	rpm		[62]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque	80	%		[2C]
317	test degrees	180.00	deg		[22]
318	test i field	0.00	amps rms		[E9]
319	test volts	0	volts		[B6]
320	test length	24.0000	in		[B1]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	SSI			[EB]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	0.0	fpm		[1F]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 65.0 fpm [9E]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 10 rpm [0B]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 100 % [83]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos-0.5981 in [8D]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0822 in [54]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

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399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	STS PLC	[7A]		
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED			[19]
445	out 5	STS DISABLED			[17]
446	sout 0	STS DISABLED			[A8]
447	sout 1	STS DISABLED			[A6]
448	sout 2	STS DISABLED			[A4]
449	sout 3	STS DISABLED			[A2]
450	sout 4	STS DISABLED			[A9]
451	sout 5	STS DISABLED			[A7]
452	sout 6	STS DISABLED			[A5]
453	sout 7	STS DISABLED			[A3]
454	sout 8	STS DISABLED			[A1]
455	sout 9	STS DISABLED			[9F]
456	sout 10	STS DISABLED			[76]

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457  sout 11      STS DISABLED          [74]
458  sout 12      STS DISABLED          [72]
459  sout 13      STS DISABLED          [70]
460  sout 14      STS DISABLED          [77]
461  sout 15      STS DISABLED          [75]
462  sout 16      STS PLC                [CC]
463  sout 17      STS PLC                [CA]
464  sout 18      STS PLC                [C8]
465  sout 19      STS PLC                [C6]
466  sout 20      STS PLC                [CD]
467  sout 21      STS PLC                [CB]
468  sout 22      STS PLC                [C9]
469  sout 23      STS PLC                [C7]
470  sout 24      STS PLC                [CE]
471  sout 25      STS PLC                [CC]
472  sout 26      STS PLC                [CA]
473  sout 27      STS PLC                [C8]
474  sout 28      STS PLC                [C6]
475  sout 29      STS PLC                [C4]
476  sout 30      STS PLC                [CB]
477  sout 31      STS PLC                [C9]
478  drive type  NONE                    [04]
479  allow pend reverse  ENABLE          [86]
480  torque mode enable  DISABLE        [57]
481  torq override enable  ENABLE          [C2]
482  pend max torq      80.00 % rtd      [BD]
483  pend max vel       12.2 mpm  units:3  [13]
484  pend index pos     30.0000  in        [BA]
485  pend index vel     34.1 fpm        [E3]
486  comp req torq      0.00 % rtd      [E7]
487  comp req vel       0.0 fpm        [E1]
488  comp index pos     0.0000  in        [E1]
489  comp index vel     0.0 fpm        [0F]
490  comp request word0          [52]
491  !comp status word0          [95]
492  comp timeout       0.000 sec      [35]
493  comp handshake ctr  0              [24]
494  !comp handshake ctr p 0        [72]
495  payout distance    0.0000  in        [2F]
496  payout preset      0.0000  in        [E6]
497  !index start pos  0.0000  in        [41]
498  !tension error     0.00 lb        [37]
499  tgt hose tension   3559.0  N  units:1  [CF]
500  !hose tension      -2220.90 lb     [F6]
501  !cable tension     -3011.40 lb     [B3]
502  hose filter gain   0.93000  gain     [2F]
503  !smooth hose tension -2218.52 lb     [34]
504  cable filter gain0.93000  gain     [E5]
505  !smooth cable tension -3012.94 lb     [EB]
506  fine control gain-0.0100  in/sec/lb  [2C]
507  !actual fine control 0.0000  in/sec/lb  [5D]
508  fade filter gain   0.97000  gain     [44]
509  hose tension offset 0.00 lb        [33]
510  cable tension offset 0.00 lb        [F3]
511  !hose load fbk     0 %            [04]
512  coil min od 2330.00  mm  units:1  [6F]
513  coil max od 3680.00  mm  units:1  [63]
514  coil diameter      2330.00  mm  units:1  [59]

```

```

515 !coil circumference 7320.04 mm units:1 [1F]
516 !coil usage 0.0 m units:1 [A1]
517 coil source MOTOR SOCKET [64]
518 material source LOAD SOCKET [2C]
519 coil od limit DISABLE [67]
520 coil od rate 3.5433 in [CF]
521 coil update distance 118.1102 in [23]
522 level direction NONE [11]
523 !level drum velocity 0.0 rpm units:10 [EE]
524 level follow gain 0.000 gain [21]
525 !level follow vel 0.0 fpm [13]
526 !level follow req vel 0.0 fpm [AA]
527 level follow vel off 0.0 fpm [D7]
528 level circumference 3.6000 in [A3]
529 level dwell count 0 [6A]
530 !level circ count 0 [C8]
531 !index pos 0.0000 in [9A]
532 !drive control mode NONE [E8]
533 pend disable time 0.000 sec [A5]
534 lo-spd line low limt 590 volts rms [90]
535 hi-spd line low limt 590 volts rms [99]
536 high-low vel cutoff 0 rpm [89]
537 payout at drum 112.1 m units:1 [C7]
538 payout at tower 100251.9427 in [47]
539 drum payout offset 0.0 m units:1 [78]
540 tower payout offset -62.9921 in [31]
541 Hose Max Load 1498.65 lb [87]
542 Hose Min Load 0.00 lb [39]
543 Cable Max Load 22481.79 lb [0D]
544 Cable Min Load 0.00 lb [EF]
545 Reel Mode Drill/Deployment [C1]
546 Tension Fault ENABLE [91]
547 Cable Tension/Unit -3013.65 lb [32]
548 Cable Upper Trip 1000.00 lb [53]
549 Cable Lower Trip 600.04 lb [7C]
550 Load Cell Fault ENABLE [56]
551 !Deploy Payout 27.1827 m units:7 [8E]
552 !Dep PLRV 27.1827 m units:7 [1F]
553 Deploy reset ENABLE [DF]
554 Load Cell Cal. DISABLE [C3]
555 Ld cell torque limit 2.00 % max [7A]
556 Ld cell pend. vel. 1.0 mpm units:7 [BC]
557 !Tower PLRV 2547.9973 m units:7 [AF]
558 Drill payout reset ENABLE [8E]
559 !raw tower payout 2547.9993 m units:7 [C3]
560 !Drum PLRV 0.0093 m units:7 [E0]
561 !raw drum payout 0.0093 m units:7 [F7]
562 !smooth hose volts -0.002 volts [FF]
563 !smooth cable volts -0.001 volts [B7]
564 max torque 0.00 ftlb units:0 [2B]
565 max tension hose 0.00 lb units:0 [D5]
566 max tension cable 0.00 lb units:0 [8C]
900 !FH 1 20011006 drive identity error [C2] $
20/Jan/2010 19:41:33 Fault
901 !FH 2 20011017 external trip [6A] $ 20/Jan/2010
19:41:33 Fault
902 !FH 3 20011013 rtc takeover [E4] $ 20/Jan/2010
19:41:05 Fault

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903	!FH 4 20011005	turn on lw unico	[A4]	\$	20/Jan/2010
	19:40:57	Fault			
904	!FH 5 20011006	drive identity error	[BA]	\$	
	20/Jan/2010 19:39:38	Fault			
905	!FH 6 20011017	external trip	[62]	\$	20/Jan/2010
	19:39:38	Fault			
906	!FH 7 18011005	turn on lw unico	[97]	\$	18/Jan/2010
	20:21:07	Fault			
907	!FH 8 18011006	drive identity error	[AD]	\$	
	18/Jan/2010 12:44:10	Fault			
908	!FH 9 18011017	external trip	[55]	\$	18/Jan/2010
	12:44:10	Fault			
909	!FH10 18011003	overrun	[82]	\$	18/Jan/2010 12:25:04
		Fault			
910	!FH11 18011015	ssi receive	[45]	\$	18/Jan/2010 12:25:03
		Fault			
911	!FH12 18011006	drive identity error	[A7]	\$	
	18/Jan/2010 12:25:01	Fault			
912	!FH13 18011017	external trip	[4F]	\$	18/Jan/2010
	12:25:01	Fault			
913	!FH14 18011005	turn on lw unico	[8B]	\$	18/Jan/2010
	12:01:05	Fault			
914	!FH15 18011006	drive identity error	[A1]	\$	
	18/Jan/2010 11:59:52	Fault			
915	!FH16 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	11:59:07	Fault			
916	!FH17 18011017	external trip	[47]	\$	18/Jan/2010
	11:38:09	Fault			
917	!FH18 18011017	external trip	[45]	\$	18/Jan/2010
	11:38:08	Fault			
918	!FH19 18011017	external trip	[43]	\$	18/Jan/2010
	11:38:06	Fault			
919	!FH20 18011017	external trip	[4A]	\$	18/Jan/2010
	11:38:06	Fault			
920	!FH21 18011017	external trip	[51]	\$	18/Jan/2010
	11:38:05	Fault			
921	!FH22 18011017	external trip	[4F]	\$	18/Jan/2010
	11:37:03	Fault			
922	!FH23 18011017	external trip	[4D]	\$	18/Jan/2010
	11:37:02	Fault			
923	!FH24 18011017	external trip	[4B]	\$	18/Jan/2010
	11:37:01	Fault			
924	!FH25 18011017	external trip	[49]	\$	18/Jan/2010
	11:37:01	Fault			
925	!FH26 18011017	external trip	[47]	\$	18/Jan/2010
	11:37:01	Fault			
926	!FH27 18011017	external trip	[45]	\$	18/Jan/2010
	11:37:00	Fault			
927	!FH28 18011017	external trip	[43]	\$	18/Jan/2010
	11:36:59	Fault			
928	!FH29 18011017	external trip	[41]	\$	18/Jan/2010
	11:36:59	Fault			
929	!FH30 18011017	external trip	[48]	\$	18/Jan/2010
	11:33:47	Fault			
930	!FH31 18011017	external trip	[4F]	\$	18/Jan/2010
	11:33:46	Fault			
931	!FH32 18011017	external trip	[4D]	\$	18/Jan/2010
	11:33:46	Fault			

932	!FH33 18011017	external trip	[4B]	\$	18/Jan/2010
	11:33:45	Fault			
933	!FH34 18011017	external trip	[49]	\$	18/Jan/2010
	11:29:12	Fault			
934	!FH35 18011017	external trip	[47]	\$	18/Jan/2010
	11:29:11	Fault			
935	!FH36 18011006	drive identity error	[9B]	\$	
	18/Jan/2010 11:27:24	Fault			
936	!FH37 18011017	external trip	[43]	\$	18/Jan/2010
	11:27:24	Fault			
937	!FH38 18011006	drive identity error	[97]	\$	
	18/Jan/2010 11:27:23	Fault			
938	!FH39 18011017	external trip	[3F]	\$	18/Jan/2010
	11:27:23	Fault			
939	!FH40 18011006	drive identity error	[9C]	\$	
	18/Jan/2010 11:27:21	Fault			
940	!FH41 18011017	external trip	[4D]	\$	18/Jan/2010
	11:27:21	Fault			
941	!FH42 18011006	drive identity error	[A1]	\$	
	18/Jan/2010 11:27:04	Fault			
942	!FH43 18011017	external trip	[49]	\$	18/Jan/2010
	11:27:04	Fault			
943	!FH44 18011006	drive identity error	[9D]	\$	
	18/Jan/2010 11:27:03	Fault			
944	!FH45 18011017	external trip	[45]	\$	18/Jan/2010
	11:27:03	Fault			
945	!FH46 18011006	drive identity error	[99]	\$	
	18/Jan/2010 11:27:03	Fault			
946	!FH47 18011017	external trip	[41]	\$	18/Jan/2010
	11:27:03	Fault			
947	!FH48 18011006	drive identity error	[95]	\$	
	18/Jan/2010 11:27:01	Fault			
948	!FH49 18011017	external trip	[3D]	\$	18/Jan/2010
	11:27:01	Fault			
949	!FH50 18011006	drive identity error	[9A]	\$	
	18/Jan/2010 11:26:50	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 1 - Enabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 1 - Enabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 1 - Enabled

```

```
$ load fbk loss 1 - Enabled
$ motor runaway 1 - Enabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout 1 - Enabled
$ Line Undervoltage 1 - Enabled
$ Load Cell Error 1 - Enabled
$ Hose Tension Error 1 - Enabled
$ Cable Tension Error 1 - Enabled
$ Turn On LW Unico 1 - Enabled
$ Drive Identity Error 1 - Enabled
$ DB Over Temp 1 - Enabled
$ user fault 8 req 1 - Enabled
$ user fault 9 req 1 - Enabled
$ user fault 10 req 1 - Enabled
$ user fault 11 req 1 - Enabled
$ user fault 12 req 1 - Enabled
$ user fault 13 req 1 - Enabled
$ user fault 14 req 1 - Enabled
$ user fault 15 req 1 - Enabled
$ user fault 16 req 1 - Enabled
$ user fault 17 req 1 - Enabled
$ user fault 18 req 1 - Enabled
$ user fault 19 req 1 - Enabled
$ user fault 20 req 1 - Enabled
$ user fault 21 req 1 - Enabled
$ user fault 22 req 1 - Enabled
$ user fault 23 req 1 - Enabled
$ user fault 24 req 1 - Enabled
$ user fault 25 req 1 - Enabled
$ user fault 26 req 1 - Enabled
$ user fault 27 req 1 - Enabled
$ user fault 28 req 1 - Enabled
$ user fault 29 req 1 - Enabled
$ user fault 30 req 1 - Enabled
$ user fault 31 req 1 - Enabled

$ Warning Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch 0 - Disabled
```

\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Hose Tension Error 0 - Disabled  
\$ Cable Tension Error 0 - Disabled  
\$ Turn On LW Unico 0 - Disabled  
\$ Drive Identity Error 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled

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$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled

$ Event Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss 0 - Disabled
$ load pg loss 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage 0 - Disabled
$ Load Cell Error 0 - Disabled
$ Hose Tension Error 0 - Disabled
$ Cable Tension Error 0 - Disabled
$ Turn On LW Unico 0 - Disabled
```

```
$ Drive Identity Error 0 - Disabled
$ DB Over Temp 0 - Disabled
$ user fault 8 req 0 - Disabled
$ user fault 9 req 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
$ user fault 14 req0 - Disabled
$ user fault 15 req0 - Disabled
$ user fault 16 req0 - Disabled
$ user fault 17 req0 - Disabled
$ user fault 18 req0 - Disabled
$ user fault 19 req0 - Disabled
$ user fault 20 req0 - Disabled
$ user fault 21 req0 - Disabled
$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:29:25

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth 1	[7F]	
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth 1	[12]	
25	load output teeth 1	[90]	
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	3.00 amps rms	[00]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	9.60 amps rms	[5E]
32	current limit	9.60 amps rms	[3C]
33	motor rms limit	6.00 amps rms	[A4]
34	current rate limit	0 amps pk/sec	[18]
35	field current	1.63 amps rms	[59]
36	field boost 200	%	[68]
37	slip frequency	1.667 hertz	[90]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 3.3871 ohms	[AE]
44	leakage Sigma	Ls 0.03825 henries	[63]
45	Lm squared over Lr	0.33252 henries	[97]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	6.02 ftlb	[9D]
50	motor max torque	22.69 ftlb	[6E]

51	motor rtd power	2.01 hp	[EC]
52	motor max power	7.56 hp	[E0]
53	motor kt	2.403 ftlb/amp	[2F]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.008 ftlbs^2	[E7]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	102.694 1/sec/sec	[AD]
58	system gain	102.694 1/sec/sec	[99]
59	system wn	3.0 rad/sec	[89]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.088 upid gain	[CD]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.088 upid gain	[CC]
65	kv fbk	0.051 upid gain	[CF]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	102.694 1/sec/sec	[48]
77	system wn 1	14.0 rad/sec	[06]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.136 upid gain	[82]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.136 upid gain	[81]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	ENABLE	[67]
95	base rpm	1750 rpm	[3F]
96	max vel	1080.0 fpm	[4D]
97	jog vel	1050.0 fpm	[55]
98	!max motor rpm	3600.0 rpm	[C5]
99	accel time	1.000 sec	[70]
100	decel time	1.000 sec	[4C]
101	jerk time	1.000 sec	[9C]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	1.000 sec	[F7]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]



109	!motor vel	0.0	fpm	[AF]	
110	inv thermal warning	80.0	%		[E6]
111	motor rms warning	80.0	%	[9C]	
112	modulation select	DIGITAL			[65]
113	switch frequency	6000	hertz	[C7]	
114	thermal protection	STANDARD			[78]
115	dsv synchronized	DISABLE			[BB]
116	dsv wn	200.0	rad/sec	[58]	
117	dsv vphz wn	10.0	rad/sec	[A0]	
118	dsv kv percent	85.00	%	[BA]	
119	dsv kp cmd percent	100	%		[D5]
120	dsv kp cmd	0.470	gain	[0C]	
121	dsv ki	47.038	gain	[2B]	
122	dsv kp fbk	0.470	gain	[0B]	
123	dsv deadtime percent	25	%		[F6]
124	dsv v boost	0	%	[BD]	
125	dsv bus correction	DISABLE			[38]
126	acr i loop	5.000	acr gain	[B9]	
127	acr v ffwd	1.000	acr gain	[C2]	
128	acr field i loop	40.000	acr gain		[64]
129	acr field v ffwd	1.000	acr gain	[9C]	
130	dbm const switch freq	ENABLE			[9E]
131	dbm pulses	4		[1B]	
132	dbm min vel	5.0	hertz	[7F]	
133	dbm volts per hertz	8.0			[67]
134	dbm clamp voltage	0	volts	[61]	
135	dbm block modulation	30	% clamp		[CB]
136	dbm run current limit	0.00	amps rms		[4E]
137	dbm run limit gain	0.000	gain	[05]	
138	damping kp	0.00006	gain	[69]	
139	damping max	1000.00	ftlb	[F9]	
140	damping min freq	20.0	hertz	[3F]	
141	damping max freq	90.0	hertz	[35]	
142	vbus reg filter	300.00	hertz		[2A]
143	vbus filter	0.80	hertz	[E2]	
144	vbus notch frequency	0.0	hertz	[91]	
145	vbus notch damping	1.414	gain	[A6]	
146	vbus kp	3.000	gain	[ED]	
147	vbus ki	3.000	gain	[F3]	
148	vbus window shift	-1.22	volts	[58]	
149	vbus dac limit	10.00	volts	[C7]	
150	db watts	0	watts	[C1]	
151	db resistance	0.000	ohms	[80]	
152	db time constant	25	secs	[07]	
153	!db percent used	0	%	[1C]	
154	flux control	CLOSED LOOP			[45]
155	flux cutoff min	10.0	rad/sec	[0E]	
156	flux cutoff max	20.0	rad/sec	[0A]	
157	flux kp	1.000	gain	[EE]	
158	flux id obs bandwidth	50	rad/sec		[4A]
159	torq est filter	0.01000	sec	[D2]	
160	torq reg select	DISABLED			[40]
161	torq reg wn	0.0	rad/sec	[E3]	
162	torq reg kp cmd pct	0	%		[0B]
163	torq reg kp cmd	0.000	gain	[39]	
164	torq reg ki	0.00	gain	[C3]	
165	torq reg kp fbk	0.000	gain	[38]	
166	coulomb torque	0.00	ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu    -75  pulses         [32]
169 dac offset iv    20  pulses         [67]
170 adc offset iu    -60  pulses         [3F]
171 adc offset iv    31  pulses         [6C]
172 adc offset fu    -31  pulses         [42]
173 adc offset fv     3  pulses         [9E]
174 adc 1 select      VELOCITY          [8F]
175 adc 1 set  DISABLED                  [19]
176 adc 1 min  0.00  %                   [75]
177 adc 1 max 10800.00 %                 [A9]
178 adc 1 min volts 0.009 volts         [CF]
179 adc 1 max volts 8.833 volts         [BF]
180 adc 1 destination-1                 [A1]
181 !adc 1 raw value 8.833 volts         [BC]
182 !adc 1 value    10800.00 %          [B5]
183 adc 2 select      VOLTS             [65]
184 adc 2 set  DISABLED                  [18]
185 adc 2 min  0.00  %                   [74]
186 adc 2 max  0.00  %                   [71]
187 adc 2 min volts 0.000 volts         [D7]
188 adc 2 max volts 0.000 volts         [D4]
189 adc 2 destination-1                 [97]
190 !adc 2 raw value -1.070 volts       [9C]
191 !adc 2 value    0.00  %             [7D]
192 adc 3 select      VOLTS             [64]
193 adc 3 set  DISABLED                  [17]
194 adc 3 min  0.00  %                   [73]
195 adc 3 max  0.00  %                   [70]
196 adc 3 min volts 0.000 volts         [D6]
197 adc 3 max volts 0.000 volts         [D3]
198 adc 3 destination-1                 [96]
199 !adc 3 raw value -1.099 volts       [87]
200 !adc 3 value    0.00  %             [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select      TORQUE CMD        [32]
203 dac 1 ptr  28965                    [41]
204 dac 1 item 0                            [C5]
205 dac 1 mul  1                            [24]
206 dac 1 div  1                            [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output    0.000 volts        [A8]
209 dac 2 select      UPID VEL FBK      [D2]
210 dac 2 ptr  26033                    [52]
211 dac 2 item 0                            [C6]
212 dac 2 mul  32767                    [4D]
213 dac 2 div  251658                    [25]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output    0.000 volts        [A9]
216 level 1 password 1111                [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time     900.000 sec         [D5]
220 !lockout status  LOCKED              [A7]
221 ssi rx mode DISABLED                  [E8]
222 !ssi rx value    0                    [56]
223 ssi torque offset0.00 %              [A3]
224 ssi tx mode DISABLED                  [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	NONE		[68]	
232	console baud rate	1200 BAUD			[A2]
233	console parity	NONE		[3F]	
234	console address	0		[11]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	19		[A4]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	REV		[5F]	
247	porta vel units	MINUTES			[31]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec			[24]
255	!motor rpm	0.0 rpm	[99]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	662 volts		[E1]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.01 amps rms			[85]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb			[30]
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000000 \$			[0C]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000000 \$			[9B]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287199		[07]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	0.0 rpm		[DB]
309	test jog rpm	900.0 rpm		[62]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	3100.000 rev		[17]
315	test time	1.000 sec	[81]	
316	test torque	95 %	[26]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in	[B0]	
321	test accel time	4.000 sec	[69]	
322	test freq ramp time	5.000 sec		[E1]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	0.0 fpm		[21]
331	vel preset 2	900.0 fpm		[B6]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	0.0 fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 5 rpm [37]
371 bus reg tol time 0 secs [74]
372 bus reg kp 1.000 gain [06]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 4500 rpm [4C]
377 rpm rev shutoff -4500 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 25 % [DF]
381 inj brake time 3.000 sec [D6]
382 magnet flux0.0000 Wb [04]
383 ext trip DISABLE [11]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF	[16]	
412	decelerate req	REQ FORCED OFF	[10]	
413	speed adjust req	REQ FORCED OFF	[61]	
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF	[A7]	
418	inj brake req	REQ FORCED OFF	[B2]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS PLC	[7A]	
441	out 1	STS PLC	[78]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED	[74]		
458	sout 12	STS DISABLED	[72]		
459	sout 13	STS DISABLED	[70]		
460	sout 14	STS DISABLED	[77]		
461	sout 15	STS DISABLED	[75]		
462	sout 16	STS PLC	[CC]		
463	sout 17	STS PLC	[CA]		
464	sout 18	STS PLC	[C8]		
465	sout 19	STS PLC	[C6]		
466	sout 20	STS PLC	[CD]		
467	sout 21	STS PLC	[CB]		
468	sout 22	STS PLC	[C9]		
469	sout 23	STS PLC	[C7]		
470	sout 24	STS PLC	[CE]		
471	sout 25	STS PLC	[CC]		
472	sout 26	STS PLC	[CA]		
473	sout 27	STS PLC	[C8]		
474	sout 28	STS PLC	[C6]		
475	sout 29	STS PLC	[C4]		
476	sout 30	STS PLC	[CB]		
477	sout 31	STS PLC	[C9]		
900	!FH 1 12011007	BUS UNDERVOLTAGE	[14]	\$	12/Jan/2010
	23:40:37	Fault			
901	!FH 2 12011016	INVERTER RMS	[2B]	\$	12/Jan/2010
	22:18:44	Fault			
902	!FH 3 11011007	BUS UNDERVOLTAGE	[11]	\$	11/Jan/2010
	16:09:53	Fault			
903	!FH 4 07011007	BUS UNDERVOLTAGE	[0A]	\$	07/Jan/2010
	09:23:32	Fault			
904	!FH 5 04011007	BUS UNDERVOLTAGE	[0B]	\$	04/Jan/2010
	05:24:04	Fault			
905	!FH 6 03011016	INVERTER RMS	[23]	\$	03/Jan/2010
	20:38:58	Fault			
906	!FH 7 03011016	INVERTER RMS	[21]	\$	03/Jan/2010
	01:28:14	Fault			
907	!FH 8 03011016	INVERTER RMS	[1F]	\$	03/Jan/2010
	01:26:19	Fault			
908	!FH 9 03011016	INVERTER RMS	[1D]	\$	03/Jan/2010
	01:10:20	Fault			
909	!FH10 02011016	INVERTER RMS	[15]	\$	02/Jan/2010
	23:26:57	Fault			
910	!FH11 29120916	INVERTER RMS	[09]	\$	29/Dec/2009
	17:21:59	Fault			
911	!FH12 29120916	INVERTER RMS	[07]	\$	29/Dec/2009
	15:34:46	Fault			
912	!FH13 29120920	OVERSPEED TRIP	[7F]	\$	29/Dec/2009
	15:32:28	Fault			
913	!FH14 23120907	BUS UNDERVOLTAGE	[F0]	\$	23/Dec/2009
	17:28:46	Fault			
914	!FH15 23120905	FAST OVERCURRENT	[DD]	\$	23/Dec/2009
	15:25:16	Fault			
915	!FH16 23120905	FAST OVERCURRENT	[DB]	\$	23/Dec/2009
	15:24:37	Fault			
916	!FH17 23120905	FAST OVERCURRENT	[D9]	\$	23/Dec/2009
	15:23:15	Fault			
917	!FH18 23120905	FAST OVERCURRENT	[D7]	\$	23/Dec/2009
	15:20:56	Fault			

918	!FH19 22120905	FAST OVERCURRENT	[D6]	\$	22/Dec/2009
	07:59:27	Fault			
919	!FH20 22120905	FAST OVERCURRENT	[DD]	\$	22/Dec/2009
	07:57:25	Fault			
920	!FH21 22120905	FAST OVERCURRENT	[E4]	\$	22/Dec/2009
	06:33:18	Fault			
921	!FH22 22120905	FAST OVERCURRENT	[E2]	\$	22/Dec/2009
	03:09:32	Fault			
922	!FH23 22120905	FAST OVERCURRENT	[E0]	\$	22/Dec/2009
	03:08:41	Fault			
923	!FH24 22120920	OVERSPEED TRIP	[82]	\$	22/Dec/2009
	03:06:50	Fault			
924	!FH25 22120905	FAST OVERCURRENT	[DC]	\$	22/Dec/2009
	03:06:50	Fault			
925	!FH26 22120905	FAST OVERCURRENT	[DA]	\$	22/Dec/2009
	03:06:16	Fault			
926	!FH27 22120905	FAST OVERCURRENT	[D8]	\$	22/Dec/2009
	03:03:49	Fault			
927	!FH28 22120905	FAST OVERCURRENT	[D6]	\$	22/Dec/2009
	03:03:18	Fault			
928	!FH29 22120905	FAST OVERCURRENT	[D4]	\$	22/Dec/2009
	03:02:36	Fault			
929	!FH30 22120905	FAST OVERCURRENT	[DB]	\$	22/Dec/2009
	03:00:53	Fault			
930	!FH31 22120916	INVERTER RMS	[0C]	\$	22/Dec/2009
	02:28:40	Fault			
931	!FH32 22120916	INVERTER RMS	[0A]	\$	22/Dec/2009
	02:27:37	Fault			
932	!FH33 22120917	external trip	[46]	\$	22/Dec/2009
	02:06:57	Fault			
933	!FH34 22120916	INVERTER RMS	[06]	\$	22/Dec/2009
	02:06:07	Fault			
934	!FH35 22120916	INVERTER RMS	[04]	\$	22/Dec/2009
	02:05:59	Fault			
935	!FH36 22120905	FAST OVERCURRENT	[D8]	\$	22/Dec/2009
	01:53:57	Fault			
936	!FH37 22120917	external trip	[3E]	\$	22/Dec/2009
	01:34:42	Fault			
937	!FH38 22120917	external trip	[3C]	\$	22/Dec/2009
	01:07:32	Fault			
938	!FH39 22120917	external trip	[3A]	\$	22/Dec/2009
	00:29:39	Fault			
939	!FH40 21120916	INVERTER RMS	[04]	\$	21/Dec/2009
	23:53:33	Fault			
940	!FH41 21120917	external trip	[49]	\$	21/Dec/2009
	23:42:14	Fault			
941	!FH42 21120917	external trip	[47]	\$	21/Dec/2009
	23:31:41	Fault			
942	!FH43 21120917	external trip	[45]	\$	21/Dec/2009
	23:31:38	Fault			
943	!FH44 21120917	external trip	[43]	\$	21/Dec/2009
	23:31:28	Fault			
944	!FH45 21120917	external trip	[41]	\$	21/Dec/2009
	22:51:46	Fault			
945	!FH46 21120917	EXTERNAL TRIP	[BF]	\$	21/Dec/2009
	22:51:23	Fault			
946	!FH47 21120914	IREG SHUTOFF	[1C]	\$	21/Dec/2009
	22:51:23	Fault			



947 !FH48 21120917 external trip [3B] \$ 21/Dec/2009  
22:50:52 Fault  
948 !FH49 21120917 external trip [39] \$ 21/Dec/2009  
22:35:21 Fault

\$ Fault Masks:  
\$ bus overvoltage 1 - Enabled  
\$ AMB thermal switch 1 - Enabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 1 - Enabled  
\$ gate driver dsat 1 - Enabled  
\$ ireg shutoff 1 - Enabled  
\$ low voltage supply 1 - Enabled  
\$ external trip 1 - Enabled  
\$ dynamic brake limit 1 - Enabled  
\$ watchdog timer 1 - Enabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 1 - Enabled  
\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ Mtr Connection Error 1 - Enabled  
\$ user fault 1 req 1 - Enabled  
\$ user fault 2 req 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled

\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled

\$ communication error 0 - Disabled  
\$ ehalt fault0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ Mtr Connection Error 0 - Disabled  
\$ user fault 1 req 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled

\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ Mtr Connection Error 0 - Disabled  
\$ user fault 1 req 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:43:40

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	452 volts	[23]
29	motor rated current	10.50 amps rms	[CD]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	10.50 amps rms	[74]
34	current rate limit	0 amps pk/sec	[18]
35	field current	5.43 amps rms	[57]
36	field boost	200 %	[68]
37	slip frequency	1.167 hertz	[95]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.5793 ohms	[AC]
44	leakage Sigma	Ls 0.01329 henries	[66]
45	Lm squared over Lr	0.10196 henries	[95]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	22.00 ftlb	[71]
50	motor max torque	67.20 ftlb	[72]

51	motor rtd power	7.39	hp	[DC]
52	motor max power	22.58	hp	[B1]
53	motor kt	2.449	ftlb/amp	[25]
54	motor inertia	0.000	ftlbs^2	[94]
55	machine inertia	0.029	ftlbs^2	[E4]
56	acc obs bandwidth	40	rad/sec	[03]
57	system gain id	76.523	1/sec/sec	[DC]
58	system gain	76.523	1/sec/sec	[C8]
59	system wn	5.0	rad/sec	[87]
60	system order		VELOCITY	[1D]
61	kv cmd	0.000	upid gain	[D8]
62	kp cmd	0.327	upid gain	[D1]
63	ki	0.0	upid gain	[97]
64	kp fbk	0.327	upid gain	[D0]
65	kv fbk	0.113	upid gain	[D0]
66	kr	1.000	upid gain	[2A]
67	kp cmd percent	0	%	[D1]
68	ki load enable		DISABLE	[56]
69	kp load ratio	0	%	[35]
70	kv load ratio	0	%	[37]
71	torque limit	100.00	% max	[E2]
72	low pass frequency	100.0	hertz	[33]
73	low pass damping	1.414	gain	[A9]
74	notch frequency	0.0	hertz	[9F]
75	notch damping	1.414	gain	[B4]
76	system gain 1	76.523	1/sec/sec	[77]
77	system wn 1	20.0	rad/sec	[09]
78	system order 1		TORQUE	[52]
79	kv cmd 1	0.000	upid gain	[7E]
80	kp cmd 1	0.261	upid gain	[83]
81	ki 1	0.0	upid gain	[46]
82	kp fbk 1	0.261	upid gain	[82]
83	kv fbk 1	0.000	upid gain	[84]
84	kr 1	0.000	upid gain	[DA]
85	kp cmd percent 1	0	%	[80]
86	ki load enable 1		DISABLE	[05]
87	kp load ratio 1	0	%	[E4]
88	kv load ratio 1	0	%	[DD]
89	torque limit 1	100.00	% max	[88]
90	low pass frequency 1	100.0	hertz	[E2]
91	low pass damping 1	1.414	gain	[58]
92	notch frequency 1	10.0	hertz	[4E]
93	notch damping 1	1.414	gain	[63]
94	torque invert		ENABLE	[67]
95	base rpm	1765	rpm	[39]
96	max vel	1260.0	fpm	[4D]
97	jog vel	175.0	fpm	[7E]
98	!max motor rpm	4200.0	rpm	[C8]
99	accel time	3.000	sec	[6E]
100	decel time	3.000	sec	[4A]
101	jerk time	0.000	sec	[9D]
102	settle time	0.200	sec	[B5]
103	accel time 1	1.000	sec	[FD]
104	decel time 1	1.000	sec	[F7]
105	jerk time 1	10.000	sec	[48]
106	settle time 1	0.200	sec	[60]
107	fast decel time	0.200	sec	[76]
108	drive invert		DISABLE	[74]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.162 gain	[0E]	
121	dsv ki	16.208 gain	[30]	
122	dsv kp fbk	0.162 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -65  pulses      [33]
169 dac offset iv      -18  pulses      [33]
170 adc offset iu      -63  pulses      [3C]
171 adc offset iv       0   pulses      [A0]
172 adc offset fu       0   pulses      [A3]
173 adc offset fv      -34  pulses      [3D]
174 adc 1 select        VOLTS          [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00  %                    [75]
177 adc 1 max  0.00  %                    [72]
178 adc 1 min volts  0.004 volts          [D4]
179 adc 1 max volts -3.770 volts         [97]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value 0.009 volts          [C9]
182 !adc 1 value    0.00  %              [7E]
183 adc 2 select        VOLTS          [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00  %                    [74]
186 adc 2 max  0.00  %                    [71]
187 adc 2 min volts  0.000 volts          [D7]
188 adc 2 max volts  0.000 volts          [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value -0.005 volts        [9F]
191 !adc 2 value    0.00  %              [7D]
192 adc 3 select        VOLTS          [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00  %                    [73]
195 adc 3 max  0.00  %                    [70]
196 adc 3 min volts  0.000 volts          [D6]
197 adc 3 max volts  0.000 volts          [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value -0.005 volts        [95]
200 !adc 3 value    0.00  %              [85]
201 dac clock level  DRIVE CLOCK          [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr  28965                    [41]
204 dac 1 item 0                    [C5]
205 dac 1 mul  1                    [24]
206 dac 1 div  1                    [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output    0.000 volts          [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr  26033                    [52]
211 dac 2 item 0                    [C6]
212 dac 2 mul  32767                    [4D]
213 dac 2 div  293601                    [2B]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output    0.000 volts          [A9]
216 level 1 password 1111                    [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time      900.000 sec          [D5]
220 !lockout status  LEVEL 3              [8E]
221 ssi rx mode DISABLED                    [E8]
222 !ssi rx value    0                    [56]
223 ssi torque offset0.00  %              [A3]
224 ssi tx mode DISABLED                    [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	14		[DC]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	661 volts		[E2]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000040 \$			[08]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000002 \$			[19]
282	!int word 0	000800 \$			[93]

283	!int word 1	000000	\$		[99]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294965948			[E2]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	0			[7E]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	0			[B2]
307	test cycle rpm	1500.0	rpm		[67]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	200.0	rpm		[69]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque 90	%			[2B]
317	test degrees	180.00	deg		[22]
318	test i field	1.30	amps rms		[E5]
319	test volts 0	volts			[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	0.0	fpm		[1F]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

341	torque offset enable	AUTO PERMISSIVE			[0D]
342	torque offset	0.00 % max		[AA]	
343	torque offset rate	0.000 sec		[FD]	
344	offset rate select	BOTH		[18]	
345	preset upr torq lmt	80.00 % max		[59]	
346	preset lwr torq lmt	-80.00 % max		[2D]	
347	upr torq lmt rate	0.000 sec		[96]	
348	lwr torq lmt rate	0.000 sec		[97]	
349	torque slave source	DISABLED		[6F]	
350	torque slave data	0.00 % max		[5D]	
351	track enable	DISABLE		[AA]	
352	track source	MOTOR SOCKET		[F9]	
353	track ref pos	0.0000 in		[5F]	
354	!track position	0.0000 in		[77]	
355	track preset pos	0.0000 in		[07]	
356	droop ref select	DISABLED		[DC]	
357	droop ref torque	100.0 %		[DF]	
358	droop maximum	0.0 fpm		[20]	
359	droop start torque	0.0 %		[4D]	
360	droop filter tc	10.000 sec		[1F]	
361	!droop vel actual	0.0 fpm		[22]	
362	offset vel err tol	0.0 fpm		[A1]	
363	offset filter tc	2.000 sec		[E8]	
364	torq slave vel ovrd	ENABLE		[4C]	
365	vel ovrd torq thrsh	0.00 % max		[9B]	
366	vel ovrd select	OVERIDE VEL		[5D]	
367	vel ovrd vel	39.6 fpm		[97]	
368	bus reg	DISABLE		[96]	
369	bus reg min vel	50 rpm		[0A]	
370	bus reg tol vel	0 rpm		[3C]	
371	bus reg tol time	0 secs		[74]	
372	bus reg kp	2.000 gain		[05]	
373	bus reg kd	0.000 gain		[12]	
374	bus reg upper lmt	758 volts		[F8]	
375	bus reg torq lmt	20 %		[B2]	
376	rpm fwd shutoff	3600 rpm		[4C]	
377	rpm rev shutoff	-3600 rpm		[12]	
378	ssi data req vel	0.0 fpm		[88]	
379	drive stop mode	COAST		[F1]	
380	inj brake pct	0 %		[16]	
381	inj brake time	0.000 sec		[D9]	
382	magnet flux	0.0000 Wb		[04]	
383	ext trip	ENABLE		[5E]	
384	!motor socket vel	0.0 fpm		[01]	
385	!motor socket pos	0.0000 in		[D1]	
386	!load socket vel	0.0 fpm		[90]	
387	!load socket pos	0.0000 in		[60]	
388	!follow socket vel	0.0 fpm		[9B]	
389	!follow socket pos	0.0000 in		[6B]	
390	!main state	MAIN USER STATE		[0B]	
391	!application state	MOTOR OFF WAIT		[5F]	
392	motor on req	REQ PLC		[B8]	
393	motor on enable req	REQ FORCED ON		[9F]	
394	fault reset req	REQ PLC		[85]	
395	warning reset req	REQ PLC		[AA]	
396	jog fwd req	REQ PLC		[41]	
397	jog rev req	REQ PLC		[34]	
398	fast stop req	REQ FORCED ON		[BB]	

399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ PLC	[36]	
402	auto run req	REQ PLC	[C0]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ PLC	[0C]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT OFF	[94]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT OFF	[CB]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	MOTOR ON STS	[0B]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	TU15	[25]	
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	80.00 % rtd	[BD]	
483	pend max vel	1057.5 fpm	[4D]	
484	pend index pos	333.2400 in	[7E]	
485	pend index vel	39.6 fpm	[D9]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	0.0 fpm	[E1]	
488	comp index pos	0.0000 in	[E1]	
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word0		[95]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0	[24]	
494	!comp handshake ctr p	0	[72]	
495	payout distance	0.0000 in	[2F]	
496	payout preset	0.0000 in	[E6]	
497	!index start pos	0.0000 in	[41]	
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain	[2B]	
503	!smooth hose tension	0.00 lb	[05]	
504	target hose load %	25 %	[53]	
505	cable filter gain	0.97000 gain	[E0]	
506	!smooth cable tension	0.00 lb	[BA]	
507	fine control gain	0.0000 in/sec/lb	[59]	
508	!actual fine control	0.0000 in/sec/lb	[5C]	
509	fade filter gain	0.97000 gain	[43]	
510	hose tension offset	0.00 lb	[3B]	
511	cable tension offset	0.00 lb	[F2]	
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in	[47]	
514	coil max od	0.0000 in	[44]	

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.1127	in	[C3]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	17:43:47	Fault				
901	!FH 2 20011017	external trip		[6A]	\$	20/Jan/2010
	17:43:03	Fault				
902	!FH 3 19011017	EXTERNAL TRIP		[E0]	\$	19/Jan/2010
	23:24:19	Fault				
903	!FH 4 19011008	GATE DRIVER DSAT		[27]	\$	19/Jan/2010
	21:13:06	Fault				
904	!FH 5 19011017	external trip		[5C]	\$	19/Jan/2010
	17:12:44	Fault				
905	!FH 6 19011017	external trip		[5A]	\$	19/Jan/2010
	17:12:22	Fault				
906	!FH 7 18011017	EXTERNAL TRIP		[D9]	\$	18/Jan/2010
	10:58:59	Fault				
907	!FH 8 17011008	GATE DRIVER DSAT		[21]	\$	17/Jan/2010
	22:12:01	Fault				
908	!FH 9 16011017	external trip		[57]	\$	16/Jan/2010
	23:48:20	Fault				
909	!FH10 16011017	external trip		[4E]	\$	16/Jan/2010
	06:15:39	Fault				
910	!FH11 14011017	external trip		[57]	\$	14/Jan/2010
	19:39:30	Fault				
911	!FH12 14011017	external trip		[55]	\$	14/Jan/2010
	19:39:17	Fault				
912	!FH13 13011017	EXTERNAL TRIP		[D4]	\$	13/Jan/2010
	18:39:46	Fault				

913	!FH14 12011017	external trip	[53]	\$	12/Jan/2010
	11:21:58	Fault			
914	!FH15 12011017	EXTERNAL TRIP	[D1]	\$	12/Jan/2010
	11:17:50	Fault			
915	!FH16 12011017	external trip	[4F]	\$	12/Jan/2010
	10:30:49	Fault			
916	!FH17 08011017	EXTERNAL TRIP	[C8]	\$	08/Jan/2010
	04:30:18	Fault			
917	!FH18 08011016	INVERTER RMS	[08]	\$	08/Jan/2010
	02:37:16	Fault			
918	!FH19 06011017	EXTERNAL TRIP	[C6]	\$	06/Jan/2010
	22:18:14	Fault			
919	!FH20 05011017	EXTERNAL TRIP	[CE]	\$	05/Jan/2010
	00:08:21	Fault			
920	!FH21 04011017	EXTERNAL TRIP	[D6]	\$	04/Jan/2010
	22:00:50	Fault			
921	!FH22 04011017	external trip	[54]	\$	04/Jan/2010
	18:28:09	Fault			
922	!FH23 03011017	external trip	[53]	\$	03/Jan/2010
	15:09:18	Fault			
923	!FH24 01011017	EXTERNAL TRIP	[D3]	\$	01/Jan/2010
	09:34:35	Fault			
924	!FH25 01011017	EXTERNAL TRIP	[D1]	\$	01/Jan/2010
	06:05:13	Fault			
925	!FH26 31120908	GATE DRIVER DSAT	[0B]	\$	31/Dec/2009
	04:27:45	Fault			
926	!FH27 31120908	GATE DRIVER DSAT	[09]	\$	31/Dec/2009
	03:57:46	Fault			
927	!FH28 30120917	external trip	[3F]	\$	30/Dec/2009
	12:06:53	Fault			
928	!FH29 29120917	EXTERNAL TRIP	[B5]	\$	29/Dec/2009
	03:13:07	Fault			
929	!FH30 28120917	EXTERNAL TRIP	[BD]	\$	28/Dec/2009
	23:13:36	Fault			
930	!FH31 28120917	external trip	[44]	\$	28/Dec/2009
	23:07:28	Fault			
931	!FH32 24120917	external trip	[46]	\$	24/Dec/2009
	16:24:00	Fault			
932	!FH33 24120907	BUS UNDERVOLTAGE	[ED]	\$	24/Dec/2009
	12:37:04	Fault			
933	!FH34 22120917	EXTERNAL TRIP	[C4]	\$	22/Dec/2009
	21:14:56	Fault			
934	!FH35 19120917	EXTERNAL TRIP	[BC]	\$	19/Dec/2009
	15:36:49	Fault			
935	!FH36 18120917	EXTERNAL TRIP	[BB]	\$	18/Dec/2009
	08:18:59	Fault			
936	!FH37 18120917	external trip	[39]	\$	18/Dec/2009
	03:33:01	Fault			
937	!FH38 18120917	external trip	[37]	\$	18/Dec/2009
	02:33:51	Fault			
938	!FH39 15120917	EXTERNAL TRIP	[B8]	\$	15/Dec/2009
	18:23:38	Fault			
939	!FH40 15120917	EXTERNAL TRIP	[BF]	\$	15/Dec/2009
	17:03:10	Fault			
940	!FH41 15120917	EXTERNAL TRIP	[C6]	\$	15/Dec/2009
	17:03:08	Fault			
941	!FH42 15120917	EXTERNAL TRIP	[C4]	\$	15/Dec/2009
	16:58:31	Fault			

942	!FH43 15120917	external trip	[42]	\$	15/Dec/2009
	16:25:56	Fault			
943	!FH44 15120907	BUS UNDERVOLTAGE	[E9]	\$	15/Dec/2009
	15:40:11	Fault			
944	!FH45 13120917	external trip	[40]	\$	13/Dec/2009
	04:58:01	Fault			
945	!FH46 13120917	EXTERNAL TRIP	[BE]	\$	13/Dec/2009
	02:34:50	Fault			
946	!FH47 13120917	EXTERNAL TRIP	[BC]	\$	13/Dec/2009
	02:02:28	Fault			
947	!FH48 13120917	external trip	[3A]	\$	13/Dec/2009
	01:53:05	Fault			
948	!FH49 12120917	external trip	[39]	\$	12/Dec/2009
	20:43:29	Fault			
949	!FH50 10120917	external trip	[42]	\$	10/Dec/2009
	17:21:29	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor resolv 1 loss 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg tol 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

```



\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ DB Over Temp 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled

\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

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$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 00:31:52

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	77.00 amps rms	[C5]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	130.00 amps rms	[09]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	77.00 amps rms	[6C]
34	current rate limit	0 amps pk/sec	[18]
35	field current	24.79 amps rms	[1D]
36	field boost	200 %	[68]
37	slip frequency	2.500 hertz	[9D]
38	motor poles	2	[C2]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.2372 ohms	[B6]
44	leakage Sigma	Ls 0.00220 henries	[71]
45	Lm squared over Lr	0.02183 henries	[98]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	87.30 ftlb	[63]
50	motor max torque	152.82 ftlb	[3F]

51	motor rtd power	57.35 hp	[AB]
52	motor max power	100.39 hp	[85]
53	motor kt	1.198 ftlb/amp	[25]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.028 ftlbs^2	[E5]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	217.189 1/sec/sec	[A7]
58	system gain	217.189 1/sec/sec	[93]
59	system wn	5.0 rad/sec	[87]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.115 upid gain	[D6]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.115 upid gain	[D5]
65	kv fbk	0.040 upid gain	[D1]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	217.189 1/sec/sec	[42]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.092 upid gain	[81]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.092 upid gain	[80]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	ENABLE	[67]
95	base rpm	3450 rpm	[40]
96	max vel	1500.0 fpm	[50]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	5000.0 rpm	[C9]
99	accel time	10.000 sec	[40]
100	decel time	10.000 sec	[1C]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	1.000 sec	[F7]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	DISABLE	[74]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	4000 hertz	[C9]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.027 gain	[0E]	
121	dsv ki	2.705 gain	[63]	
122	dsv kp fbk	0.027 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm      [2F]
168 dac offset iu    -40  pulses     [3A]
169 dac offset iv    20  pulses     [67]
170 adc offset iu    -15  pulses     [3F]
171 adc offset iv    65  pulses     [65]
172 adc offset fu    39  pulses     [67]
173 adc offset fv    -4  pulses     [70]
174 adc 1 select      VOLTS         [66]
175 adc 1 set  DISABLED             [19]
176 adc 1 min  0.00  %              [75]
177 adc 1 max  0.00  %              [72]
178 adc 1 min volts  0.000 volts    [D8]
179 adc 1 max volts  0.000 volts    [D5]
180 adc 1 destination-1            [A1]
181 !adc 1 raw value 0.009 volts    [C9]
182 !adc 1 value    0.00  %         [7E]
183 adc 2 select      VOLTS         [65]
184 adc 2 set  DISABLED             [18]
185 adc 2 min  0.00  %              [74]
186 adc 2 max  0.00  %              [71]
187 adc 2 min volts  0.000 volts    [D7]
188 adc 2 max volts  0.000 volts    [D4]
189 adc 2 destination-1            [97]
190 !adc 2 raw value -0.005        volts [9F]
191 !adc 2 value    0.00  %         [7D]
192 adc 3 select      VOLTS         [64]
193 adc 3 set  DISABLED             [17]
194 adc 3 min  0.00  %              [73]
195 adc 3 max  0.00  %              [70]
196 adc 3 min volts  0.000 volts    [D6]
197 adc 3 max volts  0.000 volts    [D3]
198 adc 3 destination-1            [96]
199 !adc 3 raw value -0.005        volts [95]
200 !adc 3 value    0.00  %         [85]
201 dac clock level  DRIVE CLOCK    [AE]
202 dac 1 select      TORQUE CMD     [32]
203 dac 1 ptr  28965                [41]
204 dac 1 item  0                    [C5]
205 dac 1 mul   1                    [24]
206 dac 1 div   1                    [2E]
207 dac 1 abs  DISABLE              [77]
208 !dac 1 output  0.000 volts      [A8]
209 dac 2 select      UPID VEL FBK   [D2]
210 dac 2 ptr  26033                [52]
211 dac 2 item  0                    [C6]
212 dac 2 mul   32767               [4D]
213 dac 2 div   349525              [24]
214 dac 2 abs  DISABLE              [78]
215 !dac 2 output  0.000 volts      [A9]
216 level 1 password 1111           [7A]
217 level 2 password 0              [0C]
218 level 3 password 0              [0A]
219 lockout time    900.000        sec [D5]
220 !lockout status LOCKED          [A7]
221 ssi rx mode DISABLED            [E8]
222 !ssi rx value   0                [56]
223 ssi torque offset0.00  %        [A3]
224 ssi tx mode DISABLED            [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	13		[DD]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	13		[AA]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	86.45 amps rms			[84]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	663 volts		[E0]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000001 \$			[0B]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000200 \$			[99]

283	!int word 1	000000	\$		[99]
284	!int word 2	001000	\$		[96]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	0		[E2]	
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	0			[1F]
293	software mask	4294965951			[E8]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	0			[7E]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	0			[B2]
307	test cycle rpm	1200.0	rpm		[6A]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	200.0	rpm		[69]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque	20	%		[32]
317	test degrees	180.00	deg		[22]
318	test i field	0.00	amps rms		[E9]
319	test volts	0	volts		[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	600.0	fpm		[B9]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source DISABLED [6F]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd DISABLE [FF]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select VEL SELECT [AB]
367 vel ovrd vel 0.0 fpm [D9]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 3700 rpm [4B]
377 rpm rev shutoff -3700 rpm [11]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF		[16]
412	decelerate req	REQ FORCED OFF		[10]
413	speed adjust req	REQ FORCED OFF		[61]
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF		[A7]
418	inj brake req	REQ FORCED OFF		[B2]
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	RETURN WATER PUMP		[4F]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	50.00 % rtd	[C0]	
483	pend max vel	150.0 fpm	[89]	
484	pend index pos	180.0000 in		[84]
485	pend index vel	150.0 fpm	[B5]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	1035.0 fpm		[48]
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word192		[29]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	target hose load %	25 %		[53]
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	575	volts rms	[8C]		
536	hi-spd line low limt	575	volts rms	[95]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
547	Mode	Computer Control		[5E]		
548	Start	DISABLE	[30]			
549	1 bit pump	ENABLE	[18]			
900	!FH 1 28120917	external trip	[5A]	\$	28/Dec/2009	
	23:06:38	Fault				
901	!FH 2 24120917	external trip	[5C]	\$	24/Dec/2009	
	16:23:00	Fault				
902	!FH 3 22120917	external trip	[5C]	\$	22/Dec/2009	
	09:16:16	Fault				
903	!FH 4 22120917	external trip	[5A]	\$	22/Dec/2009	
	09:14:27	Fault				
904	!FH 5 18120917	external trip	[53]	\$	18/Dec/2009	
	04:15:30	Fault				
905	!FH 6 18120917	external trip	[51]	\$	18/Dec/2009	
	03:28:03	Fault				
906	!FH 7 15120917	external trip	[52]	\$	15/Dec/2009	
	18:22:51	Fault				
907	!FH 8 13120917	external trip	[52]	\$	13/Dec/2009	
	05:59:37	Fault				
908	!FH 9 13120917	external trip	[50]	\$	13/Dec/2009	
	01:52:27	Fault				
909	!FH10 04120906	hs thermal switch	[F1]	\$	04/Dec/2009	
	13:17:50	Fault				
910	!FH11 01120917	external trip	[51]	\$	01/Dec/2009	
	03:32:51	Fault				

\$ Fault Masks:  
\$ bus overvoltage 1 - Enabled  
\$ AMB thermal switch 1 - Enabled  
\$ fast overcurrent 1 - Enabled  
\$ HS thermal switch 1 - Enabled  
\$ gate driver dsat 1 - Enabled  
\$ ireg shutoff 1 - Enabled  
\$ low voltage supply 1 - Enabled  
\$ external trip 1 - Enabled  
\$ dynamic brake limit 1 - Enabled  
\$ watchdog timer 1 - Enabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 1 - Enabled  
\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage 1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled  
\$ user fault 12 req 1 - Enabled  
\$ user fault 13 req 1 - Enabled  
\$ user fault 14 req 1 - Enabled  
\$ user fault 15 req 1 - Enabled  
\$ user fault 16 req 1 - Enabled

\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled



\$ Line Undervoltage0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage suppply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled

\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/19 22:37:27

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	IN MM	[89]
2	velocity units	SECONDS	[D0]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	0.1505 in/rev	[4C]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	6.20 amps rms	[FB]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	6.20 amps rms	[A2]
34	current rate limit	0 amps pk/sec	[18]
35	field current	2.03 amps rms	[5E]
36	field boost 200	%	[68]
37	slip frequency	1.500 hertz	[9E]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 1.4211 ohms	[BB]
44	leakage Sigma	Ls 0.02978 henries	[5B]
45	Lm squared over Lr	0.32388 henries	[8E]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	17.02 ftlb	[6B]
50	motor max torque	81.23 ftlb	[73]

51	motor rtd power	5.69 hp	[DB]
52	motor max power	27.14 hp	[B4]
53	motor kt	2.911 ftlb/amp	[2B]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.026 ftlbs^2	[E7]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	121.451 1/sec/sec	[B5]
58	system gain	121.451 1/sec/sec	[A1]
59	system wn	16.0 rad/sec	[55]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	2.108 upid gain	[D2]
63	ki	0.0 upid gain	[97]
64	kp fbk	2.108 upid gain	[D1]
65	kv fbk	0.228 upid gain	[C9]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	121.451 1/sec/sec	[50]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.165 upid gain	[80]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.165 upid gain	[7F]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1755 rpm	[3A]
96	max vel	50.0 fpm	[B1]
97	jog vel	50.0 fpm	[B6]
98	!max motor rpm	3986.7 rpm	[AD]
99	accel time	2.000 sec	[6F]
100	decel time	2.000 sec	[4B]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	2.000 sec	[FC]
104	decel time 1	2.000 sec	[F6]
105	jerk time 1	0.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.366 gain	[08]	
121	dsv ki	36.622 gain	[2E]	
122	dsv kp fbk	0.366 gain	[07]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	405 watts	[58]	
151	db resistance	138.900 ohms	[0B]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone 100.0 rpm          [2F]
168 dac offset iu      -12 pulses        [3B]
169 dac offset iv      -82 pulses        [32]
170 adc offset iu       7 pulses         [9B]
171 adc offset iv      -58 pulses        [36]
172 adc offset fu       15 pulses        [6D]
173 adc offset fv      -35 pulses        [3C]
174 adc 1 select       VELOCITY          [8F]
175 adc 1 set          DISABLED          [19]
176 adc 1 min          0.00 %            [75]
177 adc 1 max          500.00 %          [0D]
178 adc 1 min volts    0.024 volts       [D2]
179 adc 1 max volts    9.824 volts       [BE]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value   0.004 volts       [CE]
182 !adc 1 value       -0.74 %          [46]
183 adc 2 select       VOLTS             [65]
184 adc 2 set          DISABLED          [18]
185 adc 2 min          0.00 %            [74]
186 adc 2 max          0.00 %            [71]
187 adc 2 min volts    0.000 volts       [D7]
188 adc 2 max volts    0.000 volts       [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value   0.000 volts       [D1]
191 !adc 2 value       0.00 %           [7D]
192 adc 3 select       VOLTS             [64]
193 adc 3 set          DISABLED          [17]
194 adc 3 min          0.00 %            [73]
195 adc 3 max          0.00 %            [70]
196 adc 3 min volts    0.000 volts       [D6]
197 adc 3 max volts    0.000 volts       [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value   0.000 volts       [C7]
200 !adc 3 value       0.00 %           [85]
201 dac clock level    DRIVE CLOCK       [AE]
202 dac 1 select       TORQUE CMD        [32]
203 dac 1 ptr          28965             [41]
204 dac 1 item         0                 [C5]
205 dac 1 mul          1                 [24]
206 dac 1 div          1                 [2E]
207 dac 1 abs          DISABLE           [77]
208 !dac 1 output      0.000 volts       [A8]
209 dac 2 select       UPID VEL FBK      [D2]
210 dac 2 ptr          26033            [52]
211 dac 2 item         0                 [C6]
212 dac 2 mul          32767            [4D]
213 dac 2 div          278691           [1F]
214 dac 2 abs          DISABLE           [78]
215 !dac 2 output      0.000 volts       [A9]
216 level 1 password   1111             [7A]
217 level 2 password   0                 [0C]
218 level 3 password   0                 [0A]
219 lockout time       900.000          sec [D5]
220 !lockout status    LEVEL 3          [8E]
221 ssi rx mode        DISABLED          [E8]
222 !ssi rx value      0                 [56]
223 ssi torque offset  0.00 %           [A3]
224 ssi tx mode        DISABLED          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	17		[D9]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	661 volts		[E2]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000041 \$			[07]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000800 \$			[93]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280025087		[15]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	1000.0	rpm	[6C]
308	test id min rpm	0.0	rpm	[DB]
309	test jog rpm	1000.0	rpm	[3A]
310	test max rpm	900.0	rpm	[64]
311	test min rpm	-900.0	rpm	[38]
312	test period	0.000	sec	[B1]
313	test ramp	DISABLE		[B8]
314	test position	10.000	rev	[7A]
315	test time	1.000	sec	[81]
316	test torque	90	%	[2B]
317	test degrees	180.00	deg	[22]
318	test i field	0.00	amps rms	[E9]
319	test volts	0	volts	[B6]
320	test length	24.0001	in	[B0]
321	test accel time	4.000	sec	[69]
322	test freq ramp time	6.000	sec	[E0]
323	test adc	1		[02]
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0	fpm	[0E]
330	vel preset 1	0.0	fpm	[21]
331	vel preset 2	0.0	fpm	[1F]
332	vel preset 3	0.0	fpm	[1D]
333	vel preset 4	0.0	fpm	[1B]
334	vel preset 5	0.0	fpm	[19]
335	vel preset 6	0.0	fpm	[17]
336	vel preset 7	0.0	fpm	[15]
337	vel preset 8	0.0	fpm	[13]
338	vel offset	0.0	fpm	[76]
339	vel gain	100.00	%	[EA]
340	vel tolerance	0.0	fpm	[47]



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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 4.0 fpm [D5]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 10 rpm [0B]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 100 % [83]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode INJ BRAKE [05]
380 inj brake pct 50 % [E1]
381 inj brake time 1.000 sec [D8]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main state MAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ PLC	[36]	
402	auto run req	REQ PLC	[C0]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ PLC	[0C]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT OFF	[CB]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	MOTOR ON STS	[0B]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED			[74]
458	sout 12	STS DISABLED			[72]
459	sout 13	STS DISABLED			[70]
460	sout 14	STS DISABLED			[77]
461	sout 15	STS DISABLED			[75]
462	sout 16	STS PLC		[CC]	
463	sout 17	STS PLC		[CA]	
464	sout 18	STS PLC		[C8]	
465	sout 19	STS PLC		[C6]	
466	sout 20	STS PLC		[CD]	
467	sout 21	STS PLC		[CB]	
468	sout 22	STS PLC		[C9]	
469	sout 23	STS PLC		[C7]	
470	sout 24	STS PLC		[CE]	
471	sout 25	STS PLC		[CC]	
472	sout 26	STS PLC		[CA]	
473	sout 27	STS PLC		[C8]	
474	sout 28	STS PLC		[C6]	
475	sout 29	STS PLC		[C4]	
476	sout 30	STS PLC		[CB]	
477	sout 31	STS PLC		[C9]	
478	drive type	TOWER HOIST		[FC]	
479	allow pend reverse	ENABLE			[86]
480	torque mode enable	DISABLE			[57]
481	torq override enable	ENABLE			[C2]
482	pend max torq	80.00 % rtd		[BD]	
483	pend max vel	25.0 fpm		[B8]	
484	pend index pos	36.0000	in		[B4]
485	pend index vel	35.0 fpm		[E3]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	0.0 fpm		[E1]	
488	comp index pos	0.0000	in		[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word0			[52]	
491	!comp status word128			[2A]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000	in		[2F]
496	payout preset	0.0000	in		[E6]
497	!index start pos	0.0000	in		[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000	gain		[2B]
503	!smooth hose tension	0.00 lb			[05]
504	target hose load %	25	%		[53]
505	cable filter gain	0.97000	gain		[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000	in/sec/lb		[59]
508	!actual fine control	0.0000	in/sec/lb		[5C]
509	fade filter gain	0.97000	gain		[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0	%		[03]
513	coil min od	0.0000	in		[47]
514	coil max od	0.0000	in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 19011007	BUS UNDERVOLTAGE		[0D]	\$	19/Jan/2010
	06:13:01	Fault				
901	!FH 2 18011017	EXTERNAL TRIP		[E3]	\$	18/Jan/2010
	21:26:15	Fault				
902	!FH 3 18011020	OVERSPEED TRIP		[9D]	\$	18/Jan/2010
	16:24:54	Fault				
903	!FH 4 18011017	EXTERNAL TRIP		[DF]	\$	18/Jan/2010
	12:22:21	Fault				
904	!FH 5 18011017	EXTERNAL TRIP		[DD]	\$	18/Jan/2010
	11:59:34	Fault				
905	!FH 6 18011017	EXTERNAL TRIP		[DB]	\$	18/Jan/2010
	11:59:22	Fault				
906	!FH 7 18011017	EXTERNAL TRIP		[D9]	\$	18/Jan/2010
	11:59:12	Fault				
907	!FH 8 18011017	EXTERNAL TRIP		[D7]	\$	18/Jan/2010
	11:47:42	Fault				
908	!FH 9 18011017	EXTERNAL TRIP		[D5]	\$	18/Jan/2010
	11:47:34	Fault				
909	!FH10 18011017	EXTERNAL TRIP		[CC]	\$	18/Jan/2010
	11:46:24	Fault				
910	!FH11 18011017	EXTERNAL TRIP		[D3]	\$	18/Jan/2010
	11:45:23	Fault				
911	!FH12 18011017	EXTERNAL TRIP		[D1]	\$	18/Jan/2010
	11:45:20	Fault				
912	!FH13 18011017	EXTERNAL TRIP		[CF]	\$	18/Jan/2010
	11:45:19	Fault				

913	!FH14 18011017	EXTERNAL TRIP	[CD]	\$	18/Jan/2010
	11:45:14	Fault			
914	!FH15 18011017	EXTERNAL TRIP	[CB]	\$	18/Jan/2010
	11:45:12	Fault			
915	!FH16 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	11:28:39	Fault			
916	!FH17 18011017	EXTERNAL TRIP	[C7]	\$	18/Jan/2010
	11:22:57	Fault			
917	!FH18 18011017	EXTERNAL TRIP	[C5]	\$	18/Jan/2010
	11:11:57	Fault			
918	!FH19 18011017	EXTERNAL TRIP	[C3]	\$	18/Jan/2010
	11:11:54	Fault			
919	!FH20 18011017	EXTERNAL TRIP	[CA]	\$	18/Jan/2010
	11:11:49	Fault			
920	!FH21 17011007	BUS UNDERVOLTAGE	[FB]	\$	17/Jan/2010
	16:15:43	Fault			
921	!FH22 16011017	EXTERNAL TRIP	[D1]	\$	16/Jan/2010
	23:48:46	Fault			
922	!FH23 16011017	EXTERNAL TRIP	[CF]	\$	16/Jan/2010
	23:48:37	Fault			
923	!FH24 16011017	EXTERNAL TRIP	[CD]	\$	16/Jan/2010
	23:48:16	Fault			
924	!FH25 16011017	external trip	[4B]	\$	16/Jan/2010
	06:15:35	Fault			
925	!FH26 15011007	BUS UNDERVOLTAGE	[F3]	\$	15/Jan/2010
	13:07:02	Fault			
926	!FH27 15011014	IREG SHUTOFF	[27]	\$	15/Jan/2010
	13:07:02	Fault			
927	!FH28 14011017	EXTERNAL TRIP	[C7]	\$	14/Jan/2010
	13:01:11	Fault			
928	!FH29 13011017	EXTERNAL TRIP	[C6]	\$	13/Jan/2010
	20:26:30	Fault			
929	!FH30 13011017	EXTERNAL TRIP	[CD]	\$	13/Jan/2010
	18:39:43	Fault			
930	!FH31 12011017	external trip	[55]	\$	12/Jan/2010
	11:21:55	Fault			
931	!FH32 12011017	EXTERNAL TRIP	[D3]	\$	12/Jan/2010
	11:17:47	Fault			
932	!FH33 12011017	EXTERNAL TRIP	[D1]	\$	12/Jan/2010
	10:30:46	Fault			
933	!FH34 12011017	external trip	[4F]	\$	12/Jan/2010
	10:03:10	Fault			
934	!FH35 12011017	external trip	[4D]	\$	12/Jan/2010
	10:02:58	Fault			
935	!FH36 08011007	BUS UNDERVOLTAGE	[EF]	\$	08/Jan/2010
	15:38:01	Fault			
936	!FH37 08011017	EXTERNAL TRIP	[C4]	\$	08/Jan/2010
	05:25:22	Fault			
937	!FH38 08011017	EXTERNAL TRIP	[C2]	\$	08/Jan/2010
	04:30:19	Fault			
938	!FH39 06011017	EXTERNAL TRIP	[C2]	\$	06/Jan/2010
	22:18:15	Fault			
939	!FH40 06011017	EXTERNAL TRIP	[C9]	\$	06/Jan/2010
	20:32:30	Fault			
940	!FH41 05011017	EXTERNAL TRIP	[D1]	\$	05/Jan/2010
	13:17:57	Fault			
941	!FH42 05011017	EXTERNAL TRIP	[CF]	\$	05/Jan/2010
	02:55:27	Fault			

942	!FH43 05011017	EXTERNAL TRIP	[CD]	\$	05/Jan/2010
	00:31:58	Fault			
943	!FH44 05011017	EXTERNAL TRIP	[CB]	\$	05/Jan/2010
	00:17:07	Fault			
944	!FH45 05011017	EXTERNAL TRIP	[C9]	\$	05/Jan/2010
	00:08:23	Fault			
945	!FH46 03011017	external trip	[49]	\$	03/Jan/2010
	15:22:44	Fault			
946	!FH47 01011017	EXTERNAL TRIP	[C9]	\$	01/Jan/2010
	06:05:34	Fault			
947	!FH48 31120907	BUS UNDERVOLTAGE	[E3]	\$	31/Dec/2009
	03:17:58	Fault			
948	!FH49 31120917	EXTERNAL TRIP	[B8]	\$	31/Dec/2009
	02:53:39	Fault			
949	!FH50 30120917	EXTERNAL TRIP	[C0]	\$	30/Dec/2009
	14:49:55	Fault			

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$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

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\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ DB Over Temp 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled



\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

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$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
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DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:30:39

DATA\_START

UNITS 2 [29]

0	unit system	METRIC		[5A]	
1	position units	REV		[ED]	
2	velocity units	MINUTES		[BA]	
3	hertz units	DISABLE		[2C]	
4	clock frequency	50	hertz	[0F]	
5	drive multiple	1		[C7]	
6	upid multiple	10		[FE]	
7	ac multiple	2	[1A]		
8	ac fast multiple	1		[4C]	
9	vector source	MOTOR SOCKET		[DC]	
10	upid motor source	MOTOR SOCKET		[44]	
11	upid load source	LOAD SOCKET		[45]	
12	load vector control	DISABLE		[08]	
13	transducerless	DISABLE		[89]	
14	motor fbk size	2048	pulses/rev	[29]	
15	motor resolution	3.6000	in/rev	[4E]	
16	motor fbk invert	DISABLE		[3C]	
17	motor input teeth	1		[7F]	
18	motor output teeth	1		[FD]	
19	motor encoder bits	BITS 0		[E4]	
20	motor encoder turns	1		[B3]	
21	load fbk size	2048	pulses/rev	[BC]	
22	load resolution	3.6000	in/rev	[E1]	
23	load fbk invert	DISABLE		[CF]	
24	load input teeth	1		[12]	
25	load output teeth	1		[90]	
26	load encoder bits	BITS 0		[77]	
27	load encoder turns	1		[3D]	
28	motor rated voltage	460	volts	[24]	
29	motor rated current	3.40	amps rms	[FC]	
30	motor rated frequency	60	hertz	[8A]	
31	maximum current	9.60	amps rms	[5E]	
32	current limit	9.60	amps rms	[3C]	
33	motor rms limit	3.74	amps rms	[9C]	
34	current rate limit	0	amps pk/sec	[18]	
35	field current	2.08	amps rms	[59]	
36	field boost	200	%	[68]	
37	slip frequency	0.734	hertz	[96]	
38	motor poles	4		[C0]	
39	synchronous motor	DISABLE		[57]	
40	vector offset	0.00	deg	[47]	
41	vector ffwd	0.00000	sec	[8B]	
42	torque ffwd	0.00	deg	[18]	
43	stator resistance	Rs	1.7246	ohms	[B0]
44	leakage Sigma	Ls	0.03745	henries	[62]
45	Lm squared over	Lr	0.28621	henries	[93]
46	current filter	2.00	hertz	[D3]	
47	voltage filter	2.00	hertz	[E3]	
48	power filter	2.00	hertz	[A7]	
49	motor rtd torque	7.06	ftlb	[98]	
50	motor max torque	24.68	ftlb	[6D]	

51	motor rtd power	2.39	hp	[E1]	
52	motor max power	8.36	hp	[E1]	
53	motor kt	2.631	ftlb/amp	[2C]	
54	motor inertia	0.000	ftlbs^2		[94]
55	machine inertia	0.012	ftlbs^2		[EC]
56	acc obs bandwidth	40	rad/sec		[03]
57	system gain id	79.783	1/sec/sec		[D1]
58	system gain	79.783	1/sec/sec		[BD]
59	system wn	5.0	rad/sec		[87]
60	system order		VELOCITY		[1D]
61	kv cmd	0.000	upid gain		[D8]
62	kp cmd	0.313	upid gain		[D6]
63	ki	0.0	upid gain		[97]
64	kp fbk	0.313	upid gain		[D5]
65	kv fbk	0.109	upid gain		[CB]
66	kr	1.000	upid gain		[2A]
67	kp cmd percent	0	%		[D1]
68	ki load enable		DISABLE		[56]
69	kp load ratio	0	%		[35]
70	kv load ratio	0	%		[37]
71	torque limit	100.00	% max		[E2]
72	low pass frequency	100.0	hertz		[33]
73	low pass damping	1.414	gain		[A9]
74	notch frequency	0.0	hertz		[9F]
75	notch damping	1.414	gain		[B4]
76	system gain 1	79.783	1/sec/sec		[6C]
77	system wn 1	20.0	rad/sec		[09]
78	system order 1		TORQUE		[52]
79	kv cmd 1	0.000	upid gain		[7E]
80	kp cmd 1	0.251	upid gain		[84]
81	ki 1	0.0	upid gain		[46]
82	kp fbk 1	0.251	upid gain		[83]
83	kv fbk 1	0.000	upid gain		[84]
84	kr 1	0.000	upid gain		[DA]
85	kp cmd percent 1	0	%		[80]
86	ki load enable 1		DISABLE		[05]
87	kp load ratio 1	0	%		[E4]
88	kv load ratio 1	0	%		[DD]
89	torque limit 1	100.00	% max		[88]
90	low pass frequency 1	100.0	hertz		[E2]
91	low pass damping 1	1.414	gain		[58]
92	notch frequency 1	10.0	hertz		[4E]
93	notch damping 1	1.414	gain		[63]
94	torque invert		DISABLE		[1A]
95	base rpm	1780	rpm		[3C]
96	max vel	540.0	fpm		[7D]
97	jog vel	175.0	fpm		[7E]
98	!max motor rpm	1800.0	rpm		[C5]
99	accel time	1.000	sec		[70]
100	decel time	3.000	sec		[4A]
101	jerk time	0.000	sec		[9D]
102	settle time	0.200	sec		[B5]
103	accel time 1	1.000	sec		[FD]
104	decel time 1	1.000	sec		[F7]
105	jerk time 1	10.000	sec		[48]
106	settle time 1	1.000	sec		[61]
107	fast decel time	1.000	sec		[77]
108	drive invert		DISABLE		[74]

109	!motor vel	0.0	fpm	[AF]	
110	inv thermal warning	80.0	%		[E6]
111	motor rms warning	80.0	%	[9C]	
112	modulation select	DIGITAL			[65]
113	switch frequency	6000	hertz	[C7]	
114	thermal protection	STANDARD			[78]
115	dsv synchronized	DISABLE			[BB]
116	dsv wn	200.0	rad/sec	[58]	
117	dsv vphz wn	10.0	rad/sec	[A0]	
118	dsv kv percent	85.00	%	[BA]	
119	dsv kp cmd percent	100	%		[D5]
120	dsv kp cmd	0.460	gain	[0D]	
121	dsv ki	46.054	gain	[2E]	
122	dsv kp fbk	0.460	gain	[0C]	
123	dsv deadtime percent	25	%		[F6]
124	dsv v boost	0	%	[BD]	
125	dsv bus correction	DISABLE			[38]
126	acr i loop	5.000	acr gain	[B9]	
127	acr v ffwd	1.000	acr gain	[C2]	
128	acr field i loop	40.000	acr gain		[64]
129	acr field v ffwd	1.000	acr gain	[9C]	
130	dbm const switch freq	ENABLE			[9E]
131	dbm pulses	4		[1B]	
132	dbm min vel	5.0	hertz	[7F]	
133	dbm volts per hertz	8.0			[67]
134	dbm clamp voltage	0	volts	[61]	
135	dbm block modulation	30	% clamp		[CB]
136	dbm run current limit	0.00	amps rms		[4E]
137	dbm run limit gain	0.000	gain	[05]	
138	damping kp	0.00006	gain	[69]	
139	damping max	1000.00	ftlb	[F9]	
140	damping min freq	20.0	hertz	[3F]	
141	damping max freq	90.0	hertz	[35]	
142	vbus reg filter	300.00	hertz		[2A]
143	vbus filter	0.80	hertz	[E2]	
144	vbus notch frequency	0.0	hertz		[91]
145	vbus notch damping	1.414	gain	[A6]	
146	vbus kp	3.000	gain	[ED]	
147	vbus ki	3.000	gain	[F3]	
148	vbus window shift	-1.22	volts	[58]	
149	vbus dac limit	10.00	volts	[C7]	
150	db watts	0	watts	[C1]	
151	db resistance	0.000	ohms	[80]	
152	db time constant	25	secs	[07]	
153	!db percent used	0	%	[1C]	
154	flux control	OPEN LOOP			[CD]
155	flux cutoff min	10.0	rad/sec		[0E]
156	flux cutoff max	20.0	rad/sec		[0A]
157	flux kp	1.000	gain	[EE]	
158	flux id obs bandwidth	50	rad/sec		[4A]
159	torq est filter	0.01000	sec		[D2]
160	torq reg select	DISABLED			[40]
161	torq reg wn	0.0	rad/sec	[E3]	
162	torq reg kp cmd pct	0	%		[0B]
163	torq reg kp cmd	0.000	gain	[39]	
164	torq reg ki	0.00	gain	[C3]	
165	torq reg kp fbk	0.000	gain	[38]	
166	coulomb torque	0.00	ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -19 pulses        [34]
169 dac offset iv      -16 pulses        [35]
170 adc offset iu      -26 pulses        [3D]
171 adc offset iv      -5  pulses        [6E]
172 adc offset fu       15 pulses        [6D]
173 adc offset fv      -16 pulses        [3D]
174 adc 1 select        VOLTS            [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00 %           [75]
177 adc 1 max  0.00 %           [72]
178 adc 1 min volts  0.004 volts        [D4]
179 adc 1 max volts  9.599 volts        [B5]
180 adc 1 destination-1                    [A1]
181 !adc 1 raw value 0.004 volts        [CE]
182 !adc 1 value     0.00 %           [7E]
183 adc 2 select        VOLTS            [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00 %           [74]
186 adc 2 max  0.00 %           [71]
187 adc 2 min volts  0.000 volts        [D7]
188 adc 2 max volts  0.000 volts        [D4]
189 adc 2 destination-1                    [97]
190 !adc 2 raw value 0.004 volts        [CD]
191 !adc 2 value     0.00 %           [7D]
192 adc 3 select        VOLTS            [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00 %           [73]
195 adc 3 max  0.00 %           [70]
196 adc 3 min volts  0.000 volts        [D6]
197 adc 3 max volts  0.000 volts        [D3]
198 adc 3 destination-1                    [96]
199 !adc 3 raw value 0.000 volts        [C7]
200 !adc 3 value     0.00 %           [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select        TORQUE CMD       [32]
203 dac 1 ptr  28965           [41]
204 dac 1 item 0             [C5]
205 dac 1 mul  1             [24]
206 dac 1 div  1             [2E]
207 dac 1 abs  DISABLE        [77]
208 !dac 1 output  0.000 volts        [A8]
209 dac 2 select        UPID VEL FBK     [D2]
210 dac 2 ptr  26033         [52]
211 dac 2 item 0             [C6]
212 dac 2 mul  32767         [4D]
213 dac 2 div  125829        [25]
214 dac 2 abs  DISABLE        [78]
215 !dac 2 output  0.000 volts        [A9]
216 level 1 password 1111        [7A]
217 level 2 password 0          [0C]
218 level 3 password 0          [0A]
219 lockout time  900.000      sec       [D5]
220 !lockout status  LOCKED        [A7]
221 ssi rx mode  DISABLED        [E8]
222 !ssi rx value  0             [56]
223 ssi torque offset0.00 %      [A3]
224 ssi tx mode  DISABLED        [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	12		[DE]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	658 volts		[DC]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.01 amps rms			[85]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0070 in			[C8]
275	!feedback pos	0.0070 in			[81]
276	!in word 0	000040 \$			[08]
277	!out word 0	000006 \$			[84]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000200 \$			[99]

283	!int word 1	000000	\$	[99]	
284	!int word 2	000000	\$	[97]	
285	!int word 3	000000	\$	[95]	
286	hardware mask	4280287231		[14]	
287	hardware warning mask	0		[D2]	
288	hardware event mask	0		[A5]	
289	!hardware faults	131072		[E4]	
290	!hardware warnings	0		[10]	
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	960621106		[2F]	
294	software warning mask	0		[B7]	
295	software event mask	0		[8A]	
296	!software faults	0		[C7]	
297	!software warnings	0		[EC]	
298	!software latch	0		[48]	
299	!software unmasked	0		[FB]	
300	user mask	4294967295		[9C]	
301	user warning mask	0		[6E]	
302	user event mask	0		[41]	
303	!user faults	8		[76]	
304	!user warnings	0		[A3]	
305	!user latch	0	[FF]		
306	!user unmasked	8		[AA]	
307	test cycle rpm	900.0 rpm		[94]	
308	test id min rpm	0.0 rpm		[DB]	
309	test jog rpm	900.0 rpm		[62]	
310	test max rpm	900.0 rpm		[64]	
311	test min rpm	-900.0 rpm			[38]
312	test period	0.000 sec		[B1]	
313	test ramp	DISABLE		[B8]	
314	test position	10.000 rev			[7A]
315	test time	1.000 sec		[81]	
316	test torque	80 %		[2C]	
317	test degrees	180.00 deg			[22]
318	test i field	0.00 amps rms			[E9]
319	test volts	0 volts	[B6]		
320	test length	24.0001 in		[B0]	
321	test accel time	4.000 sec		[69]	
322	test freq ramp time	6.000 sec			[E0]
323	test adc	1	[02]		
324	!display count	0		[AA]	
325	!display flag	0		[38]	
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1		[C1]	
329	min cruise vel	0.0 fpm		[0E]	
330	vel preset 1	0.0 fpm		[21]	
331	vel preset 2	0.0 fpm		[1F]	
332	vel preset 3	0.0 fpm		[1D]	
333	vel preset 4	0.0 fpm		[1B]	
334	vel preset 5	0.0 fpm		[19]	
335	vel preset 6	0.0 fpm		[17]	
336	vel preset 7	0.0 fpm		[15]	
337	vel preset 8	0.0 fpm		[13]	
338	vel offset	0.0 fpm	[76]		
339	vel gain	100.00 %		[EA]	
340	vel tolerance	0.0 fpm		[47]	



```

341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 10 rpm [0B]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 3600 rpm [4C]
377 rpm rev shutoff -3600 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0070 in [CA]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

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399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	STS DISABLED		[21]	
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED		[19]	
445	out 5	STS DISABLED		[17]	
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

457	sout 11	STS DISABLED		[74]	
458	sout 12	STS DISABLED		[72]	
459	sout 13	STS DISABLED		[70]	
460	sout 14	STS DISABLED		[77]	
461	sout 15	STS DISABLED		[75]	
462	sout 16	STS PLC		[CC]	
463	sout 17	STS PLC		[CA]	
464	sout 18	STS PLC		[C8]	
465	sout 19	STS PLC		[C6]	
466	sout 20	STS PLC		[CD]	
467	sout 21	STS PLC		[CB]	
468	sout 22	STS PLC		[C9]	
469	sout 23	STS PLC		[C7]	
470	sout 24	STS PLC		[CE]	
471	sout 25	STS PLC		[CC]	
472	sout 26	STS PLC		[CA]	
473	sout 27	STS PLC		[C8]	
474	sout 28	STS PLC		[C6]	
475	sout 29	STS PLC		[C4]	
476	sout 30	STS PLC		[CB]	
477	sout 31	STS PLC		[C9]	
478	drive type	DRILL CABLE LEVEL		[AE]	
479	allow pend reverse	ENABLE			[86]
480	torque mode enable	DISABLE			[57]
481	torq override enable	ENABLE			[C2]
482	pend max torq	0.00 % rtd		[F5]	
483	pend max vel	540.0 fpm		[86]	
484	pend index pos	830.0002 in			[80]
485	pend index vel	540.0 fpm		[B2]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	0.0 fpm		[E1]	
488	comp index pos	0.0000 in			[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word0			[52]	
491	!comp status word0			[95]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000 in			[2F]
496	payout preset	0.0000 in			[E6]
497	!index start pos	0.0000 in			[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000 gain			[2B]
503	!smooth hose tension	0.00 lb			[05]
504	target hose load %	25 %			[53]
505	cable filter gain	0.97000 gain			[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000 in/sec/lb			[59]
508	!actual fine control	0.0000 in/sec/lb			[5C]
509	fade filter gain	0.97000 gain			[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0 %		[03]	
513	coil min od	0.0000 in			[47]
514	coil max od	0.0000 in			[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	OPPOSITE		[CD]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.434	gain	[15]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	310		[0E]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011003	soft limit error		[6E]	\$	20/Jan/2010
	21:30:54	Fault				
901	!FH 2 20011017	external trip		[6A]	\$	20/Jan/2010
	21:30:54	Fault				
902	!FH 3 20011017	external trip		[68]	\$	20/Jan/2010
	21:27:57	Fault				
903	!FH 4 20011003	soft limit error		[68]	\$	20/Jan/2010
	21:23:23	Fault				
904	!FH 5 20011003	soft limit error		[66]	\$	20/Jan/2010
	21:23:23	Fault				
905	!FH 6 20011003	soft limit error		[64]	\$	20/Jan/2010
	21:23:21	Fault				
906	!FH 7 20011003	soft limit error		[62]	\$	20/Jan/2010
	19:02:08	Fault				
907	!FH 8 20011003	soft limit error		[60]	\$	20/Jan/2010
	19:02:08	Fault				
908	!FH 9 20011003	soft limit error		[5E]	\$	20/Jan/2010
	19:02:07	Fault				
909	!FH10 20011003	soft limit error		[55]	\$	20/Jan/2010
	19:02:07	Fault				
910	!FH11 20011003	soft limit error		[5C]	\$	20/Jan/2010
	19:02:06	Fault				
911	!FH12 20011003	soft limit error		[5A]	\$	20/Jan/2010
	19:02:05	Fault				
912	!FH13 20011003	soft limit error		[58]	\$	20/Jan/2010
	17:54:08	Fault				

913	!FH14 20011003	soft limit error	[56]	\$	20/Jan/2010
	17:54:08	Fault			
914	!FH15 20011003	soft limit error	[54]	\$	20/Jan/2010
	17:54:07	Fault			
915	!FH16 20011003	soft limit error	[52]	\$	20/Jan/2010
	17:54:07	Fault			
916	!FH17 20011003	soft limit error	[50]	\$	20/Jan/2010
	17:54:06	Fault			
917	!FH18 20011003	soft limit error	[4E]	\$	20/Jan/2010
	17:54:06	Fault			
918	!FH19 20011003	soft limit error	[4C]	\$	20/Jan/2010
	17:54:06	Fault			
919	!FH20 20011003	soft limit error	[53]	\$	20/Jan/2010
	14:23:51	Fault			
920	!FH21 20011003	soft limit error	[5A]	\$	20/Jan/2010
	14:23:49	Fault			
921	!FH22 20011003	soft limit error	[58]	\$	20/Jan/2010
	14:23:49	Fault			
922	!FH23 20011003	soft limit error	[56]	\$	20/Jan/2010
	14:23:49	Fault			
923	!FH24 20011003	soft limit error	[54]	\$	20/Jan/2010
	14:23:36	Fault			
924	!FH25 20011003	soft limit error	[52]	\$	20/Jan/2010
	14:23:36	Fault			
925	!FH26 20011003	soft limit error	[50]	\$	20/Jan/2010
	14:23:35	Fault			
926	!FH27 20011003	soft limit error	[4E]	\$	20/Jan/2010
	14:23:34	Fault			
927	!FH28 20011003	soft limit error	[4C]	\$	20/Jan/2010
	14:23:33	Fault			
928	!FH29 20011003	soft limit error	[4A]	\$	20/Jan/2010
	14:23:33	Fault			
929	!FH30 20011003	soft limit error	[51]	\$	20/Jan/2010
	14:22:54	Fault			
930	!FH31 20011003	soft limit error	[58]	\$	20/Jan/2010
	14:22:53	Fault			
931	!FH32 20011003	soft limit error	[56]	\$	20/Jan/2010
	14:22:52	Fault			
932	!FH33 20011003	soft limit error	[54]	\$	20/Jan/2010
	14:22:51	Fault			
933	!FH34 20011003	soft limit error	[52]	\$	20/Jan/2010
	14:22:51	Fault			
934	!FH35 20011003	soft limit error	[50]	\$	20/Jan/2010
	14:22:50	Fault			
935	!FH36 20011003	soft limit error	[4E]	\$	20/Jan/2010
	14:22:44	Fault			
936	!FH37 20011003	soft limit error	[4C]	\$	20/Jan/2010
	14:22:42	Fault			
937	!FH38 20011003	soft limit error	[4A]	\$	20/Jan/2010
	14:22:40	Fault			
938	!FH39 20011003	soft limit error	[48]	\$	20/Jan/2010
	14:22:39	Fault			
939	!FH40 20011003	soft limit error	[4F]	\$	20/Jan/2010
	14:22:34	Fault			
940	!FH41 20011003	soft limit error	[56]	\$	20/Jan/2010
	14:22:33	Fault			
941	!FH42 20011003	soft limit error	[54]	\$	20/Jan/2010
	14:22:31	Fault			

942	!FH43 20011003	soft limit error	[52]	\$	20/Jan/2010
	14:22:31	Fault			
943	!FH44 20011003	soft limit error	[50]	\$	20/Jan/2010
	14:22:30	Fault			
944	!FH45 20011003	soft limit error	[4E]	\$	20/Jan/2010
	14:22:08	Fault			
945	!FH46 20011003	soft limit error	[4C]	\$	20/Jan/2010
	14:22:08	Fault			
946	!FH47 20011003	soft limit error	[4A]	\$	20/Jan/2010
	14:22:06	Fault			
947	!FH48 20011003	soft limit error	[48]	\$	20/Jan/2010
	14:22:05	Fault			
948	!FH49 20011017	external trip	[44]	\$	20/Jan/2010
	14:21:46	Fault			
949	!FH50 20011003	soft limit error	[4D]	\$	20/Jan/2010
	13:34:19	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 0 - Disabled
$ load pg loss 1 - Enabled
$ motor marker 0 - Disabled
$ load marker 1 - Enabled
$ overrun 0 - Disabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 0 - Disabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 1 - Enabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 1 - Enabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

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\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ Soft Limit Error 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled



\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

```
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:48:03

DATA\_START

UNITS 2 [29]

0	unit system	METRIC	[5A]	
1	position units	FEET METER	[19]	
2	velocity units	MINUTES	[BA]	
3	hertz units	DISABLE	[2C]	
4	clock frequency	50 hertz	[0F]	
5	drive multiple	1	[C7]	
6	upid multiple	10	[FE]	
7	ac multiple	2	[1A]	
8	ac fast multiple	1	[4C]	
9	vector source	MOTOR SOCKET		[DC]
10	upid motor source	MOTOR SOCKET		[44]
11	upid load source	LOAD SOCKET	[45]	
12	load vector control	DISABLE		[08]
13	transducerless	DISABLE	[89]	
14	motor fbk size	2048 pulses/rev	[29]	
15	motor resolution	121.7097 in/rev		[DC]
16	motor fbk invert	DISABLE	[3C]	
17	motor input teeth	1	[7F]	
18	motor output teeth	220	[9A]	
19	motor encoder bits	BITS 0		[E4]
20	motor encoder turns	1	[B3]	
21	load fbk size	2048 pulses/rev	[BC]	
22	load resolution	112.2047 in/rev		[79]
23	load fbk invert	ENABLE	[1C]	
24	load input teeth	1	[12]	
25	load output teeth	1	[90]	
26	load encoder bits	BITS 0		[77]
27	load encoder turns	1	[3D]	
28	motor rated voltage	460 volts	[24]	
29	motor rated current	27.00 amps rms		[CA]
30	motor rated frequency	60 hertz	[8A]	
31	maximum current	80.00 amps rms	[35]	
32	current limit	80.00 amps rms	[13]	
33	motor rms limit	29.70 amps rms	[68]	
34	current rate limit	0 amps pk/sec		[18]
35	field current	15.00 amps rms	[2D]	
36	field boost	200 %	[68]	
37	slip frequency	0.390 hertz	[98]	
38	motor poles	4	[C0]	
39	synchronous motor	DISABLE		[57]
40	vector offset	0.00 deg	[47]	
41	vector ffwd	0.00000 sec	[8B]	
42	torque ffwd	0.00 deg	[18]	
43	stator resistance	Rs 0.1433 ohms		[B9]
44	leakage Sigma	Ls 0.00565 henries		[65]
45	Lm squared over Lr	0.03814 henries		[96]
46	current filter	2.00 hertz	[D3]	
47	voltage filter	2.00 hertz	[E3]	
48	power filter	2.00 hertz	[A7]	
49	motor rtd torque	56.79 ftlb	[5A]	
50	motor max torque	198.26 ftlb	[37]	

51	motor rtd power	19.36 hp	[AC]
52	motor max power	67.57 hp	[A9]
53	motor kt	2.529 ftlb/amp	[26]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.229 ftlbs^2	[E2]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	34.061 1/sec/sec	[E5]
58	system gain	34.061 1/sec/sec	[D1]
59	system wn	5.0 rad/sec	[87]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.734 upid gain	[CF]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.734 upid gain	[CE]
65	kv fbk	0.254 upid gain	[CA]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	34.061 1/sec/sec	[80]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.587 upid gain	[78]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.587 upid gain	[77]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1790 rpm	[3B]
96	max vel	82.0 fpm	[AC]
97	jog vel	4.9 fpm	[DE]
98	!max motor rpm	1779.1 rpm	[B5]
99	accel time	3.000 sec	[6E]
100	decel time	3.000 sec	[4A]
101	jerk time	1.000 sec	[9C]
102	settle time	0.200 sec	[B5]
103	accel time 1	2.000 sec	[FC]
104	decel time 1	2.000 sec	[F6]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.069 gain	[08]	
121	dsv ki	6.948 gain	[56]	
122	dsv kp fbk	0.069 gain	[07]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	7000 watts	[2A]	
151	db resistance	16.700 ohms	[42]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	OPEN LOOP	[CD]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	ESTIMATED	[D8]	
161	torq reg wn	500.0 rad/sec	[7E]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	12.87 gain	[81]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -11 pulses        [3C]
169 dac offset iv      -10 pulses        [3B]
170 adc offset iu      -34 pulses        [3E]
171 adc offset iv       17 pulses        [68]
172 adc offset fu      -46 pulses        [3C]
173 adc offset fv       -1 pulses        [73]
174 adc 1 select        VOLTS            [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00 %                [75]
177 adc 1 max  0.00 %                [72]
178 adc 1 min volts  0.009 volts      [CF]
179 adc 1 max volts  9.609 volts      [BD]
180 adc 1 destination-1                [A1]
181 !adc 1 raw value 0.004 volts      [CE]
182 !adc 1 value    0.00 %            [7E]
183 adc 2 select        VOLTS            [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00 %                [74]
186 adc 2 max  0.00 %                [71]
187 adc 2 min volts  0.000 volts      [D7]
188 adc 2 max volts  0.000 volts      [D4]
189 adc 2 destination-1                [97]
190 !adc 2 raw value 0.009 volts      [C8]
191 !adc 2 value    0.00 %            [7D]
192 adc 3 select        VOLTS            [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00 %                [73]
195 adc 3 max  0.00 %                [70]
196 adc 3 min volts  0.000 volts      [D6]
197 adc 3 max volts  0.000 volts      [D3]
198 adc 3 destination-1                [96]
199 !adc 3 raw value -0.005 volts     [95]
200 !adc 3 value    0.00 %            [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select        TORQUE CMD      [32]
203 dac 1 ptr  28965                    [41]
204 dac 1 item 0                    [C5]
205 dac 1 mul  1                       [24]
206 dac 1 div  1                       [2E]
207 dac 1 abs  DISABLE                    [77]
208 !dac 1 output    0.000 volts      [A8]
209 dac 2 select        UPID VEL FBK    [D2]
210 dac 2 ptr  26033                    [52]
211 dac 2 item 0                    [C6]
212 dac 2 mul  32767                    [4D]
213 dac 2 div  124368                    [28]
214 dac 2 abs  DISABLE                    [78]
215 !dac 2 output    0.000 volts      [A9]
216 level 1 password 1111                [7A]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time      900.000 sec        [D5]
220 !lockout status  LEVEL 3            [8E]
221 ssi rx mode DISABLED                    [E8]
222 !ssi rx value    0                    [56]
223 ssi torque offset0.00 %            [A3]
224 ssi tx mode CMD  VEL                    [40]

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225	!ssi tx value	0		[51]	
226	ssi position lock	ENABLE		[E5]	
227	ssi tx clock	ENABLE		[0A]	
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0		[24]	
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU		[B3]	
232	console baud rate	38400 BAUD		[66]	
233	console parity	NONE	[3F]		
234	console address	18	[D8]		
235	console checksum	BCC	[0B]		
236	console units	METRIC		[2E]	
237	console pos units	IN MM	[2E]		
238	console vel units	SECONDS		[7A]	
239	porta protocol	OPTOMUX		[21]	
240	porta baud rate	19200 BAUD		[37]	
241	porta parity	NONE	[0D]		
242	porta stop bits	STOP 1		[A6]	
243	porta address	0	[DE]		
244	porta checksum	BCC	[D8]		
245	porta units	ENGLISH	[B5]		
246	porta pos units	FEET METER		[8B]	
247	porta vel units	MINUTES		[31]	
248	optomux bits dev	BITS 32		[31]	
249	optomux num devices	1		[74]	
250	optomux output 0	0	[CF]		
251	optomux output 1	65535	[F5]		
252	optomux retries	3	[CD]		
253	optomux timeout	1.000 sec	[CC]		
254	optomux wd time	5.000 sec	[24]		
255	!motor rpm	0.0 rpm	[99]		
256	!max current	53.20 amps rms		[91]	
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	660 volts	[E3]		
259	!max bus voltage	1011 volts	[55]		
260	!armature voltage	0 volts	[3F]		
261	!max voltage	0 volts	[59]		
262	!field voltage	0 volts	[9A]		
263	!motor thermal rms	0.23 amps rms		[81]	
264	!torque est command	0.00 ftlb	[A5]		
265	!torque est feedback	0.00 ftlb	[5E]		
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp	[FF]		
268	!motor current	0.00 amps rms		[DD]	
269	!motor voltage	0 volts rms	[F4]		
270	!maximum voltage	460 volts rms		[C5]	
271	!inverter power	0.00 hp	[C6]		
272	!command vel	0.0 fpm	[00]		
273	!feedback vel	0.0 fpm	[B9]		
274	!command pos	-0.0003 in		[9F]	
275	!feedback pos	-0.0003 in		[58]	
276	!in word 0	000810 \$		[03]	
277	!out word 0	000000 \$		[8A]	
278	!sin word 0	000000 \$		[97]	
279	!sin word 1	000000 \$		[95]	
280	!sout word 0	000000 \$		[1D]	
281	!sout word 1	000002 \$		[19]	
282	!int word 0	000a00 \$		[6A]	

283	!int word 1	000000	\$	[99]	
284	!int word 2	000000	\$	[97]	
285	!int word 3	000000	\$	[95]	
286	hardware mask	36700159		[7A]	
287	hardware warning mask	0		[D2]	
288	hardware event mask	0		[A5]	
289	!hardware faults	131072		[E4]	
290	!hardware warnings	0		[10]	
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294967295		[E5]	
294	software warning mask	0		[B7]	
295	software event mask	0		[8A]	
296	!software faults	0		[C7]	
297	!software warnings	0		[EC]	
298	!software latch	0		[48]	
299	!software unmasked	0		[FB]	
300	user mask	4294967271		[A2]	
301	user warning mask	0		[6E]	
302	user event mask	0		[41]	
303	!user faults	544		[11]	
304	!user warnings	0		[A3]	
305	!user latch	0		[FF]	
306	!user unmasked	544		[45]	
307	test cycle rpm	1750.0	rpm		[60]
308	test id min rpm	0.0	rpm	[DB]	
309	test jog rpm	900.0	rpm	[62]	
310	test max rpm	900.0	rpm	[64]	
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec	[B1]	
313	test ramp	DISABLE		[B8]	
314	test position	10.000	rev		[7A]
315	test time	1.000	sec	[81]	
316	test torque	80	%	[2C]	
317	test degrees	180.00	deg		[22]
318	test i field	0.00	amps rms		[E9]
319	test volts	0	volts	[B6]	
320	test length	24.0000	in	[B1]	
321	test accel time	4.000	sec	[69]	
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1		[02]	
324	!display count	0		[AA]	
325	!display flag	0		[38]	
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	LOAD SOCKET			[D1]
329	min cruise vel	0.0	fpm	[0E]	
330	vel preset 1	0.0	fpm	[21]	
331	vel preset 2	0.0	fpm	[1F]	
332	vel preset 3	0.0	fpm	[1D]	
333	vel preset 4	0.0	fpm	[1B]	
334	vel preset 5	0.0	fpm	[19]	
335	vel preset 6	0.0	fpm	[17]	
336	vel preset 7	0.0	fpm	[15]	
337	vel preset 8	0.0	fpm	[13]	
338	vel offset	0.0	fpm	[76]	
339	vel gain	100.00	%	[EA]	
340	vel tolerance	0.0	fpm	[47]	



341	torque offset enable	AUTO PERMISSIVE		[0D]
342	torque offset	0.00 % max	[AA]	
343	torque offset rate	2.500 sec	[F6]	
344	offset rate select	BOTH	[18]	
345	preset upr torq lmt	80.00 % max	[59]	
346	preset lwr torq lmt	-80.00 % max	[2D]	
347	upr torq lmt rate	0.000 sec	[96]	
348	lwr torq lmt rate	0.000 sec	[97]	
349	torque slave source	TORQUE DATA	[8D]	
350	torque slave data	0.00 % max	[5D]	
351	track enable	DISABLE	[AA]	
352	track source	MOTOR SOCKET	[F9]	
353	track ref pos	0.0000 in	[5F]	
354	!track position	0.0000 in	[77]	
355	track preset pos	0.0000 in	[07]	
356	droop ref select	DISABLED	[DC]	
357	droop ref torque	100.0 %	[DF]	
358	droop maximum	0.0 fpm	[20]	
359	droop start torque	0.0 %	[4D]	
360	droop filter tc	10.000 sec	[1F]	
361	!droop vel actual	0.0 fpm	[22]	
362	offset vel err tol	0.0 fpm	[A1]	
363	offset filter tc	2.000 sec	[E8]	
364	torq slave vel ovrd	ENABLE	[4C]	
365	vel ovrd torq thrsh	0.00 % max	[9B]	
366	vel ovrd select	OVERRIDE VEL	[5D]	
367	vel ovrd vel	82.0 fpm	[9F]	
368	bus reg	DISABLE	[96]	
369	bus reg min vel	50 rpm	[0A]	
370	bus reg tol vel	0 rpm	[3C]	
371	bus reg tol time	2 secs	[72]	
372	bus reg kp	2.000 gain	[05]	
373	bus reg kd	0.000 gain	[12]	
374	bus reg upper lmt	758 volts	[F8]	
375	bus reg torq lmt	20 %	[B2]	
376	rpm fwd shutoff	2700 rpm	[4C]	
377	rpm rev shutoff	-2700 rpm	[12]	
378	ssi data req vel	0.0 fpm	[88]	
379	drive stop mode	INJ BRAKE	[05]	
380	inj brake pct	0 %	[16]	
381	inj brake time	0.000 sec	[D9]	
382	magnet flux	0.0000 Wb	[04]	
383	ext trip	ENABLE	[5E]	
384	!motor socket vel	0.0 fpm	[01]	
385	!motor socket pos	-0.0743 in	[96]	
386	!load socket vel	0.0 fpm	[90]	
387	!load socket pos	0.1095 in	[51]	
388	!follow socket vel	0.0 fpm	[9B]	
389	!follow socket pos	0.0000 in	[6B]	
390	!main state	MAIN USER STATE	[0B]	
391	!application state	MOTOR OFF WAIT	[5F]	
392	motor on req	REQ PLC	[B8]	
393	motor on enable req	REQ FORCED ON	[9F]	
394	fault reset req	REQ PLC	[85]	
395	warning reset req	REQ PLC	[AA]	
396	jog fwd req	REQ PLC	[41]	
397	jog rev req	REQ PLC	[34]	
398	fast stop req	REQ PLC	[4C]	

399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	MOTOR ON STS		[0B]	
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED		[19]	
445	out 5	STS DISABLED		[17]	
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

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457  sout 11      STS DISABLED          [74]
458  sout 12      STS DISABLED          [72]
459  sout 13      STS DISABLED          [70]
460  sout 14      STS DISABLED          [77]
461  sout 15      STS DISABLED          [75]
462  sout 16      STS PLC              [CC]
463  sout 17      STS PLC              [CA]
464  sout 18      STS PLC              [C8]
465  sout 19      STS PLC              [C6]
466  sout 20      STS PLC              [CD]
467  sout 21      STS PLC              [CB]
468  sout 22      STS PLC              [C9]
469  sout 23      STS PLC              [C7]
470  sout 24      STS PLC              [CE]
471  sout 25      STS PLC              [CC]
472  sout 26      STS PLC              [CA]
473  sout 27      STS PLC              [C8]
474  sout 28      STS PLC              [C6]
475  sout 29      STS PLC              [C4]
476  sout 30      STS PLC              [CB]
477  sout 31      STS PLC              [C9]
478  drive type  DEPLOYMENT          [33]
479  allow pend reverse  ENABLE          [86]
480  torque mode enable  DISABLE          [57]
481  torq override enable  ENABLE          [C2]
482  pend max torq      80.00 % rtd          [BD]
483  pend max vel       23.0 mpm   units:3   [13]
484  pend index pos     36.0000   in          [B4]
485  pend index vel     3.9 fpm           [0F]
486  comp req torq      0.00 % rtd          [E7]
487  comp req vel       0.0 fpm           [E1]
488  comp index pos     0.0000   in          [E1]
489  comp index vel     0.0 fpm           [0F]
490  comp request word0          [52]
491  !comp status word0          [95]
492  comp timeout      0.000 sec          [35]
493  comp handshake ctr  0              [24]
494  !comp handshake ctr p 0          [72]
495  payout distance    0.0000   in          [2F]
496  payout preset     0.0000   in          [E6]
497  !index start pos  0.0000   in          [41]
498  !tension error     0.00 lb          [37]
499  !tgt hose tension 0.00 lb          [42]
500  !hose tension      0.00 lb          [C2]
501  !cable tension     0.00 lb          [79]
502  hose filter gain   0.97000   gain          [2B]
503  !smooth hose tension 0.00 lb          [05]
504  cable filter gain  0.97000   gain          [E1]
505  !smooth cable tension 0.00 lb          [BB]
506  fine control gain  0.0550   in/sec/lb   [50]
507  !actual fine control 0.0000   in/sec/lb   [5D]
508  fade filter gain   0.97000   gain          [44]
509  hose tension offset 0.00 lb          [33]
510  cable tension offset 0.00 lb          [F3]
511  !hose load fbk     0 %              [04]
512  coil min od 790.00 mm   units:1   [97]
513  coil max od 2480.00 mm  units:1   [66]
514  coil diameter      2088.00 mm   units:1   [4F]

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515 !coil circumference 3091.43 mm units:1 [1B]
516 !coil usage 0.0 m units:1 [A1]
517 coil source MOTOR SOCKET [64]
518 material source LOAD SOCKET [2C]
519 coil od limit DISABLE [67]
520 coil od rate 1.8110 in [D6]
521 coil update distance 118.1102 in [23]
522 level direction NONE [11]
523 !level drum velocity 0.0 rpm units:10 [EE]
524 level follow gain 0.000 gain [21]
525 !level follow vel 0.0 fpm [13]
526 !level follow req vel 0.0 fpm [AA]
527 level follow vel off 0.0 fpm [D7]
528 level circumference 3.6000 in [A3]
529 level dwell count 0 [6A]
530 !level circ count 0 [C8]
531 !index pos 0.0000 in [9A]
532 !drive control mode NONE [E8]
533 pend disable time 0.000 sec [A5]
534 lo-spd line low limt 575 volts rms [8D]
535 hi-spd line low limt 575 volts rms [96]
536 high-low vel cutoff 0 rpm [89]
537 payout at drum -8.7 m units:1 [F0]
538 payout at tower -284.7464 in [A6]
539 drum payout offset 0.0 m units:1 [78]
540 tower payout offset 152.3622 in [36]
541 Hose Max Load 0.00 lb [38]
542 Hose Min Load 0.00 lb [39]
543 Cable Max Load 0.00 lb [EE]
544 Cable Min Load 0.00 lb [EF]
545 Reel Mode Drill/Deployment [C1]
546 !Deploy Payout -2569.4747 m units:7 [EC]
547 !Dep PLRV -2569.4747 m units:7 [7D]
548 Dep reset DISABLE [E2]
549 Load Cell Cal. DISABLE [BF]
550 Ld cell torque limit 8.00 % max [79]
551 ld cell pend. vel. 0.5 mpm units:7 [9D]
552 !Tower PLRV -14.3318 m units:7 [01]
553 Drill payout reset ENABLE [93]
554 !raw tower payout -11.1026 m units:7 [20]
555 !Drum PLRV -0.0007 m units:7 [B4]
556 !raw drum payout -0.0007 m units:7 [CB]
557 max torque 0.01 ftlb units:0 [28]
900 !FH 1 20011009 turn on hose unico! [B9] $
    20/Jan/2010 21:48:59 Fault
901 !FH 2 20011005 turn on lw unico [A8] $ 20/Jan/2010
    21:48:59 Fault
902 !FH 3 20011017 external trip [68] $ 20/Jan/2010
    21:48:59 Fault
903 !FH 4 20011009 turn on hose unico! [B3] $
    20/Jan/2010 21:48:07 Fault
904 !FH 5 20011005 turn on lw unico [A2] $ 20/Jan/2010
    21:48:07 Fault
905 !FH 6 20011017 external trip [62] $ 20/Jan/2010
    21:48:07 Fault
906 !FH 7 20011008 ready hose reel!!! [93] $
    20/Jan/2010 21:28:52 Fault

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907	!FH 8 20011017	EXTERNAL TRIP	[DE]	\$	20/Jan/2010
	21:28:52	Fault			
908	!FH 9 20011008	READY HOSE REEL!!!	[2F]	\$	
	20/Jan/2010 21:11:28	Fault			
909	!FH10 20011008	ready hose reel!!!	[86]	\$	
	20/Jan/2010 14:24:27	Fault			
910	!FH11 20011008	ready hose reel!!!	[8D]	\$	
	20/Jan/2010 14:23:44	Fault			
911	!FH12 20011008	ready hose reel!!!	[8B]	\$	
	20/Jan/2010 14:23:33	Fault			
912	!FH13 20011008	ready hose reel!!!	[89]	\$	
	20/Jan/2010 14:23:24	Fault			
913	!FH14 20011008	ready hose reel!!!	[87]	\$	
	20/Jan/2010 14:22:59	Fault			
914	!FH15 20011008	ready hose reel!!!	[85]	\$	
	20/Jan/2010 14:22:40	Fault			
915	!FH16 20011017	external trip	[50]	\$	20/Jan/2010
	14:22:40	Fault			
916	!FH17 20011008	READY HOSE REEL!!!	[21]	\$	
	20/Jan/2010 13:33:48	Fault			
917	!FH18 20011008	READY HOSE REEL!!!	[1F]	\$	
	20/Jan/2010 13:18:47	Fault			
918	!FH19 20011008	READY HOSE REEL!!!	[1D]	\$	
	20/Jan/2010 13:18:37	Fault			
919	!FH20 20011008	READY HOSE REEL!!!	[24]	\$	
	20/Jan/2010 13:16:28	Fault			
920	!FH21 20011008	READY HOSE REEL!!!	[2B]	\$	
	20/Jan/2010 11:45:33	Fault			
921	!FH22 20011008	READY HOSE REEL!!!	[29]	\$	
	20/Jan/2010 11:45:28	Fault			
922	!FH23 20011008	ready hose reel!!!	[87]	\$	
	20/Jan/2010 11:42:25	Fault			
923	!FH24 20011005	turn on lw unico	[90]	\$	20/Jan/2010
	10:25:52	Fault			
924	!FH25 20011017	EXTERNAL TRIP	[D0]	\$	20/Jan/2010
	10:24:59	Fault			
925	!FH26 18011005	turn on lw unico	[85]	\$	18/Jan/2010
	20:44:49	Fault			
926	!FH27 18011007	BUS UNDERVOLTAGE	[EE]	\$	18/Jan/2010
	18:23:49	Fault			
927	!FH28 18011005	turn on lw unico	[81]	\$	18/Jan/2010
	18:03:05	Fault			
928	!FH29 18011007	BUS UNDERVOLTAGE	[EA]	\$	18/Jan/2010
	18:03:04	Fault			
929	!FH30 18011017	EXTERNAL TRIP	[C8]	\$	18/Jan/2010
	17:11:13	Fault			
930	!FH31 18011017	EXTERNAL TRIP	[CF]	\$	18/Jan/2010
	17:10:25	Fault			
931	!FH32 18011005	turn on lw unico	[8B]	\$	18/Jan/2010
	17:06:28	Fault			
932	!FH33 18011007	BUS UNDERVOLTAGE	[F4]	\$	18/Jan/2010
	17:06:27	Fault			
933	!FH34 18011017	EXTERNAL TRIP	[C9]	\$	18/Jan/2010
	16:01:40	Fault			
934	!FH35 18011005	TURN ON LW UNICO	[25]	\$	18/Jan/2010
	15:18:34	Fault			
935	!FH36 18011020	OVERSPEED TRIP	[81]	\$	18/Jan/2010
	15:13:02	Fault			

936	!FH37 18011020	OVERSPEED TRIP	[7F]	\$	18/Jan/2010
	15:11:11	Fault			
937	!FH38 18011017	external trip	[41]	\$	18/Jan/2010
	15:08:00	Fault			
938	!FH39 18011008	ready hose reel!!!	[72]	\$	
	18/Jan/2010 15:07:48	Fault			
939	!FH40 18011017	external trip	[46]	\$	18/Jan/2010
	15:07:48	Fault			
940	!FH41 15011005	turn on lw unico	[8E]	\$	15/Jan/2010
	21:59:11	Fault			
941	!FH42 15011009	turn on hose unico!	[9B]	\$	
	15/Jan/2010 21:59:03	Fault			
942	!FH43 15011017	EXTERNAL TRIP	[CC]	\$	15/Jan/2010
	21:58:43	Fault			
943	!FH44 15011017	EXTERNAL TRIP	[CA]	\$	15/Jan/2010
	13:18:09	Fault			
944	!FH45 15011005	turn on lw unico	[86]	\$	15/Jan/2010
	13:03:47	Fault			
945	!FH46 15011005	turn on lw unico	[84]	\$	15/Jan/2010
	11:13:11	Fault			
946	!FH47 15011017	EXTERNAL TRIP	[C4]	\$	15/Jan/2010
	11:11:11	Fault			
947	!FH48 14011017	EXTERNAL TRIP	[C3]	\$	14/Jan/2010
	04:55:45	Fault			
948	!FH49 14011017	EXTERNAL TRIP	[C1]	\$	14/Jan/2010
	04:55:39	Fault			
949	!FH50 14011017	EXTERNAL TRIP	[C8]	\$	14/Jan/2010
	04:54:40	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage suppply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 1 - Enabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 1 - Enabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 1 - Enabled
$ load fbk loss 1 - Enabled
$ motor runaway 1 - Enabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive1 - Enabled
$ inverter rms 1 - Enabled

```

\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage 1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ Hose Tension Error 0 - Disabled  
\$ Cable Tension Error 0 - Disabled  
\$ Turn On LW Unico 1 - Enabled  
\$ Drive Identity Error 1 - Enabled  
\$ Deployment Velocity 1 - Enabled  
\$ READY HOSE REEL!!! 1 - Enabled  
\$ Turn On Hose Unico! 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled

\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Hose Tension Error 0 - Disabled  
\$ Cable Tension Error 0 - Disabled  
\$ Turn On LW Unico 0 - Disabled  
\$ Drive Identity Error 0 - Disabled  
\$ Deployment Velocity 0 - Disabled  
\$ READY HOSE REEL!!! 0 - Disabled  
\$ Turn On Hose Unico! 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled



```
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled

$ Event Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss 0 - Disabled
$ load pg loss 0 - Disabled
$ motor marker 0 - Disabled
$ load marker0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage0 - Disabled
$ Load Cell Error 0 - Disabled
$ Hose Tension Error 0 - Disabled
$ Cable Tension Error 0 - Disabled
$ Turn On LW Unico 0 - Disabled
$ Drive Identity Error 0 - Disabled
$ Deployment Velocity 0 - Disabled
$ READY HOSE REEL!!! 0 - Disabled
$ Turn On Hose Unico! 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
```

```
$ user fault 14 req0 - Disabled
$ user fault 15 req0 - Disabled
$ user fault 16 req0 - Disabled
$ user fault 17 req0 - Disabled
$ user fault 18 req0 - Disabled
$ user fault 19 req0 - Disabled
$ user fault 20 req0 - Disabled
$ user fault 21 req0 - Disabled
$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:33:02

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH		[14]	
1	position units	REV		[ED]	
2	velocity units	MINUTES		[BA]	
3	hertz units	DISABLE		[2C]	
4	clock frequency	50	hertz	[0F]	
5	drive multiple	1		[C7]	
6	upid multiple	10		[FE]	
7	ac multiple	2		[1A]	
8	ac fast multiple	1		[4C]	
9	vector source	MOTOR SOCKET		[DC]	
10	upid motor source	MOTOR SOCKET		[44]	
11	upid load source	LOAD SOCKET		[45]	
12	load vector control	DISABLE		[08]	
13	transducerless	ENABLE		[D6]	
14	motor fbk size	2048	pulses/rev	[29]	
15	motor resolution	3.6000	in/rev	[4E]	
16	motor fbk invert	DISABLE		[3C]	
17	motor input teeth	1		[7F]	
18	motor output teeth	1		[FD]	
19	motor encoder bits	BITS 0		[E4]	
20	motor encoder turns	1		[B3]	
21	load fbk size	2048	pulses/rev	[BC]	
22	load resolution	3.6000	in/rev	[E1]	
23	load fbk invert	DISABLE		[CF]	
24	load input teeth	1		[12]	
25	load output teeth	1		[90]	
26	load encoder bits	BITS 0		[77]	
27	load encoder turns	1		[3D]	
28	motor rated voltage	480	volts	[22]	
29	motor rated current	3.00	amps rms	[00]	
30	motor rated frequency	60	hertz	[8A]	
31	maximum current	9.60	amps rms	[5E]	
32	current limit	9.60	amps rms	[3C]	
33	motor rms limit	3.40	amps rms	[A3]	
34	current rate limit	0	amps pk/sec	[18]	
35	field current	1.60	amps rms	[5C]	
36	field boost	200	%	[68]	
37	slip frequency	1.667	hertz	[90]	
38	motor poles	4		[C0]	
39	synchronous motor	DISABLE		[57]	
40	vector offset	0.00	deg	[47]	
41	vector ffwd	0.00000	sec	[8B]	
42	torque ffwd	0.00	deg	[18]	
43	stator resistance	Rs	3.1517 ohms	[B3]	
44	leakage Sigma	Ls	0.04154 henries	[67]	
45	Lm squared over Lr	0.35003	henries	[9B]	
46	current filter	2.00	hertz	[D3]	
47	voltage filter	2.00	hertz	[E3]	
48	power filter	2.00	hertz	[A7]	
49	motor rtd torque	6.27	ftlb	[96]	
50	motor max torque	23.44	ftlb	[74]	

51	motor rtd power	2.09	hp	[E4]	
52	motor max power	7.81	hp	[E2]	
53	motor kt	2.479	ftlb/amp	[22]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.012	ftlbs^2	[EC]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	313.400	1/sec/sec	[B8]	
58	system gain	313.400	1/sec/sec	[A4]	
59	system wn	5.0	rad/sec	[87]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.080	upid gain	[D5]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.080	upid gain	[D4]	
65	kv fbk	0.028	upid gain	[CB]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	25.00	% max	[0C]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	313.400	1/sec/sec	[53]	
77	system wn 1	20.0	rad/sec	[09]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.064	upid gain	[82]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.064	upid gain	[81]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	50.00	% max	[B4]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		DISABLE	[1A]	
95	base rpm	1750	rpm	[3F]	
96	max vel	1500.0	fpm	[50]	
97	jog vel	175.0	fpm	[7E]	
98	!max motor rpm	5000.0	rpm	[C9]	
99	accel time	1.000	sec	[70]	
100	decel time	1.000	sec	[4C]	
101	jerk time	0.000	sec	[9D]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	2.000	sec	[FC]	
104	decel time 1	2.000	sec	[F6]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	0.200	sec	[60]	
107	fast decel time	0.200	sec	[76]	
108	drive invert		ENABLE	[C1]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.510 gain	[11]	
121	dsv ki	51.084 gain	[2F]	
122	dsv kp fbk	0.510 gain	[10]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm      [2F]
168 dac offset iu      49    pulses   [5E]
169 dac offset iv     -33    pulses   [36]
170 adc offset iu      51    pulses   [6C]
171 adc offset iv     -34    pulses   [3C]
172 adc offset fu      17    pulses   [6B]
173 adc offset fv       3    pulses   [9E]
174 adc 1 select      VOLTS      [66]
175 adc 1 set    DISABLED      [19]
176 adc 1 min   0.00 %          [75]
177 adc 1 max   0.00 %          [72]
178 adc 1 min volts  0.004 volts [D4]
179 adc 1 max volts  9.570 volts [C0]
180 adc 1 destination-1      [A1]
181 !adc 1 raw value 0.009 volts [C9]
182 !adc 1 value    0.00 %      [7E]
183 adc 2 select      VOLTS      [65]
184 adc 2 set    DISABLED      [18]
185 adc 2 min   0.00 %          [74]
186 adc 2 max   0.00 %          [71]
187 adc 2 min volts  0.000 volts [D7]
188 adc 2 max volts  0.000 volts [D4]
189 adc 2 destination-1      [97]
190 !adc 2 raw value -0.005      volts [9F]
191 !adc 2 value    0.00 %      [7D]
192 adc 3 select      VOLTS      [64]
193 adc 3 set    DISABLED      [17]
194 adc 3 min   0.00 %          [73]
195 adc 3 max   0.00 %          [70]
196 adc 3 min volts  0.000 volts [D6]
197 adc 3 max volts  0.000 volts [D3]
198 adc 3 destination-1      [96]
199 !adc 3 raw value 0.004 volts [C3]
200 !adc 3 value    0.00 %      [85]
201 dac clock level  DRIVE CLOCK [AE]
202 dac 1 select      TORQUE CMD [32]
203 dac 1 ptr    28965          [41]
204 dac 1 item   0              [C5]
205 dac 1 mul    1              [24]
206 dac 1 div    1              [2E]
207 dac 1 abs    DISABLE      [77]
208 !dac 1 output  0.000 volts   [A8]
209 dac 2 select      UPID VEL FBK [D2]
210 dac 2 ptr    26033          [52]
211 dac 2 item   0              [C6]
212 dac 2 mul    32767          [4D]
213 dac 2 div    349525         [24]
214 dac 2 abs    DISABLE      [78]
215 !dac 2 output  0.000 volts   [A9]
216 level 1 password 1111      [7A]
217 level 2 password 0          [0C]
218 level 3 password 0          [0A]
219 lockout time    900.000      sec [D5]
220 !lockout status LEVEL 3     [8E]
221 ssi rx mode DISABLE      [E8]
222 !ssi rx value   0            [56]
223 ssi torque offset0.00 %    [A3]
224 ssi tx mode DISABLE      [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	15		[DB]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	657 volts		[DD]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.00 amps rms			[86]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000046 \$			[02]
277	!out word 0	00000e \$			[55]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000002 \$			[19]
282	!int word 0	000000 \$			[9B]

283	!int word 1	000000	\$	[99]	
284	!int word 2	000000	\$	[97]	
285	!int word 3	000000	\$	[95]	
286	hardware mask	4280287231		[14]	
287	hardware warning mask	0		[D2]	
288	hardware event mask	0		[A5]	
289	!hardware faults	131072		[E4]	
290	!hardware warnings	0		[10]	
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4227857085		[EE]	
294	software warning mask	0		[B7]	
295	software event mask	0		[8A]	
296	!software faults	0		[C7]	
297	!software warnings	0		[EC]	
298	!software latch	0		[48]	
299	!software unmasked	0		[FB]	
300	user mask	4294967295		[9C]	
301	user warning mask	0		[6E]	
302	user event mask	0		[41]	
303	!user faults	0		[7E]	
304	!user warnings	0		[A3]	
305	!user latch	0	[FF]		
306	!user unmasked	0		[B2]	
307	test cycle rpm	900.0 rpm		[94]	
308	test id min rpm	900.0 rpm		[72]	
309	test jog rpm	900.0 rpm		[62]	
310	test max rpm	900.0 rpm		[64]	
311	test min rpm	-900.0 rpm		[38]	
312	test period	0.000 sec	[B1]		
313	test ramp	DISABLE		[B8]	
314	test position	10.000 rev		[7A]	
315	test time	1.000 sec	[81]		
316	test torque	50 %	[2F]		
317	test degrees	180.00 deg		[22]	
318	test i field	0.00 amps rms		[E9]	
319	test volts	0 volts	[B6]		
320	test length	24.0001 in		[B0]	
321	test accel time	4.000 sec		[69]	
322	test freq ramp time	6.000 sec		[E0]	
323	test adc	1	[02]		
324	!display count	0		[AA]	
325	!display flag	0		[38]	
326	vel selection	INTERNAL		[AE]	
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1		[C1]	
329	min cruise vel	0.0 fpm		[0E]	
330	vel preset 1	0.0 fpm		[21]	
331	vel preset 2	150.0 fpm		[B9]	
332	vel preset 3	0.0 fpm		[1D]	
333	vel preset 4	0.0 fpm		[1B]	
334	vel preset 5	0.0 fpm		[19]	
335	vel preset 6	0.0 fpm		[17]	
336	vel preset 7	0.0 fpm		[15]	
337	vel preset 8	0.0 fpm		[13]	
338	vel offset	0.0 fpm	[76]		
339	vel gain	100.00 %		[EA]	
340	vel tolerance	0.0 fpm		[47]	



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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 30 rpm [09]
371 bus reg tol time 3 secs [71]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos -0.0009 in [2A]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

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399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	STS DISABLED	[21]		
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED	[19]		
445	out 5	STS DISABLED	[17]		
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

457	sout 11	STS DISABLED		[74]	
458	sout 12	STS DISABLED		[72]	
459	sout 13	STS DISABLED		[70]	
460	sout 14	STS DISABLED		[77]	
461	sout 15	STS DISABLED		[75]	
462	sout 16	STS PLC		[CC]	
463	sout 17	STS PLC		[CA]	
464	sout 18	STS PLC		[C8]	
465	sout 19	STS PLC		[C6]	
466	sout 20	STS PLC		[CD]	
467	sout 21	STS PLC		[CB]	
468	sout 22	STS PLC		[C9]	
469	sout 23	STS PLC		[C7]	
470	sout 24	STS PLC		[CE]	
471	sout 25	STS PLC		[CC]	
472	sout 26	STS PLC		[CA]	
473	sout 27	STS PLC		[C8]	
474	sout 28	STS PLC		[C6]	
475	sout 29	STS PLC		[C4]	
476	sout 30	STS PLC		[CB]	
477	sout 31	STS PLC		[C9]	
478	drive type	DRILL HOSE LEVEL		[D6]	
479	allow pend reverse	ENABLE			[86]
480	torque mode enable	ENABLE			[A4]
481	torq override enable	ENABLE			[C2]
482	pend max torq	25.00 % rtd		[BE]	
483	pend max vel	540.0 fpm		[86]	
484	pend index pos	830.0002	in		[80]
485	pend index vel	540.0 fpm		[B2]	
486	comp req torq	0.00 % rtd		[E7]	
487	comp req vel	0.0 fpm		[E1]	
488	comp index pos	0.0000	in		[E1]
489	comp index vel	0.0 fpm		[0F]	
490	comp request word0			[52]	
491	!comp status word0			[95]	
492	comp timeout	0.000 sec		[35]	
493	comp handshake ctr	0			[24]
494	!comp handshake ctr p	0			[72]
495	payout distance	0.0000	in		[2F]
496	payout preset	0.0000	in		[E6]
497	!index start pos	0.0000	in		[41]
498	!tension error	0.00 lb		[37]	
499	!tgt hose tension	0.00 lb		[42]	
500	!hose tension	0.00 lb		[C2]	
501	!cable tension	0.00 lb		[79]	
502	hose filter gain	0.97000	gain		[2B]
503	!smooth hose tension	0.00 lb			[05]
504	target hose load %	0	%		[8A]
505	cable filter gain	0.97000	gain		[E0]
506	!smooth cable tension	0.00 lb			[BA]
507	fine control gain	0.0000	in/sec/lb		[59]
508	!actual fine control	0.0000	in/sec/lb		[5C]
509	fade filter gain	0.97000	gain		[43]
510	hose tension offset	0.00 lb			[3B]
511	cable tension offset	0.00 lb			[F2]
512	!hose load fbk	0	%		[03]
513	coil min od	0.0000	in		[47]
514	coil max od	0.0000	in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	OPPOSITE		[CD]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.839	gain	[0C]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	672		[03]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0007	in	[56]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011017	external trip		[6C]	\$	20/Jan/2010
	21:33:27	Fault				
901	!FH 2 20011017	EXTERNAL TRIP		[EA]	\$	20/Jan/2010
	21:30:35	Fault				
902	!FH 3 20011014	IREG SHUTOFF		[47]	\$	20/Jan/2010
	21:30:35	Fault				
903	!FH 4 20011017	EXTERNAL TRIP		[E6]	\$	20/Jan/2010
	14:24:24	Fault				
904	!FH 5 20011017	EXTERNAL TRIP		[E4]	\$	20/Jan/2010
	10:26:44	Fault				
905	!FH 6 18011007	BUS UNDERVOLTAGE		[04]	\$	18/Jan/2010
	20:46:30	Fault				
906	!FH 7 18011014	IREG SHUTOFF		[38]	\$	18/Jan/2010
	20:46:30	Fault				
907	!FH 8 18011007	BUS UNDERVOLTAGE		[00]	\$	18/Jan/2010
	18:25:33	Fault				
908	!FH 9 18011017	EXTERNAL TRIP		[D5]	\$	18/Jan/2010
	17:12:12	Fault				
909	!FH10 18011017	EXTERNAL TRIP		[CC]	\$	18/Jan/2010
	16:03:26	Fault				
910	!FH11 18011017	external trip		[53]	\$	18/Jan/2010
	15:09:19	Fault				
911	!FH12 15011003	soft limit error		[56]	\$	15/Jan/2010
	13:17:33	Fault				
912	!FH13 15011017	external trip		[52]	\$	15/Jan/2010
	13:17:33	Fault				

913	!FH14 15011003	soft limit error	[52]	\$	15/Jan/2010
	13:17:32	Fault			
914	!FH15 15011017	external trip	[4E]	\$	15/Jan/2010
	13:17:32	Fault			
915	!FH16 15011003	soft limit error	[4E]	\$	15/Jan/2010
	13:17:32	Fault			
916	!FH17 15011017	external trip	[4A]	\$	15/Jan/2010
	13:17:32	Fault			
917	!FH18 15011003	soft limit error	[4A]	\$	15/Jan/2010
	13:17:32	Fault			
918	!FH19 15011017	external trip	[46]	\$	15/Jan/2010
	13:17:32	Fault			
919	!FH20 15011003	soft limit error	[4F]	\$	15/Jan/2010
	13:17:31	Fault			
920	!FH21 15011017	external trip	[54]	\$	15/Jan/2010
	13:17:31	Fault			
921	!FH22 15011003	soft limit error	[54]	\$	15/Jan/2010
	13:17:31	Fault			
922	!FH23 15011017	external trip	[50]	\$	15/Jan/2010
	13:17:31	Fault			
923	!FH24 15011003	soft limit error	[50]	\$	15/Jan/2010
	13:05:22	Fault			
924	!FH25 15011017	external trip	[4C]	\$	15/Jan/2010
	13:05:22	Fault			
925	!FH26 15011017	EXTERNAL TRIP	[CA]	\$	15/Jan/2010
	11:13:01	Fault			
926	!FH27 14011017	EXTERNAL TRIP	[C9]	\$	14/Jan/2010
	04:56:32	Fault			
927	!FH28 14011017	EXTERNAL TRIP	[C7]	\$	14/Jan/2010
	03:03:21	Fault			
928	!FH29 14011014	IREG SHUTOFF	[24]	\$	14/Jan/2010
	03:03:21	Fault			
929	!FH30 12011003	soft limit error	[50]	\$	12/Jan/2010
	11:24:44	Fault			
930	!FH31 12011017	external trip	[55]	\$	12/Jan/2010
	11:24:44	Fault			
931	!FH32 12011003	soft limit error	[55]	\$	12/Jan/2010
	10:08:57	Fault			
932	!FH33 12011017	external trip	[51]	\$	12/Jan/2010
	10:08:57	Fault			
933	!FH34 12011003	soft limit error	[51]	\$	12/Jan/2010
	10:08:57	Fault			
934	!FH35 12011017	external trip	[4D]	\$	12/Jan/2010
	10:08:57	Fault			
935	!FH36 12011003	soft limit error	[4D]	\$	12/Jan/2010
	10:08:57	Fault			
936	!FH37 12011017	external trip	[49]	\$	12/Jan/2010
	10:08:57	Fault			
937	!FH38 12011003	soft limit error	[49]	\$	12/Jan/2010
	10:08:55	Fault			
938	!FH39 12011017	external trip	[45]	\$	12/Jan/2010
	10:08:55	Fault			
939	!FH40 12011003	soft limit error	[4E]	\$	12/Jan/2010
	10:08:55	Fault			
940	!FH41 12011017	external trip	[53]	\$	12/Jan/2010
	10:08:55	Fault			
941	!FH42 12011003	soft limit error	[53]	\$	12/Jan/2010
	10:08:54	Fault			

942	!FH43 12011017	external trip	[4F]	\$	12/Jan/2010
	10:08:54	Fault			
943	!FH44 12011003	soft limit error	[4F]	\$	12/Jan/2010
	10:08:54	Fault			
944	!FH45 12011017	external trip	[4B]	\$	12/Jan/2010
	10:08:54	Fault			
945	!FH46 12011003	soft limit error	[4B]	\$	12/Jan/2010
	10:08:54	Fault			
946	!FH47 12011017	external trip	[47]	\$	12/Jan/2010
	10:08:54	Fault			
947	!FH48 12011003	soft limit error	[47]	\$	12/Jan/2010
	10:08:53	Fault			
948	!FH49 12011017	external trip	[43]	\$	12/Jan/2010
	10:08:53	Fault			
949	!FH50 12011003	soft limit error	[4C]	\$	12/Jan/2010
	10:07:22	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 0 - Disabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg tol 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 0 - Disabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

```

\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ Soft Limit Error 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled



\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Soft Limit Error 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

```
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:40:08

DATA\_START

UNITS 2 [29]

0	unit system	METRIC	[5A]	
1	position units	FEET METER	[19]	
2	velocity units	MINUTES	[BA]	
3	hertz units	DISABLE	[2C]	
4	clock frequency	50 hertz	[0F]	
5	drive multiple	1	[C7]	
6	upid multiple	10	[FE]	
7	ac multiple	2	[1A]	
8	ac fast multiple	1	[4C]	
9	vector source	MOTOR SOCKET		[DC]
10	upid motor source	MOTOR SOCKET		[44]
11	upid load source	LOAD SOCKET	[45]	
12	load vector control	DISABLE		[08]
13	transducerless	DISABLE	[89]	
14	motor fbk size	2048 pulses/rev	[29]	
15	motor resolution	288.1853 in/rev		[D4]
16	motor fbk invert	DISABLE	[3C]	
17	motor input teeth	1	[7F]	
18	motor output teeth	1182	[62]	
19	motor encoder bits	BITS 0		[E4]
20	motor encoder turns	1	[B3]	
21	load fbk size	2048 pulses/rev	[BC]	
22	load resolution	42.0905 in/rev		[A6]
23	load fbk invert	ENABLE	[1C]	
24	load input teeth	1	[12]	
25	load output teeth	1	[90]	
26	load encoder bits	BITS 0		[77]
27	load encoder turns	1	[3D]	
28	motor rated voltage	460 volts	[24]	
29	motor rated current	27.00 amps rms		[CA]
30	motor rated frequency	60 hertz	[8A]	
31	maximum current	80.00 amps rms	[35]	
32	current limit	80.00 amps rms	[13]	
33	motor rms limit	29.70 amps rms	[68]	
34	current rate limit	0 amps pk/sec		[18]
35	field current	15.00 amps rms	[2D]	
36	field boost	200 %	[68]	
37	slip frequency	0.390 hertz	[98]	
38	motor poles	4	[C0]	
39	synchronous motor	DISABLE		[57]
40	vector offset	0.00 deg	[47]	
41	vector ffwd	0.00000 sec	[8B]	
42	torque ffwd	0.00 deg	[18]	
43	stator resistance	Rs 0.1433 ohms		[B9]
44	leakage Sigma	Ls 0.00565 henries		[65]
45	Lm squared over Lr	0.03814 henries		[96]
46	current filter	2.00 hertz	[D3]	
47	voltage filter	2.00 hertz	[E3]	
48	power filter	2.00 hertz	[A7]	
49	motor rtd torque	56.79 ftlb	[5A]	
50	motor max torque	198.26 ftlb	[37]	

51	motor rtd power	19.36 hp	[AC]	
52	motor max power	67.57 hp	[A9]	
53	motor kt	2.529 ftlb/amp	[26]	
54	motor inertia	0.000 ftlbs^2	[94]	
55	machine inertia	0.273 ftlbs^2	[E3]	
56	acc obs bandwidth	40 rad/sec	[03]	
57	system gain id	29.067 1/sec/sec	[DB]	
58	system gain	29.067 1/sec/sec	[C7]	
59	system wn	5.0 rad/sec	[87]	
60	system order	VELOCITY	[1D]	
61	kv cmd	0.000 upid gain	[D8]	
62	kp cmd	0.860 upid gain	[CF]	
63	ki	0.0 upid gain	[97]	
64	kp fbk	0.860 upid gain	[CE]	
65	kv fbk	0.298 upid gain	[C2]	
66	kr	1.000 upid gain	[2A]	
67	kp cmd percent	0 %	[D1]	
68	ki load enable	DISABLE	[56]	
69	kp load ratio	0 %	[35]	
70	kv load ratio	0 %	[37]	
71	torque limit	100.00 % max	[E2]	
72	low pass frequency	100.0 hertz	[33]	
73	low pass damping	1.414 gain	[A9]	
74	notch frequency	0.0 hertz	[9F]	
75	notch damping	1.414 gain	[B4]	
76	system gain 1	29.067 1/sec/sec	[76]	
77	system wn 1	20.0 rad/sec	[09]	
78	system order 1	TORQUE	[52]	
79	kv cmd 1	0.000 upid gain	[7E]	
80	kp cmd 1	0.688 upid gain	[76]	
81	ki 1	0.0 upid gain	[46]	
82	kp fbk 1	0.688 upid gain	[75]	
83	kv fbk 1	0.000 upid gain	[84]	
84	kr 1	0.000 upid gain	[DA]	
85	kp cmd percent 1	0 %	[80]	
86	ki load enable 1	DISABLE	[05]	
87	kp load ratio 1	0 %	[E4]	
88	kv load ratio 1	0 %	[DD]	
89	torque limit 1	100.00 % max	[88]	
90	low pass frequency 1	100.0 hertz	[E2]	
91	low pass damping 1	1.414 gain	[58]	
92	notch frequency 1	10.0 hertz	[4E]	
93	notch damping 1	1.414 gain	[63]	
94	torque invert	DISABLE	[1A]	
95	base rpm	1790 rpm	[3B]	
96	max vel	65.0 fpm	[AB]	
97	jog vel	4.9 fpm	[DE]	
98	!max motor rpm	3196.8 rpm	[B3]	
99	accel time	2.000 sec	[6F]	
100	decel time	2.000 sec	[4B]	
101	jerk time	0.000 sec	[9D]	
102	settle time	0.200 sec	[B5]	
103	accel time 1	2.000 sec	[FC]	
104	decel time 1	2.000 sec	[F6]	
105	jerk time 1	10.000 sec	[48]	
106	settle time 1	0.200 sec	[60]	
107	fast decel time	0.200 sec	[76]	
108	drive invert	DISABLE	[74]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.069 gain	[08]	
121	dsv ki	6.948 gain	[56]	
122	dsv kp fbk	0.069 gain	[07]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	7000 watts	[2A]	
151	db resistance	16.700 ohms	[42]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	OPEN LOOP	[CD]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	ESTIMATED	[D8]	
161	torq reg wn	500.0 rad/sec	[7E]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	12.87 gain	[81]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

167	friction deadzone	100.0 rpm	[2F]	
168	dac offset iu	-11 pulses	[3C]	
169	dac offset iv	-10 pulses	[3B]	
170	adc offset iu	-34 pulses	[3E]	
171	adc offset iv	17 pulses	[68]	
172	adc offset fu	-46 pulses	[3C]	
173	adc offset fv	-1 pulses	[73]	
174	adc 1 select	VOLTS	[66]	
175	adc 1 set	DISABLED	[19]	
176	adc 1 min	0.00 %	[75]	
177	adc 1 max	0.00 %	[72]	
178	adc 1 min volts	0.000 volts	[D8]	
179	adc 1 max volts	9.443 volts	[C1]	
180	adc 1 destination-1		[A1]	
181	!adc 1 raw value	-0.074 volts	[9A]	
182	!adc 1 value	0.00 %	[7E]	
183	adc 2 select	TENSION	[DD]	
184	adc 2 set	DISABLED	[18]	
185	adc 2 min	0.00 %	[74]	
186	adc 2 max	4700.09 %	[CD]	
187	adc 2 min volts	2.285 volts	[C6]	
188	adc 2 max volts	9.951 volts	[BC]	
189	adc 2 destination-1		[97]	
190	!adc 2 raw value	2.036 volts	[C6]	
191	!adc 2 value	-155.49 %	[D8]	
192	adc 3 select	TENSION	[DC]	
193	adc 3 set	DISABLED	[17]	
194	adc 3 min	0.00 %	[73]	
195	adc 3 max	10000.00 %	[AF]	
196	adc 3 min volts	2.072 volts	[CB]	
197	adc 3 max volts	6.840 volts	[C1]	
198	adc 3 destination-1		[96]	
199	!adc 3 raw value	1.894 volts	[B1]	
200	!adc 3 value	-372.54 %	[E3]	
201	dac clock level	DRIVE CLOCK	[AE]	
202	dac 1 select	TORQUE CMD	[32]	
203	dac 1 ptr	28965	[41]	
204	dac 1 item	0	[C5]	
205	dac 1 mul	1	[24]	
206	dac 1 div	1	[2E]	
207	dac 1 abs	DISABLE	[77]	
208	!dac 1 output	0.000 volts	[A8]	
209	dac 2 select	UPID VEL FBK	[D2]	
210	dac 2 ptr	26033	[52]	
211	dac 2 item	0	[C6]	
212	dac 2 mul	32767	[4D]	
213	dac 2 div	223473	[2B]	
214	dac 2 abs	DISABLE	[78]	
215	!dac 2 output	0.000 volts	[A9]	
216	level 1 password	1111	[7A]	
217	level 2 password	0	[0C]	
218	level 3 password	0	[0A]	
219	lockout time	900.000 sec	[D5]	
220	!lockout status	LEVEL 3	[8E]	
221	ssi rx mode	VEL	[39]	
222	!ssi rx value	0	[56]	
223	ssi torque offset	0.00 %	[A3]	
224	ssi tx mode	DISABLED	[E3]	

225	!ssi tx value	0		[51]	
226	ssi position lock	ENABLE		[E5]	
227	ssi tx clock	DISABLE		[BD]	
228	rtc source	SSI	[4E]		
229	ssi rx error limit	1		[23]	
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU		[B3]	
232	console baud rate	38400 BAUD		[66]	
233	console parity	NONE	[3F]		
234	console address	16	[DA]		
235	console checksum	BCC	[0B]		
236	console units	METRIC		[2E]	
237	console pos units	IN MM	[2E]		
238	console vel units	SECONDS		[7A]	
239	porta protocol	OPTOMUX		[21]	
240	porta baud rate	19200 BAUD		[37]	
241	porta parity	NONE	[0D]		
242	porta stop bits	STOP 1		[A6]	
243	porta address	0	[DE]		
244	porta checksum	BCC	[D8]		
245	porta units	ENGLISH	[B5]		
246	porta pos units	FEET METER		[8B]	
247	porta vel units	MINUTES		[31]	
248	optomux bits dev	BITS 32		[31]	
249	optomux num devices	1		[74]	
250	optomux output 0	0	[CF]		
251	optomux output 1	65535	[F5]		
252	optomux retries	3	[CD]		
253	optomux timeout	1.000 sec	[CC]		
254	optomux wd time	5.000 sec	[24]		
255	!motor rpm	0.0 rpm	[99]		
256	!max current	53.20 amps rms		[91]	
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	661 volts	[E2]		
259	!max bus voltage	1011 volts	[55]		
260	!armature voltage	0 volts	[3F]		
261	!max voltage	0 volts	[59]		
262	!field voltage	0 volts	[9A]		
263	!motor thermal rms	0.15 amps rms		[80]	
264	!torque est command	0.00 ftlb	[A5]		
265	!torque est feedback	-0.01 ftlb	[30]		
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp	[FF]		
268	!motor current	0.00 amps rms		[DD]	
269	!motor voltage	0 volts rms	[F4]		
270	!maximum voltage	460 volts rms	[C5]		
271	!inverter power	0.00 hp	[C6]		
272	!command vel	0.0 fpm	[00]		
273	!feedback vel	0.0 fpm	[B9]		
274	!command pos	0.6986 in		[B2]	
275	!feedback pos	0.6986 in		[6B]	
276	!in word 0	000dc0 \$		[A5]	
277	!out word 0	000006 \$		[84]	
278	!sin word 0	000000 \$		[97]	
279	!sin word 1	000000 \$		[95]	
280	!sout word 0	000000 \$		[1D]	
281	!sout word 1	000002 \$		[19]	
282	!int word 0	000800 \$		[93]	

283	!int word 1	000008	\$		[91]
284	!int word 2	000000	\$		[97]
285	!int word 3	000000	\$		[95]
286	hardware mask	4294934399			[01]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	131072			[E4]
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	131072			[21]
293	software mask	4294967293			[E7]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	32768		[ED]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	32768			[21]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	0			[7E]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	0			[B2]
307	test cycle rpm	1770.0	rpm		[5E]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	900.0	rpm		[62]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque	80	%		[2C]
317	test degrees	180.00	deg		[22]
318	test i field	0.00	amps rms		[E9]
319	test volts	0	volts		[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	SSI			[EB]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	0.0	fpm		[1F]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]



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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 2.500 sec [F6]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 65.0 fpm [9E]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 10 rpm [0B]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 100 % [83]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos825.7887 in [44]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0360 in [57]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ PLC [4C]

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399	ehalt req	REQ FORCED ON		[40]	
400	motion enable req	REQ FORCED ON			[42]
401	auto req	REQ PLC	[36]		
402	auto run req	REQ PLC		[C0]	
403	vel slave req	REQ PLC		[6B]	
404	torque offset req	REQ PLC		[A5]	
405	torque limit req	REQ PLC		[0C]	
406	torque slave req	REQ PLC		[0F]	
407	vel select 0 req	REQ PLC		[B2]	
408	vel select 1 req	REQ PLC		[B0]	
409	vel select 2 req	REQ PLC		[AE]	
410	vel select 3 req	REQ PLC		[B5]	
411	accelerate req	REQ PLC		[E5]	
412	decelerate req	REQ PLC		[DF]	
413	speed adjust req	REQ PLC		[30]	
414	resume req	REQ PLC	[5A]		
415	manual req	REQ PLC	[6C]		
416	accel 1 req	REQ PLC	[A0]		
417	track ref req	REQ PLC		[76]	
418	inj brake req	REQ PLC		[81]	
419	motor thermal ok req	REQ FORCED ON			[1D]
420	motor blower ok req	REQ FORCED ON			[87]
421	!motor on sts	OUT OFF		[80]	
422	!no fault sts	OUT OFF		[94]	
423	!no warning sts	OUT ON		[F7]	
424	!manual sts	OUT OFF	[2D]		
425	!auto sts	OUT OFF	[F1]		
426	!motion sts	OUT ON	[51]		
427	!fwd motion sts	OUT OFF		[B1]	
428	!rev motion sts	OUT OFF		[A4]	
429	!at zero vel sts	OUT ON		[C8]	
430	!at req vel sts	OUT OFF		[0A]	
431	!at max vel sts	OUT OFF		[0B]	
432	!vel slave sts	OUT OFF		[2A]	
433	!torque offset sts	OUT OFF			[64]
434	!torque limit sts	OUT OFF		[CB]	
435	!torque slave sts	OUT OFF		[CE]	
436	!track preset sts	OUT OFF		[E0]	
437	!motor rms warn sts	OUT OFF			[2C]
438	!thermal warn sts	OUT OFF		[E1]	
439	!dc field on sts	OUT OFF		[BD]	
440	out 0	MOTOR ON STS		[0B]	
441	out 1	STS PLC	[78]		
442	out 2	STS PLC	[76]		
443	out 3	STS PLC	[74]		
444	out 4	STS DISABLED		[19]	
445	out 5	STS DISABLED		[17]	
446	sout 0	STS DISABLED		[A8]	
447	sout 1	STS DISABLED		[A6]	
448	sout 2	STS DISABLED		[A4]	
449	sout 3	STS DISABLED		[A2]	
450	sout 4	STS DISABLED		[A9]	
451	sout 5	STS DISABLED		[A7]	
452	sout 6	STS DISABLED		[A5]	
453	sout 7	STS DISABLED		[A3]	
454	sout 8	STS DISABLED		[A1]	
455	sout 9	STS DISABLED		[9F]	
456	sout 10	STS DISABLED		[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	DRILL HOSE DRUM		[16]
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	80.00 % rtd	[BD]	
483	pend max vel	12.2 mpm	units:3	[13]
484	pend index pos	29.9999	in	[8E]
485	pend index vel	34.1 fpm	[E3]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	0.0 fpm	[E1]	
488	comp index pos	0.0000	in	[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word0		[95]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000	in	[2F]
496	payout preset	0.0000	in	[E6]
497	!index start pos	0.0000	in	[41]
498	!tension error	0.00 lb	[37]	
499	tgt hose tension	2669.0	N units:1	[CE]
500	!hose tension	-155.49	lb	[1D]
501	!cable tension	-372.54	lb	[D7]
502	hose filter gain	0.93000	gain	[2F]
503	!smooth hose tension	-153.19	lb	[65]
504	cable filter gain	0.93000	gain	[E5]
505	!smooth cable tension	-374.02	lb	[1E]
506	fine control gain	-0.0100	in/sec/lb	[2C]
507	!actual fine control	0.0000	in/sec/lb	[5D]
508	fade filter gain	0.97000	gain	[44]
509	hose tension offset	0.00	lb	[33]
510	cable tension offset	0.00	lb	[F3]
511	!hose load fbk	0	%	[04]
512	coil min od	2330.00	mm units:1	[6F]
513	coil max od	3680.00	mm units:1	[63]
514	coil diameter	2330.00	mm units:1	[59]

515	!coil circumference	0.00	mm	units:1	[BF]	
516	!coil usage	0.0	m	units:1	[A1]	
517	coil source	MOTOR SOCKET			[64]	
518	material source	LOAD SOCKET			[2C]	
519	coil od limit	DISABLE			[67]	
520	coil od rate	3.5433	in		[CF]	
521	coil update distance	118.1102	in		[23]	
522	level direction	NONE			[11]	
523	!level drum velocity	0.0	rpm	units:10	[EE]	
524	level follow gain	0.000	gain		[21]	
525	!level follow vel	0.0	fpm		[13]	
526	!level follow req vel	0.0	fpm		[AA]	
527	level follow vel off	0.0	fpm		[D7]	
528	level circumference	3.6000	in		[A3]	
529	level dwell count	0			[6A]	
530	!level circ count	0			[C8]	
531	!index pos	0.0000	in		[9A]	
532	!drive control mode	NONE			[E8]	
533	pend disable time	0.000	sec		[A5]	
534	lo-spd line low limt	590	volts rms		[90]	
535	hi-spd line low limt	590	volts rms		[99]	
536	high-low vel cutoff	0	rpm		[89]	
537	payout at drum	0.0	m	units:1	[2C]	
538	payout at tower	-62.9561	in		[DC]	
539	drum payout offset	0.0	m	units:1	[78]	
540	tower payout offset	-62.9921	in		[31]	
541	Hose Max Load	1250.45	lb		[97]	
542	Hose Min Load	0.00	lb		[39]	
543	Cable Max Load	12005.40	lb		[22]	
544	Cable Min Load	0.00	lb		[EF]	
545	Reel Mode	Drill/Deployment			[C1]	
546	Tension Fault	ENABLE			[91]	
547	Cable Tension/Unit	-373.39	lb		[5B]	
548	Cable Upper Trip	1000.00	lb		[53]	
549	Cable Lower Trip	600.04	lb		[7C]	
550	Load Cell Fault	ENABLE			[56]	
551	!Deploy Payout	2.6695	m	units:7	[BD]	
552	!Dep PLRV	2.6850	m	units:7	[55]	
553	Deploy reset	ENABLE			[DF]	
554	Load Cell Cal.	DISABLE			[C3]	
555	Ld cell torque limit	5.00	% max		[77]	
556	Ld cell pend. vel.	10.0	mpm	units:7	[8C]	
557	!Tower PLRV	0.0000	m	units:7	[6D]	
558	Drill payout reset	DISABLE			[41]	
559	!raw tower payout	0.0009	m	units:7	[7A]	
560	!Drum PLRV	0.0000	m	units:7	[EC]	
561	!raw drum payout	0.0000	m	units:7	[03]	
562	!smooth hose volts	2.034	volts		[25]	
563	!smooth cable volts	1.894	volts		[CF]	
564	max torque	0.00	ftlb	units:0	[2B]	
565	max tension hose	0.00	lb	units:0	[D5]	
566	max tension cable	0.00	lb	units:0	[8C]	
900	!FH 1 20011015	ssi receive		[5E]	\$	20/Jan/2010 21:31:00
	Fault					
901	!FH 2 20011017	external trip		[6A]	\$	20/Jan/2010
	21:30:58	Fault				
902	!FH 3 20011005	turn on lw unico		[A6]	\$	20/Jan/2010
	21:30:27	Fault				

903	!FH 4 20011013	rtc takeover	[E2]	\$	20/Jan/2010
	21:28:30	Fault			
904	!FH 5 20011017	EXTERNAL TRIP	[E4]	\$	20/Jan/2010
	21:27:58	Fault			
905	!FH 6 20011017	EXTERNAL TRIP	[E2]	\$	20/Jan/2010
	14:21:47	Fault			
906	!FH 7 20011015	ssi receive	[52]	\$	20/Jan/2010 11:41:26
		Fault			
907	!FH 8 20011005	turn on lw unico	[9C]	\$	20/Jan/2010
	10:25:15	Fault			
908	!FH 9 20011013	rtc takeover	[D8]	\$	20/Jan/2010
	10:25:12	Fault			
909	!FH10 20011017	EXTERNAL TRIP	[D3]	\$	20/Jan/2010
	10:24:07	Fault			
910	!FH11 18011007	BUS UNDERVOLTAGE	[FC]	\$	18/Jan/2010
	23:20:37	Fault			
911	!FH12 18011003	hose tension error	[7F]	\$	
	18/Jan/2010 20:47:07	Fault			
912	!FH13 18011002	load cell error	[ED]	\$	18/Jan/2010
	20:47:07	Fault			
913	!FH14 18011003	hose tension error	[7B]	\$	
	18/Jan/2010 20:47:06	Fault			
914	!FH15 18011002	load cell error	[E9]	\$	18/Jan/2010
	20:47:06	Fault			
915	!FH16 18011003	hose tension error	[77]	\$	
	18/Jan/2010 20:47:06	Fault			
916	!FH17 18011002	load cell error	[E5]	\$	18/Jan/2010
	20:47:06	Fault			
917	!FH18 18011003	hose tension error	[73]	\$	
	18/Jan/2010 20:47:06	Fault			
918	!FH19 18011002	load cell error	[E1]	\$	18/Jan/2010
	20:47:06	Fault			
919	!FH20 18011003	hose tension error	[78]	\$	
	18/Jan/2010 20:47:05	Fault			
920	!FH21 18011002	load cell error	[EF]	\$	18/Jan/2010
	20:47:05	Fault			
921	!FH22 18011002	load cell error	[ED]	\$	18/Jan/2010
	20:47:05	Fault			
922	!FH23 18011002	load cell error	[EB]	\$	18/Jan/2010
	20:47:05	Fault			
923	!FH24 18011002	load cell error	[E9]	\$	18/Jan/2010
	20:47:04	Fault			
924	!FH25 18011002	load cell error	[E7]	\$	18/Jan/2010
	20:47:04	Fault			
925	!FH26 18011002	load cell error	[E5]	\$	18/Jan/2010
	20:47:03	Fault			
926	!FH27 18011003	overrun	[7B]	\$	18/Jan/2010 20:44:42
		Fault			
927	!FH28 18011005	turn on lw unico	[81]	\$	18/Jan/2010
	20:43:54	Fault			
928	!FH29 18011003	hose tension error	[6F]	\$	
	18/Jan/2010 20:38:42	Fault			
929	!FH30 18011002	load cell error	[E6]	\$	18/Jan/2010
	20:38:42	Fault			
930	!FH31 18011003	hose tension error	[7D]	\$	
	18/Jan/2010 20:38:41	Fault			
931	!FH32 18011002	load cell error	[EB]	\$	18/Jan/2010
	20:38:41	Fault			

932	!FH33 18011003	hose tension error	[79]	\$	
	18/Jan/2010 20:38:41	Fault			
933	!FH34 18011002	load cell error	[E7]	\$	18/Jan/2010
	20:38:40	Fault			
934	!FH35 18011002	load cell error	[E5]	\$	18/Jan/2010
	20:38:40	Fault			
935	!FH36 18011002	load cell error	[E3]	\$	18/Jan/2010
	20:38:39	Fault			
936	!FH37 18011002	load cell error	[E1]	\$	18/Jan/2010
	20:38:38	Fault			
937	!FH38 18011002	load cell error	[DF]	\$	18/Jan/2010
	20:38:38	Fault			
938	!FH39 18011007	BUS UNDERVOLTAGE	[E8]	\$	18/Jan/2010
	18:22:04	Fault			
939	!FH40 18011013	rtc takeover	[C2]	\$	18/Jan/2010
	18:02:18	Fault			
940	!FH41 18011005	turn on lw unico	[8B]	\$	18/Jan/2010
	18:02:14	Fault			
941	!FH42 18011004	cable tension error	[30]	\$	
	18/Jan/2010 17:53:53	Fault			
942	!FH43 18011002	load cell error	[E7]	\$	18/Jan/2010
	17:50:40	Fault			
943	!FH44 18011003	HOSE TENSION ERROR	[75]	\$	
	18/Jan/2010 17:48:13	Fault			
944	!FH45 18011003	HOSE TENSION ERROR	[73]	\$	
	18/Jan/2010 17:48:12	Fault			
945	!FH46 18011003	HOSE TENSION ERROR	[71]	\$	
	18/Jan/2010 17:48:12	Fault			
946	!FH47 18011003	HOSE TENSION ERROR	[6F]	\$	
	18/Jan/2010 17:48:11	Fault			
947	!FH48 18011003	overrun	[75]	\$	18/Jan/2010 17:44:46
		Fault			
948	!FH49 18011017	EXTERNAL TRIP	[BD]	\$	18/Jan/2010
	17:09:36	Fault			
949	!FH50 18011005	turn on lw unico	[82]	\$	18/Jan/2010
	17:05:35	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss 1 - Enabled
$ load pg loss 1 - Enabled
$ motor marker 1 - Enabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 1 - Enabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 1 - Enabled

```

```
$ load fbk loss      1 - Enabled
$ motor runaway     1 - Enabled
$ load runaway      1 - Enabled
$ non volatile mem  1 - Enabled
$ rtc takeover      1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive1 - Enabled
$ inverter rms      1 - Enabled
$ sync receive      1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip    1 - Enabled
$ sync data error   1 - Enabled
$ bus reg toll - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error  1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout  1 - Enabled
$ Line Undervoltage1 - Enabled
$ Load Cell Error  1 - Enabled
$ Hose Tension Error 1 - Enabled
$ Cable Tension Error 1 - Enabled
$ Turn On LW Unico 1 - Enabled
$ Drive Identity Error 1 - Enabled
$ DB Over Temp      1 - Enabled
$ user fault 8 req 1 - Enabled
$ user fault 9 req 1 - Enabled
$ user fault 10 req1 - Enabled
$ user fault 11 req1 - Enabled
$ user fault 12 req1 - Enabled
$ user fault 13 req1 - Enabled
$ user fault 14 req1 - Enabled
$ user fault 15 req1 - Enabled
$ user fault 16 req1 - Enabled
$ user fault 17 req1 - Enabled
$ user fault 18 req1 - Enabled
$ user fault 19 req1 - Enabled
$ user fault 20 req1 - Enabled
$ user fault 21 req1 - Enabled
$ user fault 22 req1 - Enabled
$ user fault 23 req1 - Enabled
$ user fault 24 req1 - Enabled
$ user fault 25 req1 - Enabled
$ user fault 26 req1 - Enabled
$ user fault 27 req1 - Enabled
$ user fault 28 req1 - Enabled
$ user fault 29 req1 - Enabled
$ user fault 30 req1 - Enabled
$ user fault 31 req1 - Enabled

$ Warning Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
```

\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss 0 - Disabled  
\$ load pg loss 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ Hose Tension Error 0 - Disabled  
\$ Cable Tension Error 0 - Disabled  
\$ Turn On LW Unico 0 - Disabled  
\$ Drive Identity Error 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled



```
$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled

$ Event Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss 0 - Disabled
$ load pg loss 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ computer timeout 0 - Disabled
$ Line Undervoltage 0 - Disabled
$ Load Cell Error 0 - Disabled
$ Hose Tension Error 0 - Disabled
$ Cable Tension Error 0 - Disabled
$ Turn On LW Unico 0 - Disabled
```

```
$ Drive Identity Error 0 - Disabled
$ DB Over Temp 0 - Disabled
$ user fault 8 req 0 - Disabled
$ user fault 9 req 0 - Disabled
$ user fault 10 req0 - Disabled
$ user fault 11 req0 - Disabled
$ user fault 12 req0 - Disabled
$ user fault 13 req0 - Disabled
$ user fault 14 req0 - Disabled
$ user fault 15 req0 - Disabled
$ user fault 16 req0 - Disabled
$ user fault 17 req0 - Disabled
$ user fault 18 req0 - Disabled
$ user fault 19 req0 - Disabled
$ user fault 20 req0 - Disabled
$ user fault 21 req0 - Disabled
$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:07:29

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	4.00 amps rms	[FF]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	9.60 amps rms	[5E]
32	current limit	9.60 amps rms	[3C]
33	motor rms limit	9.60 amps rms	[9B]
34	current rate limit	0 amps pk/sec	[18]
35	field current	1.60 amps rms	[5C]
36	field boost	200 %	[68]
37	slip frequency	1.667 hertz	[90]
38	motor poles	4	[C0]
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector fwd	0.00000 sec	[8B]
42	torque fwd	0.00 deg	[18]
43	stator resistance	Rs 3.5856 ohms	[A9]
44	leakage Sigma	Ls 0.03811 henries	[68]
45	Lm squared over Lr	0.34613 henries	[95]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	6.20 ftlb	[9D]
50	motor max torque	23.18 ftlb	[73]

51	motor rtd power	2.07	hp	[E6]	
52	motor max power	7.72	hp	[E2]	
53	motor kt	1.697	ftlb/amp	[21]	
54	motor inertia	0.000	ftlbs^2	[94]	
55	machine inertia	0.006	ftlbs^2	[E9]	
56	acc obs bandwidth	40	rad/sec	[03]	
57	system gain id	102.694	1/sec/sec	[AD]	
58	system gain	102.694	1/sec/sec	[99]	
59	system wn	3.0	rad/sec	[89]	
60	system order		VELOCITY	[1D]	
61	kv cmd	0.000	upid gain	[D8]	
62	kp cmd	0.088	upid gain	[CD]	
63	ki	0.0	upid gain	[97]	
64	kp fbk	0.088	upid gain	[CC]	
65	kv fbk	0.051	upid gain	[CF]	
66	kr	1.000	upid gain	[2A]	
67	kp cmd percent	0	%	[D1]	
68	ki load enable		DISABLE	[56]	
69	kp load ratio	0	%	[35]	
70	kv load ratio	0	%	[37]	
71	torque limit	100.00	% max	[E2]	
72	low pass frequency	100.0	hertz	[33]	
73	low pass damping	1.414	gain	[A9]	
74	notch frequency	0.0	hertz	[9F]	
75	notch damping	1.414	gain	[B4]	
76	system gain 1	102.694	1/sec/sec	[48]	
77	system wn 1	14.0	rad/sec	[06]	
78	system order 1		TORQUE	[52]	
79	kv cmd 1	0.000	upid gain	[7E]	
80	kp cmd 1	0.136	upid gain	[82]	
81	ki 1	0.0	upid gain	[46]	
82	kp fbk 1	0.136	upid gain	[81]	
83	kv fbk 1	0.000	upid gain	[84]	
84	kr 1	0.000	upid gain	[DA]	
85	kp cmd percent 1	0	%	[80]	
86	ki load enable 1		DISABLE	[05]	
87	kp load ratio 1	0	%	[E4]	
88	kv load ratio 1	0	%	[DD]	
89	torque limit 1	100.00	% max	[88]	
90	low pass frequency 1	100.0	hertz	[E2]	
91	low pass damping 1	1.414	gain	[58]	
92	notch frequency 1	10.0	hertz	[4E]	
93	notch damping 1	1.414	gain	[63]	
94	torque invert		ENABLE	[67]	
95	base rpm	1750	rpm	[3F]	
96	max vel	1080.0	fpm	[4D]	
97	jog vel	1050.0	fpm	[55]	
98	!max motor rpm	3600.0	rpm	[C5]	
99	accel time	1.000	sec	[70]	
100	decel time	1.000	sec	[4C]	
101	jerk time	1.000	sec	[9C]	
102	settle time	0.200	sec	[B5]	
103	accel time 1	1.000	sec	[FD]	
104	decel time 1	1.000	sec	[F7]	
105	jerk time 1	10.000	sec	[48]	
106	settle time 1	0.200	sec	[60]	
107	fast decel time	0.200	sec	[76]	
108	drive invert		ENABLE	[C1]	

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.468 gain	[05]	
121	dsv ki	46.866 gain	[23]	
122	dsv kp fbk	0.468 gain	[04]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

```

167 friction deadzone 100.0 rpm          [2F]
168 dac offset iu      -12 pulses        [3B]
169 dac offset iv      -8  pulses        [64]
170 adc offset iu      -47 pulses        [3A]
171 adc offset iv      -70 pulses        [3C]
172 adc offset fu       34 pulses        [6C]
173 adc offset fv      -63 pulses        [3B]
174 adc 1 select       VELOCITY          [8F]
175 adc 1 set         DISABLED           [19]
176 adc 1 min         0.00 %             [75]
177 adc 1 max        10800.00 %          [A9]
178 adc 1 min volts   0.014 volts        [D3]
179 adc 1 max volts   8.862 volts        [BD]
180 adc 1 destination-1 [A1]
181 !adc 1 raw value  -0.015 volts        [9F]
182 !adc 1 value      -35.03 %           [16]
183 adc 2 select       VOLTS             [65]
184 adc 2 set         DISABLED           [18]
185 adc 2 min         0.00 %             [74]
186 adc 2 max         0.00 %             [71]
187 adc 2 min volts   0.000 volts        [D7]
188 adc 2 max volts   0.000 volts        [D4]
189 adc 2 destination-1 [97]
190 !adc 2 raw value  -0.030 volts        [A1]
191 !adc 2 value       0.00 %            [7D]
192 adc 3 select       VOLTS             [64]
193 adc 3 set         DISABLED           [17]
194 adc 3 min         0.00 %             [73]
195 adc 3 max         0.00 %             [70]
196 adc 3 min volts   0.000 volts        [D6]
197 adc 3 max volts   0.000 volts        [D3]
198 adc 3 destination-1 [96]
199 !adc 3 raw value  -0.025 volts        [93]
200 !adc 3 value       0.00 %            [85]
201 dac clock level   DRIVE CLOCK        [AE]
202 dac 1 select       TORQUE CMD         [32]
203 dac 1 ptr         28965              [41]
204 dac 1 item        0                  [C5]
205 dac 1 mul         1                  [24]
206 dac 1 div         1                  [2E]
207 dac 1 abs         DISABLE            [77]
208 !dac 1 output     0.050 volts        [A3]
209 dac 2 select       UPID VEL FBK       [D2]
210 dac 2 ptr         26033              [52]
211 dac 2 item        0                  [C6]
212 dac 2 mul         32767              [4D]
213 dac 2 div         251658             [25]
214 dac 2 abs         DISABLE            [78]
215 !dac 2 output     -0.001 volts       [7B]
216 level 1 password  1111              [7A]
217 level 2 password  0                  [0C]
218 level 3 password  0                  [0A]
219 lockout time      900.000 sec         [D5]
220 !lockout status   LOCKED            [A7]
221 ssi rx mode       DISABLED           [E8]
222 !ssi rx value     0                  [56]
223 ssi torque offset 0.00 %            [A3]
224 ssi tx mode       DISABLED           [E3]

```

225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	NONE		[68]	
232	console baud rate	1200 BAUD			[A2]
233	console parity	NONE		[3F]	
234	console address	0		[11]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	19		[A4]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	REV		[5F]	
247	porta vel units	MINUTES			[31]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec			[24]
255	!motor rpm	-0.1 rpm	[6B]		
256	!max current	6.38 amps rms			[BA]
257	!torque cmd	0.50 % max	[D2]		
258	!bus voltage	654 volts		[E0]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.03 amps rms			[83]
264	!torque est command	0.31 ftlb		[A1]	
265	!torque est feedback	-0.03 ftlb			[2E]
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.02 amps rms			[DB]
269	!motor voltage	-1 volts rms			[C6]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm			[B9]
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0484 in			[78]
276	!in word 0	000009 \$			[03]
277	!out word 0	000001 \$			[89]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000000 \$			[9B]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287199		[07]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	900.0 rpm		[94]
308	test id min rpm	0.0 rpm		[DB]
309	test jog rpm	900.0 rpm		[62]
310	test max rpm	900.0 rpm		[64]
311	test min rpm	-900.0 rpm		[38]
312	test period	0.000 sec	[B1]	
313	test ramp	DISABLE		[B8]
314	test position	3100.000 rev		[17]
315	test time	1.000 sec	[81]	
316	test torque	95 %	[26]	
317	test degrees	180.00 deg		[22]
318	test i field	0.00 amps rms		[E9]
319	test volts	0 volts	[B6]	
320	test length	24.0001 in	[B0]	
321	test accel time	4.000 sec	[69]	
322	test freq ramp time	5.000 sec		[E1]
323	test adc	1	[02]	
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0 fpm		[0E]
330	vel preset 1	0.0 fpm		[21]
331	vel preset 2	900.0 fpm		[B6]
332	vel preset 3	0.0 fpm		[1D]
333	vel preset 4	0.0 fpm		[1B]
334	vel preset 5	0.0 fpm		[19]
335	vel preset 6	0.0 fpm		[17]
336	vel preset 7	0.0 fpm		[15]
337	vel preset 8	0.0 fpm		[13]
338	vel offset	0.0 fpm	[76]	
339	vel gain	100.00 %		[EA]
340	vel tolerance	0.0 fpm		[47]



```

341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 540.0 fpm [70]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 5 rpm [37]
371 bus reg tol time 0 secs [74]
372 bus reg kp 1.000 gain [06]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 4500 rpm [4C]
377 rpm rev shutoff -4500 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 25 % [DF]
381 inj brake time 3.000 sec [D6]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0513 in [C8]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state AUTO RUN [F2]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

```

399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON	[2F]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON	[7B]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF	[16]	
412	decelerate req	REQ FORCED OFF	[10]	
413	speed adjust req	REQ FORCED OFF	[61]	
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF	[A7]	
418	inj brake req	REQ FORCED OFF	[B2]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT ON	[BE]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT ON	[2F]	
426	!motion sts	OUT OFF	[13]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT ON	[48]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS PLC	[7A]	
441	out 1	STS PLC	[78]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED	[74]		
458	sout 12	STS DISABLED	[72]		
459	sout 13	STS DISABLED	[70]		
460	sout 14	STS DISABLED	[77]		
461	sout 15	STS DISABLED	[75]		
462	sout 16	STS PLC	[CC]		
463	sout 17	STS PLC	[CA]		
464	sout 18	STS PLC	[C8]		
465	sout 19	STS PLC	[C6]		
466	sout 20	STS PLC	[CD]		
467	sout 21	STS PLC	[CB]		
468	sout 22	STS PLC	[C9]		
469	sout 23	STS PLC	[C7]		
470	sout 24	STS PLC	[CE]		
471	sout 25	STS PLC	[CC]		
472	sout 26	STS PLC	[CA]		
473	sout 27	STS PLC	[C8]		
474	sout 28	STS PLC	[C6]		
475	sout 29	STS PLC	[C4]		
476	sout 30	STS PLC	[CB]		
477	sout 31	STS PLC	[C9]		
900	!FH 1 19011017	EXTERNAL TRIP	[E4]	\$	19/Jan/2010
	16:01:02	Fault			
901	!FH 2 17011017	EXTERNAL TRIP	[E4]	\$	17/Jan/2010
	21:37:43	Fault			
902	!FH 3 17011017	external trip	[62]	\$	17/Jan/2010
	20:43:55	Fault			
903	!FH 4 16011017	external trip	[61]	\$	16/Jan/2010
	05:22:17	Fault			
904	!FH 5 14011007	BUS UNDERVOLTAGE	[0A]	\$	14/Jan/2010
	18:40:18	Fault			
905	!FH 6 14011017	EXTERNAL TRIP	[DF]	\$	14/Jan/2010
	16:47:19	Fault			
906	!FH 7 14011016	INVERTER RMS	[1F]	\$	14/Jan/2010
	15:39:25	Fault			
907	!FH 8 14011016	INVERTER RMS	[1D]	\$	14/Jan/2010
	02:34:24	Fault			
908	!FH 9 14011016	INVERTER RMS	[1B]	\$	14/Jan/2010
	02:33:49	Fault			
909	!FH10 14011016	INVERTER RMS	[12]	\$	14/Jan/2010
	02:26:21	Fault			
910	!FH11 14011016	INVERTER RMS	[19]	\$	14/Jan/2010
	02:25:47	Fault			
911	!FH12 14011016	INVERTER RMS	[17]	\$	14/Jan/2010
	02:24:19	Fault			
912	!FH13 13011016	INVERTER RMS	[16]	\$	13/Jan/2010
	14:56:26	Fault			
913	!FH14 13011017	EXTERNAL TRIP	[D2]	\$	13/Jan/2010
	10:30:50	Fault			
914	!FH15 13011017	EXTERNAL TRIP	[D0]	\$	13/Jan/2010
	08:37:38	Fault			
915	!FH16 11011017	EXTERNAL TRIP	[D0]	\$	11/Jan/2010
	14:28:48	Fault			
916	!FH17 11011016	INVERTER RMS	[10]	\$	11/Jan/2010
	13:09:27	Fault			
917	!FH18 11011016	INVERTER RMS	[0E]	\$	11/Jan/2010
	02:26:42	Fault			

918	!FH19 11011016	INVERTER RMS	[0C]	\$	11/Jan/2010
	02:21:35	Fault			
919	!FH20 11011016	INVERTER RMS	[13]	\$	11/Jan/2010
	02:20:49	Fault			
920	!FH21 11011016	INVERTER RMS	[1A]	\$	11/Jan/2010
	02:18:53	Fault			
921	!FH22 10011017	external trip	[57]	\$	10/Jan/2010
	10:49:43	Fault			
922	!FH23 10011017	EXTERNAL TRIP	[D5]	\$	10/Jan/2010
	05:04:53	Fault			
923	!FH24 07011017	external trip	[4D]	\$	07/Jan/2010
	17:04:52	Fault			
924	!FH25 07011017	external trip	[4B]	\$	07/Jan/2010
	14:30:04	Fault			
925	!FH26 05011017	EXTERNAL TRIP	[CB]	\$	05/Jan/2010
	20:39:04	Fault			
926	!FH27 05011017	EXTERNAL TRIP	[C9]	\$	05/Jan/2010
	19:45:46	Fault			
927	!FH28 05011016	INVERTER RMS	[09]	\$	05/Jan/2010
	18:16:28	Fault			
928	!FH29 05011017	external trip	[45]	\$	05/Jan/2010
	12:31:38	Fault			
929	!FH30 04011000	BUS OVERVOLTAGE	[3F]	\$	04/Jan/2010
	13:53:17	Fault			
930	!FH31 04011017	EXTERNAL TRIP	[D4]	\$	04/Jan/2010
	11:19:58	Fault			
931	!FH32 04011017	EXTERNAL TRIP	[D2]	\$	04/Jan/2010
	09:50:41	Fault			
932	!FH33 31120917	EXTERNAL TRIP	[C6]	\$	31/Dec/2009
	08:13:22	Fault			
933	!FH34 31120916	INVERTER RMS	[06]	\$	31/Dec/2009
	08:08:59	Fault			
934	!FH35 30120917	EXTERNAL TRIP	[C3]	\$	30/Dec/2009
	00:29:23	Fault			
935	!FH36 29120917	external trip	[39]	\$	29/Dec/2009
	21:26:17	Fault			
936	!FH37 26120917	EXTERNAL TRIP	[BA]	\$	26/Dec/2009
	18:59:18	Fault			
937	!FH38 24120917	external trip	[3A]	\$	24/Dec/2009
	10:46:58	Fault			
938	!FH39 24120917	external trip	[38]	\$	24/Dec/2009
	08:39:41	Fault			
939	!FH40 24120917	EXTERNAL TRIP	[BF]	\$	24/Dec/2009
	04:47:22	Fault			
940	!FH41 24120917	EXTERNAL TRIP	[C6]	\$	24/Dec/2009
	04:36:56	Fault			
941	!FH42 24120917	external trip	[44]	\$	24/Dec/2009
	04:25:17	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled

```

\$ dynamic brake limit 1 - Enabled  
\$ watchdog timer 1 - Enabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 1 - Enabled  
\$ motor marker 1 - Enabled  
\$ load marker 1 - Enabled  
\$ overrun 1 - Enabled  
\$ motor rms limit 1 - Enabled  
\$ circuit breaker 1 - Enabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 1 - Enabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 1 - Enabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 1 - Enabled  
\$ non volatile mem 1 - Enabled  
\$ rtc takeover 1 - Enabled  
\$ fbk circuit breaker 1 - Enabled  
\$ ssi receive 1 - Enabled  
\$ inverter rms 1 - Enabled  
\$ sync receive 1 - Enabled  
\$ armature curr error 1 - Enabled  
\$ field current loss 1 - Enabled  
\$ overspeed trip 1 - Enabled  
\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault 1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ Mtr Connection Error 1 - Enabled  
\$ user fault 1 req 1 - Enabled  
\$ user fault 2 req 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req 1 - Enabled  
\$ user fault 11 req 1 - Enabled  
\$ user fault 12 req 1 - Enabled  
\$ user fault 13 req 1 - Enabled  
\$ user fault 14 req 1 - Enabled  
\$ user fault 15 req 1 - Enabled  
\$ user fault 16 req 1 - Enabled  
\$ user fault 17 req 1 - Enabled  
\$ user fault 18 req 1 - Enabled  
\$ user fault 19 req 1 - Enabled  
\$ user fault 20 req 1 - Enabled  
\$ user fault 21 req 1 - Enabled  
\$ user fault 22 req 1 - Enabled  
\$ user fault 23 req 1 - Enabled  
\$ user fault 24 req 1 - Enabled  
\$ user fault 25 req 1 - Enabled

```
$ user fault 26 req1 - Enabled
$ user fault 27 req1 - Enabled
$ user fault 28 req1 - Enabled
$ user fault 29 req1 - Enabled
$ user fault 30 req1 - Enabled
$ user fault 31 req1 - Enabled

$ Warning Masks:
$ bus overvoltage 0 - Disabled
$ AMB thermal switch 0 - Disabled
$ fast overcurrent 0 - Disabled
$ HS thermal switch0 - Disabled
$ gate driver dsat 0 - Disabled
$ ireg shutoff 0 - Disabled
$ low voltage supply 0 - Disabled
$ external trip 0 - Disabled
$ dynamic brake limit 0 - Disabled
$ watchdog timer 0 - Disabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 0 - Disabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 0 - Disabled
$ motor rms limit 0 - Disabled
$ circuit breaker 0 - Disabled
$ pos error 0 - Disabled
$ bus undervoltage 0 - Disabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 0 - Disabled
$ motor runaway 0 - Disabled
$ load runaway 0 - Disabled
$ non volatile mem 0 - Disabled
$ rtc takeover 0 - Disabled
$ fbk circuit breaker 0 - Disabled
$ ssi receive 0 - Disabled
$ inverter rms 0 - Disabled
$ sync receive 0 - Disabled
$ armature curr error 0 - Disabled
$ field current loss 0 - Disabled
$ overspeed trip 0 - Disabled
$ sync data error 0 - Disabled
$ bus reg tol 0 - Disabled
$ unknown fbk module 0 - Disabled
$ torque reg error 0 - Disabled
$ communication error 0 - Disabled
$ ehalt fault 0 - Disabled
$ motor thermal switch 0 - Disabled
$ motor blower off 0 - Disabled
$ Mtr Connection Error 0 - Disabled
$ user fault 1 req 0 - Disabled
$ user fault 2 req 0 - Disabled
$ user fault 3 req 0 - Disabled
$ user fault 4 req 0 - Disabled
$ user fault 5 req 0 - Disabled
$ user fault 6 req 0 - Disabled
$ user fault 7 req 0 - Disabled
$ user fault 8 req 0 - Disabled
$ user fault 9 req 0 - Disabled
```

\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled

\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ Mtr Connection Error 0 - Disabled  
\$ user fault 1 req 0 - Disabled  
\$ user fault 2 req 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

DATA\_END

\$END



\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:13:37

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple	2	[1A]
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	DISABLE	[89]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	0.0754 in/rev	[47]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth	1	[7F]
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 14	[AF]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth	1	[12]
25	load output teeth	1	[90]
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	452 volts	[23]
29	motor rated current	13.00 amps rms	[CF]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	13.00 amps rms	[76]
34	current rate limit	0 amps pk/sec	[18]
35	field current	0.00 amps rms	[63]
36	field boost	200 %	[68]
37	slip frequency	0.000 hertz	[A4]
38	motor poles	6	[BE]
39	synchronous motor	ENABLE	[A4]
40	vector offset	119.11 deg	[DA]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg	[18]
43	stator resistance	Rs 0.4100 ohms	[BF]
44	leakage Sigma	Ls 0.00593 henries	[64]
45	Lm squared over Lr	0.02994 henries	[8E]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	33.59 ftlb	[61]
50	motor max torque	72.35 ftlb	[70]

51	motor rtd power	11.19 hp	[B3]
52	motor max power	24.11 hp	[BA]
53	motor kt	2.583 ftlb/amp	[26]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.018 ftlbs^2	[E6]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	152.695 1/sec/sec	[A7]
58	system gain	152.695 1/sec/sec	[93]
59	system wn	20.0 rad/sec	[5A]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	2.620 upid gain	[D3]
63	ki	0.0 upid gain	[97]
64	kp fbk	2.620 upid gain	[D2]
65	kv fbk	0.227 upid gain	[CA]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	152.695 1/sec/sec	[42]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.131 upid gain	[87]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.131 upid gain	[86]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1750 rpm	[3F]
96	max vel	39.6 fpm	[A4]
97	jog vel	17.0 fpm	[B3]
98	!max motor rpm	6302.3 rpm	[C0]
99	accel time	3.000 sec	[6E]
100	decel time	3.000 sec	[4A]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	1.000 sec	[F7]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	DISABLE	[74]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.072 gain	[0E]	
121	dsv ki	7.292 gain	[5D]	
122	dsv kp fbk	0.072 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	OPEN LOOP	[CD]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	ESTIMATED	[D8]	
161	torq reg wn	1000.0 rad/sec	[52]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	50.58 gain	[81]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      154 pulses        [31]
169 dac offset iv      -69 pulses        [2D]
170 adc offset iu       1 pulses          [A1]
171 adc offset iv      17 pulses          [68]
172 adc offset fu      35 pulses          [6B]
173 adc offset fv       0 pulses          [A1]
174 adc 1 select        VOLTS            [66]
175 adc 1 set  DISABLED                    [19]
176 adc 1 min  0.00 %           [75]
177 adc 1 max  0.00 %           [72]
178 adc 1 min volts  0.004 volts  [D4]
179 adc 1 max volts -3.770 volts  [97]
180 adc 1 destination-1          [A1]
181 !adc 1 raw value 0.009 volts  [C9]
182 !adc 1 value    0.00 %        [7E]
183 adc 2 select        VOLTS            [65]
184 adc 2 set  DISABLED                    [18]
185 adc 2 min  0.00 %           [74]
186 adc 2 max  0.00 %           [71]
187 adc 2 min volts  0.000 volts  [D7]
188 adc 2 max volts  0.000 volts  [D4]
189 adc 2 destination-1          [97]
190 !adc 2 raw value 0.004 volts  [CD]
191 !adc 2 value    0.00 %        [7D]
192 adc 3 select        VOLTS            [64]
193 adc 3 set  DISABLED                    [17]
194 adc 3 min  0.00 %           [73]
195 adc 3 max  0.00 %           [70]
196 adc 3 min volts  0.000 volts  [D6]
197 adc 3 max volts  0.000 volts  [D3]
198 adc 3 destination-1          [96]
199 !adc 3 raw value 0.000 volts  [C7]
200 !adc 3 value    0.00 %        [85]
201 dac clock level  DRIVE CLOCK          [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr  28965            [41]
204 dac 1 item 0              [C5]
205 dac 1 mul  1               [24]
206 dac 1 div  1               [2E]
207 dac 1 abs  DISABLE          [77]
208 !dac 1 output  0.000 volts  [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr  26033            [52]
211 dac 2 item 0              [C6]
212 dac 2 mul  32767            [4D]
213 dac 2 div  440563          [2A]
214 dac 2 abs  DISABLE          [78]
215 !dac 2 output  -0.123 volts  [76]
216 level 1 password 1111      [7A]
217 level 2 password 0         [0C]
218 level 3 password 0         [0A]
219 lockout time  900.000 sec    [D5]
220 !lockout status  LEVEL 3      [8E]
221 ssi rx mode  DISABLE          [E8]
222 !ssi rx value  0              [56]
223 ssi torque offset0.00 %     [A3]
224 ssi tx mode  DISABLE          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	14		[DC]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH			[B5]
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	657 volts		[DD]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.03 amps rms			[83]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	-0.3 fpm		[D0]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0010 in			[CE]
275	!feedback pos	0.0019 in			[7E]
276	!in word 0	000041 \$			[07]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000800 \$			[93]

283	!int word 1	000000	\$		[99]
284	!int word 2	001000	\$		[96]
285	!int word 3	000000	\$		[95]
286	hardware mask	4280287231			[14]
287	hardware warning mask	0			[D2]
288	hardware event mask	0			[A5]
289	!hardware faults	0		[E2]	
290	!hardware warnings	0			[10]
291	!hardware latch	0		[6C]	
292	!hardware unmasked	2097152			[E5]
293	software mask	4294965948			[E2]
294	software warning mask	0			[B7]
295	software event mask	0			[8A]
296	!software faults	0		[C7]	
297	!software warnings	0			[EC]
298	!software latch	0		[48]	
299	!software unmasked	0			[FB]
300	user mask	4294967295			[9C]
301	user warning mask	0			[6E]
302	user event mask	0			[41]
303	!user faults	0			[7E]
304	!user warnings	0			[A3]
305	!user latch	0		[FF]	
306	!user unmasked	0			[B2]
307	test cycle rpm	1500.0	rpm		[67]
308	test id min rpm	0.0	rpm		[DB]
309	test jog rpm	200.0	rpm		[69]
310	test max rpm	900.0	rpm		[64]
311	test min rpm	-900.0	rpm		[38]
312	test period	0.000	sec		[B1]
313	test ramp	DISABLE			[B8]
314	test position	10.000	rev		[7A]
315	test time	1.000	sec		[81]
316	test torque	90	%		[2B]
317	test degrees	180.00	deg		[22]
318	test i field	1.30	amps rms		[E5]
319	test volts	0	volts		[B6]
320	test length	24.0001	in		[B0]
321	test accel time	4.000	sec		[69]
322	test freq ramp time	6.000	sec		[E0]
323	test adc	1			[02]
324	!display count	0			[AA]
325	!display flag	0			[38]
326	vel selection	INTERNAL			[AE]
327	vel mstr select	PRESET VEL 1			[3F]
328	vel slv select	ADC 1			[C1]
329	min cruise vel	0.0	fpm		[0E]
330	vel preset 1	0.0	fpm		[21]
331	vel preset 2	0.0	fpm		[1F]
332	vel preset 3	0.0	fpm		[1D]
333	vel preset 4	0.0	fpm		[1B]
334	vel preset 5	0.0	fpm		[19]
335	vel preset 6	0.0	fpm		[17]
336	vel preset 7	0.0	fpm		[15]
337	vel preset 8	0.0	fpm		[13]
338	vel offset	0.0	fpm		[76]
339	vel gain	100.00	%		[EA]
340	vel tolerance	0.0	fpm		[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 80.00 % max [59]
346 preset lwr torq lmt -80.00 % max [2D]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 39.6 fpm [97]
368 bus reg DISABLE [96]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 0 secs [74]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.5505 Wb [F5]
383 ext trip ENABLE [5E]
384 !motor socket vel-0.2 fpm [D2]
385 !motor socket pos0.0003 in [CE]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ PLC	[36]	
402	auto run req	REQ PLC	[C0]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ PLC	[0C]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT OFF	[CB]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	MOTOR ON STS	[0B]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	



457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	RETURN HOSE WINCH		[6C]
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	20.00 % rtd	[C3]	
483	pend max vel	12.0 fpm	[BC]	
484	pend index pos	0.0000 in		[ED]
485	pend index vel	4.0 fpm	[17]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	0.0 fpm	[E1]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word192		[29]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	target hose load %	25 %		[53]
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	650	volts rms	[92]		
536	hi-spd line low limt	0	volts rms	[06]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011017	EXTERNAL TRIP		[EC]	\$	20/Jan/2010
	10:25:02	Fault				
901	!FH 2 18011017	external trip		[63]	\$	18/Jan/2010
	15:07:24	Fault				
902	!FH 3 17011017	external trip		[62]	\$	17/Jan/2010
	16:06:21	Fault				
903	!FH 4 15011017	external trip		[62]	\$	15/Jan/2010
	11:11:17	Fault				
904	!FH 5 14011008	GATE DRIVER DSAT		[2A]	\$	14/Jan/2010
	20:59:43	Fault				
905	!FH 6 14011008	GATE DRIVER DSAT		[28]	\$	14/Jan/2010
	20:56:34	Fault				
906	!FH 7 14011017	EXTERNAL TRIP		[DD]	\$	14/Jan/2010
	04:54:48	Fault				
907	!FH 8 14011017	EXTERNAL TRIP		[DB]	\$	14/Jan/2010
	03:01:37	Fault				
908	!FH 9 12011017	EXTERNAL TRIP		[DB]	\$	12/Jan/2010
	08:52:46	Fault				
909	!FH10 11011017	EXTERNAL TRIP		[D3]	\$	11/Jan/2010
	05:26:18	Fault				
910	!FH11 11011017	external trip		[5A]	\$	11/Jan/2010
	05:15:34	Fault				
911	!FH12 11011017	external trip		[58]	\$	11/Jan/2010
	05:13:40	Fault				
912	!FH13 10011017	EXTERNAL TRIP		[D7]	\$	10/Jan/2010
	23:28:50	Fault				

```
$ Fault Masks:
$ bus overvoltage 1 - Enabled
$   AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor resolv 1 loss 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 0 - Disabled
$ load marker 0 - Disabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive 1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll 1 - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault 1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled
$ computer timeout 1 - Enabled
$ Line Undervoltage 1 - Enabled
$ Load Cell Error 1 - Enabled
$ user fault 3 req 1 - Enabled
$ user fault 4 req 1 - Enabled
$ user fault 5 req 1 - Enabled
$ user fault 6 req 1 - Enabled
$ DB Over Temp 1 - Enabled
$ user fault 8 req 1 - Enabled
$ user fault 9 req 1 - Enabled
$ user fault 10 req 1 - Enabled
$ user fault 11 req 1 - Enabled
$ user fault 12 req 1 - Enabled
$ user fault 13 req 1 - Enabled
$ user fault 14 req 1 - Enabled
$ user fault 15 req 1 - Enabled
```

\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled

\$ computer timeout 0 - Disabled  
\$ Line Undervoltage0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req0 - Disabled  
\$ user fault 11 req0 - Disabled  
\$ user fault 12 req0 - Disabled  
\$ user fault 13 req0 - Disabled  
\$ user fault 14 req0 - Disabled  
\$ user fault 15 req0 - Disabled  
\$ user fault 16 req0 - Disabled  
\$ user fault 17 req0 - Disabled  
\$ user fault 18 req0 - Disabled  
\$ user fault 19 req0 - Disabled  
\$ user fault 20 req0 - Disabled  
\$ user fault 21 req0 - Disabled  
\$ user fault 22 req0 - Disabled  
\$ user fault 23 req0 - Disabled  
\$ user fault 24 req0 - Disabled  
\$ user fault 25 req0 - Disabled  
\$ user fault 26 req0 - Disabled  
\$ user fault 27 req0 - Disabled  
\$ user fault 28 req0 - Disabled  
\$ user fault 29 req0 - Disabled  
\$ user fault 30 req0 - Disabled  
\$ user fault 31 req0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor resolv 1 loss 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:04:44

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	REV	[ED]
2	velocity units	MINUTES	[BA]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	3.6000 in/rev	[4E]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth 1	[7F]	
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0001 in/rev	[B8]
23	load fbk invert	DISABLE	[CF]
24	load input teeth 1	[12]	
25	load output teeth 1	[90]	
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	77.00 amps rms	[C5]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	130.00 amps rms	[09]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	77.00 amps rms	[6C]
34	current rate limit	0 amps pk/sec	[18]
35	field current	24.79 amps rms	[1D]
36	field boost 200	% [68]	
37	slip frequency	2.500 hertz	[9D]
38	motor poles 2	[C2]	
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg [18]	
43	stator resistance	Rs 0.2372 ohms	[B6]
44	leakage Sigma	Ls 0.00220 henries	[71]
45	Lm squared over Lr	0.02183 henries	[98]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	87.30 ftlb	[63]
50	motor max torque	152.82 ftlb	[3F]

51	motor rtd power	57.35 hp	[AB]
52	motor max power	100.39 hp	[85]
53	motor kt	1.198 ftlb/amp	[25]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.028 ftlbs^2	[E5]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	217.189 1/sec/sec	[A7]
58	system gain	217.189 1/sec/sec	[93]
59	system wn	5.0 rad/sec	[87]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.115 upid gain	[D6]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.115 upid gain	[D5]
65	kv fbk	0.040 upid gain	[D1]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	217.189 1/sec/sec	[42]
77	system wn 1	20.0 rad/sec	[09]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.092 upid gain	[81]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.092 upid gain	[80]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	ENABLE	[67]
95	base rpm	3450 rpm	[40]
96	max vel	1500.0 fpm	[50]
97	jog vel	175.0 fpm	[7E]
98	!max motor rpm	5000.0 rpm	[C9]
99	accel time	10.000 sec	[40]
100	decel time	10.000 sec	[1C]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	1.000 sec	[F7]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	DISABLE	[74]



109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	4000 hertz	[C9]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.027 gain	[0E]	
121	dsv ki	2.705 gain	[63]	
122	dsv kp fbk	0.027 gain	[0D]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	0 watts	[C1]	
151	db resistance	0.000 ohms	[80]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	

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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu    -40  pulses        [3A]
169 dac offset iv     20  pulses        [67]
170 adc offset iu    -15  pulses        [3F]
171 adc offset iv     65  pulses        [65]
172 adc offset fu     39  pulses        [67]
173 adc offset fv     -4  pulses        [70]
174 adc 1 select      VOLTS             [66]
175 adc 1 set  DISABLED                 [19]
176 adc 1 min  0.00  %                   [75]
177 adc 1 max  0.00  %                   [72]
178 adc 1 min volts  0.000 volts         [D8]
179 adc 1 max volts  0.000 volts         [D5]
180 adc 1 destination-1                 [A1]
181 !adc 1 raw value 0.004 volts         [CE]
182 !adc 1 value    0.00  %              [7E]
183 adc 2 select      VOLTS             [65]
184 adc 2 set  DISABLED                 [18]
185 adc 2 min  0.00  %                   [74]
186 adc 2 max  0.00  %                   [71]
187 adc 2 min volts  0.000 volts         [D7]
188 adc 2 max volts  0.000 volts         [D4]
189 adc 2 destination-1                 [97]
190 !adc 2 raw value 0.004 volts         [CD]
191 !adc 2 value    0.00  %              [7D]
192 adc 3 select      VOLTS             [64]
193 adc 3 set  DISABLED                 [17]
194 adc 3 min  0.00  %                   [73]
195 adc 3 max  0.00  %                   [70]
196 adc 3 min volts  0.000 volts         [D6]
197 adc 3 max volts  0.000 volts         [D3]
198 adc 3 destination-1                 [96]
199 !adc 3 raw value 0.004 volts         [C3]
200 !adc 3 value    0.00  %              [85]
201 dac clock level  DRIVE CLOCK        [AE]
202 dac 1 select      TORQUE CMD        [32]
203 dac 1 ptr  28965                    [41]
204 dac 1 item 0                    [C5]
205 dac 1 mul  1                      [24]
206 dac 1 div  1                      [2E]
207 dac 1 abs  DISABLE                 [77]
208 !dac 1 output    0.000 volts         [A8]
209 dac 2 select      UPID VEL FBK      [D2]
210 dac 2 ptr  26033                    [52]
211 dac 2 item 0                    [C6]
212 dac 2 mul  32767                    [4D]
213 dac 2 div  349525                  [24]
214 dac 2 abs  DISABLE                 [78]
215 !dac 2 output    0.000 volts         [A9]
216 level 1 password 0                    [0E]
217 level 2 password 0                    [0C]
218 level 3 password 0                    [0A]
219 lockout time     900.000    sec      [D5]
220 !lockout status  UNLOCKED           [04]
221 ssi rx mode DISABLED                 [E8]
222 !ssi rx value    0                    [56]
223 ssi torque offset0.00  %            [A3]
224 ssi tx mode DISABLED                 [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	13		[DD]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	REV		[92]	
238	console vel units	MINUTES			[64]
239	porta protocol	ESP		[75]	
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	13		[AA]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	86.45 amps rms			[84]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	656 volts		[DE]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.14 amps rms			[81]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	0.00 ftlb		[5E]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms			[F4]
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	-0.01 hp		[98]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000001 \$			[0B]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000000 \$			[1B]
282	!int word 0	000000 \$			[9B]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	1200.0	rpm	[6A]
308	test id min rpm	0.0	rpm	[DB]
309	test jog rpm	200.0	rpm	[69]
310	test max rpm	900.0	rpm	[64]
311	test min rpm	-900.0	rpm	[38]
312	test period	0.000	sec	[B1]
313	test ramp	DISABLE		[B8]
314	test position	10.000	rev	[7A]
315	test time	1.000	sec	[81]
316	test torque	20	%	[32]
317	test degrees	180.00	deg	[22]
318	test i field	0.00	amps rms	[E9]
319	test volts	0	volts	[B6]
320	test length	24.0001	in	[B0]
321	test accel time	4.000	sec	[69]
322	test freq ramp time	6.000	sec	[E0]
323	test adc	1		[02]
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL	1	[3F]
328	vel slv select	ADC	1	[C1]
329	min cruise vel	0.0	fpm	[0E]
330	vel preset 1	0.0	fpm	[21]
331	vel preset 2	1035.0	fpm	[86]
332	vel preset 3	0.0	fpm	[1D]
333	vel preset 4	0.0	fpm	[1B]
334	vel preset 5	0.0	fpm	[19]
335	vel preset 6	0.0	fpm	[17]
336	vel preset 7	0.0	fpm	[15]
337	vel preset 8	0.0	fpm	[13]
338	vel offset	0.0	fpm	[76]
339	vel gain	100.00	%	[EA]
340	vel tolerance	0.0	fpm	[47]

```

341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source DISABLED [6F]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd DISABLE [FF]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select VEL SELECT [AB]
367 vel ovrd vel 0.0 fpm [D9]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 0 rpm [3C]
371 bus reg tol time 5 secs [6F]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 5.000 gain [0D]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 20 % [B2]
376 rpm fwd shutoff 3700 rpm [4B]
377 rpm rev shutoff -3700 rpm [11]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode COAST [F1]
380 inj brake pct 0 % [16]
381 inj brake time 0.000 sec [D9]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

```

399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON		[42]
401	auto req	REQ FORCED ON	[A5]	
402	auto run req	REQ FORCED ON		[2F]
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ FORCED ON		[7B]
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ FORCED OFF		[16]
412	decelerate req	REQ FORCED OFF		[10]
413	speed adjust req	REQ FORCED OFF		[61]
414	resume req	REQ FORCED OFF	[8B]	
415	manual req	REQ FORCED OFF	[9D]	
416	accel 1 req	REQ FORCED OFF	[D1]	
417	track ref req	REQ FORCED OFF		[A7]
418	inj brake req	REQ FORCED OFF		[B2]
419	motor thermal ok req	REQ FORCED ON		[1D]
420	motor blower ok req	REQ FORCED ON		[87]
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF		[64]
434	!torque limit sts	OUT ON	[09]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF		[2C]
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	STS DISABLED	[21]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	RETURN WATER PUMP		[4F]
479	allow pend reverse	DISABLE		[39]
480	torque mode enable	DISABLE		[57]
481	torq override enable	DISABLE		[75]
482	pend max torq	50.00 % rtd	[C0]	
483	pend max vel	150.0 fpm	[89]	
484	pend index pos	180.0000 in		[84]
485	pend index vel	150.0 fpm	[B5]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	945.0 fpm	[6F]	
488	comp index pos	0.0000 in		[E1]
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word192		[29]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0		[24]
494	!comp handshake ctr p	0		[72]
495	payout distance	0.0000 in		[2F]
496	payout preset	0.0000 in		[E6]
497	!index start pos	0.0000 in		[41]
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain		[2B]
503	!smooth hose tension	0.00 lb		[05]
504	target hose load %	25 %		[53]
505	cable filter gain	0.97000 gain		[E0]
506	!smooth cable tension	0.00 lb		[BA]
507	fine control gain	0.0000 in/sec/lb		[59]
508	!actual fine control	0.0000 in/sec/lb		[5C]
509	fade filter gain	0.97000 gain		[43]
510	hose tension offset	0.00 lb		[3B]
511	cable tension offset	0.00 lb		[F2]
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in		[47]
514	coil max od	0.0000 in		[44]

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0002	in	[8C]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	575	volts rms	[8C]		
536	hi-spd line low limt	575	volts rms	[95]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
547	Mode	Computer Control		[5E]		
548	Start	DISABLE	[30]			
549	1 bit pump	ENABLE	[18]			
900	!FH 1 11011017	EXTERNAL TRIP	[EC]	\$	11/Jan/2010	
	14:15:52	Fault				
901	!FH 2 05011020	OVERSPEED TRIP	[A3]	\$	05/Jan/2010	
	09:52:21	Fault				
902	!FH 3 05011020	OVERSPEED TRIP	[A1]	\$	05/Jan/2010	
	09:05:35	Fault				
903	!FH 4 05011020	OVERSPEED TRIP	[9F]	\$	05/Jan/2010	
	09:00:22	Fault				
904	!FH 5 05011020	OVERSPEED TRIP	[9D]	\$	05/Jan/2010	
	08:47:25	Fault				
905	!FH 6 05011020	OVERSPEED TRIP	[9B]	\$	05/Jan/2010	
	08:41:26	Fault				
906	!FH 7 05011020	OVERSPEED TRIP	[99]	\$	05/Jan/2010	
	08:39:09	Fault				
907	!FH 8 05011020	OVERSPEED TRIP	[97]	\$	05/Jan/2010	
	08:38:29	Fault				
908	!FH 9 05011020	OVERSPEED TRIP	[95]	\$	05/Jan/2010	
	08:37:44	Fault				
909	!FH10 05011020	OVERSPEED TRIP	[8C]	\$	05/Jan/2010	
	08:37:06	Fault				
910	!FH11 05011005	FAST OVERCURRENT	[EF]	\$	05/Jan/2010	
	08:34:49	Fault				



911	!FH12 22120917	external trip	[4C]	\$	22/Dec/2009
	09:16:16	Fault			
912	!FH13 20120917	external trip	[4C]	\$	20/Dec/2009
	03:57:21	Fault			
913	!FH14 17120906	HS THERMAL SWITCH	[CE]	\$	17/Dec/2009
	13:05:49	Fault			
914	!FH15 17120906	HS THERMAL SWITCH	[CC]	\$	17/Dec/2009
	13:05:49	Fault			
915	!FH16 17120906	HS THERMAL SWITCH	[CA]	\$	17/Dec/2009
	13:05:49	Fault			
916	!FH17 17120906	HS THERMAL SWITCH	[C8]	\$	17/Dec/2009
	13:05:48	Fault			
917	!FH18 17120906	HS THERMAL SWITCH	[C6]	\$	17/Dec/2009
	13:05:18	Fault			
918	!FH19 16120917	external trip	[3B]	\$	16/Dec/2009
	03:15:49	Fault			
919	!FH20 16120917	external trip	[42]	\$	16/Dec/2009
	02:38:22	Fault			
920	!FH21 11120917	external trip	[4E]	\$	11/Dec/2009
	07:34:17	Fault			
921	!FH22 06120917	external trip	[48]	\$	06/Dec/2009
	08:11:11	Fault			
922	!FH23 06120920	OVERSPEED TRIP	[82]	\$	06/Dec/2009
	05:54:07	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled

```

\$ sync data error 1 - Enabled  
\$ bus reg toll 1 - Enabled  
\$ unknown fbk module 1 - Enabled  
\$ torque reg error 1 - Enabled  
\$ communication error 1 - Enabled  
\$ ehalt fault1 - Enabled  
\$ motor thermal switch 1 - Enabled  
\$ motor blower off 1 - Enabled  
\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ user fault 7 req 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled

\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:

\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ user fault 7 req 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled

```
$ user fault 18 req0 - Disabled
$ user fault 19 req0 - Disabled
$ user fault 20 req0 - Disabled
$ user fault 21 req0 - Disabled
$ user fault 22 req0 - Disabled
$ user fault 23 req0 - Disabled
$ user fault 24 req0 - Disabled
$ user fault 25 req0 - Disabled
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

\$This file was created by UEdit Version 300(804758.300).

\$BEGIN

\$ Application:804932.408

\$ OS:809800.370

\$ 2010/01/20 02:17:46

DATA\_START

UNITS 2 [29]

0	unit system	ENGLISH	[14]
1	position units	IN MM	[89]
2	velocity units	SECONDS	[D0]
3	hertz units	DISABLE	[2C]
4	clock frequency	50 hertz	[0F]
5	drive multiple	1	[C7]
6	upid multiple	10	[FE]
7	ac multiple 2	[1A]	
8	ac fast multiple	1	[4C]
9	vector source	MOTOR SOCKET	[DC]
10	upid motor source	MOTOR SOCKET	[44]
11	upid load source	LOAD SOCKET	[45]
12	load vector control	DISABLE	[08]
13	transducerless	ENABLE	[D6]
14	motor fbk size	2048 pulses/rev	[29]
15	motor resolution	0.1504 in/rev	[4D]
16	motor fbk invert	DISABLE	[3C]
17	motor input teeth 1	[7F]	
18	motor output teeth	1	[FD]
19	motor encoder bits	BITS 0	[E4]
20	motor encoder turns	1	[B3]
21	load fbk size	0 pulses/rev	[5A]
22	load resolution	10.0000 in/rev	[B9]
23	load fbk invert	DISABLE	[CF]
24	load input teeth 1	[12]	
25	load output teeth 1	[90]	
26	load encoder bits	BITS 0	[77]
27	load encoder turns	1	[3D]
28	motor rated voltage	460 volts	[24]
29	motor rated current	6.20 amps rms	[FB]
30	motor rated frequency	60 hertz	[8A]
31	maximum current	28.00 amps rms	[33]
32	current limit	28.00 amps rms	[11]
33	motor rms limit	6.20 amps rms	[A2]
34	current rate limit	0 amps pk/sec	[18]
35	field current	2.03 amps rms	[5E]
36	field boost 200	% [68]	
37	slip frequency	1.500 hertz	[9E]
38	motor poles	4 [C0]	
39	synchronous motor	DISABLE	[57]
40	vector offset	0.00 deg	[47]
41	vector ffwd	0.00000 sec	[8B]
42	torque ffwd	0.00 deg [18]	
43	stator resistance	Rs 1.4211 ohms	[BB]
44	leakage Sigma	Ls 0.02978 henries	[5B]
45	Lm squared over Lr	0.32388 henries	[8E]
46	current filter	2.00 hertz	[D3]
47	voltage filter	2.00 hertz	[E3]
48	power filter	2.00 hertz	[A7]
49	motor rtd torque	17.02 ftlb	[6B]
50	motor max torque	81.23 ftlb	[73]

51	motor rtd power	5.69 hp	[DB]
52	motor max power	27.14 hp	[B4]
53	motor kt	2.911 ftlb/amp	[2B]
54	motor inertia	0.000 ftlbs^2	[94]
55	machine inertia	0.026 ftlbs^2	[E7]
56	acc obs bandwidth	40 rad/sec	[03]
57	system gain id	121.451 1/sec/sec	[B5]
58	system gain	121.451 1/sec/sec	[A1]
59	system wn	10.0 rad/sec	[5B]
60	system order	VELOCITY	[1D]
61	kv cmd	0.000 upid gain	[D8]
62	kp cmd	0.823 upid gain	[D0]
63	ki	0.0 upid gain	[97]
64	kp fbk	0.823 upid gain	[CF]
65	kv fbk	0.143 upid gain	[CD]
66	kr	1.000 upid gain	[2A]
67	kp cmd percent	0 %	[D1]
68	ki load enable	DISABLE	[56]
69	kp load ratio	0 %	[35]
70	kv load ratio	0 %	[37]
71	torque limit	100.00 % max	[E2]
72	low pass frequency	100.0 hertz	[33]
73	low pass damping	1.414 gain	[A9]
74	notch frequency	0.0 hertz	[9F]
75	notch damping	1.414 gain	[B4]
76	system gain 1	121.451 1/sec/sec	[50]
77	system wn 1	18.0 rad/sec	[02]
78	system order 1	TORQUE	[52]
79	kv cmd 1	0.000 upid gain	[7E]
80	kp cmd 1	0.148 upid gain	[7F]
81	ki 1	0.0 upid gain	[46]
82	kp fbk 1	0.148 upid gain	[7E]
83	kv fbk 1	0.000 upid gain	[84]
84	kr 1	0.000 upid gain	[DA]
85	kp cmd percent 1	0 %	[80]
86	ki load enable 1	DISABLE	[05]
87	kp load ratio 1	0 %	[E4]
88	kv load ratio 1	0 %	[DD]
89	torque limit 1	100.00 % max	[88]
90	low pass frequency 1	100.0 hertz	[E2]
91	low pass damping 1	1.414 gain	[58]
92	notch frequency 1	10.0 hertz	[4E]
93	notch damping 1	1.414 gain	[63]
94	torque invert	DISABLE	[1A]
95	base rpm	1755 rpm	[3A]
96	max vel	50.0 fpm	[B1]
97	jog vel	50.0 fpm	[B6]
98	!max motor rpm	3989.3 rpm	[AE]
99	accel time	2.000 sec	[6F]
100	decel time	2.000 sec	[4B]
101	jerk time	0.000 sec	[9D]
102	settle time	0.200 sec	[B5]
103	accel time 1	1.000 sec	[FD]
104	decel time 1	1.000 sec	[F7]
105	jerk time 1	10.000 sec	[48]
106	settle time 1	0.200 sec	[60]
107	fast decel time	0.200 sec	[76]
108	drive invert	ENABLE	[C1]

109	!motor vel 0.0	fpm	[AF]	
110	inv thermal warning	80.0 %	[E6]	
111	motor rms warning	80.0 %	[9C]	
112	modulation select	DIGITAL	[65]	
113	switch frequency	6000 hertz	[C7]	
114	thermal protection	STANDARD	[78]	
115	dsv synchronized	DISABLE	[BB]	
116	dsv wn	200.0 rad/sec	[58]	
117	dsv vphz wn	10.0 rad/sec	[A0]	
118	dsv kv percent	85.00 %	[BA]	
119	dsv kp cmd percent	100 %	[D5]	
120	dsv kp cmd	0.366 gain	[08]	
121	dsv ki	36.622 gain	[2E]	
122	dsv kp fbk	0.366 gain	[07]	
123	dsv deadtime percent	25 %	[F6]	
124	dsv v boost	0 %	[BD]	
125	dsv bus correction	DISABLE	[38]	
126	acr i loop	5.000 acr gain	[B9]	
127	acr v ffwd	1.000 acr gain	[C2]	
128	acr field i loop	40.000 acr gain	[64]	
129	acr field v ffwd	1.000 acr gain	[9C]	
130	dbm const switch freq	ENABLE	[9E]	
131	dbm pulses	4	[1B]	
132	dbm min vel	5.0 hertz	[7F]	
133	dbm volts per hertz	8.0	[67]	
134	dbm clamp voltage	0 volts	[61]	
135	dbm block modulation	30 % clamp	[CB]	
136	dbm run current limit	0.00 amps rms	[4E]	
137	dbm run limit gain	0.000 gain	[05]	
138	damping kp	0.00006 gain	[69]	
139	damping max	1000.00 ftlb	[F9]	
140	damping min freq	20.0 hertz	[3F]	
141	damping max freq	90.0 hertz	[35]	
142	vbus reg filter	300.00 hertz	[2A]	
143	vbus filter	0.80 hertz	[E2]	
144	vbus notch frequency	0.0 hertz	[91]	
145	vbus notch damping	1.414 gain	[A6]	
146	vbus kp	3.000 gain	[ED]	
147	vbus ki	3.000 gain	[F3]	
148	vbus window shift	-1.22 volts	[58]	
149	vbus dac limit	10.00 volts	[C7]	
150	db watts	405 watts	[58]	
151	db resistance	138.900 ohms	[0B]	
152	db time constant	25 secs	[07]	
153	!db percent used	0 %	[1C]	
154	flux control	CLOSED LOOP	[45]	
155	flux cutoff min	10.0 rad/sec	[0E]	
156	flux cutoff max	20.0 rad/sec	[0A]	
157	flux kp	1.000 gain	[EE]	
158	flux id obs bandwidth	50 rad/sec	[4A]	
159	torq est filter	0.01000 sec	[D2]	
160	torq reg select	DISABLED	[40]	
161	torq reg wn	0.0 rad/sec	[E3]	
162	torq reg kp cmd pct	0 %	[0B]	
163	torq reg kp cmd	0.000 gain	[39]	
164	torq reg ki	0.00 gain	[C3]	
165	torq reg kp fbk	0.000 gain	[38]	
166	coulomb torque	0.00 ftlb	[1F]	



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167 friction deadzone100.0 rpm          [2F]
168 dac offset iu      -12 pulses        [3B]
169 dac offset iv      -82 pulses        [32]
170 adc offset iu       7 pulses         [9B]
171 adc offset iv      -58 pulses        [36]
172 adc offset fu       15 pulses        [6D]
173 adc offset fv      -35 pulses        [3C]
174 adc 1 select        VELOCITY         [8F]
175 adc 1 set          DISABLED          [19]
176 adc 1 min          0.00 %            [75]
177 adc 1 max          500.00 %          [0D]
178 adc 1 min volts    0.014 volts       [D3]
179 adc 1 max volts    9.770 volts       [BE]
180 adc 1 destination-1
181 !adc 1 raw value   0.009 volts       [C9]
182 !adc 1 value        -0.22 %          [4D]
183 adc 2 select        VOLTS            [65]
184 adc 2 set          DISABLED          [18]
185 adc 2 min          0.00 %            [74]
186 adc 2 max          0.00 %            [71]
187 adc 2 min volts    0.000 volts       [D7]
188 adc 2 max volts    0.000 volts       [D4]
189 adc 2 destination-1
190 !adc 2 raw value   0.004 volts       [CD]
191 !adc 2 value        0.00 %           [7D]
192 adc 3 select        VOLTS            [64]
193 adc 3 set          DISABLED          [17]
194 adc 3 min          0.00 %            [73]
195 adc 3 max          0.00 %            [70]
196 adc 3 min volts    0.000 volts       [D6]
197 adc 3 max volts    0.000 volts       [D3]
198 adc 3 destination-1
199 !adc 3 raw value   0.004 volts       [C3]
200 !adc 3 value        0.00 %           [85]
201 dac clock level    DRIVE CLOCK       [AE]
202 dac 1 select        TORQUE CMD        [32]
203 dac 1 ptr          28965             [41]
204 dac 1 item          0                 [C5]
205 dac 1 mul           1                 [24]
206 dac 1 div           1                 [2E]
207 dac 1 abs          DISABLE           [77]
208 !dac 1 output       0.000 volts       [A8]
209 dac 2 select        UPID VEL FBK      [D2]
210 dac 2 ptr          26033             [52]
211 dac 2 item          0                 [C6]
212 dac 2 mul           32767            [4D]
213 dac 2 div           278872           [1E]
214 dac 2 abs          DISABLE           [78]
215 !dac 2 output       0.000 volts       [A9]
216 level 1 password    1111             [7A]
217 level 2 password    0                 [0C]
218 level 3 password    0                 [0A]
219 lockout time        900.000          sec [D5]
220 !lockout status     LEVEL 3           [8E]
221 ssi rx mode         DISABLED          [E8]
222 !ssi rx value        0                 [56]
223 ssi torque offset   0.00 %           [A3]
224 ssi tx mode         DISABLED          [E3]

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225	!ssi tx value	0		[51]	
226	ssi position lock	DISABLE			[98]
227	ssi tx clock	DISABLE			[BD]
228	rtc source	INTERNAL		[E0]	
229	ssi rx error limit	0			[24]
230	term type	RCA	[CE]		
231	console protocol	MODBUS RTU			[B3]
232	console baud rate	38400 BAUD			[66]
233	console parity	NONE		[3F]	
234	console address	17		[D9]	
235	console checksum	BCC		[0B]	
236	console units	ENGLISH			[E8]
237	console pos units	IN MM		[2E]	
238	console vel units	SECONDS			[7A]
239	porta protocol	OPTOMUX			[21]
240	porta baud rate	19200 BAUD			[37]
241	porta parity	NONE		[0D]	
242	porta stop bits	STOP 1			[A6]
243	porta address	0		[DE]	
244	porta checksum	BCC		[D8]	
245	porta units	ENGLISH		[B5]	
246	porta pos units	IN MM		[FB]	
247	porta vel units	SECONDS			[47]
248	optomux bits dev	BITS 32			[31]
249	optomux num devices	1			[74]
250	optomux output 0	0		[CF]	
251	optomux output 1	65535		[F5]	
252	optomux retries	3		[CD]	
253	optomux timeout	1.000 sec		[CC]	
254	optomux wd time	5.000 sec		[24]	
255	!motor rpm	0.0 rpm	[99]		
256	!max current	18.62 amps rms			[8A]
257	!torque cmd	0.00 % max	[D7]		
258	!bus voltage	665 volts		[DE]	
259	!max bus voltage	1011 volts		[55]	
260	!armature voltage	0 volts		[3F]	
261	!max voltage	0 volts		[59]	
262	!field voltage	0 volts		[9A]	
263	!motor thermal rms	0.06 amps rms			[80]
264	!torque est command	0.00 ftlb		[A5]	
265	!torque est feedback	-0.01 ftlb		[30]	
266	!load power	0.00 hp	[91]		
267	!motor power	0.00 hp		[FF]	
268	!motor current	0.00 amps rms			[DD]
269	!motor voltage	0 volts rms		[F4]	
270	!maximum voltage	460 volts rms			[C5]
271	!inverter power	0.00 hp		[C6]	
272	!command vel	0.0 fpm		[00]	
273	!feedback vel	0.0 fpm		[B9]	
274	!command pos	0.0000 in			[CF]
275	!feedback pos	0.0000 in			[88]
276	!in word 0	000041 \$			[07]
277	!out word 0	000000 \$			[8A]
278	!sin word 0	000000 \$			[97]
279	!sin word 1	000000 \$			[95]
280	!sout word 0	000000 \$			[1D]
281	!sout word 1	000001 \$			[1A]
282	!int word 0	000a00 \$			[6A]

283	!int word 1	000000	\$	[99]
284	!int word 2	000000	\$	[97]
285	!int word 3	000000	\$	[95]
286	hardware mask	4280287231		[14]
287	hardware warning mask	0		[D2]
288	hardware event mask	0		[A5]
289	!hardware faults	0		[E2]
290	!hardware warnings	0		[10]
291	!hardware latch	0		[6C]
292	!hardware unmasked	0		[1F]
293	software mask	4294965951		[E8]
294	software warning mask	0		[B7]
295	software event mask	0		[8A]
296	!software faults	0		[C7]
297	!software warnings	0		[EC]
298	!software latch	0		[48]
299	!software unmasked	0		[FB]
300	user mask	4294967295		[9C]
301	user warning mask	0		[6E]
302	user event mask	0		[41]
303	!user faults	0		[7E]
304	!user warnings	0		[A3]
305	!user latch	0	[FF]	
306	!user unmasked	0		[B2]
307	test cycle rpm	1000.0	rpm	[6C]
308	test id min rpm	0.0	rpm	[DB]
309	test jog rpm	1000.0	rpm	[3A]
310	test max rpm	900.0	rpm	[64]
311	test min rpm	-900.0	rpm	[38]
312	test period	0.000	sec	[B1]
313	test ramp	DISABLE		[B8]
314	test position	10.000	rev	[7A]
315	test time	1.000	sec	[81]
316	test torque	90	%	[2B]
317	test degrees	180.00	deg	[22]
318	test i field	0.00	amps rms	[E9]
319	test volts	0	volts	[B6]
320	test length	24.0000	in	[B1]
321	test accel time	4.000	sec	[69]
322	test freq ramp time	6.000	sec	[E0]
323	test adc	1		[02]
324	!display count	0		[AA]
325	!display flag	0		[38]
326	vel selection	INTERNAL		[AE]
327	vel mstr select	PRESET VEL 1		[3F]
328	vel slv select	ADC 1		[C1]
329	min cruise vel	0.0	fpm	[0E]
330	vel preset 1	0.0	fpm	[21]
331	vel preset 2	0.0	fpm	[1F]
332	vel preset 3	0.0	fpm	[1D]
333	vel preset 4	0.0	fpm	[1B]
334	vel preset 5	0.0	fpm	[19]
335	vel preset 6	0.0	fpm	[17]
336	vel preset 7	0.0	fpm	[15]
337	vel preset 8	0.0	fpm	[13]
338	vel offset	0.0	fpm	[76]
339	vel gain	100.00	%	[EA]
340	vel tolerance	0.0	fpm	[47]

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341 torque offset enable AUTO PERMISSIVE [0D]
342 torque offset 0.00 % max [AA]
343 torque offset rate 0.000 sec [FD]
344 offset rate select BOTH [18]
345 preset upr torq lmt 100.00 % max [30]
346 preset lwr torq lmt -100.00 % max [04]
347 upr torq lmt rate0.000 sec [96]
348 lwr torq lmt rate0.000 sec [97]
349 torque slave source TORQUE DATA [8D]
350 torque slave data0.00 % max [5D]
351 track enable DISABLE [AA]
352 track source MOTOR SOCKET [F9]
353 track ref pos 0.0000 in [5F]
354 !track position 0.0000 in [77]
355 track preset pos 0.0000 in [07]
356 droop ref select DISABLED [DC]
357 droop ref torque 100.0 % [DF]
358 droop maximum 0.0 fpm [20]
359 droop start torque 0.0 % [4D]
360 droop filter tc 10.000 sec [1F]
361 !droop vel actual0.0 fpm [22]
362 offset vel err tol 0.0 fpm [A1]
363 offset filter tc 2.000 sec [E8]
364 torq slave vel ovrd ENABLE [4C]
365 vel ovrd torq thrsh 0.00 % max [9B]
366 vel ovrd select OVERRIDE VEL [5D]
367 vel ovrd vel 4.0 fpm [D5]
368 bus reg ENABLE [E3]
369 bus reg min vel 50 rpm [0A]
370 bus reg tol vel 50 rpm [07]
371 bus reg tol time 1 secs [73]
372 bus reg kp 2.000 gain [05]
373 bus reg kd 0.000 gain [12]
374 bus reg upper lmt758 volts [F8]
375 bus reg torq lmt 100 % [83]
376 rpm fwd shutoff 2700 rpm [4C]
377 rpm rev shutoff -2700 rpm [12]
378 ssi data req vel 0.0 fpm [88]
379 drive stop mode INJ BRAKE [05]
380 inj brake pct 50 % [E1]
381 inj brake time 1.000 sec [D8]
382 magnet flux0.0000 Wb [04]
383 ext trip ENABLE [5E]
384 !motor socket vel0.0 fpm [01]
385 !motor socket pos0.0000 in [D1]
386 !load socket vel 0.0 fpm [90]
387 !load socket pos 0.0000 in [60]
388 !follow socket vel 0.0 fpm [9B]
389 !follow socket pos 0.0000 in [6B]
390 !main stateMAIN USER STATE [0B]
391 !application state MOTOR OFF WAIT [5F]
392 motor on req REQ PLC [B8]
393 motor on enable req REQ FORCED ON [9F]
394 fault reset req REQ PLC [85]
395 warning reset reqREQ PLC [AA]
396 jog fwd reqREQ PLC [41]
397 jog rev reqREQ PLC [34]
398 fast stop req REQ FORCED ON [BB]

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399	ehalt req	REQ FORCED ON	[40]	
400	motion enable req	REQ FORCED ON	[42]	
401	auto req	REQ PLC	[36]	
402	auto run req	REQ PLC	[C0]	
403	vel slave req	REQ PLC	[6B]	
404	torque offset req	REQ PLC	[A5]	
405	torque limit req	REQ PLC	[0C]	
406	torque slave req	REQ PLC	[0F]	
407	vel select 0 req	REQ PLC	[B2]	
408	vel select 1 req	REQ PLC	[B0]	
409	vel select 2 req	REQ PLC	[AE]	
410	vel select 3 req	REQ PLC	[B5]	
411	accelerate req	REQ PLC	[E5]	
412	decelerate req	REQ PLC	[DF]	
413	speed adjust req	REQ PLC	[30]	
414	resume req	REQ PLC	[5A]	
415	manual req	REQ PLC	[6C]	
416	accel 1 req	REQ PLC	[A0]	
417	track ref req	REQ PLC	[76]	
418	inj brake req	REQ PLC	[81]	
419	motor thermal ok req	REQ FORCED ON	[1D]	
420	motor blower ok req	REQ FORCED ON	[87]	
421	!motor on sts	OUT OFF	[80]	
422	!no fault sts	OUT ON	[D2]	
423	!no warning sts	OUT ON	[F7]	
424	!manual sts	OUT OFF	[2D]	
425	!auto sts	OUT OFF	[F1]	
426	!motion sts	OUT ON	[51]	
427	!fwd motion sts	OUT OFF	[B1]	
428	!rev motion sts	OUT OFF	[A4]	
429	!at zero vel sts	OUT ON	[C8]	
430	!at req vel sts	OUT OFF	[0A]	
431	!at max vel sts	OUT OFF	[0B]	
432	!vel slave sts	OUT OFF	[2A]	
433	!torque offset sts	OUT OFF	[64]	
434	!torque limit sts	OUT OFF	[CB]	
435	!torque slave sts	OUT OFF	[CE]	
436	!track preset sts	OUT OFF	[E0]	
437	!motor rms warn sts	OUT OFF	[2C]	
438	!thermal warn sts	OUT OFF	[E1]	
439	!dc field on sts	OUT OFF	[BD]	
440	out 0	MOTOR ON STS	[0B]	
441	out 1	STS DISABLED	[1F]	
442	out 2	STS DISABLED	[1D]	
443	out 3	STS DISABLED	[1B]	
444	out 4	STS DISABLED	[19]	
445	out 5	STS DISABLED	[17]	
446	sout 0	STS DISABLED	[A8]	
447	sout 1	STS DISABLED	[A6]	
448	sout 2	STS DISABLED	[A4]	
449	sout 3	STS DISABLED	[A2]	
450	sout 4	STS DISABLED	[A9]	
451	sout 5	STS DISABLED	[A7]	
452	sout 6	STS DISABLED	[A5]	
453	sout 7	STS DISABLED	[A3]	
454	sout 8	STS DISABLED	[A1]	
455	sout 9	STS DISABLED	[9F]	
456	sout 10	STS DISABLED	[76]	

457	sout 11	STS DISABLED		[74]
458	sout 12	STS DISABLED		[72]
459	sout 13	STS DISABLED		[70]
460	sout 14	STS DISABLED		[77]
461	sout 15	STS DISABLED		[75]
462	sout 16	STS PLC	[CC]	
463	sout 17	STS PLC	[CA]	
464	sout 18	STS PLC	[C8]	
465	sout 19	STS PLC	[C6]	
466	sout 20	STS PLC	[CD]	
467	sout 21	STS PLC	[CB]	
468	sout 22	STS PLC	[C9]	
469	sout 23	STS PLC	[C7]	
470	sout 24	STS PLC	[CE]	
471	sout 25	STS PLC	[CC]	
472	sout 26	STS PLC	[CA]	
473	sout 27	STS PLC	[C8]	
474	sout 28	STS PLC	[C6]	
475	sout 29	STS PLC	[C4]	
476	sout 30	STS PLC	[CB]	
477	sout 31	STS PLC	[C9]	
478	drive type	TOWER HOIST	[FC]	
479	allow pend reverse	ENABLE		[86]
480	torque mode enable	DISABLE		[57]
481	torq override enable	ENABLE		[C2]
482	pend max torq	80.00 % rtd	[BD]	
483	pend max vel	25.0 fpm	[B8]	
484	pend index pos	36.0000 in	[B4]	
485	pend index vel	30.0 fpm	[E8]	
486	comp req torq	0.00 % rtd	[E7]	
487	comp req vel	0.0 fpm	[E1]	
488	comp index pos	0.0000 in	[E1]	
489	comp index vel	0.0 fpm	[0F]	
490	comp request word0		[52]	
491	!comp status word128		[2A]	
492	comp timeout	0.000 sec	[35]	
493	comp handshake ctr	0	[24]	
494	!comp handshake ctr p	0	[72]	
495	payout distance	0.0000 in	[2F]	
496	payout preset	0.0000 in	[E6]	
497	!index start pos	0.0000 in	[41]	
498	!tension error	0.00 lb	[37]	
499	!tgt hose tension	0.00 lb	[42]	
500	!hose tension	0.00 lb	[C2]	
501	!cable tension	0.00 lb	[79]	
502	hose filter gain	0.97000 gain	[2B]	
503	!smooth hose tension	0.00 lb	[05]	
504	target hose load %	25 %	[53]	
505	cable filter gain	0.97000 gain	[E0]	
506	!smooth cable tension	0.00 lb	[BA]	
507	fine control gain	0.0000 in/sec/lb	[59]	
508	!actual fine control	0.0000 in/sec/lb	[5C]	
509	fade filter gain	0.97000 gain	[43]	
510	hose tension offset	0.00 lb	[3B]	
511	cable tension offset	0.00 lb	[F2]	
512	!hose load fbk	0 %	[03]	
513	coil min od	0.0000 in	[47]	
514	coil max od	0.0000 in	[44]	

515	coil diameter	0.0000	in	[31]		
516	!coil circumference	0.0000	in	[FF]		
517	coil usage	0.0	ft	[F2]		
518	coil source	MOTOR SOCKET		[63]		
519	material source	MOTOR SOCKET		[BA]		
520	coil od limit	DISABLE		[6F]		
521	coil od rate	0.0000	in	[E0]		
522	coil update distance	2.0000	in	[8E]		
523	level direction	NONE		[10]		
524	!level drum velocity	0.0	rpm	units:10	[ED]	
525	level follow gain	0.000	gain	[20]		
526	!level follow vel	0.0	fpm	[12]		
527	!level follow req vel	0.0	fpm	[A9]		
528	level follow vel off	0.0	fpm	[D6]		
529	level circumference	3.6000	in	[A2]		
530	level dwell count	0		[72]		
531	!level circ count	0		[C7]		
532	!index pos	0.0000	in	[99]		
533	!drive control mode	NONE		[E7]		
534	pend disable time	0.000	sec	[A4]		
535	lo-spd line low limt	600	volts rms	[97]		
536	hi-spd line low limt	600	volts rms	[A0]		
537	high-low vel cutoff	0	rpm	[88]		
538	additional hose load	0.00	lb	[FF]		
539	payout at drum	0.0000	in	[CE]		
540	payout at tower	0.0000	in	[5D]		
541	drum payout offset	0.0000	in	[23]		
542	tower payout offset	0.0000	in	[A9]		
543	Hose Max Load	0.00	lb	[36]		
544	Hose Min Load	0.00	lb	[37]		
545	Cable Max Load	0.00	lb	[EC]		
546	Cable Min Load	0.00	lb	[ED]		
900	!FH 1 20011007	BUS UNDERVOLTAGE		[15]	\$	20/Jan/2010
	21:20:03	Fault				
901	!FH 2 20011017	EXTERNAL TRIP		[EA]	\$	20/Jan/2010
	14:23:32	Fault				
902	!FH 3 20011017	EXTERNAL TRIP		[E8]	\$	20/Jan/2010
	11:40:46	Fault				
903	!FH 4 20011017	EXTERNAL TRIP		[E6]	\$	20/Jan/2010
	10:28:19	Fault				
904	!FH 5 20011017	EXTERNAL TRIP		[E4]	\$	20/Jan/2010
	10:27:37	Fault				
905	!FH 6 20011017	EXTERNAL TRIP		[E2]	\$	20/Jan/2010
	10:25:51	Fault				
906	!FH 7 20011014	IREG SHUTOFF		[3F]	\$	20/Jan/2010
	10:25:51	Fault				
907	!FH 8 18011017	EXTERNAL TRIP		[D7]	\$	18/Jan/2010
	17:11:15	Fault				
908	!FH 9 18011017	EXTERNAL TRIP		[D5]	\$	18/Jan/2010
	16:02:51	Fault				
909	!FH10 18011023	BUS REG TOL		[9A]	\$	18/Jan/2010 05:15:38
		Fault				
910	!FH11 15011017	EXTERNAL TRIP		[D6]	\$	15/Jan/2010
	22:54:43	Fault				
911	!FH12 15011020	OVERSPEED TRIP		[90]	\$	15/Jan/2010
	19:59:35	Fault				
912	!FH13 15011017	EXTERNAL TRIP		[D2]	\$	15/Jan/2010
	12:57:57	Fault				

913	!FH14 15011017	EXTERNAL TRIP	[D0]	\$	15/Jan/2010
	11:22:01	Fault			
914	!FH15 15011017	EXTERNAL TRIP	[CE]	\$	15/Jan/2010
	11:21:44	Fault			
915	!FH16 15011017	EXTERNAL TRIP	[CC]	\$	15/Jan/2010
	11:21:41	Fault			
916	!FH17 15011017	EXTERNAL TRIP	[CA]	\$	15/Jan/2010
	11:21:28	Fault			
917	!FH18 15011017	EXTERNAL TRIP	[C8]	\$	15/Jan/2010
	11:21:14	Fault			
918	!FH19 15011017	EXTERNAL TRIP	[C6]	\$	15/Jan/2010
	11:20:56	Fault			
919	!FH20 15011017	EXTERNAL TRIP	[CD]	\$	15/Jan/2010
	11:20:32	Fault			
920	!FH21 15011017	EXTERNAL TRIP	[D4]	\$	15/Jan/2010
	11:20:21	Fault			
921	!FH22 15011017	EXTERNAL TRIP	[D2]	\$	15/Jan/2010
	11:20:17	Fault			
922	!FH23 15011017	EXTERNAL TRIP	[D0]	\$	15/Jan/2010
	11:20:16	Fault			
923	!FH24 15011017	EXTERNAL TRIP	[CE]	\$	15/Jan/2010
	11:20:15	Fault			
924	!FH25 15011017	EXTERNAL TRIP	[CC]	\$	15/Jan/2010
	11:20:09	Fault			
925	!FH26 15011017	EXTERNAL TRIP	[CA]	\$	15/Jan/2010
	11:20:06	Fault			
926	!FH27 15011017	EXTERNAL TRIP	[C8]	\$	15/Jan/2010
	11:20:01	Fault			
927	!FH28 15011017	EXTERNAL TRIP	[C6]	\$	15/Jan/2010
	11:19:56	Fault			
928	!FH29 15011017	EXTERNAL TRIP	[C4]	\$	15/Jan/2010
	11:15:10	Fault			
929	!FH30 14011017	EXTERNAL TRIP	[CC]	\$	14/Jan/2010
	04:55:28	Fault			
930	!FH31 14011017	EXTERNAL TRIP	[D3]	\$	14/Jan/2010
	03:02:21	Fault			
931	!FH32 13011017	external trip	[52]	\$	13/Jan/2010
	22:30:39	Fault			
932	!FH33 13011020	OVERSPEED TRIP	[8C]	\$	13/Jan/2010
	07:28:49	Fault			
933	!FH34 13011017	EXTERNAL TRIP	[CE]	\$	13/Jan/2010
	04:02:20	Fault			
934	!FH35 12011017	EXTERNAL TRIP	[CD]	\$	12/Jan/2010
	11:19:28	Fault			
935	!FH36 12011017	EXTERNAL TRIP	[CB]	\$	12/Jan/2010
	10:12:24	Fault			
936	!FH37 12011017	EXTERNAL TRIP	[C9]	\$	12/Jan/2010
	08:55:14	Fault			
937	!FH38 12011017	EXTERNAL TRIP	[C7]	\$	12/Jan/2010
	08:53:30	Fault			
938	!FH39 12011017	EXTERNAL TRIP	[C5]	\$	12/Jan/2010
	08:53:27	Fault			
939	!FH40 12011017	EXTERNAL TRIP	[CC]	\$	12/Jan/2010
	08:53:22	Fault			
940	!FH41 12011020	OVERSPEED TRIP	[8F]	\$	12/Jan/2010
	08:53:11	Fault			
941	!FH42 12011020	OVERSPEED TRIP	[8D]	\$	12/Jan/2010
	08:50:17	Fault			



942	!FH43 11011017	EXTERNAL TRIP	[D0]	\$	11/Jan/2010
	14:16:20	Fault			
943	!FH44 10011017	EXTERNAL TRIP	[CF]	\$	10/Jan/2010
	23:29:25	Fault			
944	!FH45 08011017	external trip	[46]	\$	08/Jan/2010
	03:02:09	Fault			
945	!FH46 06011017	EXTERNAL TRIP	[C6]	\$	06/Jan/2010
	16:37:33	Fault			
946	!FH47 06011017	EXTERNAL TRIP	[C4]	\$	06/Jan/2010
	15:03:40	Fault			
947	!FH48 06011017	EXTERNAL TRIP	[C2]	\$	06/Jan/2010
	14:52:33	Fault			
948	!FH49 05011017	EXTERNAL TRIP	[C1]	\$	05/Jan/2010
	05:44:31	Fault			
949	!FH50 05011017	EXTERNAL TRIP	[C8]	\$	05/Jan/2010
	04:15:14	Fault			

```

$ Fault Masks:
$ bus overvoltage 1 - Enabled
$ AMB thermal switch 1 - Enabled
$ fast overcurrent 1 - Enabled
$ HS thermal switch1 - Enabled
$ gate driver dsat 1 - Enabled
$ ireg shutoff 1 - Enabled
$ low voltage supply 1 - Enabled
$ external trip 1 - Enabled
$ dynamic brake limit 1 - Enabled
$ watchdog timer 1 - Enabled
$ motor pg loss a 0 - Disabled
$ load pg loss a 1 - Enabled
$ motor marker 1 - Enabled
$ load marker1 - Enabled
$ overrun 1 - Enabled
$ motor rms limit 1 - Enabled
$ circuit breaker 1 - Enabled
$ pos error 0 - Disabled
$ bus undervoltage 1 - Enabled
$ motor fbk loss 0 - Disabled
$ load fbk loss 1 - Enabled
$ motor runaway 0 - Disabled
$ load runaway 1 - Enabled
$ non volatile mem 1 - Enabled
$ rtc takeover 1 - Enabled
$ fbk circuit breaker 1 - Enabled
$ ssi receive1 - Enabled
$ inverter rms 1 - Enabled
$ sync receive 1 - Enabled
$ armature curr error 1 - Enabled
$ field current loss 1 - Enabled
$ overspeed trip 1 - Enabled
$ sync data error 1 - Enabled
$ bus reg toll - Enabled
$ unknown fbk module 1 - Enabled
$ torque reg error 1 - Enabled
$ communication error 1 - Enabled
$ ehalt fault1 - Enabled
$ motor thermal switch 1 - Enabled
$ motor blower off 1 - Enabled

```

\$ computer timeout 1 - Enabled  
\$ Line Undervoltage1 - Enabled  
\$ Load Cell Error 1 - Enabled  
\$ user fault 3 req 1 - Enabled  
\$ user fault 4 req 1 - Enabled  
\$ user fault 5 req 1 - Enabled  
\$ user fault 6 req 1 - Enabled  
\$ DB Over Temp 1 - Enabled  
\$ user fault 8 req 1 - Enabled  
\$ user fault 9 req 1 - Enabled  
\$ user fault 10 req1 - Enabled  
\$ user fault 11 req1 - Enabled  
\$ user fault 12 req1 - Enabled  
\$ user fault 13 req1 - Enabled  
\$ user fault 14 req1 - Enabled  
\$ user fault 15 req1 - Enabled  
\$ user fault 16 req1 - Enabled  
\$ user fault 17 req1 - Enabled  
\$ user fault 18 req1 - Enabled  
\$ user fault 19 req1 - Enabled  
\$ user fault 20 req1 - Enabled  
\$ user fault 21 req1 - Enabled  
\$ user fault 22 req1 - Enabled  
\$ user fault 23 req1 - Enabled  
\$ user fault 24 req1 - Enabled  
\$ user fault 25 req1 - Enabled  
\$ user fault 26 req1 - Enabled  
\$ user fault 27 req1 - Enabled  
\$ user fault 28 req1 - Enabled  
\$ user fault 29 req1 - Enabled  
\$ user fault 30 req1 - Enabled  
\$ user fault 31 req1 - Enabled

\$ Warning Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled  
\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled

\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled  
\$ user fault 26 req 0 - Disabled  
\$ user fault 27 req 0 - Disabled  
\$ user fault 28 req 0 - Disabled  
\$ user fault 29 req 0 - Disabled  
\$ user fault 30 req 0 - Disabled  
\$ user fault 31 req 0 - Disabled

\$ Event Masks:  
\$ bus overvoltage 0 - Disabled  
\$ AMB thermal switch 0 - Disabled  
\$ fast overcurrent 0 - Disabled  
\$ HS thermal switch 0 - Disabled  
\$ gate driver dsat 0 - Disabled  
\$ ireg shutoff 0 - Disabled  
\$ low voltage supply 0 - Disabled  
\$ external trip 0 - Disabled

\$ dynamic brake limit 0 - Disabled  
\$ watchdog timer 0 - Disabled  
\$ motor pg loss a 0 - Disabled  
\$ load pg loss a 0 - Disabled  
\$ motor marker 0 - Disabled  
\$ load marker 0 - Disabled  
\$ overrun 0 - Disabled  
\$ motor rms limit 0 - Disabled  
\$ circuit breaker 0 - Disabled  
\$ pos error 0 - Disabled  
\$ bus undervoltage 0 - Disabled  
\$ motor fbk loss 0 - Disabled  
\$ load fbk loss 0 - Disabled  
\$ motor runaway 0 - Disabled  
\$ load runaway 0 - Disabled  
\$ non volatile mem 0 - Disabled  
\$ rtc takeover 0 - Disabled  
\$ fbk circuit breaker 0 - Disabled  
\$ ssi receive 0 - Disabled  
\$ inverter rms 0 - Disabled  
\$ sync receive 0 - Disabled  
\$ armature curr error 0 - Disabled  
\$ field current loss 0 - Disabled  
\$ overspeed trip 0 - Disabled  
\$ sync data error 0 - Disabled  
\$ bus reg tol 0 - Disabled  
\$ unknown fbk module 0 - Disabled  
\$ torque reg error 0 - Disabled  
\$ communication error 0 - Disabled  
\$ ehalt fault 0 - Disabled  
\$ motor thermal switch 0 - Disabled  
\$ motor blower off 0 - Disabled  
\$ computer timeout 0 - Disabled  
\$ Line Undervoltage 0 - Disabled  
\$ Load Cell Error 0 - Disabled  
\$ user fault 3 req 0 - Disabled  
\$ user fault 4 req 0 - Disabled  
\$ user fault 5 req 0 - Disabled  
\$ user fault 6 req 0 - Disabled  
\$ DB Over Temp 0 - Disabled  
\$ user fault 8 req 0 - Disabled  
\$ user fault 9 req 0 - Disabled  
\$ user fault 10 req 0 - Disabled  
\$ user fault 11 req 0 - Disabled  
\$ user fault 12 req 0 - Disabled  
\$ user fault 13 req 0 - Disabled  
\$ user fault 14 req 0 - Disabled  
\$ user fault 15 req 0 - Disabled  
\$ user fault 16 req 0 - Disabled  
\$ user fault 17 req 0 - Disabled  
\$ user fault 18 req 0 - Disabled  
\$ user fault 19 req 0 - Disabled  
\$ user fault 20 req 0 - Disabled  
\$ user fault 21 req 0 - Disabled  
\$ user fault 22 req 0 - Disabled  
\$ user fault 23 req 0 - Disabled  
\$ user fault 24 req 0 - Disabled  
\$ user fault 25 req 0 - Disabled

```
$ user fault 26 req0 - Disabled
$ user fault 27 req0 - Disabled
$ user fault 28 req0 - Disabled
$ user fault 29 req0 - Disabled
$ user fault 30 req0 - Disabled
$ user fault 31 req0 - Disabled
```

DATA\_END

\$END

**1100 / 1105 / 1110 / 1130 / 1150**  
**Variable-Frequency AC Drives**



---

**Guide to Installation,  
Troubleshooting,  
and Maintenance**

1 1/2 to 600 hp  
(1.1 to 450 kW)

*For revisions ECL 10 and above*

---

## **Notices**

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# Safety Information

---

## Overview

This section states important safety information that must be followed when installing, operating, and servicing the drive. Study this information carefully before working on or with the unit. Failure to follow these instructions may lead to personal injury or death or to damage to the drive, motor, or driven equipment.

Additional safety instructions specific to the application software can be found in the application documentation. Please study and follow those instructions as well.

## Conventions Used

The following notation conventions are used throughout this manual to indicate information important to personal safety or machine hazards.



### Attention

Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.

---

## General Precautions

---



### Attention

Only qualified personnel with the proper skills, instruction, and familiarity with the drive and its applications should install, start up, operate, troubleshoot, and maintain the drive. You must be familiar with the electrical and mechanical components of the system to perform the procedures outlined in this manual. Failure to comply may result in personal injury, death, and/or equipment damage.

---



### Attention

Failure to take proper precautions for electrical hazard could cause injury or death.

---



### Attention

Failure to follow industry safety standards and instructions in this manual could damage the drive and void the manufacturer's warranty.

---



### Attention

The drive may be sensitive to electrostatic discharge. Static precautions are required when servicing or repairing the unit.

---



### Attention

If an aluminum electrolytic capacitor in the drive fails from a build-up of internal pressure, a safety vent will operate, spraying electrolyte vapor from the capacitor. If a capacitor vents, avoid contact with the liquid, avoid inhaling the vapors, and ventilate the area. If your skin comes in contact with the electrolyte, flush it immediately with cold water. If electrolyte gets in your eyes, immediately remove any contact lenses and flush the open eyes with plenty of clean water. If electrolyte is ingested, dilute it by drinking warm water and seek immediate medical attention.

---



### Attention

Drives are intended for fixed, permanent connection to earthed three-phase supply mains. Use of EMC filters along with the equipment will increase leakage current in the protective conductor and may affect compatibility with residual-current-operated protective devices.

---



### Attention

The drive provides solid-state motor overload protection. The level of protection is dependent upon the rating of the unit (given in Table 2-2) as well as the software overload specified by the user. Please refer to the application documentation for instructions on adjusting the overload.

---

## Installation Precautions

---



### Attention

An incorrectly installed or operated drive can result in damage to the equipment it controls. Make certain installation and operating specifications are followed.

---



### Attention

To provide protection against electrical shock, drives must be mounted in an enclosure meeting at least the requirements of Protective Type IP20 (or NEMA equivalent) according to EN60529 and with top surfaces meeting at least the requirements of IP40 (or NEMA equivalent). It is recommended that a key or tool be required to open the enclosure and that enclosure doors be interlocked with the electrical supply disconnect.

---



### Attention

The drive and associated equipment must be properly earth grounded.

---



### Attention

Any site insulation tests must be performed before making electrical connections to the drive.

---



### Attention

The drive is not equipped with a supply-disconnecting device. An external supply-disconnecting device must be provided to isolate incoming electrical supplies during installation and maintenance work. This device should comply with the requirements of EN 60204-1 as well as all applicable national and local regulations.

---

## Application Precautions

---



### Attention

Emergency stop devices shall be located at each operator control station and at other operating stations where emergency stop may be required. Control inputs and keypad motor-control functions do not generate an emergency stop of the motor and do not remove power that can cause hazardous conditions. Regardless of the operating state, the drive's motor output terminals may be at dangerous voltage levels whenever input power is applied and the bus is charged.

---

**Attention**

Drive functionality depends upon the application software installed. Some application software offers automatic restart functions that allow the unit to reset and resume operation after a fault. These functions must not be enabled when hazardous conditions might arise from such action. Certain features may present additional hazardous situations. Refer to the associated application documentation for further safety information.

---

**Service Precautions**

---

**Attention**

Always disconnect and lock out all electrical supplies before working on the drive or associated equipment. Do this before touching any electrical or mechanical components associated with the drive application.

---

**Attention**

High voltage may be present even when all electrical power supplies are disconnected. After switching off electrical power, wait at least 15 minutes for bus circuit capacitors to discharge before working on the drive or associated equipment. Use an appropriate voltmeter to further verify that capacitors are discharged before beginning work. Do not rely exclusively on the bus voltage indicator. Dangerous voltage levels may remain even when the indicator is off.

---

**Attention**

High voltage may be present at the motor output terminals (U, V, W) whenever input power is applied, regardless of whether the motor is moving or not.

---

**Attention**

Before energizing the motor, verify that there are no loose components associated with the drive train and that motor motion will not result in injury or damage to the equipment.

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**Safe Service Practices**

Follow industry-recognized safety procedures:

- Use only one hand to hold test equipment probes
- Wear approved eye protection
- Stand on insulated material
- Use an isolated oscilloscope
- Keep unnecessary personnel out of the work area
- Never leave a drive cabinet open or unattended

# 1 About the Manual

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## 1.1 Overview

This chapter describes the contents and intended audience of this document.

## 1.2 Contents

The manual provides the instructions and technical information necessary to install and maintain the hardware of Unico's 1000 family of AC drives. Specifically, the manual pertains to units listed in Table 1-1. The 1140 Variable-Voltage AC Drive is covered separately in publication 1140.40 (111-564).

**Table 1-1—1000 Family**

Drive	Description
1100	Variable-Frequency AC Drive
1105	Variable-Frequency AC Drive
1110	Phase-Converting AC Drive
1130	Line-Regenerative AC Drive
1150	Modular AC Drive

### What's covered

- *Safety Instructions*, discusses safety hazards and procedures important to anyone working with the drive
- Chapter 2, *Product Overview*, tells how to receive the drive and provides an overview of its architecture, features, and specifications
- Chapter 3, *Mechanical Installation*, provides instructions on physically installing the drive
- Chapter 4, *Electrical Installation*, explains how to make routine electrical connections
- Chapter 5, *Troubleshooting/Maintenance*, discusses troubleshooting and maintenance of the drive hardware and lists field-replaceable components

### What's not covered

This manual does not address aspects of the drive that depend upon the application software. Please refer to the application documentation for the following:

- Application-specific control signal wiring and definitions
- Operator interface instructions
- Start-up procedure
- Detailed description of drive features and modes of operation
- Parameter descriptions
- Fault identification and troubleshooting

This manual is not intended to provide in-depth service instructions. For service beyond that described in this manual, please contact Unico or your representative.

### **1.2.1 Intended Audience**

The manual is intended for anyone who will be installing and servicing the drive. Installation should be performed by qualified electrical personnel to ensure that correct electrical practices and applicable electrical codes are applied.

The audience is expected to have a basic knowledge of physical and electrical fundamentals, electrical wiring practices and components, and electrical schematics. No prior experience with the drive is presumed or required.

#### **Follow instructions**

You can prevent injury and damage to the drive or equipment by carefully following the procedures outlined in this manual.

#### **Follow regulations**

All electrical work should conform to the National Electrical Code as well as all state and local government regulations. Please familiarize yourself with these regulations.

#### **Read both manuals first**

Read this manual *and* the application manual entirely before installing the drive.

# 2 Product Overview

---

## 2.1 Overview

This chapter provides an overview of the 1000 family of drives. It gives instructions on unpacking, identifying, storing, and transporting a drive. It also familiarizes the user with the basic features, architecture, and specifications of the drives.

## 2.2 Unpacking

After opening the package, you should verify delivery and inspect the drive before installing, storing, or transporting the unit.

### 2.2.1 Lifting Instructions

Smaller drives are mounted on wooden supports and shipped in corrugated boxes, while the large drives are transported on skids. When unpacking a boxed drive, carefully follow the lifting instructions below.



#### Attention

The drive may weigh a considerable amount. To avoid the risk of personal injury and/or damage to the drive, two people should work in unison when lifting and maneuvering the unit. Follow industry prescribed safe-lifting practices at all times.

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#### [1] Remove protective holder

Lift off the cardboard protector that holds the instruction manuals.

#### [2] Remove screws

Remove the four wood screws that secure the heat sink of the drive to the wooden shipping supports.

#### [3] Lift by the heat sink

Two people may be required to safely lift the drive from its box. Each person should stand at one end of the drive, facing the other. Using both hands, place your fingertips beneath the rim of the aluminum heat sink and lift carefully in unison.

---



#### Attention

To avoid damage, do not lift the drive by the keypad/display bracket or by the control modules.

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### 2.2.2 Verify delivery

Check that you received the drive that was ordered as well as any options or accessories. Minimally, you should have received a drive and two manuals (this installation guide and an application guide). Contact your supplier regarding any discrepancies.

### 2.2.3 Inspect for damage

Inspect the drive for any damage that may have occurred during shipment. Remove the cover, if present, and visually examine the insides for obvious problems. If damage is found, do not operate the drive. Report the problem immediately to the supplier.

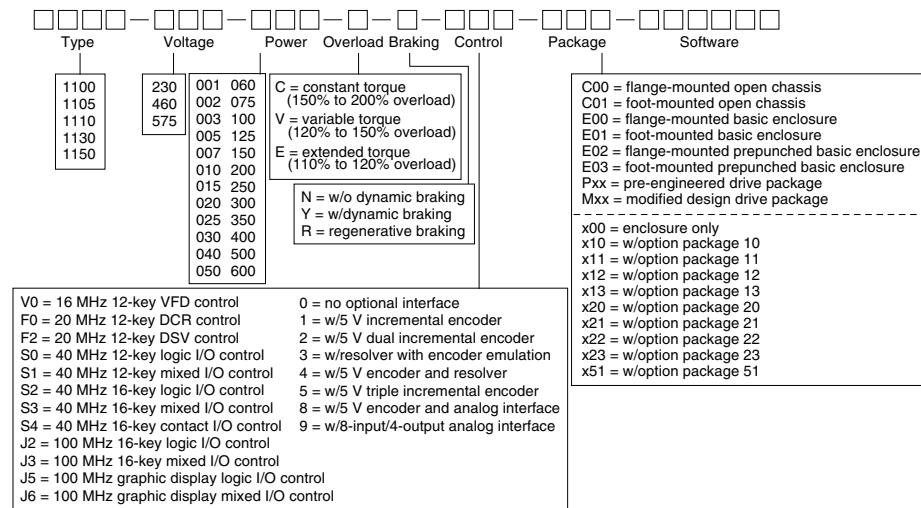
### 2.2.4 Storage/Transportation

If the drive must be stored or transported to another location before installation, verify that the ambient conditions are acceptable according to the environmental specifications given in Table 2-3. Choose a storage location that is clean, dry, and noncorrosive. Repack and store the drive in its original packaging.

### 2.2.5 Nameplate Identification

Drives are ordered using a model number similar to that shown in Figure 2-1. The model number identifies the drive type (1100, 1105, 1110, or 1130) and its configuration, including voltage, power, overload, control type, braking and packaging options, and application software. Each drive is labeled with an identification tag that indicates its part number, serial number, and input/output ratings.

**Figure 2-1—Drive Model Number**



## 2.3 Family Overview

The 1000 family of AC drives provides digital flux vector control of ordinary three-phase AC motors. The drives combine the latest insulated-gate-bipolar-transistor (IGBT), pulse-width modulation (PWM), and digital signal processor (DSP) technologies with digital-current-regulator (DCR) or digital-space-vector (DSV) control to deliver optimum motor performance, complete programmability, and simplicity of operation. Variable-frequency drive (VFD) operation is also available for cost-effective control of motor speed in simple applications.

The complete family is comprised of the 1100, 1105, 1110, and 1130 series of variable-frequency drives as well as the 1140 variable-voltage drive. These drives share a common architecture that provides a high degree of internal consistency. By combining this core drive topology with unique input sections, the 1000 family furnishes flexible, efficient, and cost-effective solutions to a variety of application needs. Table 2-1 summarizes the various models within the family. The 1140 is described in a separate publication.

**Table 2-1—1000 Family Summary**

Drive	Description	Input Voltages	Power Range	Input Operation
1100	Variable-Frequency AC Drive	230/460/575 V	1 1/2-600 hp	Three- or six-phase rectifier
1105	Variable-Frequency AC Drive	230/460/575 V	1 1/2-300 hp	Three- or six-phase rectifier
1110	Phase-Converting AC Drive	230/460 V	1 1/2-100 hp	Single-phase rectifier
1130	Line-Regenerative AC Drive	230/460/575 V	7 1/2-200 hp	Three-phase rectifier/inverter
1140	Variable-Voltage AC Drive	230/460/575 V	5-250 hp	Three-phase SCR control
1150	Modular AC Drive	230/460 V	1 1/2-200 hp	Rectified DC bus

### 2.3.1 Features

#### Performance Flexibility

The 1000 family accommodates a broad range of performance requirements. Units may be configured for constant-torque operation for heavy-duty cyclic loads, variable-torque operation for medium-duty requirements, or extended-torque operation for centrifugal loads such as fans and pumps. The drive operates in a transducerless vector control mode that does not require a feedback device and produces full torque to base speed with full starting torque. For demanding applications, an incremental encoder or resolver interface can be added for precise position, velocity, and torque regulation and improved dynamic performance. Dual- and triple-encoder interfaces are also available for position-following and dual-transducer applications. Variable-frequency control is alternately available for applications that do not require critical velocity or torque control.

### **Motor-Independent Design**

The 1000 family drives operate any standard- or inverter-duty AC induction or synchronous motor, making it ideal for retrofits and new applications alike. A unique, proprietary digital current regulator (DCR) tunes the drive continuously in real time, eliminating the usual current-loop tuning process required by conventional drives. Digital space vector (DSV) control can be selected for reduced motor noise and low current ripple.

### **Auto Tuning**

Once routine electrical connections have been made, simple-to-use auto-tuning features adjust virtually all motor- and load-dependent parameters. No motor maps are required. Simply enter basic motor information from the nameplate, and the advanced setup routines do the rest. The drive is completely tuned within minutes.

### **Control Options**

Numerous control and interface options are available. The 16 MHz control module provides variable-frequency drive (VFD) control for simple applications. The 20 MHz control module is available in digital-current-regulator (DCR) and digital-space-vector (DSV) versions. The 40 MHz control modules provide both DCR and DSV control with either a logic-, mixed-, or contact-type I/O interface. The 100 MHz control modules provide both DCR and DSV control with either a logic- or mixed-type I/O interface. Each control module provides digital and analog inputs and outputs as well as asynchronous serial communication capabilities. The 20 MHz, 40 MHz, and 100 MHz modules also provide synchronous serial communication capabilities. The 100 MHz module includes provisions for an optional AnyBus<sup>®</sup> module for communication using a variety of industry-standard protocols and a MaxStream<sup>™</sup> module for wireless communication. Depending upon the control module, drives can accept motor and/or machine feedback with a single, dual, or triple incremental encoder interface, a resolver interface, or resolver and encoder interfaces. An optional analog interface module is also available for expanding the analog I/O capabilities of a drive. One of three keypad/display units is available, depending upon the application.

### **Application Software**

A wide variety of software options is available to tailor a drive to its application, from a fully featured velocity/torque control for general purposes to a host of powerful programs pre-engineered for specific applications. Customization is possible with many programs using *UEdit*<sup>™</sup>, a Windows-based programming tool that allows users extend an application using IEC 1131 standard ladder diagrams and function blocks.

### **Braking Options**

The 1000 family offers both dynamic and regenerative braking options. A dynamic braking IGBT allows motor braking energy to be dissipated in an external resistor. The dynamic braking IGBT is optional on the 1100 and 1110 drives and included as standard on some 1105 drives. Appropriately sized external braking resistors are required. The 1130 line-regenerative drive provides true four-quadrant control without requiring dynamic braking. Energy generated by stopping the motor and load is put back onto the power grid rather than wasted as heat in a resistor.

### **Digital Setup, Easy Operation**

A keypad and liquid crystal display provide a simple interface for setting and viewing operating parameters and diagnostics. All controller settings are made digitally for precision and repeatability. Readouts and fault messages are displayed in readily understandable language. A graphical display option provides on-board oscilloscope-type viewing of drive and system parameters.

### **Multiaxis Operation**

A built-in high-speed synchronous communication port allows the motion of multiple slave drives to be precisely coordinated. With optional master/slave software, the velocity ratio and position phasing of the drives can also be controlled. Multiple motors can be operated in parallel from a single drive using optional variable-frequency control.

### **Power Quality**

A built-in link choke on the 1100, 1105, and 1110 drives provides near-unity overall power factor and low harmonic line currents at all motor speeds. High-power 1100 and 1105 drives also offer a six-phase (twelve-pulse) configuration for further minimizing line harmonics in critical applications. The 1130 line-regenerative drive provides near-unity power factor for both motoring- and braking-type loads by using an IGBT bridge to control the flow of power into and out of the drive.

### **Protection and Advanced Diagnostics**

Drives monitor their operating conditions and provide a comprehensive set of overload, short circuit, and other electronic protective features to ensure safe, reliable operation. Faults indications are displayed in plain language. A log maintains a history of fault occurrences and externally triggered events.

### **Serial Connectivity**

A fully isolated RS-422/485 serial interface is provided for connecting a drive to a process controller, communication network, or programmable controller. A variety of popular communication protocols is available. The 100 MHz module also accepts an AnyBus module with numerous industry-standard protocol options and a MaxStream module for wireless communications. An RS-232 connection is also provided on 40 MHz and 100 MHz controllers for connecting a personal computer. Windows-based PCs can set up, monitor, and control a network of drives using optional DriveLink™ or UEdit™ software. Drive Archive™ and Drive Chart™ for the Palm OS make it easy to save and restore setups and capture charts using a handheld computer.

### **Packaging**

Compact and rugged, drives are available either enclosed or as an open chassis for mounting inside an enclosure. Both versions can be foot-mounted to a wall or subplate or flange-mounted through a cutout to dissipate heat outside an enclosure. Standard packaged systems are also available that incorporate additional components within an enclosure.

### 2.3.2 Drive Architecture

The general function of the drive is to convert a fixed voltage and frequency from an electrical power source into a variable voltage and frequency for controlling an AC motor. The basic architecture of the 1100, 1105, and 1110 drives is shown in Figure 2-2, that of the 1130 drive in Figure 2-3, and that of the 1150 drive in Figure 2-4.

A *rectifier section* is used on the 1100, 1105, and 1110 drives to convert the fixed AC line voltage into a DC bus voltage. The 1150 is a modular design intended for operating a number of units from a common DC bus. Low-power drives use a diode rectifier and resistors to charge the bus capacitors, which is then bypassed by a contact once the bus is up to full voltage. Medium- and high-power drives use silicon-controlled rectifiers (SCRs) to control the charging of the bus capacitors. High-power drives provide for optional twelve-pulse (six-phase) connection of the input to reduce harmonic currents. The 1110 drive is designed for single-phase operation using two, rather than three, AC line voltage terminals. A *rectifier control* coordinates the charging of the bus.

A *link choke* and *bus capacitors* in the 1100, 1105, and 1110 drives form a filter that smoothes the output of the rectifier section into a steady DC voltage. An optional *dynamic brake* device on these units allows regenerative energy from the load to be dissipated in an external resistor when the drive is braking. The link choke and dynamic brake device are normally part of the converter supplying the DC bus to 1150 units.

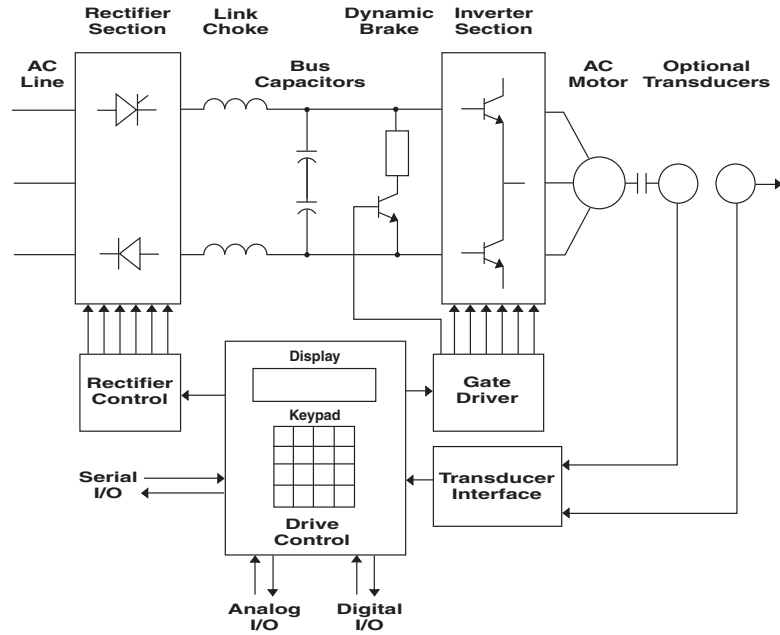
A *converter section* is used on the 1130 drive to regulate power flow between the AC line and DC bus. The converter uses an insulated gate bipolar transistor (IGBT) bridge to rectify the AC line voltage into a DC bus voltage. This section also regenerates energy from the DC bus to the AC line when the drive is braking.

An *inverter section* consisting of six insulated gate bipolar transistors (IGBTs) is used to power an AC motor. This section can produce sine-wave motor voltages and currents of any desired amplitude by rapidly switching the IGBTs using a technique called pulse-width modulation (PWM). A *gate driver* is used to pass switching signals from the drive controller to the IGBTs.

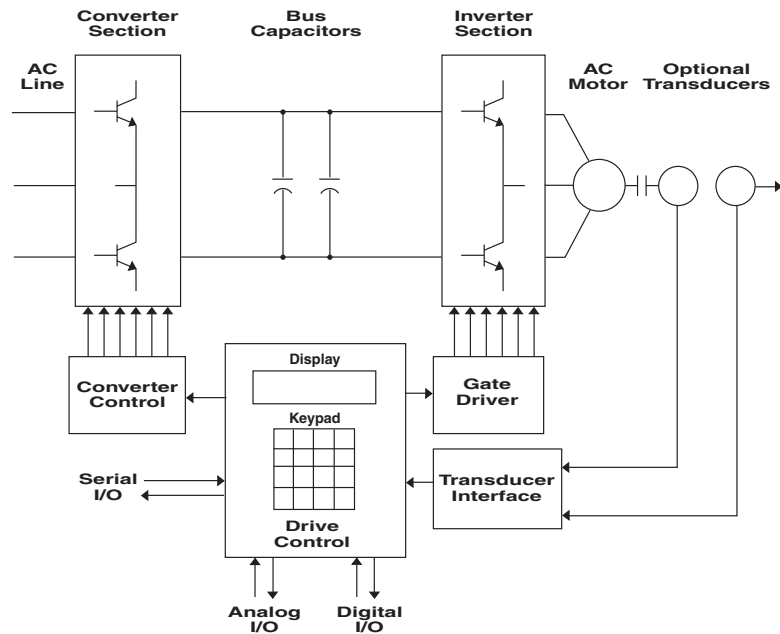
Overall operation of the unit is regulated by a *drive control* that incorporates a digital signal processor (DSP) and a digital current regulator (DCR) or digital space vector (DSV) control. This high-speed digital control uses both voltage and current feedback to regulate the output to the motor. Optional *encoder* and *resolver interfaces* are available to provide closed-loop control of motor velocity and/or position. A dual encoder option is available to slave the motor to other sections of a machine or to reduce machine resonance using dual transducer control. Variable-frequency drive (VFD) operation is an option for controlling AC motors in simple applications.

A *keypad* and *display* on the control module provide access to operating and setup parameters. The control module also provides analog and digital inputs that can be used as input to and output from the drive. Serial communication channels are also available for connecting drives to process controllers, communication networks, programmable controllers, or personal computers.

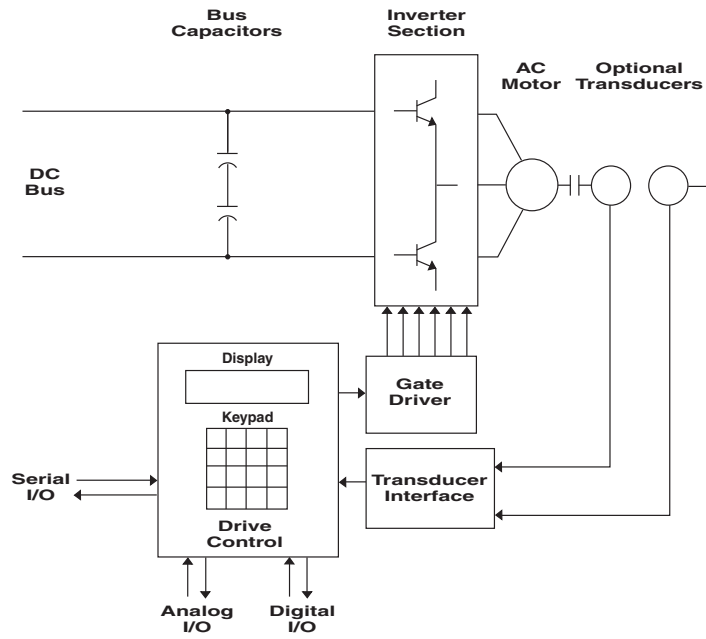
**Figure 2-2—Architecture of the 1100, 1105, and 1110 Drives**



**Figure 2-3—Architecture of the 1130 Drive**



**Figure 2-4—Architecture of the 1150 Drive**



## 2.4 Specifications

Detailed drive specifications are provided in Table 2-2 through Table 2-14 below.

**Table 2-2—Electrical Specifications**

### Input Supply

Line voltage:	200 to 240 V AC, three phase (1100, 1105, 1130, and 1150) 220 to 240 V AC, single-phase (1110) 380 to 480 V AC, three-phase (1100, 1105, 1130, and 1150) 440 to 480 V AC, single-phase (1110) 500 to 600 V AC, three-phase (1100, 1105, and 1130)
	Phase-sequence insensitive
	Overvoltage Category III (IEC 664-1)
Voltage tolerance:	–10% of minimum, +10% of maximum
Imbalance:	Maximum ±3% of nominal input voltage
Frequency:	47 to 63 Hz
Power factor:	Displacement: 1.00 at all loads and speeds
	Overall: 0.94 at rated load (1100, 1105, and 1130) 0.65 at rated load (1110)

### Output Rating

Voltage:	Zero to input supply voltage, three-phase (1100, 1105, 1130, and 1150) Zero to 90% of input supply voltage, three-phase (1110)
Frequency:	Zero to 120 Hz for transducerless vector control Zero to 180 Hz for transducer-based vector control Zero to 300 Hz for variable-frequency control
Switching frequency:	16 MHz control: 1.0, 1.9, 3.9, 7.8, and 15.6 kHz (see Table 2-14)
	20 MHz control: Programmable from 1.1 to 6.5 kHz (see Table 2-14)
	40 and 100 MHz controls: Programmable from 1.0 to 12.0 kHz (see Table 2-14)

### Service Conditions

Efficiency:	97% nominal at rated switching frequency		
Overload current:	<i>Torque</i>	<i>Overload (1 min)</i>	<i>Maximum</i>
	Constant	150% to 200% of rated <sup>(†)</sup>	200% of rated
	Variable	120% to 150% of rated <sup>(†)</sup>	140% to 160% of rated
	Extended (1100, 1105, 1130, and 1150)	110% to 120% of rated <sup>(†)</sup>	120% to 140% of rated

<sup>(†)</sup> Depending upon the application software, the overload may reach the listed upper limit with a corresponding decrease in overload time. Refer to the application documentation for further information.



**Table 2-3—Environmental Specifications**

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**Operating Environment**

Temperature:	Control section: 32° to 131° F (0° to 55° C) Heat sink (standard): 32° to 104° F (0° to 40° C) Heat sink (derated): 32° to 122° F (0° to 50° C)
Relative humidity:	5% to 95%, noncondensing
Altitude:	0 to 3,300 ft (0 to 1,000 m) above sea level <i>Derate output power 1% per 330 ft (100 m) above 3,300 ft (1,000 m).</i>
Air pressure:	20.67" to 31.30" (70 to 106 kPa)
Vibration:	0.3 mm (2 to 9 Hz), 1 m/s <sup>2</sup> (9 to 200 Hz) sinusoidal (IEC 68-2-6)
Pollution:	Nonconductive pollution according to Pollution Degree 2 of IEC 664-1  <i>If the drive is to be used in a more polluted environment (Pollution Degree 3 or 4), suitable enclosures and air filtering or conditioning equipment must be used. To protect against dust ingress, an IP6x-rated enclosure (or NEMA equivalent) must be used.</i>
Contamination levels:	Class 3C2 for chemicals (IEC 721-3-3) Class 3S2 for dust (IEC 721-3-3)

**Storage Environment**

Temperature:	−40° to 158° F (−40° to 70° C)
Relative humidity:	5% to 95%, noncondensing
Air pressure:	20.67" to 31.30" (70 to 106 kPa)

**Transportation Environment**

Temperature:	−40° to 158° F (−40° to 70° C)
Relative humidity:	5% to 95%, noncondensing
Air pressure:	20.67" to 31.30" (70 to 106 kPa)

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**Table 2-4—Performance Specifications**

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**Frequency Control (16 MHz control)**

Range:	Zero to base speed at full torque Base speed to 300 Hz at constant power
Resolution:	0.024% with analog input (12-bit) 0.1 Hz with digital input

**Velocity Control (20, 40, and 100 MHz control)**

Range:	Zero to base speed at full torque Base speed to 180 Hz at constant power with transducer Base speed to 120 Hz at constant power without transducer
Regulation:	±0.001% of base speed, down to zero, with transducer ±0.5% of base speed, 2 Hz and above, without transducer

**Torque Control (20, 40, and 100 MHz control)**

Starting torque:	Constant torque: zero to 150% to 200% of rated Variable torque: zero to 120% to 150% of rated Extended torque: zero to 110% to 120% of rated (1100, 1105, and 1130)
Regulation:	±2.0% of maximum with transducer ±5.0% of maximum without transducer

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**Table 2-5—Processor/Memory Specifications**

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Central processing unit:	16 MHz control: 80C196 microprocessor  20 and 40 MHz controls: 56002 digital signal processor (DSP)  100 MHz control: 56309 digital signal processor (DSP)
Clock frequency:	16 MHz 20 MHz 40 MHz 100 MHz
Data memory:	16 MHz control: 2 kilobyte battery-backed static RAM  20 MHz control: 16 kilobyte battery-backed static RAM  40 MHz control: 32 kilobyte battery-backed static RAM  100 MHz control: 128 kilobyte battery-backed static RAM
Scratch pad memory:	16 MHz control: 256 byte high-speed RAM  20 MHz control: 24 kilobyte high-speed RAM  40 MHz control: 142 kilobyte high-speed RAM  100 MHz control: 1.5 megabyte high-speed RAM
Program memory:	16 MHz control: 64 kilobyte flash EPROM  20 MHz control: 384 kilobyte flash EPROM  40 MHz control: 1.5 megabyte flash EPROM  100 MHz control: 3.0 megabyte flash EPROM

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**Table 2-6—Input/Output Specifications**

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**Analog**

Inputs:	16 MHz and 20 MHz controls: Three (3) 12-bit analog inputs (0 to $\pm 10$ V DC, 0 to 10 V DC, and 0 to 20 mA)  40 MHz and 100 MHz controls: Three (3) 12-bit analog inputs (0 to $\pm 10$ V DC or 0 to 20 mA)  Analog Interface Module (optional): Eight (8) 12-bit analog inputs (0 to 10 V DC or 0 to 20 mA)
Outputs:	16 MHz and 20 MHz controls: Two (2) 12-bit analog outputs (0 to $\pm 10$ V DC)  40 MHz and 100 MHz controls: Two (2) 12-bit analog outputs (0 to $\pm 10$ V DC and 0 to 20 mA)  Analog Interface Module (optional): Four (4) 12-bit analog outputs (0 to $\pm 10$ V DC)

**Digital**

Inputs:	16 MHz, 40 MHz, and 100 MHz controls: Twelve (12) digital inputs (require sink of 1 mA to common)  20 MHz control: Eleven (11) digital inputs (require sink of 1 mA to common)  I/O Fanning Strip (optional): Provision for input converters rated 2.5 to 2.8 V DC @ 30 mA, 90 to 140 V AC @ 11 mA, and 180 to 280 V AC @ 5 mA
Outputs:	16 MHz, 20 MHz, 40 MHz, and 100 MHz mixed I/O controls: Three (3) digital outputs (Form C contacts rated 125 V AC @ 5 A, Form A contact rated 125 V AC @ 5 A, and open-collector driver rated 24 V DC @ 500 mA)  40 MHz and 100 MHz logic I/O controls: Six (6) digital outputs (open-collector driver rated 24 V DC @ 500 mA)  40 MHz contact I/O control: Three (3) digital outputs (Form A contact rated 125 V AC @ 5 A)  I/O Fanning Strip (optional): Provision for output converters rated 5 to 60 V DC @ 3 A, 12 to 140 V AC @ 3 A, or 24 to 280 V AC @ 3 A; or for normally-open or normally-closed relay converters rated 250 V AC @ 8 A

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**Table 2-7—Serial Communication Specifications**

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**Asynchronous**

Port(s):	16 MHz and 20 MHz controls: RS-422/485, isolated  40 MHz control: RS-232/422/485, isolated Auxiliary RS-422/485  100 MHz control: RS-232/422/485, isolated Two (2) auxiliary RS-422/485
Baud rate:	Application dependent
Protocol:	Application dependent

**Synchronous**

Port:	20 MHz, 40 MHz, and 100 MHz controls: RS-485 for high-speed master/slave networking
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**Table 2-8—Communication Module Specifications**

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Interfaces:	100 MHz control: One (1) AnyBus <sup>®</sup> communication provision One (1) MaxStream <sup>™</sup> wireless communication provision
AnyBus <sup>®</sup> options:	AnyBus <sup>®</sup> ControlNet <sup>™</sup> communication module AnyBus <sup>®</sup> DeviceNet <sup>™</sup> communication module AnyBus <sup>®</sup> Ethernet communication module AnyBus <sup>®</sup> Interbus communication module AnyBus <sup>®</sup> LonWorks <sup>®</sup> communication module AnyBus <sup>®</sup> Modbus <sup>®</sup> Plus communication module AnyBus <sup>®</sup> Profibus DPV1 communication module
MaxStream <sup>™</sup> options:	MaxStream <sup>™</sup> 900 MHz wireless communication module MaxStream <sup>™</sup> 2.4 GHz wireless communication module

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**Table 2-9—Encoder Interface Specifications**


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Internal supply:	5 V DC @ 250 mA
Channels:	100 MHz Control Module (323-397 and 323-547): A, B, marker, reference Encoder Interface Module: A, B, marker Dual Encoder Interface Module: A, B, marker, reference
Allowable quadrature error:	$\pm 36^\circ$
Maximum input frequency:	250 kHz
Switching threshold:	200 mV
Input Impedance:	120 $\Omega$
Differential input voltage:	$\pm 5$ V
Common mode input voltage:	$\pm 5$ V

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**Table 2-10—Resolver Interface Module with Encoder Emulation Specifications**


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<b>Reference Output</b>		
Frequency:	5 kHz	
Amplitude:	4 V <sub>rms</sub>	
<b>Feedback Input</b>		
Sine/cosine amplitude:	2 V <sub>rms</sub>	
Transformation ratio:	0.5	
<b>Resolution</b>	10- to 16-bit, programmable	
<b>Maximum Recommended Speed</b>	<i>Resolution</i>	<i>Speed</i>
	10-bit	50,000 rpm
	12-bit	12,000 rpm
	14-bit	3,000 rpm
	16-bit	800 rpm
<b>Encoder Emulation</b>		
Channels:	A, B, marker, feedback error	
Resolution:	<i>Resolver Resolution</i>	<i>Quadrature Output</i>
	10-bit	256 ppr
	12-bit	1,024 ppr
	14-bit	4,096 ppr
	16-bit	16,384 ppr

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**Table 2-11—Protection Specifications**

• Ground fault	• Ambient overtemperature
• Motor phase-to-phase short circuit	• Power transistor fault (20, 40, and 100 MHz controls)
• DC bus overvoltage	• Logic power undervoltage (20, 40, and 100 MHz controls)
• DC bus undervoltage	• Memory malfunction
• Instantaneous overcurrent	• Processor not running fault (20, 40, and 100 MHz controls)
• Motor overload	
• Heat sink overtemperature	

Refer to the application documentation for additional protective features.

**Table 2-12—Product Range**

Input Voltage	A p p l i c a t i o n		
	Constant-Torque	Variable-Torque	Extended-Torque
<b>1100</b>			
230 V AC	1 1/2-60 hp (1.1-45 kW)	2-75 hp (1.5-55 kW)	—
380 V AC	1 1/2-400 hp (1.1-300 kW)	2-500 hp (1.5-375 kW)	—
460 V AC	1 1/2-400 hp (1.1-300 kW)	2-500 hp (1.5-375 kW)	25-600 hp (18-450 kW)
575 V AC	1 1/2-400 hp (1.1-300 kW)	2-500 hp (1.5-375 kW)	25-600 hp (18-450 kW)
<b>1105</b>			
230 V AC	1 1/2-20 hp (1.1-15 kW)	2-25 hp (1.5-18 kW)	10-25 hp (7.5-18 kW)
380 V AC	1 1/2-150 hp (1.1-110 kW)	2-200 hp (1.5-150 kW)	—
460 V AC	1 1/2-150 hp (1.1-110 kW)	2-200 hp (1.5-150 kW)	10-250 hp (7.5-185 kW)
575 V AC	1 1/2-200 hp (1.1-150 kW)	2-250 hp (1.5-185 kW)	10-300 hp (7.5-225 kW)
<b>1110</b>			
230 V AC	1 1/2-40 hp (1.1-30 kW)	2-50 hp (1.5-37 kW)	—
460 V AC	1 1/2-75 hp (1.1-55 kW)	2-100 hp (1.5-75 kW)	—
<b>1130</b>			
230 V AC	7 1/2-60 hp (5.5-45 kW)	10-75 hp (7.5-55 kW)	—
380 V AC	7 1/2-125 hp (5.5-90 kW)	10-150 hp (7.5-110 kW)	—
460 V AC	7 1/2-125 hp (5.5-90 kW)	10-150 hp (7.5-110 kW)	25-200 hp (18-150 kW)
575 V AC	7 1/2-125 hp (5.5-90 kW)	10-150 hp (7.5-110 kW)	25-200 hp (18-150 kW)
<b>1150</b>			
230 V AC	1 1/2-60 hp (1.1-45 kW)	2-75 hp (1.5-55 kW)	10-100 hp (7.5-75 kW)
460 V AC	1 1/2-125 hp (1.1-90 kW)	2-150 hp (1.5-110 kW)	10-200 hp (7.5-150 kW)

**Table 2-13—Output Current Ratings**

Power <i>hp (kW)</i>	Current		Constant Torque		Variable Torque		Extended Torque	
	Continuous <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>	
<b>230 V</b>								
1 1/2 (1.1)	6.0	9.0	12.0	—	—	—	—	
2 (1.5)	6.8	10.2	13.6	8.2	12.0	—	—	
3 (2.2)	9.6	14.4	19.2	11.5	13.6	—	—	
5 (3.7)	15.2	22.8	30.4	18.2	19.2	—	—	
7 1/2 (5.5)	22.0	33.0	44.0	26.4	30.4	—	—	
10 (7.5)	28.0	42.0	56.0	33.6	44.0	30.4	30.4	
15 (11)	42.0	63.0	84.0	50.4	56.0	44.0	44.0	
20 (15)	54.0	81.0	108.0	64.8	84.0	56.0	56.0	
25 (18)	68.0	102.0	136.0	81.6	108.0	74.8	84.0	
30 (22)	80.0	120.0	160.0	96.0	136.0	88.0	108.0	
40 (30)	104.0	156.0	208.0	124.8	160.0	114.4	136.0	
50 (37)	130.0	195.0	260.0	156.0	208.0	143.0	160.0	
60 (45)	154.0	231.0	308.0	184.8	260.0	169.4	208.0	
75 (55)	192.0	—	—	230.4	308.0	211.2	260.0	
100 (75)	248.0	—	—	—	—	272.8	308.0	

*(continued)*

*The ratings provided in this table reflect standard overloads of 150% (CT), 120% (VT), and 110% (ET). Depending upon the application software, units may be operated at up to 200% (CT), 150% (VT), and 120% (ET) overload. To determine the maximum overload current for alternate VT and ET ratings, use the CT overload for the same power rating but limit it to the VT or ET maximum current. Refer to the application documentation for further information.*



**Table 2-13—Output Current Ratings (continued)**

Power <i>hp (kW)</i>	Current	Constant Torque		Variable Torque	
	Continuous <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>
<b>380 V</b>					
1 1/2 (1.1)	3.4	5.2	6.0	—	—
2 (1.5)	3.9	5.9	6.8	4.7	6.0
3 (2.2)	5.5	8.3	9.6	6.6	6.8
5 (3.7)	8.7	13.1	15.2	9.6	9.6
7 1/2 (5.5)	12.7	19.0	22.0	15.2	15.2
10 (7.5)	16.1	24.2	28.0	19.3	22.0
15 (11)	24.2	36.2	42.0	28.0	28.0
20 (15)	31.1	46.6	54.0	37.3	42.0
25 (18)	39.1	58.7	68.0	46.9	54.0
30 (22)	46.0	69.0	80.0	55.2	68.0
40 (30)	59.8	89.7	104.0	71.8	80.0
50 (37)	74.8	112.1	130.0	89.7	104.0
60 (45)	88.6	132.8	154.0	106.3	130.0
75 (55)	110.4	165.6	192.0	132.5	154.0
100 (75)	142.6	213.9	248.0	171.1	192.0
125 (90)	179.4	269.1	312.0	215.3	248.0
150 (110)	207.0	310.5	360.0	248.4	312.0
200 (150)	276.0	414.0	480.0	331.2	360.0
250 (185)	345.0	517.5	600.0	414.0	480.0
300 (225)	414.0	621.0	720.0	496.8	600.0
350 (262)	483.0	724.5	840.0	579.6	720.0
400 (300)	552.0	828.0	960.0	662.4	840.0
500 (375)	690.0	—	—	828.0	960.0

*(continued)*

**Table 2-13—Output Current Ratings (continued)**

Power <i>hp (kW)</i>	Current	Constant Torque		Variable Torque		Extended Torque	
	Continuous	Overload	Maximum	Overload	Maximum	Overload	Maximum
	$A_{rms}$	$A_{rms}$	$A_{rms}$	$A_{rms}$	$A_{rms}$	$A_{rms}$	$A_{rms}$
<b>460 V</b>							
1 1/2 (1.1)	3.0	4.5	6.0	—	—	—	—
2 (1.5)	3.4	5.1	6.8	4.1	6.0	—	—
3 (2.2)	4.8	7.2	9.6	5.8	6.8	—	—
5 (3.7)	7.6	11.4	15.2	9.1	9.6	—	—
7 1/2 (5.5)	11.0	16.5	22.0	13.2	15.2	—	—
10 (7.5)	14.0	21.0	28.0	16.8	22.0	15.2	15.2
15 (11)	21.0	31.5	42.0	25.2	28.0	22.0	22.0
20 (15)	27.0	40.5	54.0	32.4	42.0	28.0	28.0
25 (18)	34.0	51.0	68.0	40.8	54.0	37.4	42.0
30 (22)	40.0	60.0	80.0	48.0	68.0	44.0	54.0
40 (30)	52.0	78.0	104.0	62.4	80.0	57.2	68.0
50 (37)	65.0	97.5	130.0	78.0	104.0	71.5	80.0
60 (45)	77.0	115.5	154.0	92.4	130.0	84.7	104.0
75 (55)	96.0	144.0	192.0	115.2	154.0	105.6	130.0
100 (75)	124.0	186.0	248.0	148.8	192.0	136.4	154.0
125 (90)	156.0	234.0	312.0	187.2	248.0	171.6	192.0
150 (110)	180.0	270.0	360.0	216.0	312.0	198.0	248.0
200 (150)	240.0	360.0	480.0	288.0	360.0	264.0	312.0
250 (185)	300.0	450.0	600.0	360.0	480.0	330.0	360.0
300 (225)	360.0	540.0	720.0	432.0	600.0	396.0	480.0
350 (262)	420.0	630.0	840.0	504.0	720.0	462.0	600.0
400 (300)	480.0	720.0	960.0	576.0	840.0	528.0	720.0
500 (375)	600.0	—	—	720.0	960.0	660.0	840.0
600 (450)	720.0	—	—	—	—	792.0	960.0

*(continued)*

**Table 2-13—Output Current Ratings (continued)**

Power <i>hp (kW)</i>	Current	Constant Torque		Variable Torque		Extended Torque	
	Continuous <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>	Overload <i>A<sub>rms</sub></i>	Maximum <i>A<sub>rms</sub></i>
<b>575 V</b>							
1 1/2 (1.1)	2.4	3.6	4.8	—	—	—	—
2 (1.5)	2.7	4.1	5.4	3.2	4.8	—	—
3 (2.2)	3.9	5.9	7.8	4.7	5.4	—	—
5 (3.7)	6.1	9.2	12.2	7.3	7.8	—	—
7 1/2 (5.5)	9.0	13.5	18.0	10.8	12.2	—	—
10 (7.5)	11.0	16.5	22.0	13.2	18.0	11.0	12.2
15 (11)	17.0	25.5	34.0	20.4	22.0	17.0	18.0
20 (15)	22.0	33.0	44.0	26.4	34.0	22.0	22.0
25 (18)	27.0	40.5	54.0	32.4	44.0	29.7	34.0
30 (22)	32.0	48.0	64.0	38.4	54.0	35.2	44.0
40 (30)	41.0	61.5	82.0	49.2	64.0	45.1	54.0
50 (37)	52.0	78.0	104.0	62.4	82.0	57.2	64.0
60 (45)	62.0	93.0	124.0	74.4	104.0	68.2	82.0
75 (55)	77.0	115.5	154.0	92.4	124.0	84.7	104.0
100 (75)	99.0	148.5	198.0	118.8	154.0	108.9	124.0
125 (90)	125.0	187.5	250.0	150.0	198.0	137.5	154.0
150 (110)	144.0	216.0	288.0	172.8	250.0	158.4	198.0
200 (150)	192.0	288.0	384.0	230.4	288.0	211.2	250.0
250 (185)	240.0	360.0	480.0	288.0	384.0	264.0	288.0
300 (225)	288.0	432.0	576.0	345.6	480.0	316.8	384.0
350 (262)	336.0	504.0	672.0	403.2	576.0	369.6	480.0
400 (300)	384.0	576.0	768.0	460.8	672.0	422.4	576.0
500 (375)	480.0	—	—	576.0	768.0	528.0	672.0
600 (450)	576.0	—	—	—	—	633.6	768.0

**Table 2-14—Switching Frequencies**

<b>Power</b>	<b>CT</b>	<b>VT</b>	<b>ET</b>
<i>hp (kW)</i>	<i>kHz</i>	<i>kHz</i>	<i>kHz</i>
<b>230 V</b>			
1 1/2 (1.1)	10.0	—	—
2 (1.5)	10.0	8.8	—
3 (2.2)	10.0	6.0	—
5 (3.7)	10.0	4.8	—
7 1/2 (5.5)	10.0	6.1	—
10 (7.5)	10.0	7.3	3.8
15 (11)	10.0	5.6	3.4
20 (15)	8.0	7.6	3.2
25 (18)	8.0	6.3	5.5
30 (22)	8.0	6.7	5.1
40 (30)	8.0	5.8	4.7
50 (37)	8.0	6.4	3.9
60 (45)	8.0	6.8	5.2
75 (55)	—	6.1	5.2
100 (75)	—	—	4.0

*(continued)*

*(†) Digital space vector (DSV) control must be used to achieve switching frequencies less than 3.2 kHz.*

**Table 2-14—Switching Frequencies**  
(continued)

<b>Power</b>	<b>CT</b>	<b>VT</b>
<i>hp (kW)</i>	<i>kHz</i>	<i>kHz</i>
<b>380 V</b>		
1 1/2 (1.1)	7.5	—
2 (1.5)	7.5	6.8
3 (2.2)	7.5	5.1
5 (3.7)	7.5	4.4
7 1/2 (5.5)	7.5	5.2
10 (7.5)	7.5	5.9
15 (11)	7.5	4.9
20 (15)	5.5	6.1
25 (18)	5.5	4.6
30 (22)	5.5	4.8
40 (30)	5.5	4.3
50 (37)	5.5	4.6
60 (45)	5.5	4.8
75 (55)	5.5	4.5
100 (75)	5.5	4.3
126 (90)	4.0	4.6
150 (110)	4.0	3.5
200 (150)	4.0	2.8
250 (185)	4.0	3.2
300 (225)	4.0	3.5
350 (262)	3.5	3.7
400 (300)	2.7 <sup>(†)</sup>	3.1 <sup>(†)</sup>
500 (375)	—	2.1 <sup>(†)</sup>

(continued)

**Table 2-14—Switching Frequencies**  
(continued)

<b>Power</b>	<b>CT</b>	<b>VT</b>	<b>ET</b>
<i>hp (kW)</i>	<i>kHz</i>	<i>kHz</i>	<i>kHz</i>
<b>460 V</b>			
1 1/2 (1.1)	8.0	—	—
2 (1.5)	8.0	7.3	—
3 (2.2)	8.0	5.5	—
5 (3.7)	8.0	4.8	—
7 1/2 (5.5)	8.0	5.6	—
10 (7.5)	8.0	6.4	4.2
15 (11)	8.0	5.3	3.9
20 (15)	6.0	6.5	3.8
25 (18)	6.0	5.0	5.2
30 (22)	6.0	5.3	4.4
40 (30)	6.0	4.7	4.1
50 (37)	6.0	5.1	3.7
60 (45)	6.0	5.3	4.4
75 (55)	6.0	4.9	4.4
100 (75)	6.0	4.7	3.7
125 (90)	4.5	5.1	3.7
150 (110)	4.5	4.0	4.5
200 (150)	4.5	3.3	2.9 <sup>(†)</sup>
250 (185)	4.5	3.7	2.4 <sup>(†)</sup>
300 (225)	4.5	4.0	3.0 <sup>(†)</sup>
350 (262)	4.0	4.2	3.5
400 (300)	3.0	3.6	3.9
500 (375)	—	2.5 <sup>(†)</sup>	2.9 <sup>(†)</sup>
600 (450)	—	—	2.0 <sup>(†)</sup>

(continued)

**Table 2-14—Switching Frequencies** (continued)

<b>Power</b>	<b>CT</b>	<b>VT</b>	<b>ET</b>
<i>hp (kW)</i>	<i>kHz</i>	<i>kHz</i>	<i>kHz</i>
<b>575 V</b>			
1 1/2 (1.1)	6.0	—	—
2 (1.5)	6.0	5.5	—
3 (2.2)	6.0	4.1	—
5 (3.7)	6.0	3.6	—
7 1/2 (5.5)	6.0	4.2	—
10 (7.5)	6.0	4.8	3.1
15 (11)	6.0	4.0	2.9
20 (15)	6.0	4.9	2.8
25 (18)	4.0	5.1	3.9
30 (22)	4.0	3.5	4.5
40 (30)	4.0	3.1 <sup>(†)</sup>	2.7 <sup>(†)</sup>
50 (37)	4.0	3.4	2.4 <sup>(†)</sup>
60 (45)	4.0	3.5	2.9 <sup>(†)</sup>
75 (55)	4.0	3.3	2.9 <sup>(†)</sup>
100 (75)	4.0	3.1 <sup>(†)</sup>	2.4 <sup>(†)</sup>
125 (90)	4.0	3.4	2.4 <sup>(†)</sup>
150 (110)	4.0	3.5	3.0 <sup>(†)</sup>
200 (150)	4.0	3.1 <sup>(†)</sup>	2.6 <sup>(†)</sup>
250 (185)	4.0	3.4	2.4 <sup>(†)</sup>
300 (225)	3.5	3.6	2.9 <sup>(†)</sup>
350 (262)	2.5 <sup>(†)</sup>	3.3	3.3
400 (300)	2.0 <sup>(†)</sup>	2.3 <sup>(†)</sup>	3.1 <sup>(†)</sup>
500 (375)	—	1.9 <sup>(†)</sup>	1.9 <sup>(†)</sup>
600 (450)	—	—	1.3 <sup>(†)</sup>

# 3 Mechanical Installation

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## 3.1 Overview

Proper mechanical installation of the drive is essential for safe, reliable operation and to simplify electrical wiring and maintenance. This chapter provides information and instructions for determining the best mounting location, selecting an enclosure, planning a layout, and installing the unit.

## 3.2 Forms

Drives are classified into nine different *forms* according to their physical size and construction. These forms correspond, for the most part, to different heat sink sizes and sometimes to different box sizes or mounting methods. Refer to Table 3-3 through Table 3-6 near the end of this chapter to determine the form of a unit based upon its voltage, torque, and power ratings.

## 3.3 Installation Site Considerations

It is important to choose a mounting location that protects the drive from harmful environmental conditions while, at the same time, safeguarding personnel from the dangerous voltages of the drive system.

### 3.3.1 Enclosure

A drive can be supplied either unmounted as an open-chassis or enclosed unit or already mounted as part of a packaged drive system incorporating additional components within an enclosure. Open-chassis (IP00) units must be mounted inside an enclosure for safety. The integral enclosures provided with 1100, 1110, and 1130 drives are rated NEMA 1 (IP23). Those provided with 1105 and 1150 drives are rated NEMA 4 (IP66) for units of 10 hp (CT) or less and NEMA 1 (IP23) for 15 hp or more. Both open-chassis and enclosed versions of all models may be either foot- or flange-mounted.

Figure 3-1 through Figure 3-3 provide the physical dimensions and mechanical layouts of the drives. Refer to these figures when planning your layout. For simplicity, only the dimensions of enclosed drives are shown. Chassis units occupy approximately the same space.

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### Attention



To provide protection against electrical shock, chassis units must be mounted in an enclosure meeting at least the requirements of Protective Type IP20 (or NEMA equivalent) according to EN60529 and with top surfaces meeting at least the requirements of IP40 (or NEMA equivalent). It is recommended that a key or tool be required to open the enclosure and that enclosure doors be interlocked with the electrical supply disconnect.

---



### **3.3.2 Operating Environment**

The drive should be mounted in an environment that is free from corrosive and volatile vapors, dust and particles, mechanical shock, excessive vibration, water or excessive moisture, and temperature extremes. The required ambient operating conditions are specified in Table 2-3.

### **3.3.3 Cooling**

Thermal management techniques may be necessary to keep the drive operating within required temperature specifications, particularly when units are installed within confined spaces. Drives cool themselves using fans that circulate air across a heat sink. Air can be drawn from either inside the enclosure or outside, depending upon the mounting configuration. Some applications may require additional ventilating or cooling equipment.

#### **3.3.3.1 Thermal Load**

If the drive is to be installed in a separate enclosure, its thermal load must be considered. The total power dissipated by each drive is given in Table 3-8 (1100, 1105, and 1130 drives), Table 3-9 (1110 drives), and Table 3-10 (1150 drives) at the end of this chapter. Dissipation figures are provided for the control section and heat sink independently since the heat sink can be mounted externally to the enclosure. Use this information, in conjunction with the enclosure manufacturer's recommendations, to size the enclosure and to determine cooling airflow requirements. Power dissipation of units operating on 380 V power lines is the same as that listed for 460 V.

#### **3.3.3.2 Air Circulation**

Air circulation can be controlled by selecting the mounting configuration. Foot-mounted drives stand away from the mounting surface and pull ambient air from behind the unit to cool the heat sink. Flange-mounted drives dissipate heat outside an enclosure by allowing the heat sink to protrude through a cutout in the enclosure wall. The smallest units, which do not have finned heat sinks, must be flush mounted. Refer to Section 3.5 for mounting instructions.

### 3.4 Layout Considerations

The following information should be considered when planning a mechanical layout.

#### 3.4.1 Dimensions and Weights

The physical dimensions of each drive are provided in Figure 3-1 through Figure 3-3. The approximate weight of each unit is given in Table 3-3 through Table 3-7.



#### Attention

Make certain that the mounting surface is strong enough to support the weight of all components to be mounted on it.

#### 3.4.2 Space Requirements

Sufficient space must be provided around each drive for cooling airflow, access to electrical connections, and maintenance. Minimum recommended clearances above and below, to the side of, and behind the heat sink and fans of the various units are indicated in Table 3-1. If multiple drives are to be installed adjacent to each other, allow twice the indicated clearances between units. Be sure to also leave enough clearance for removing and replacing the cover during installation and servicing.

**Table 3-1—Minimum Mounting Clearances**

Form	Vertical	Horizontal	Behind
	<i>in (mm)</i>	<i>in (mm)</i>	<i>in (mm)</i>
①, ②, ③, and ⑦	6.00" (152)	3.00" (76)	1.13" (29)
④	3.00" (76)	6.00" (152)	2.25" (57)
⑤ and ⑥	6.00" (152)	3.00" (76)	—
⑧	3.00" (76)	6.00" (152)	2.25" (57)

#### 3.4.3 Orientation

Drives must be mounted upright (so that the cover label reads correctly) to permit proper cooling airflow. Under no circumstances should units be installed upside down or on their sides in an attempt to change the direction of airflow or to facilitate wiring.

Position the drive so that its keypad/display can be accessed comfortably by the operator. The average adult is 5' 6" (168 cm) tall, so mount accordingly if possible.

#### 3.4.4 Cable Routing

Separate electrical conduits are required for incoming power, output to the motor, and control wiring.

### 3.5 Installation Procedure

Both chassis and enclosed drives can be either foot- or flange-mounted. Figure 3-1 through Figure 3-3 provide the physical dimensions and mechanical layouts of the units. Refer to these figures when planning your layout.



#### Attention

Make certain that the mounting surface is secure before mounting the drive. Equipment damage could result from an improperly mounted unit.

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#### Attention

Exercise care during installation to prevent metal shavings, conduit knockouts, and other debris from falling into the unit(s). Personal injury and/or equipment damage could result.

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#### Attention

The drive may weigh a considerable amount. To avoid the risk of personal injury and/or damage to the drive, two or more people should work in unison when lifting and maneuvering a unit. Follow industry prescribed safe lifting practices at all times.

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#### 3.5.1 Foot Mounting

A drive may be foot-mounted to a subpanel inside an enclosure or directly to an enclosure wall. Mounting feet are provided with Form 5 and 6 1105 and 1150 drives and are available as a factory-installed option with Form 3, 7, and 8 1105 and 1150 drives and all 1100, 1110, and 1130 drives. Mounting feet keep the heat sink and fans, if so supplied, the proper distance from the mounting surface. Certain low-power Form 1 models do not have finned heat sinks and, therefore, cannot accept feet. These models must be mounted flush with the surface.

Mount Form 1, 2, 3, and 7 drives using four 1/4" (6 mm) bolts or studs with nuts. Mount Form 4 and 8 drives using four 3/8" (10 mm) bolts or studs with nuts. Attach the top feet first to suspend the drive, then secure the bottom feet. Mount Form 5 and 6 drives using four #10 (5 mm) bolts or studs with nuts. Attach the bottom feet first, then secure the the top feet. Refer to the flange-mounting diagrams for hole locations.

### 3.5.2 Flange Mounting

A drive may also be flange-mounted with its heat sink protruding through a cutout in the enclosure wall. This allows heat to be dissipated outside the enclosure. A mounting flange is provided with 1100, 1110, 1130, and Form 3, 7, and 8 1105 and 1150 drives and is available as a factory-installed option with Form 5 and 6 1105 and 1150 drives.

Factory-installed mounting adapters are also available for reusing existing cutouts when retrofitting certain units (see Table 3-2). Allow the recommended clearance behind the heat sink and fans for airflow (see Table 3-1). Certain low-power Form 1 models do not have finned heat sinks and must be mounted flush with the surface.

Mount Form 1, 2, 3, 5, 6, and 7 drives using #10 (5 mm) bolts or studs with nuts. The number of bolts or studs required varies with the size of the drive. Form 4 and 8 drives have 1/4"-20 mounting studs protruding through both sides of the heat sink that require (12) 5/16" (8 mm) mounting holes. Secure the unit across the top and bottom using six additional 1/4" (6 mm) bolts with nuts. Refer to the flange-mounting diagrams for hole locations and cutout dimensions. Retrofit adapters use the same hole patterns as the drives they replace. Chassis units are designed to provide NEMA 4 (IP66) integrity when flange-mounted inside a suitable NEMA 4 enclosure using the gasket provided.

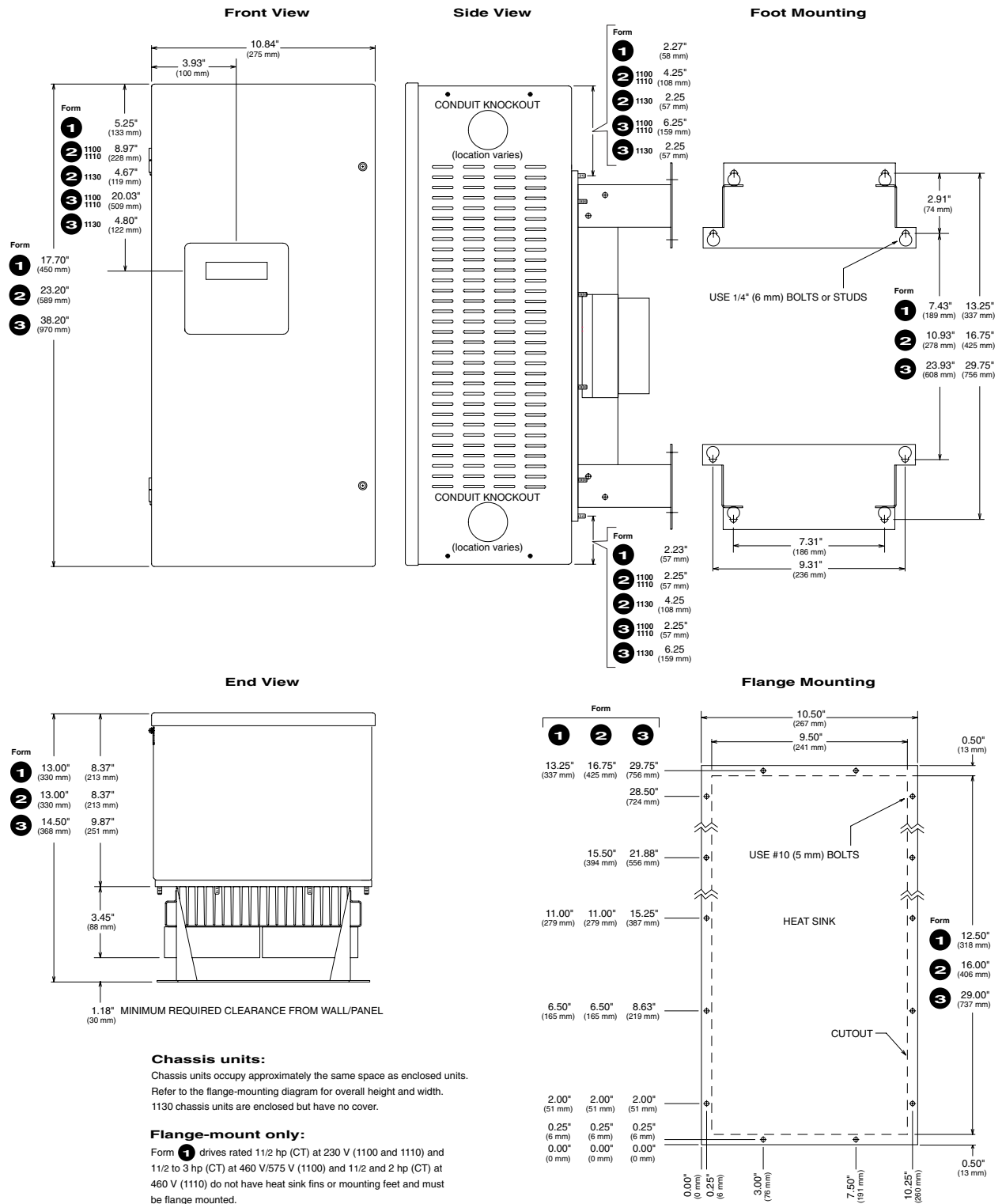
**Table 3-2—Flange-Mounting Retrofit Adapters**

Form	Part Number	Description
② and ⑦	709-623	Adapter for mounting drive within cutout for Form ③ drive
⑤ and ⑥	709-625	Adapter for mounting drive within cutout for Form ② drive

### 3.6 Mounting the I/O Fanning Strip

The optional I/O fanning strip is generally mounted beneath the drive. Attach the strip from behind the mounting surface using nuts to secure the four #6-32 standoff screws.

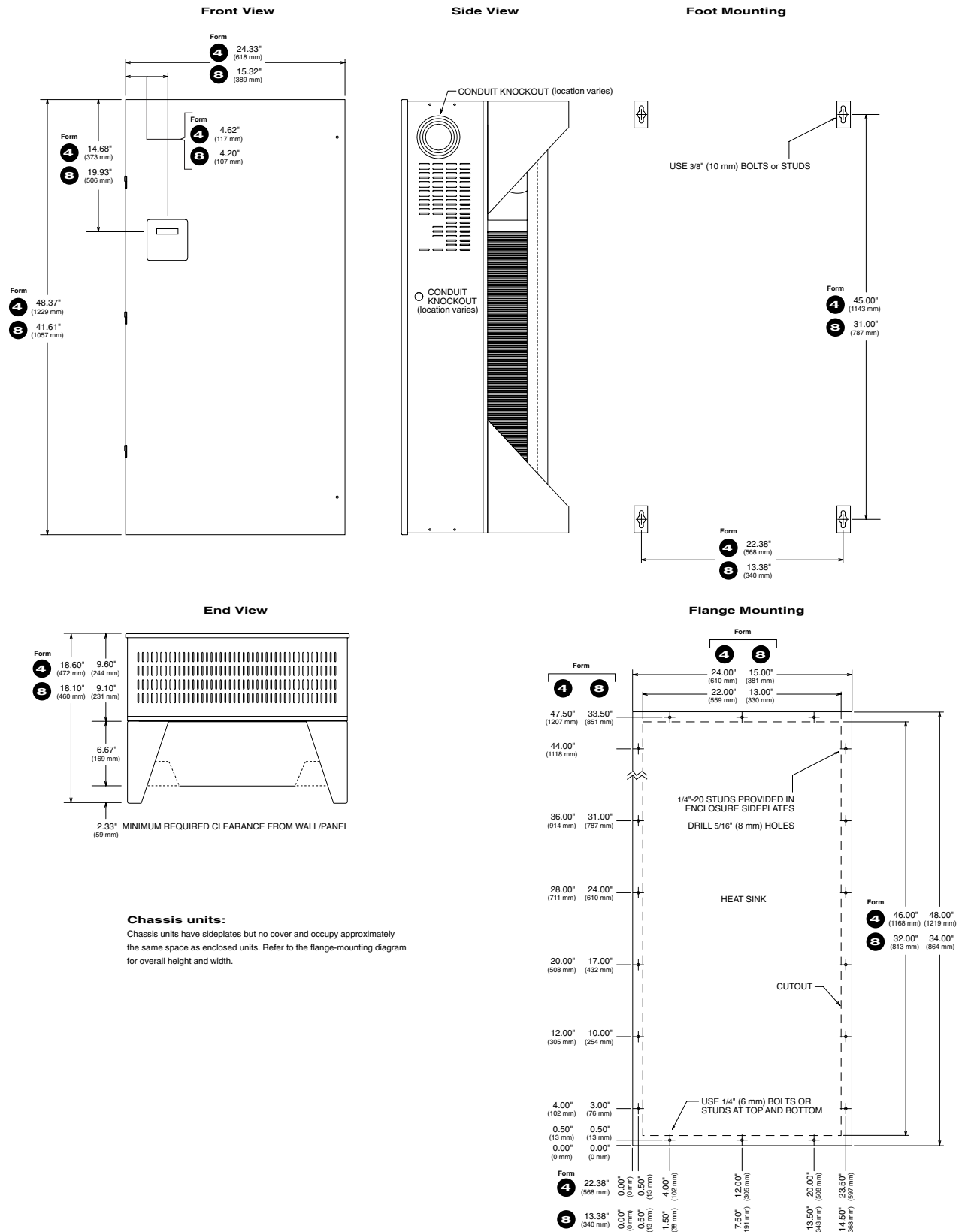
**Figure 3-1—1100, 1105, 1110, 1130, and 1150 Mounting Dimensions (Forms 1, 2, 3, and 7)**



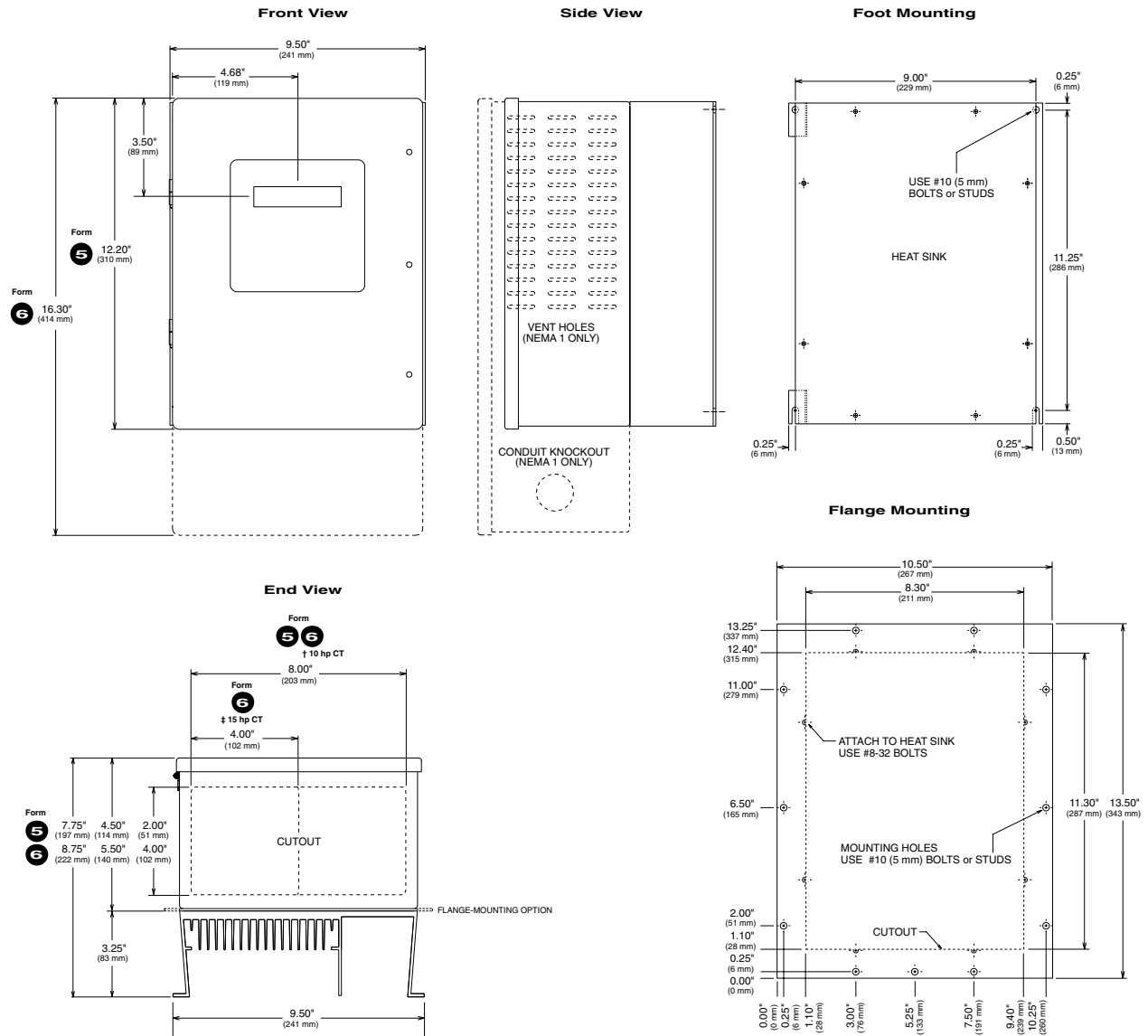
**Chassis units:**  
Chassis units occupy approximately the same space as enclosed units. Refer to the flange-mounting diagram for overall height and width. 1130 chassis units are enclosed but have no cover.

**Flange-mount only:**  
Form 1 drives rated 1 1/2 hp (CT) at 230 V (1100 and 1110) and 1 1/2 to 3 hp (CT) at 460 V/575 V (1100) and 1 1/2 and 2 hp (CT) at 460 V (1110) do not have heat sink fins or mounting feet and must be flange mounted.

**Figure 3-2—1100 and 1105 Mounting Dimensions (Forms 4 and 8)**



**Figure 3-3—1105 and 1150 Mounting Dimensions (Forms 5 and 6)**



**Chassis units:**

Chassis units occupy approximately the same space as enclosed units. Refer to the front view Form 5 dimensions for overall height and width of foot-mounted units and to the flange-mounting diagram for overall height and width of flange-mounted units.

**Table 3-3—1100 Drive Forms / Weights**

P o w e r			Form	W e i g h t s	
CT	VT	ET		Chassis	Enclosed
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>		<i>lb (kg)</i>	<i>lb (kg)</i>
<b>230 V</b>					
1 1/2–7 1/2 (1.1-5.5)	2–10 (1.5-7.5)	—	①	30 (14)	45 (20)
10–15 (7.5-11)	15–20 (11-15)	—	②	40 (18)	60 (27)
20–30 (15-22)	25–40 (18-30)	—	②	50 (23)	70 (32)
40–60 (30-45)	50–75 (37-55)	—	③	100 (45)	130 (59)
<b>460 V</b>					
1 1/2–5 (1.1-3.7)	2–7 1/2 (1.5-5.5)	—	①	30 (14)	45 (20)
7 1/2–20 (5.5-15)	10–25 (7.5-18)	25–30 (18-22)	②	40 (18)	60 (27)
25–50 (18-37)	30–60 (22-45)	40–75 (30-55)	②	50 (23)	70 (32)
60–125 (45-90)	75–150 (55-110)	100–150 (75-110)	③	100 (45)	130 (59)
150–250 (110-185)	200-300 (150-225)	250–350 (185-262)	④	400 (181)	430 (195)
300–400 (225-300)	350-500 (262-375)	400–600 (300-450)	④	500 (227)	530 (240)
<b>575 V</b>					
1 1/2–5 (1.1-3.7)	2–7 1/2 (1.5-5.5)	—	①	30 (14)	45 (20)
7 1/2–20 (7.5-15)	10–25 (7.5-18)	25–30 (18-22)	②	40 (18)	60 (27)
25–50 (18-37)	30–60 (22-45)	40–75 (30-55)	②	50 (23)	70 (32)
60–125 (45-90)	75–150 (55-110)	100–150 (75-110)	③	100 (45)	130 (59)
150–300 (110-225)	200-350 (150-262)	250–400 (185-300)	④	400 (181)	430 (195)
350–400 (262-300)	400-500 (300-375)	500–600 (375-450)	④	500 (227)	530 (240)



**Table 3-4—1105 Drive Forms / Weights**

Power			Form	Weights	
CT	VT	ET		Chassis	Enclosed
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>		<i>lb (kg)</i>	<i>lb (kg)</i>
<b>230 V</b>					
1 1/2–3 (1.1-2.2)	2–5 (1.5-3.7)	—	5	15 (7)	20 (9)
5–20 (3.7-15)	7 1/2–25 (5.5-18)	10–25 (7.5-18)	6	20 (9)	30 (14)
<b>460 V</b>					
1 1/2–5 (1.1-3.7)	2–7 1/2 (1.5-5.5)	10 (7.5)	5	15 (7)	20 (9)
7 1/2–20 (5.5-15)	10–25 (7.5-18)	15–30 (11-22)	6	20 (9)	30 (14)
25–40 (18-30)	30–50 (22-37)	40–60 (30-45)	7	50 (23)	70 (32)
50–100 (37-75)	60–125 (45-90)	75–150 (55-110)	3	100 (45)	130 (59)
125–150 (90-110)	150–200 (110-150)	200–250 (150-185)	8	200 (91)	240 (109)
<b>575 V</b>					
1 1/2–10 (1.1-7.5)	2–15 (1.5-11)	10–20 (7.5-15)	6	20 (9)	30 (14)
15–40 (11-30)	20–50 (15-37)	25–60 (18-45)	7	50 (23)	70 (32)
50–100 (37-75)	60–125 (45-90)	75–150 (55-110)	3	100 (45)	130 (59)
125–200 (90-150)	150–250 (110-185)	200–300 (150-225)	8	200 (91)	240 (109)

**Table 3-5—1110 Drive Forms / Weights**

Power			Form	Weights	
CT	VT			Chassis	Enclosed
<i>hp (kW)</i>	<i>hp (kW)</i>			<i>lb (kg)</i>	<i>lb (kg)</i>
<b>230 V</b>					
1 1/2–3 (1.1-2.2)	2–5 (1.5-3.7)		1	30 (14)	45 (20)
5–20 (5.5-15)	7 1/2–25 (7.5-18)		2	40 (18)	60 (27)
25 (18)	30 (22)		2	50 (23)	70 (32)
30–40 (22-30)	40–50 (30-37)		3	100 (45)	130 (59)
<b>460 V</b>					
1 1/2–5 (1.1-3.7)	2–7 1/2 (1.5-5.5)		1	30 (14)	45 (20)
7 1/2–20 (5.5-15)	10–25 (7.5-18)		2	40 (18)	60 (27)
25–40 (18-30)	30–50 (22-37)		2	50 (23)	70 (32)
50–75 (37-55)	60–100 (45-75)		3	100 (45)	130 (59)

**Table 3-6—1130 Drive Forms / Weights**

Power			Form	Weights	
CT	VT	ET		Chassis	Enclosed
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>		<i>lb (kg)</i>	<i>lb (kg)</i>
<b>230 V</b>					
7 1/2–20 (5.5-15)	10–25 (7.5-18)	—	2	55 (25)	60 (27)
25–30 (18-22)	30–40 (22-30)	—	2	65 (29)	70 (32)
40–60 (30-45)	50–75 (37-55)	—	3	120 (54)	130 (59)
<b>460 V</b>					
7 1/2–20 (5.5-15)	10–25 (7.5-18)	25-30 (18-22)	2	55 (25)	60 (27)
25–50 (18-37)	30–60 (22-45)	40-75 (30-55)	2	65 (29)	70 (32)
60–125 (45-90)	75–150 (55-110)	100-200 (75-150)	3	120 (54)	130 (59)
<b>575 V</b>					
7 1/2–20 (5.5-15)	10–25 (7.5-18)	25-30 (18-22)	2	55 (25)	60 (27)
25–50 (18-37)	30–60 (22-45)	40-75 (30-55)	2	65 (29)	70 (32)
60–125 (45-90)	75–150 (55-110)	100-200 (75-150)	3	120 (54)	130 (59)

**Table 3-7—1150 Drive Forms / Weights**

Power			Form	Weights	
CT	VT	ET		Chassis	Enclosed
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>		<i>lb (kg)</i>	<i>lb (kg)</i>
<b>230 V</b>					
1 1/2–3 (1.1-2.2)	2–5 (1.5-3.7)	—	5	15 (7)	20 (9)
5–20 (3.7-15)	7 1/2–25 (5.5-18)	10–30 (7.5-22)	6	20 (9)	30 (14)
25–30 (18-22)	30–40 (22-30)	40–50 (30-37)	7	50 (23)	70 (32)
40–60 (30-45)	50–75 (37-55)	60–100 (45-75)	3	100 (45)	130 (59)
<b>460 V</b>					
1 1/2–5 (1.1-3.7)	2–7 1/2 (1.5-5.5)	10 (7.5)	5	15 (7)	20 (9)
7 1/2–20 (5.5-15)	10–25 (7.5-18)	15–30 (11-22)	6	20 (9)	30 (14)
25–40 (18-30)	30–50 (22-37)	40–60 (30-45)	7	50 (23)	70 (32)
50–125 (37-90)	60–150 (45-110)	75–200 (55-150)	3	100 (45)	130 (59)

**Table 3-8—1100, 1105, and 1130 Power Dissipation**

Power			Dissipation		
CT	VT	ET	Control	Heat Sink	Total
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>kW</i>	<i>kW</i>	<i>kW</i>
<b>230 V</b>					
1 1/2 (1.1)	2 (1.5)	—	0.042	0.054	0.095
2 (1.5)	3 (2.2)	—	0.043	0.062	0.105
3 (2.2)	5 (3.7)	—	0.048	0.088	0.136
5 (3.7)	7 1/2 (5.5)	10 (7.5)	0.054	0.140	0.194
7 1/2 (5.5)	10 (7.5)	15 (11)	0.063	0.204	0.266
10 (7.5)	15 (11)	20 (15)	0.072	0.261	0.333
15 (11)	20 (15)	25 (18)	0.095	0.392	0.487
20 (15)	25 (18)	30 (22)	0.111	0.506	0.617
25 (18)	30 (22)	40 (30)	0.127	0.637	0.764
30 (22)	40 (30)	50 (37)	0.151	0.751	0.902
40 (30)	50 (37)	60 (45)	0.184	0.979	1.163
50 (37)	60 (45)	75 (55)	0.214	1.224	1.438
60 (45)	75 (55)	100 (75)	0.247	1.452	1.699
<b>460 V</b>					
1 1/2 (1.1)	2 (1.5)	—	0.042	0.040	0.082
2 (1.5)	3 (2.2)	—	0.043	0.046	0.089
3 (2.2)	5 (3.7)	—	0.046	0.065	0.111
5 (3.7)	7 1/2 (5.5)	10 (7.5)	0.054	0.104	0.158
7 1/2 (5.5)	10 (7.5)	15 (11)	0.062	0.151	0.212
10 (7.5)	15 (11)	20 (15)	0.071	0.193	0.264
15 (11)	20 (15)	25 (18)	0.087	0.289	0.376
20 (15)	25 (18)	30 (22)	0.102	0.373	0.475
25 (18)	30 (22)	40 (30)	0.117	0.469	0.586
30 (22)	40 (30)	50 (37)	0.142	0.553	0.695
40 (30)	50 (37)	60 (45)	0.173	0.720	0.893
50 (37)	60 (45)	75 (55)	0.203	0.901	1.104
<i>(continued)</i>					

**Table 3-8—1100, 1105, and 1130 Power Dissipation (continued)**

Power			Dissipation		
CT	VT	ET	Control	Heat Sink	Total
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>kW</i>	<i>kW</i>	<i>kW</i>
<b>460 V</b>					
60 (45)	75 (55)	100 (75)	0.241	1.068	1.309
75 (55)	100 (75)	125 (90)	0.289	1.332	1.621
100 (75)	125 (90)	150 (110)	0.364	1.725	2.089
125 (90)	150 (110)	200 (150)	0.448	2.169	2.617
150 (110)	200 (150)	250 (185)	0.225	3.062	3.287
200 (150)	250 (185)	300 (225)	0.275	3.999	4.274
250 (185)	300 (225)	350 (262)	0.325	4.937	5.262
300 (225)	350 (262)	400 (300)	0.375	5.874	6.249
350 (262)	400 (300)	500 (375)	0.425	6.811	7.236
400 (300)	500 (375)	600 (450)	0.475	7.749	8.224
<b>575 V</b>					
1 1/2 (1.1)	2 (1.5)	—	0.042	0.039	0.081
2 (1.5)	3 (2.2)	—	0.043	0.045	0.088
3 (2.2)	5 (3.7)	—	0.046	0.065	0.111
5 (3.7)	7 1/2 (5.5)	10 (7.5)	0.054	0.102	0.156
7 1/2 (5.5)	10 (7.5)	15 (11)	0.062	0.150	0.212
10 (7.5)	15 (11)	20 (15)	0.071	0.185	0.256
15 (11)	20 (15)	25 (18)	0.087	0.285	0.372
20 (15)	25 (18)	30 (22)	0.102	0.369	0.471
25 (18)	30 (22)	40 (30)	0.117	0.454	0.571
30 (22)	40 (30)	50 (37)	0.142	0.538	0.680
40 (30)	50 (37)	60 (45)	0.173	0.692	0.865
50 (37)	60 (35)	75 (55)	0.203	0.876	1.079
60 (45)	75 (55)	100 (75)	0.241	1.046	1.287
75 (55)	100 (75)	125 (90)	0.289	1.299	1.588
100 (75)	125 (90)	150 (110)	0.364	1.675	2.039
125 (90)	150 (110)	200 (150)	0.448	2.113	2.561

*(continued)*

**Table 3-8—1100, 1105, and 1130 Power Dissipation** *(continued)*

Power			Dissipation		
CT	VT	ET	Control	Heat Sink	Total
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>kW</i>	<i>kW</i>	<i>kW</i>
<b>575 V</b>					
150 (110)	200 (150)	250 (185)	0.225	2.992	3.217
200 (150)	250 (185)	300 (225)	0.275	3.906	4.181
250 (185)	300 (225)	350 (262)	0.325	4.819	5.144
300 (225)	350 (262)	400 (300)	0.375	5.733	6.108
350 (262)	400 (300)	500 (375)	0.425	6.647	7.072
400 (300)	500 (375)	600 (450)	0.475	7.561	8.036

**Table 3-9—1110 Power Dissipation**

Power		Dissipation		
CT	VT	Control	Heat Sink	Total
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>kW</i>	<i>kW</i>	<i>kW</i>
<b>230 V</b>				
1 1/2 (1.1)	2 (1.5)	0.045	0.054	0.098
2 (1.5)	3 (2.2)	0.049	0.062	0.111
3 (2.2)	5 (3.7)	0.054	0.088	0.142
5 (3.7)	7 1/2 (5.5)	0.065	0.140	0.205
7 1/2 (5.5)	10 (7.5)	0.079	0.204	0.283
10 (7.5)	15 (11)	0.100	0.261	0.361
15 (11)	20 (15)	0.126	0.392	0.518
20 (15)	25 (18)	0.152	0.506	0.658
25 (18)	30 (22)	0.186	0.637	0.823
30 (22)	40 (30)	0.214	0.751	0.965
40 (30)	50 (37)	0.264	0.979	1.243

*(continued)*

**Table 3-9—1110 Power Dissipation (continued)**

Power		Dissipation		
CT	VT	Control	Heat Sink	Total
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>kW</i>	<i>kW</i>	<i>kW</i>
<b>460 V</b>				
1 1/2 (1.1)	2 (1.5)	0.045	0.040	0.085
2 (1.5)	3 (2.2)	0.047	0.046	0.093
3 (2.2)	5 (3.7)	0.054	0.065	0.119
5 (3.7)	7 1/2 (5.5)	0.064	0.104	0.168
7 1/2 (5.5)	10 (7.5)	0.079	0.151	0.229
10 (7.5)	15 (11)	0.092	0.193	0.285
15 (11)	20 (15)	0.117	0.289	0.406
20 (15)	25 (18)	0.142	0.373	0.515
25 (18)	30 (22)	0.177	0.469	0.646
30 (22)	40 (30)	0.203	0.553	0.756
40 (30)	50 (37)	0.253	0.720	0.973
50 (37)	60 (45)	0.311	0.901	1.212
60 (45)	75 (55)	0.364	1.068	1.432
75 (55)	100 (75)	0.439	1.332	1.771

**Table 3-10—1150 Power Dissipation**

Power			Dissipation		
CT	VT	ET	Control	Heat Sink	Total
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>kW</i>	<i>kW</i>	<i>kW</i>
<b>230 V</b>					
1 1/2 (1.1)	2 (1.5)	—	0.039	0.042	0.080
2 (1.5)	3 (2.2)	—	0.039	0.047	0.086
3 (2.2)	5 (3.7)	—	0.042	0.067	0.109
5 (3.7)	7 1/2 (5.5)	10 (7.5)	0.044	0.106	0.150
7 1/2 (5.5)	10 (7.5)	15 (11)	0.048	0.153	0.201
10 (7.5)	15 (11)	20 (15)	0.052	0.195	0.247
15 (11)	20 (15)	25 (18)	0.065	0.292	0.357

*(continued)*

**Table 3-10—1150 Power Dissipation (continued)**

Power			Dissipation		
CT	VT	ET	Control	Heat Sink	Total
hp (kW)	hp (kW)	hp (kW)	kW	kW	kW
<b>230 V</b>					
20 (15)	25 (18)	30 (22)	0.071	0.376	0.447
25 (18)	30 (22)	40 (30)	0.077	0.473	0.550
30 (22)	40 (30)	50 (37)	0.091	0.557	0.648
40 (30)	50 (37)	60 (45)	0.104	0.724	0.828
50 (37)	60 (45)	75 (55)	0.114	0.905	1.019
60 (45)	75 (55)	100 (75)	0.127	1.072	1.199
<b>460 V</b>					
1 1/2 (1.1)	2 (1.5)	—	0.039	0.034	0.073
2 (1.5)	3 (2.2)	—	0.039	0.039	0.078
3 (2.2)	5 (3.7)	—	0.040	0.055	0.095
5 (3.7)	7 1/2 (5.5)	10 (7.5)	0.044	0.087	0.131
7 1/2 (5.5)	10 (7.5)	15 (11)	0.047	0.125	0.172
10 (7.5)	15 (11)	20 (15)	0.051	0.160	0.211
15 (11)	20 (15)	25 (18)	0.057	0.239	0.296
20 (15)	25 (18)	30 (22)	0.062	0.308	0.370
25 (18)	30 (22)	40 (30)	0.067	0.388	0.455
30 (22)	40 (30)	50 (37)	0.082	0.456	0.538
40 (30)	50 (37)	60 (45)	0.093	0.593	0.686
50 (37)	60 (35)	75 (55)	0.103	0.741	0.844
60 (45)	75 (55)	100 (75)	0.121	0.878	0.999
75 (55)	100 (75)	125 (90)	0.139	1.094	1.233
100 (75)	125 (90)	150 (110)	0.164	1.414	1.578
125 (90)	150 (110)	200 (150)	0.198	1.778	1.976

# 4 Electrical Installation

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## 4.1 Overview

This chapter explains the electrical installation of the drive. It covers grounding, input power, motor output, dynamic braking, bus connections, and basic control connections. Since control signals vary from application to application, specific wiring instructions are discussed in the application documentation.

## 4.2 Wiring Requirements

Follow the instructions below to ensure safe, reliable electrical connections.

### 4.2.1 Standards and Codes

All wiring must conform to applicable local and national codes.

---



#### Attention

The supplier cannot assume responsibility for compliance or noncompliance to any code governing the proper installation of this unit. The following information is intended only as a guide for proper installation. All wiring must conform to the National Electrical Code (NEC), described in publication NFPA No. 70. Local codes may overrule this information.

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### 4.2.2 Conductors

Size conductors according to the National Electrical Code (NEC) based upon the required current-carrying capacity. All wires should be stranded copper with a rating of 167° F (75° C) or higher.

Wires terminating in terminal blocks must meet the gauge limitations of the terminal as well. Acceptable wire sizes for ground and power connection terminals are specified in Table 4-4 through Table 4-7 and for control signal connection terminals in Table 4-17.

Wires terminating at studs or bolts must use ring lugs to provide a solid connection. Use UL-approved lugs suitable for the currents required. For these connections, Table 4-4 through Table 4-7 list the stud or bolt size rather than the acceptable wire size.

### 4.2.3 Tightening Torque

Tighten connections by applying the recommended tightening torque listed in Table 4-4 through Table 4-7 (for ground and power connections) and in Table 4-17 and (for control signal connections). Use a torque wrench to ensure that connections are properly tightened.



### 4.3 Insulation Tests

Any site insulation tests must be performed before making electrical connections to the drive. These tests should conform to all applicable national and local codes. A suggested procedure for checking installation insulation is outlined below.



#### Attention

Before performing the insulation tests, make certain that the drive is disconnected from the input power (S, T or R, S, T or R1, R2, S1, S2, T1, T2). Also verify that the motor cable is disconnected from drive output terminals (U, V, W) and from the motor.

- Measure the insulation resistance of the motor between the phases and between each phase and protective ground. The voltage range of the meter must be at least equal to the line voltage but not higher than 1,000 V. The insulation resistance must be greater than 1 MΩ.
- Measure the insulation resistance of the motor cable between the phases and between each phase and protective ground. The insulation resistance must be greater than 1 MΩ.

### 4.4 Ground Connections

Proper grounding procedures are essential to the safe, successful operation of the drive. Careful attention to these procedures can prevent electrical noise from disrupting drive operation.

The drive, power supply, motor, and control circuits should all share a common earth ground. Refer to the appropriate connection diagram as listed in Table 4-1 below. Refer to Section 4.2 for wiring requirements. Ground connection terminal specifications for the various drives are provided in the tables summarized in Table 4-1.



PE

#### Ground terminal designation

Ground terminals are designated by the IEC symbol at left, by PE (protective earth), or both. Such terminals are internally connected and tied to the chassis or enclosure. They are intended for connecting both the protective earth ground electrode as well as any external protective grounding conductors.

**Table 4-1—Power/Ground Connection Tables**

Drive	Connection Diagram	Terminal Specifications
1100	Figure 4-1	Table 4-4
1105	Figure 4-2	Table 4-5
1110	Figure 4-4	Table 4-6
1130	Figure 4-5	Table 4-7
1150	Figure 4-6	Table 4-8

#### 4.4.1 Ground the drive

The ground terminals (PE) of the drive should be connected to either a grounding electrode buried in the earth or a suitable plant ground with a solid connection to earth ground. The ground connector should be an electrode conductor or bonding jumper of sufficient capacity.

Refer to Publication NFPA No. 70, Article 250, and to the IEEE “greenbook” for details on grounding and grounding electrodes.

#### 4.4.2 Ground the Power Supply

The incoming power supply must be earth grounded for ground fault protection.

#### 4.4.3 Ground the Motor and Transducer

The motor case and encoder or resolver case, if present, must also be earth grounded. To minimize electrical noise emissions, it is recommended that a ground lead from the motor case return with the motor stator leads to the drive ground terminals.

#### 4.4.4 Connect the Control Grounds

Connect the logic commons of the various low-voltage control circuits and any external control circuits to the drive ground.

### 4.5 Input Power Supply

The 1100, 1105, 1110, and 1130 drives must be connected to the input power supply. Fuses or a circuit breaker must be used to protect the unit from short circuits. A line reactor or isolation transformer may also be necessary to condition the power source.

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#### Attention



- Do not supply input voltages higher than that specified. Higher input voltages may damage the drive.
- Input power (S, T or R, S, T or R1, R2, S1, S2, T1, T2) should be able to supply at least 1.5 times the inverter capacity.
- Do not connect supply input voltage (S, T or R, S, T or R1, R2, S1, S2, T1, T2) to output terminals (U, V, W).
- Do not use power factor correction capacitors on the input or the output.
- Do not run or stop the inverter by applying and removing power. Use only the keypad, digital inputs, or serial commands to operate the drive.
- Do not perform the Megger test.

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#### Attention



The drive is not equipped with a supply-disconnecting device. An external supply-disconnecting device must be provided to isolate incoming electrical supplies during installation and maintenance work. This supply-disconnecting device should comply with all applicable national and local codes.

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### **Attention**

High voltage may be present even when all electrical power supplies are disconnected. After switching off electrical power, wait at least 15 minutes for bus circuit capacitors to discharge before working on the drive or associated equipment. Use an appropriate voltmeter to further verify that capacitors are discharged before beginning work. Do not rely exclusively on the bus voltage indicator. Dangerous voltage levels may remain even when the indicator is off.

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#### **4.5.1 Power Source Conditioning**

The use of an AC line reactor and/or isolation transformer is recommended under certain circumstances. The drive is designed for direct connection to AC lines of the correct voltage and impedance. Use the guidelines that follow to determine whether an isolation transformer or line reactor is required. Refer to Table 4-11 for isolation transformer sizing specifications and to Table 4-12 through Table 4-14 for line reactor sizing specifications for three-phase connections. When using a single-phase input, select a line reactor based upon the input current requirements of the 1110 drive as specified in Table 4-10. You may purchase isolation transformers and line reactors directly from Unico or from your value-added reseller. Contact your representative or the factory for more information.

##### **Impedance mismatch**

Input lines must have a minimum impedance of 1% relative to the rated input kVA of the drive (assume the drive's horsepower rating is approximately equal to its kVA rating). If the line has a lower impedance, a line reactor or isolation transformer must be added ahead of the drive to increase line impedance. If line impedance is too low, transient voltage spikes or interruptions can create excessive current spikes that may cause nuisance input fuse blowing and may damage the drive. Generally, if the kVA capacity of the AC line is greater than four times the rated power of the motor (in horsepower), an isolation transformer or AC line reactor should be used.

##### **No neutral or referenced phase**

If the AC input power system does not have a neutral or one phase referenced to ground, an isolation transformer with the neutral of the secondary grounded is highly recommended. If the line-to-ground voltages on any phase exceed 125% of the nominal line-to-line voltage, an isolation transformer with the neutral of the secondary grounded is always required.

##### **Transient power interruptions or voltage spikes**

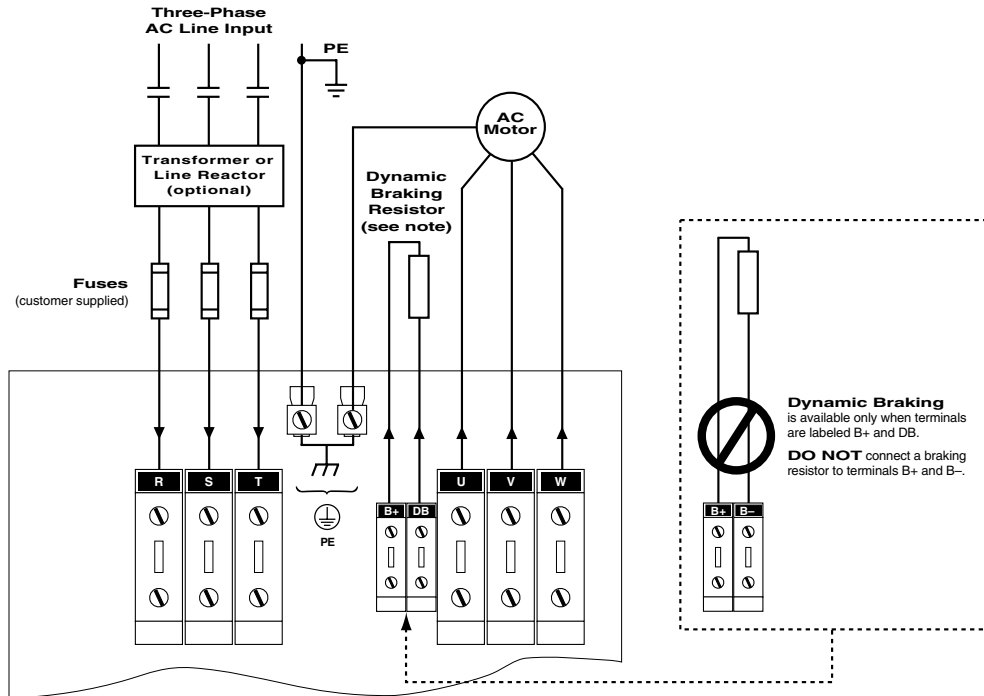
If the AC line frequency experiences transient power interruptions or significant voltage spikes, an isolation transformer or AC line reactor must be installed. The drive can be damaged by extreme voltage and current spikes.

##### **Power factor correction capacitors**

If the AC line supplying the drive has power factor correction capacitors that are switched in and out, an isolation transformer or AC line reactor must be installed between the drive and the capacitors. The drive can be damaged by the extreme voltage and current spikes caused by capacitor switching. If the capacitors are permanently connected and not switched, the guideline for impedance mismatch applies.

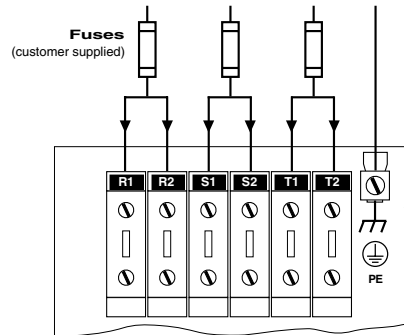
# Figure 4-1—1100 Power and Grounding Connections

1 1/2 to 60 hp (CT) 230 V and 1 1/2 to 100 hp (CT) 460 V and 575 V

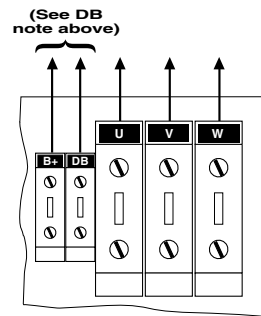


125 to 400 hp (CT) 460 V and 575 V

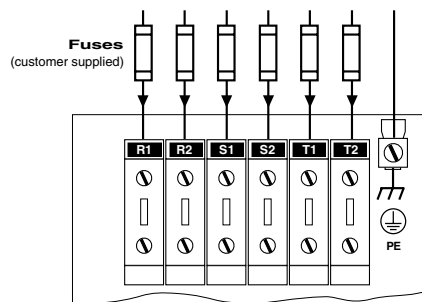
**Three-Phase Input (Six-Pulse Operation)**  
125 hp (CT)



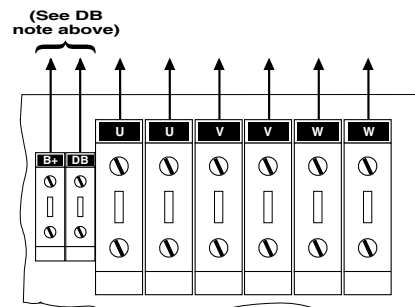
**Drive Output**  
150 hp (CT) 460 V and  
150 to 200 hp (CT) 575 V



**Six-Phase Input (Twelve-Pulse Operation)**  
150 to 400 hp (CT)

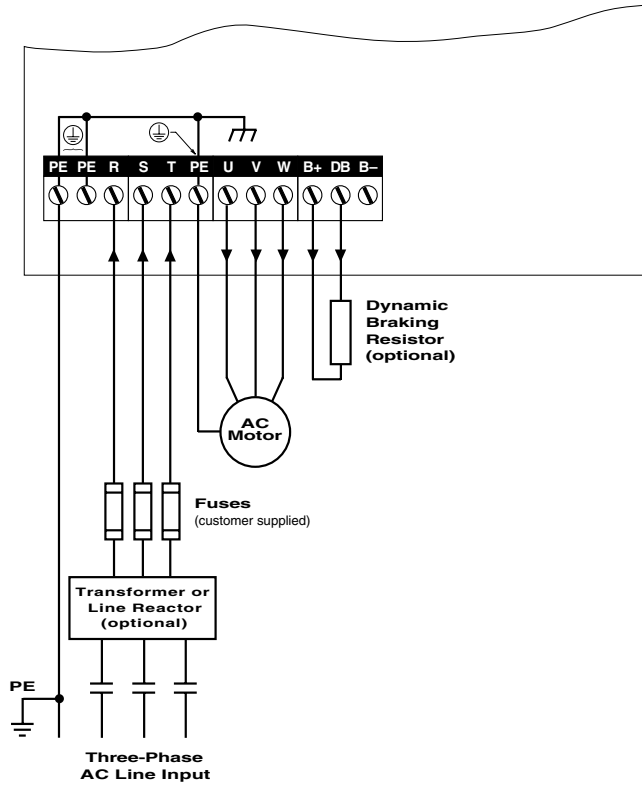


**Drive Output**  
125 / 200 to 350 (CT) 460 V and  
125 / 250 to 400 hp (CT) 575 V

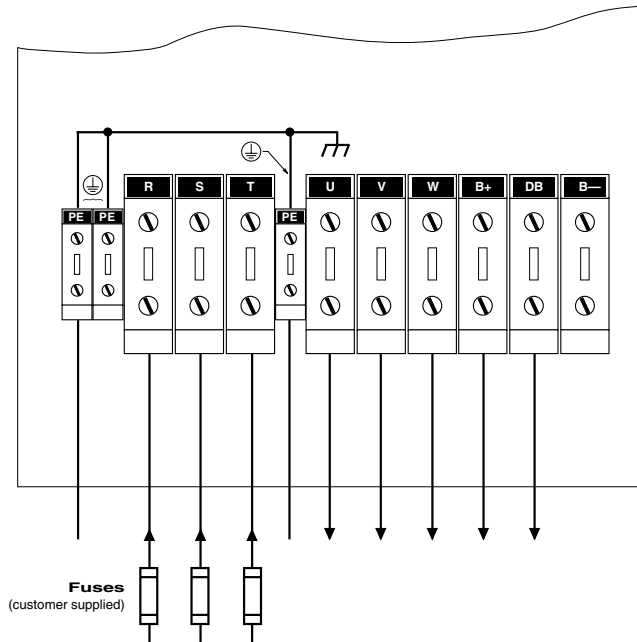


**Figure 4-2—1105 Power and Grounding Connections**

1 1/2 to 20 hp (CT) 230 V and 460 V



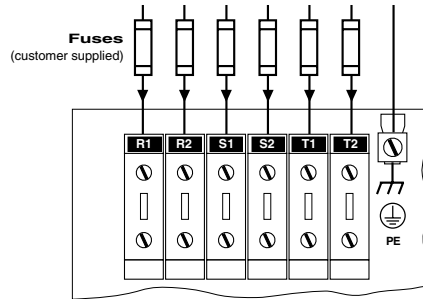
25 to 40 hp (CT) 460 V



**Figure 4-3—1105 Power and Grounding Connections** (continued)

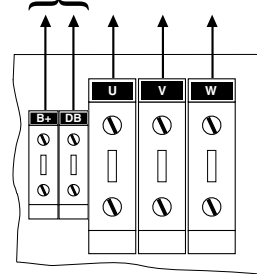
50 to 150 hp (CT) 460 V and 50 to 200 hp 575 V

**Six-Phase Input** (Twelve-Pulse Operation)  
 50 to 150 hp (CT) 460 V and  
 50 to 200 hp (CT) 575 V



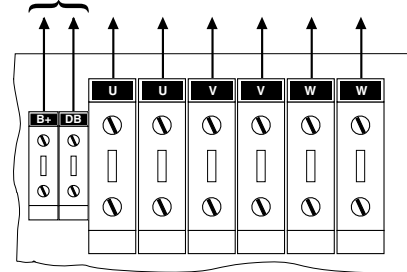
**Drive Output**  
 50 to 100 hp (CT) 460 V and 575 V

(See DB note above)

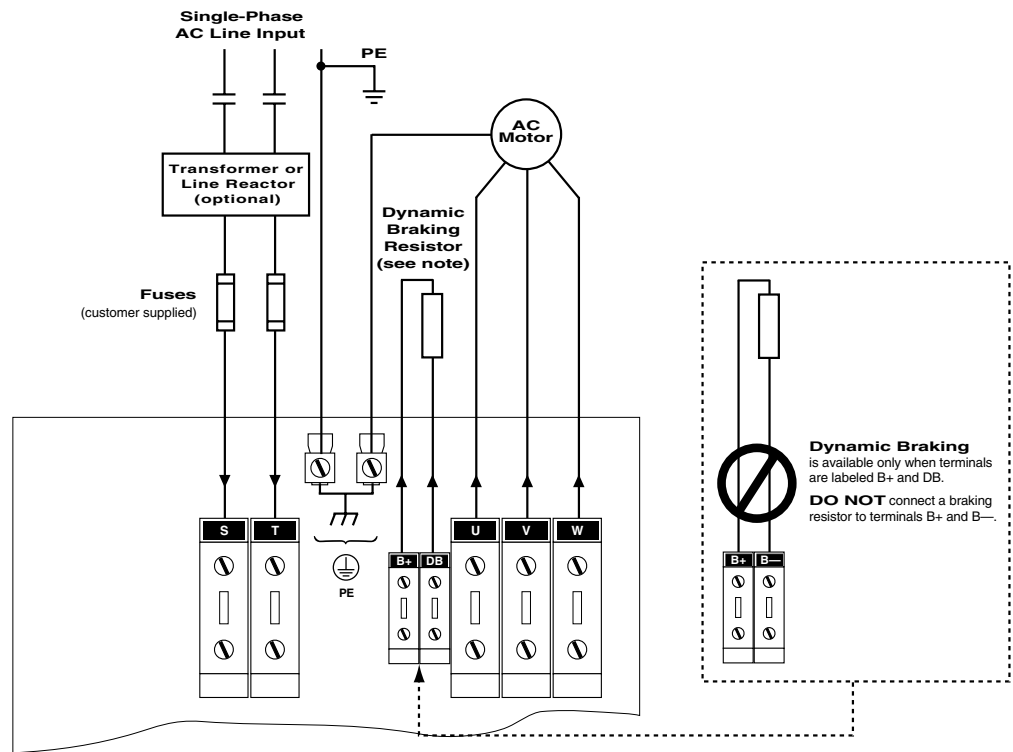


**Drive Output**  
 125 to 150 hp (CT) 460 V and  
 125 to 200 hp (CT) 575 V

(See DB note above)

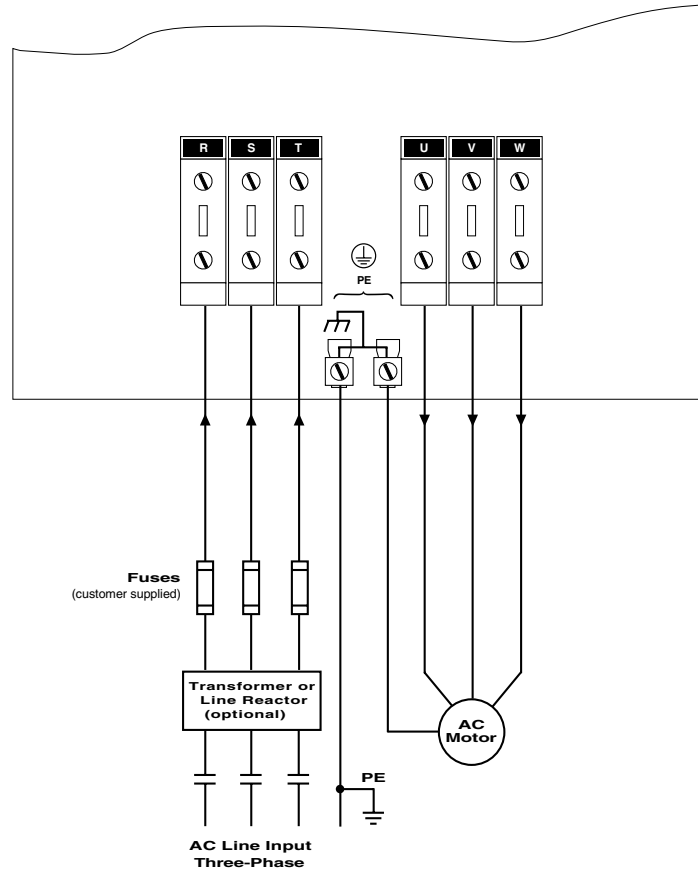


**Figure 4-4—1110 Power and Grounding Connections**

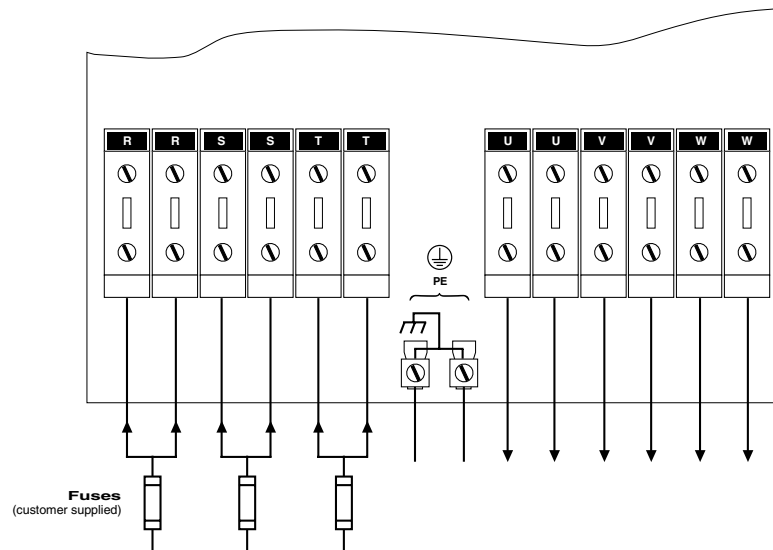


**Figure 4-5—1130 Power and Grounding Connections**

7 1/2 to 40 hp (CT) 230 V and 7 1/2 to 100 hp (CT) 460 V and 575 V



50 to 60 hp (CT) 230 V and 125 hp (CT) 460 V and 575 V





**Figure 4-6—1150 Power and Grounding Connections**

#### **4.5.2 Connect the Power Supply**

Connect the line power supply leads to the 1100, 1105, 1110, and 1130 drives using the appropriate connection diagram as listed in Table 4-1. Depending upon the drive model and its power rating, the drive may accept either a single-phase (S, T), a three-phase (R, S, T), or a six-phase (R1, R2, S1, S2, T1, T2) input. If six-phase (12-pulse) operation is unnecessary, six-phase drives may also be configured for three-phase (six-pulse) operation. Refer to the connection examples in Figure 4-1. Input connection terminal specifications for the various drives are provided in the tables summarized in Table 4-1. Large drives use double terminals (indicated by x2) to accommodate the maximum required currents. High-power drive sizes provide for optional six-phase (12-pulse) connection and, therefore, also have double terminals (indicated x2). Refer to Section 4.2 for wiring requirements. The inverter is phase-sequence insensitive, so the input leads may be connected in any order. Make certain that AC power inputs are routed separately from control signals.

#### **4.5.3 Input Protection**

The 1100, 1105, 1110, and 1130 drives must be protected from short circuits using either a circuit breaker or fusing.

Fuses are not supplied with the unit and must be provided externally. Fuse recommendations and specifications are provided in Table 4-9 (1100, 1105, and 1130 drives) and Table 4-10 (1110 drives). Select fuses according to the power of the application, not necessarily according to the drive rating. For example, a drive rated 40 hp CT can also be applied at 50 hp VT or 60 hp ET, depending upon the overload requirements of the application. The nominal ratings of the drive can be found on the rating label. Fuse recommendations differ for single-, three-, and six-phase configurations. The recommended fuse ratings for the six-phase (twelve-pulse) connections are 60% of those listed for the three-phase (six-pulse) connection in Table 4-9.

Fuses from other manufacturers may be used as long as they meet the specifications given. Semiconductor fuses provide the highest level of protection and are recommended. UL-listed drives must use UL-recognized fuses under category 2. For help in locating additional UL-recognized fuse manufacturers, please contact the factory.

If a circuit breaker is to be used, refer to Table 4-9 (1100, 1105, and 1130 drives) or Table 4-10 (1110 drives) to determine the proper current rating using the input current and applying a margin of approximately 33%. You may purchase a circuit breaker directly from Unico or from your value-added reseller. Contact your representative or the factory directly for more information.

#### **4.6 Connect the Motor**

Connect the motor leads using the appropriate connection diagram as listed in Table 4-1. Motor output terminal specifications for the various drives are provided in the tables summarized in Table 4-1. High-power drives have two terminals per motor phase (indicated x2) to provide for convenient wire gauges. Refer to Section 4.2 for wiring requirements. Use of a metal-jacketed motor cable is recommended to minimize noise emissions. Refer to Table 2-13 to determine the output current rating of the drive.

If the motor has a transducer, the motor leads may be connected in any order and the drive will determine the correct phasing accordingly. If the motor does not have a transducer, you may have to rephase it during start-up. Refer to the application documentation for further information.

High-frequency voltage switching on these connections necessitates care to minimize electrical noise interference. Make certain that motor outputs are routed separately from control signals and AC input power and that control signals are appropriately shielded.

#### 4.7 Connect the Dynamic Braking Resistor

Dynamic braking control for use with an external resistor is included on 230 V and 460 V 1105 drives through 40 hp (CT). It is optional on all other 1105 drives and on 1100 and 1110 drives. Drives with optional braking control have terminals labeled B+ and DB. Units having B+ and B– terminals, including 1150 drives, do not feature dynamic braking.

Connect the braking resistor to the B+ and DB terminals using the appropriate connection diagram as listed in Table 4-1. Dynamic braking terminal specifications for the various drives are provided in the tables summarized in Table 4-1. Refer to Section 4.2 for wiring requirements.

Dynamic braking resistors are available from the factory or you may supply your own. Resistors are sized to give a braking torque of either 100%, 150%, or 200% of rated torque or 100% of rated torque (for 1105 drives with integral control) with a capacity of 5%, 10%, or 20% of the associated drive constant-torque power rating. Consult the factory for other combinations. If providing your own resistor, size it according to Table 4-15. Make certain braking resistors provide at least the minimum resistance specified in Table 4-16 to accommodate braking device current limitations. Consult the factory for sizing assistance.

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##### Attention



The braking resistor should be mounted in a well-ventilated area. Avoid placing it in a location where heat could cause injury or property damage. The resistor should be housed in a metal enclosure to shield neighboring equipment from electromagnetic emissions. If it is mounted outside of the enclosure, a guard should be constructed to prevent accidental contact.

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##### Attention



Do not connect any kind of power supply to the dynamic braking resistor terminals. Do not connect a resistor rated less than specified.

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## 4.8 Bus Connections

The drive bus can be connected externally for sharing energy between units or for storing energy in a capacitor bank. Bus connections are available on 1100 and 1110 drives without optional braking control, on low-power 1105 drives and higher-power 1105 drives without braking control, and on all 1130 and 1150 drives. Units having bus connections provide terminals labeled B+ and B-.

Connect the B+ and B- terminals of the 1150 drive to the common DC bus using the appropriate connection diagram as listed in Table 4-1 [really? Bus in 4-1 or input?]. Bus terminal specifications for the 1150 drive are provided in the tables summarized in Table 4-1. Use the bus current information listed in Table 4-3 to determine proper wire sizing. Nominal bus voltages are provided in Table 4-2. Refer to Section 4.2 for wiring requirements.

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### Attention



High voltage may be present even when all electrical power supplies are disconnected. After switching off electrical power, wait at least 15 minutes for bus circuit capacitors to discharge before working on the drive or associated equipment. Use an appropriate voltmeter to further verify that capacitors are discharged before beginning work. Do not rely exclusively on the bus voltage indicator. Dangerous voltage levels may remain even when the indicator is off.

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### 4.8.1 Common-Bus Operation

The buses of multiple drives can be interconnected in certain applications to enable motoring and braking energies to circulate between units. The 1150 drive is intended for multidrive operation from a common bus. Consult the factory for assistance in using a common-bus connection with other drives.

**Table 4-2—Nominal Bus Voltages**

Input Power	Bus Voltage
230 V AC	311 V DC
380 V AC	513 V DC
460 V AC	621 V DC
575 V AC	776 V DC

**Table 4-3—DC Bus Currents**

<b>Power</b>	<b>230 V</b>	<b>380 V</b>	<b>460 V</b>
<i>hp (kW)</i>	<i>A<sub>dc</sub></i>	<i>A<sub>dc</sub></i>	<i>A<sub>dc</sub></i>
1 1/2 (1.1)	4.9	2.8	2.5
2 (1.5)	6.1	3.5	3.0
3 (2.2)	8.9	5.1	4.4
5 (3.7)	14.4	8.3	7.2
7 1/2 (5.5)	21.2	12.2	10.6
10 (7.5)	27.6	15.9	13.8
15 (11)	41.4	23.8	20.7
20 (15)	54.2	31.2	27.1
25 (18)	68.0	39.1	34.0
30 (22)	80.8	46.5	40.4
40 (30)	106.4	61.2	53.2
50 (37)	133.0	76.5	66.5
60 (45)	158.6	91.2	79.3
75 (55)	—	113.8	99.0
100 (75)	—	149.4	129.9
125 (90)	—	187.3	162.9
150 (110)	—	220.4	191.7
200 (150)	—	293.9	255.6
250 (185)	—	367.4	319.5
300 (225)	—	440.9	383.4
350 (262)	—	514.4	447.3
400 (300)	—	587.9	511.2
500 (375)	—	734.8	639.0
600 (450)	—	—	766.8

**Table 4-4—1100 Ground and Power Terminal Specifications**

Power			Terminal							
			Ground	AC Line Input		Motor Output		Dynamic Braking or Bus		
			(PE)	(R, S, T or R1, R2, S1, S2, T1, T2)				(U, V, W)		
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>230 V</b>										
1 1/2 (1.1)	2 (1.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
2 (1.5)	3 (2.2)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
3 (2.2)	5 (3.7)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
5 (3.7)	7 1/2 (5.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
7 1/2 (5.5)	10 (7.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
10 (7.5)	15 (11)	—	12-1 (3.3-42)	200 (23)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
15 (11)	20 (15)	—	12-1 (3.3-42)	200 (23)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
20 (15)	25 (18)	—	12-1 (3.3-42)	200 (23)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
25 (18)	30 (22)	—	12-1 (3.3-42)	200 (23)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
30 (22)	40 (30)	—	12-1 (3.3-42)	200 (23)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
40 (30)	50 (37)	—	12-1 (3.3-42)	200 (23)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
50 (37)	60 (45)	—	12-1 (3.3-42)	200 (23)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
60 (45)	75 (55)	—	12-1 (3.3-42)	200 (23)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
<b>460 V</b>										
1 1/2 (1.1)	2 (1.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
2 (1.5)	3 (2.2)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
3 (2.2)	5 (3.7)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
5 (3.7)	7 1/2 (5.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
7 1/2 (5.5)	10 (7.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
10 (7.5)	15 (11)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
15 (11)	20 (15)	25 (18)	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
20 (15)	25 (18)	30 (22)	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
25 (18)	30 (22)	40 (30)	12-1 (3.3-42)	200 (23)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)

(continued)

**Table 4-4—1100 Ground and Power Terminal Specifications (continued)**

Power			Terminal							
			Ground	AC Line Input		Motor Output		Dynamic Braking or Bus		
			(PE)	(R, S, T or R1, R2, S1, S2, T1, T2)		(U, V, W)		(B+, DB or B+, B-)		
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>460 V</b>										
30 (22)	40 (30)	50 (37)	12-1 (3.3-42)	200 (23)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
40 (30)	50 (37)	60 (45)	12-1 (3.3-42)	200 (23)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
50 (37)	60 (45)	75 (55)	12-1 (3.3-42)	200 (23)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
60 (45)	75 (55)	100 (75)	12-1 (3.3-42)	200 (23)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
75 (55)	100 (75)	125 (90)	12-1 (3.3-42)	200 (23)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
100 (75)	125 (90)	150 (110)	12-1 (3.3-42)	200 (23)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
125 (90)	150 (110)	—	12-1 (3.3-42)	200 (23)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
150 (110)	200 (150)	250 (185)	12-1 (3.3-42)	200 (23)	2-4/0 (x2) (34-107)	133-177 (15-20)	2/0-500 (67-253)	221-266 (25-30)	6-1/0 (13-53)	53.1-70.9 (6.0-8.0)
200 (150)	250 (185)	300 (225)	12-1 (3.3-42)	200 (23)	2-300 (x2) (34-152)	221-266 (25-30)	2-4/0 (x2) (34-107)	133-177 (15-20)	6-1/0 (13-53)	53.1-70.9 (6.0-8.0)
250 (185)	300 (225)	350 (262)	12-1 (3.3-42)	200 (23)	2-300 (x2) (34-152)	221-266 (25-30)	2-300 (x2) (34-152)	221-266 (25-30)	2-4/0 (34-107)	133-177 (15-20)
300 (225)	350 (262)	400 (300)	12-1 (3.3-42)	200 (23)	2/0-500 (x2) (67-253)	221-266 (25-30)	2/0-500 (x2) (67-253)	221-266 (25-30)	2-4/0 (34-107)	133-177 (15-20)
350 (262)	400 (300)	500 (375)	12-1 (3.3-42)	200 (23)	2/0-500 (x2) (67-253)	221-266 (25-30)	2/0-500 (x2) (67-253)	221-266 (25-30)	2-4/0 (34-107)	133-177 (15-20)
400 (300)	500 (375)	600 (450)	12-1 (3.3-42)	200 (23)	2/0-500 (x2) (67-253)	221-266 (25-30)	2-300 (x3) (34-152)	221-266 (25-30)	2-300 (34-152)	221-266 (25-30)
<b>575 V</b>										
1 1/2 (1.1)	2 (1.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
2 (1.5)	3 (2.2)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
3 (2.2)	5 (3.7)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
5 (3.7)	7 1/2 (5.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
7 1/2 (5.5)	10 (7.5)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
10 (7.5)	15 (11)	—	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
15 (11)	20 (15)	25 (18)	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
20 (15)	25 (18)	30 (22)	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
25 (18)	30 (22)	40 (30)	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)

(continued)

**Table 4-4—1100 Ground and Power Terminal Specifications (continued)**

Power			Terminal							
			Ground	AC Line Input		Motor Output		Dynamic Braking or Bus		
			(PE)	(R, S, T or R1, R2, S1, S2, T1, T2)		(U, V, W)		(B+, DB or B+, B-)		
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>575 V</b>										
30 (22)	40 (30)	50 (37)	12-1 (3.3-42)	200 (23)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
40 (30)	50 (37)	60 (45)	12-1 (3.3-42)	200 (23)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
50 (37)	60 (45)	75 (55)	12-1 (3.3-42)	200 (23)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
60 (45)	75 (55)	100 (75)	12-1 (3.3-42)	200 (23)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
75 (55)	100 (75)	125 (90)	12-1 (3.3-42)	200 (23)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
100 (75)	125 (90)	150 (110)	12-1 (3.3-42)	200 (23)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	20-6 (0.5-13)	10.6-12.4 (1.2-1.4)
125 (90)	150 (110)	—	12-1 (3.3-42)	200 (23)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
150 (110)	200 (150)	250 (185)	12-1 (3.3-42)	200 (23)	2-4/0 (x2) (34-107)	133-177 (15-20)	2/0-500 (x2) (67-253)	221-266 (25-30)	6-1/0 (13-53)	53.1-70.9 (6.0-8.0)
200 (150)	250 (185)	300 (225)	12-1 (3.3-42)	200 (23)	2-4/0 (x2) (34-107)	133-177 (15-20)	2/0-500 (x2) (67-253)	221-266 (25-30)	6-1/0 (13-53)	53.1-70.9 (6.0-8.0)
250 (185)	300 (225)	350 (262)	12-1 (3.3-42)	200 (23)	2-4/0 (x2) (34-107)	133-177 (15-20)	2-4/0 (x2) (34-107)	133-177 (15-20)	6-1/0 (13-53)	53.1-70.9 (6.0-8.0)
300 (225)	350 (262)	400 (300)	12-1 (3.3-42)	200 (23)	2-300 (x2) (34-152)	221-266 (25-30)	2-300 (x2) (34-152)	221-266 (25-30)	2-4/0 (34-107)	133-177 (15-20)
350 (262)	400 (300)	500 (375)	12-1 (3.3-42)	200 (23)	2/0-500 (x2) (67-253)	221-266 (25-30)	2/0-500 (x2) (67-253)	221-266 (25-30)	2-4/0 (34-107)	133-177 (15-20)
400 (300)	500 (375)	600 (450)	12-1 (3.3-42)	200 (23)	2/0-500 (x2) (67-253)	221-266 (25-30)	2/0-500 (x2) (67-253)	221-266 (25-30)	2-4/0 (34-107)	133-177 (15-20)



**Table 4-5—1105 Ground and Power Terminal Specifications**

Power			Terminal							
			Ground		AC Line Input		Motor Output		Dynamic Braking or Bus	
			(PE, SH)		(R, S, T)		(U, V, W)		(B+, DB, B-)	
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>230 V</b>										
1 1/2 (1.1)	2 (1.5)	—	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
2 (1.5)	3 (2.2)	—	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
3 (2.2)	5 (3.7)	—	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
5 (3.7)	7 1/2 (5.5)	10 (7.5)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
7 1/2 (5.5)	10 (7.5)	15 (11)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
10 (7.5)	15 (11)	20 (15)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
15 (11)	20 (15)	25 (18)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
20 (15)	25 (18)	—	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
<b>460 V</b>										
1 1/2 (1.1)	2 (1.5)	—	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
2 (1.5)	3 (2.2)	—	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
3 (2.2)	5 (3.7)	—	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
5 (3.7)	7 1/2 (5.5)	10 (7.5)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)	24–10 (0.2-5.3)	4.4–5.3 (0.5-0.6)
7 1/2 (5.5)	10 (7.5)	15 (11)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
10 (7.5)	15 (11)	20 (15)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
15 (11)	20 (15)	25 (18)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
20 (15)	25 (18)	30 (22)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)	18–4 (0.8-21)	16 (1.8)
25 (18)	30 (22)	40 (30)	20–6 (0.5-13)	10.6–12.3 (1.4)	20–6 (0.5-13)	10.6–12.4 (1.4)	20–6 (0.5-13)	10.6–12.4 (1.4)	20–6 (0.5-13)	10.6–12.4 (1.4)
30 (22)	40 (30)	50 (37)	20–6 (0.5-13)	10.6–12.3 (1.4)	18–6 (0.8-13)	10.6–12.4 (1.2-1.4)	18–6 (0.8-13)	10.6–12.4 (1.2-1.4)	20–6 (0.5-13)	10.6–12.4 (1.4)
40 (30)	50 (37)	60 (45)	20–6 (0.5-13)	10.6–12.3 (1.4)	10–1/0 (5.3-53)	24.9–26.7 (2.8-3.0)	10–1/0 (5.3-53)	24.9–26.7 (2.8-3.0)	20–6 (0.5-13)	10.6–12.4 (1.4)
50 (37)	60 (45)	75 (55)	12–1 (3.3-42)	200 (23)	20–6 (x2) (0.5-13)	10.6–12.4 (1.4)	10–1/0 (5.3-53)	24.9–26.7 (2.8-3.0)	20–6 (0.5-13)	10.6–12.4 (1.4)
60 (45)	75 (55)	100 (75)	12–1 (3.3-42)	200 (23)	18–6 (x2) (0.8-13)	10.6–12.4 (1.2-1.4)	4–2/0 (21-67)	53.4–62.3 (6.0-7.0)	20–6 (0.5-13)	10.6–12.4 (1.4)
75 (55)	100 (75)	125 (90)	12–1 (3.3-42)	200 (23)	10–1/0 (x2) (5.3-53)	24.9–26.7 (2.8-3.0)	4–4/0 (21-107)	75.3–84.1 (8.5-9.5)	20–6 (0.5-13)	10.6–12.4 (1.4)

(continued)

**Table 4-5—1105 Ground and Power Terminal Specifications (continued)**

Power			Terminal							
			Ground	AC Line Input		Motor Output		Dynamic Braking or Bus		
			(PE)	(R, S, T or R1, R2, S1, (U, V, W) S2, T1, T2)				(B+, DB, B-)		
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>460 V</b>										
100 (75)	125 (90)	150 (110)	12-1 (3.3-42)	200 (23)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	20-6 (13)	10.6-12.4 (1.4)
125 (90)	150 (110)	200 (150)	12-1 (3.3-42)	200 (23)	4-2/0 (x2) (21-67)	53.4-62.3 (6.0-7.0)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
150 (110)	200 (150)	250 (185)	12-1 (3.3-42)	200 (23)	4-4/0 (x2) (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (x2) (21-107)	75.3-84.1 (8.5-9.5)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)
<b>575 V</b>										
1 1/2 (1.1)	2 (1.5)	—	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)
2 (1.5)	3 (2.2)	—	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)
3 (2.2)	5 (3.7)	—	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)
5 (3.7)	7 1/2 (5.5)	10 (7.5)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)
7 1/2 (5.5)	10 (7.5)	15 (11)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)
10 (7.5)	15 (11)	20 (15)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)	18-4 (0.8-21)	16 (1.8)
15 (11)	20 (15)	25 (18)	20-6 (0.5-13)	10.6-12.3 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)
20 (15)	25 (18)	30 (22)	20-6 (0.5-13)	10.6-12.3 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)
25 (18)	30 (22)	40 (30)	20-6 (0.5-13)	10.6-12.3 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)
30 (22)	40 (30)	50 (37)	20-6 (0.5-13)	10.6-12.3 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)
40 (30)	50 (37)	60 (45)	20-6 (0.5-13)	10.6-12.3 (1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)	20-6 (0.5-13)	10.6-12.4 (1.4)
50 (37)	60 (45)	75 (55)	12-1 (3.3-42)	200 (23)	20-6 (x2) (0.5-13)	10.6-12.4 (1.4)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.4)
60 (45)	75 (55)	100 (75)	12-1 (3.3-42)	200 (23)	18-6 (x2) (0.8-13)	10.6-12.4 (1.2-1.4)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)	20-6 (0.5-13)	10.6-12.4 (1.4)
75 (55)	100 (75)	125 (90)	12-1 (3.3-42)	200 (23)	18-6 (x2) (0.8-13)	10.6-12.4 (1.2-1.4)	4-2/0 (21-67)	53.4-62.3 (6.0-7.0)	20-6 (0.5-13)	10.6-12.4 (1.4)
100 (75)	125 (90)	150 (110)	12-1 (3.3-42)	200 (23)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	4-4/0 (21-107)	75.3-84.1 (8.5-9.5)	20-6 (0.5-13)	10.6-12.4 (1.4)
125 (90)	150 (110)	200 (150)	12-1 (3.3-42)	200 (23)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
150 (110)	200 (150)	250 (185)	12-1 (3.3-42)	200 (23)	4-2/0 (x2) (21-67)	53.4-62.3 (6.0-7.0)	10-1/0 (x2) (5.3-53)	24.9-26.7 (2.8-3.0)	18-6 (0.8-13)	10.6-12.4 (1.2-1.4)
200 (150)	250 (185)	300 (225)	12-1 (3.3-42)	200 (23)	4-4/0 (x2) (21-107)	75.3-84.1 (8.5-9.5)	4-4/0 (x2) (21-107)	75.3-84.1 (8.5-9.5)	10-1/0 (5.3-53)	24.9-26.7 (2.8-3.0)

**Table 4-6—1110 Ground and Power Terminal Specifications**

Power		Terminal							
		Ground		AC Line Input		Motor Output		Dynamic Braking or Bus	
		(PE)		(S, T)		(U, V, W)		(B+, DB or B+, B-)	
CT	VT	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
hp (kW)	hp (kW)	AWG (mm <sup>2</sup> )	in•lb (Nm)	AWG (mm <sup>2</sup> )	in•lb (Nm)	AWG (mm <sup>2</sup> )	in•lb (Nm)	AWG (mm <sup>2</sup> )	in•lb (Nm)
<b>230 V</b>									
1 1/2 (1.1)	2 (1.5)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
2 (1.5)	3 (2.2)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
3 (2.2)	5 (3.7)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
5 (3.7)	7 1/2 (5.5)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
7 1/2 (5.5)	10 (7.5)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
10 (7.5)	15 (11)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
15 (11)	20 (15)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	4 (16)	12 (1.4)	6 (10)	12 (1.4)
20 (15)	25 (18)	6 (x2) (10)	12 (1.4)	1/0 (x2) (35)	25 (2.8)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)
25 (18)	30 (22)	6 (x2) (10)	12 (1.4)	1/0 (x2) (35)	25 (2.8)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)
30 (22)	40 (30)	2 (x2) (33)	15 (1.8)	4/0 (x2) (95)	150 (17)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)
40 (30)	50 (37)	2 (x2) (33)	15 (1.8)	4/0 (x2) (95)	150 (17)	4/0 (95)	50 (5.6)	4 (16)	12 (1.4)
<b>460 V</b>									
1 1/2 (1.1)	2 (1.5)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
2 (1.5)	3 (2.2)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
3 (2.2)	5 (3.7)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
5 (3.7)	7 1/2 (5.5)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
7 1/2 (5.5)	10 (7.5)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
10 (7.5)	15 (11)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
15 (11)	20 (15)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
20 (15)	25 (18)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
25 (18)	30 (22)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	4 (16)	12 (1.4)	6 (10)	12 (1.4)

(continued)

**Table 4-6—1110 Ground and Power Terminal Specifications** (continued)

Power		Terminal							
		Ground		AC Line Input		Motor Output		Dynamic Braking or Bus	
		(PE)		(S, T)		(U, V, W)		(B+, DB or B+, B-)	
CT	VT	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>460 V</b>									
30 (22)	40 (30)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)
40 (30)	50 (37)	6 (x2) (10)	12 (1.4)	1/0 (x2) (35)	25 (2.8)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)
50 (37)	60 (45)	2 (x2) (33)	15 (1.8)	4/0 (95)	150 (17)	1/0 (35)	25 (2.8)	6 (10)	12 (1.4)
60 (45)	75 (55)	2 (x2) (33)	15 (1.8)	4/0 (x2) (95)	150 (17)	4/0 (95)	50 (5.6)	6 (10)	12 (1.4)
75 (55)	100 (75)	2 (x2) (33)	15 (1.8)	4/0 (x2) (95)	150 (17)	4/0 (95)	50 (5.6)	6 (10)	12 (1.4)

**Table 4-7—1130 Ground and Power Terminal Specifications**

Power			Terminal					
CT	VT	ET	Ground (PE)		AC Line Input (R, S, T)		Motor Output (U, V, W)	
			Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>230 V</b>								
7 1/2 (5.5)	10 (7.5)	—	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
10 (7.5)	15 (11)	—	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
15 (11)	20 (15)	—	6 (x2) (10)	12 (1.4)	4 (16)	12 (1.4)	4 (16)	12 (1.4)
20 (15)	25 (18)	—	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)
25 (18)	30 (22)	—	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)
30 (22)	40 (30)	—	2 (x2) (33)	15 (1.8)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)
40 (30)	50 (37)	—	2 (x2) (33)	15 (1.8)	2/0 (70)	50 (5.6)	2/0 (70)	50 (5.6)
50 (37)	60 (45)	—	2 (x2) (33)	15 (1.8)	4/0 (95)	150 (17)	4/0 (95)	150 (17)
60 (45)	75 (55)	—	2 (x2) (33)	15 (1.8)	1/0 (x2) (35)	25 (2.8)	1/0 (x2) (35)	25 (2.8)
<b>460 V</b>								
7 1/2 (5.5)	10 (7.5)	—	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
10 (7.5)	15 (11)	—	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
15 (11)	20 (15)	25 (18)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
20 (15)	25 (18)	30 (22)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (10)	12 (1.4)
25 (18)	30 (22)	40 (30)	6 (x2) (10)	12 (1.4)	4 (16)	12 (1.4)	4 (16)	12 (1.4)
30 (22)	40 (30)	50 (37)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)
40 (30)	50 (37)	60 (45)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)
50 (37)	60 (45)	75 (55)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (35)	25 (2.8)
60 (45)	75 (55)	100 (75)	2 (x2) (33)	15 (1.8)	2/0 (70)	50 (5.6)	2/0 (70)	50 (5.6)
75 (55)	100 (75)	125 (90)	2 (x2) (33)	15 (1.8)	4/0 (95)	150 (17)	4/0 (95)	150 (17)
100 (75)	125 (90)	150 (110)	2 (x2) (33)	15 (1.8)	4/0 (95)	150 (17)	4/0 (95)	150 (17)
125 (90)	150 (110)	200 (150)	2 (x2) (33)	15 (1.8)	2/0 (x2) (70)	50 (5.6)	2/0 (x2) (70)	50 (5.6)

(continued)

**Table 4-7—1130 Ground and Power Terminal Specifications (continued)**

Power			Terminal					
CT	VT	ET	Ground (PE)		AC Line Input (R, S, T)		Motor Output (U, V, W)	
			Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>575 V</b>								
7 1/2 (5.5)	10 (7.5)	—	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (13)	12 (1.4)
10 (7.5)	15 (11)	—	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (13)	12 (1.4)
15 (11)	20 (15)	25 (18)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (13)	12 (1.4)
20 (15)	25 (18)	30 (22)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (13)	12 (1.4)
25 (18)	30 (22)	40 (30)	6 (x2) (10)	12 (1.4)	6 (10)	12 (1.4)	6 (13)	12 (1.4)
30 (22)	40 (30)	50 (37)	6 (x2) (10)	12 (1.4)	4 (16)	12 (1.4)	4 (21)	12 (1.4)
40 (30)	50 (37)	60 (45)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (54)	25 (2.8)
50 (37)	60 (45)	75 (55)	6 (x2) (10)	12 (1.4)	1/0 (35)	25 (2.8)	1/0 (54)	25 (2.8)
60 (45)	75 (55)	100 (75)	2 (x2) (33)	15 (1.8)	1/0 (35)	25 (2.8)	1/0 (54)	25 (2.8)
75 (55)	100 (75)	125 (90)	2 (x2) (33)	15 (1.8)	2/0 (70)	50 (5.6)	2/0 (67)	50 (5.6)
100 (75)	125 (90)	150 (110)	2 (x2) (33)	15 (1.8)	4/0 (95)	150 (17)	4/0 (107)	150 (17)
125 (90)	150 (110)	200 (150)	2 (x2) (33)	15 (1.8)	1/0 (x2) (35)	25 (2.8)	1/0 (x2) (54)	25 (2.8)

**Table 4-8—1150 Ground and Power Terminal Specifications**

Power			Terminal					
			Ground (PE)		Bus (B+, B-)		Motor Output (U, V, W)	
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>230 V</b>								
1 1/2 (1.1)	2 (1.5)	—						
2 (1.5)	3 (2.2)	—						
3 (2.2)	5 (3.7)	—						
5 (3.7)	7 1/2 (5.5)	10 (7.5)						
7 1/2 (5.5)	10 (7.5)	15 (11)						
10 (7.5)	15 (11)	20 (15)						
15 (11)	20 (15)	25 (18)						
20 (15)	25 (18)	30 (22)						
25 (18)	30 (22)	40 (30)						
30 (22)	40 (30)	50 (37)						
40 (30)	50 (37)	60 (45)						
50 (37)	60 (45)							
60 (45)	75 (55)							
<b>460 V</b>								
1 1/2 (1.1)	2 (1.5)	—						
2 (1.5)	3 (2.2)	—						
3 (2.2)	5 (3.7)	—						
5 (3.7)	7 1/2 (5.5)	10 (7.5)						
7 1/2 (5.5)	10 (7.5)	15 (11)						
10 (7.5)	15 (11)	20 (15)						
15 (11)	20 (15)	25 (18)						
20 (15)	25 (18)	30 (22)						
25 (18)	30 (22)	40 (30)						
30 (22)	40 (30)	50 (37)						

(continued)

**Table 4-8—1150 Ground and Power Terminal Specifications** *(continued)*

Power			Terminal					
			Ground (PE)	Bus (B+, B-)		Motor Output (U, V, W)		
CT	VT	ET	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque	Acceptable Wire Sizes	Tightening Torque
<i>hp (kW)</i>	<i>hp (kW)</i>	<i>hp (kW)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>	<i>AWG (mm<sup>2</sup>)</i>	<i>in•lb (Nm)</i>
<b>460 V</b>								
40 (30)	50 (37)	60 (45)						
50 (37)	60 (45)	75 (55)						
60 (45)	75 (55)	100 (75)						
75 (55)	100 (75)	125 (90)						
100 (75)	125 (90)	150 (110)						
125 (90)	150 (110)	200 (150)						



**Table 4-9—1100, 1105, and 1130 Fuse Specifications**

<b>Rated Power</b>	<b>Input Current</b>	<b>Fuse Current</b>	<b>Fuse Voltage</b>	<b>Recommended Semiconductor Fuse</b>	
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>A<sub>rms</sub></i>	<i>V<sub>rms</sub></i>	<i>Manufacturer</i>	<i>Part Number</i>
<b>230 V</b>					
1 1/2 (1.1)	4.2	10	250	Bussman	FWX 10A14F
2 (1.5)	5.1	10	250	Bussman	FWX 10A14F
3 (2.2)	7.5	10	250	Bussman	FWX 10A14F
5 (3.7)	12.1	20	250	Bussman	FWX 20A14F
7 1/2 (5.5)	17.8	25	250	Bussman	FWX 25A14F
10 (7.5)	23.2	30	250	Bussman	FWX 30A14F
15 (11)	34.9	50	250	Bussman	FWX 50A
20 (15)	45.7	60	250	Bussman	FWX 60A
25 (18)	57.3	80	250	Bussman	FWX 80A
30 (22)	68.1	90	250	Bussman	FWX 90A
40 (30)	89.6	125	250	Bussman	FWX 125A
50 (37)	112.0	150	250	Bussman	FWX 150A
60 (45)	133.6	175	250	Bussman	FWX 175A
75 (55)	166.7	225	250	Bussman	FWX 225A
<b>380 V</b>					
1 1/2 (1.1)	2.5	4	500	Bussman	FWH 4A14F
2 (1.5)	3.1	4	500	Bussman	FWH 4A14F
3 (2.2)	4.4	6	500	Bussman	FWH 6A14F
5 (3.7)	7.2	10	500	Bussman	FWH 10A14F
7 1/2 (5.5)	10.6	15	500	Bussman	FWH 15A14F
10 (7.5)	13.8	20	500	Bussman	FWH 20A14F
15 (11)	20.8	25	500	Bussman	FWH 25A14F
20 (15)	27.2	35	500	Bussman	FWH 35B
25 (18)	34.1	45	500	Bussman	FWH 45B
30 (22)	40.5	50	500	Bussman	FWH 50B
40 (30)	53.4	70	500	Bussman	FWH 70B

*(continued)*

**Table 4-9—1100, 1105, and 1130 Fuse Specifications** (continued)

<b>Rated Power</b>	<b>Input Current</b>	<b>Fuse Current</b>	<b>Fuse Voltage</b>	<b>Recommended Semiconductor Fuse</b>	
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>A<sub>rms</sub></i>	<i>V<sub>rms</sub></i>	<i>Manufacturer</i>	<i>Part Number</i>
<b>380 V</b>					
50 (37)	66.7	90	500	Bussman	FWH 90B
60 (45)	79.5	100	500	Bussman	FWH 100B
75 (55)	99.3	125	500	Bussman	FWH 125B
100 (75)	130.3	175	500	Bussman	FWH 175B
125 (90)	163.4	225	500	Bussman	FWH 225B
150 (110)	192.3	250	500	Bussman	FWH 250A
200 (150)	256.4	325	500	Bussman	FWH 325A
250 (185)	320.5	400	500	Bussman	FWH 400A
300 (225)	384.6	500	500	Bussman	FWH 500A
350 (262)	448.6	600	500	Bussman	FWH 600A
400 (300)	513.7	700	500	Bussman	FWH 700A
500 (375)	643.0	800	500	Bussman	FWP 800A
<b>460 V</b>					
1 1/2 (1.1)	2.1	3	500	Bussman	FWH 3A14F
2 (1.5)	2.6	4	500	Bussman	FWH 4A14F
3 (2.2)	3.7	5	500	Bussman	FWH 5A14F
5 (3.7)	6.1	10	500	Bussman	FWH 10A14F
7 1/2 (5.5)	8.9	12	500	Bussman	FWH 12A14F
10 (7.5)	11.6	15	500	Bussman	FWH 15A14F
15 (11)	17.4	25	500	Bussman	FWH 25A14F
20 (15)	22.8	30	500	Bussman	FWH 30A14F
25 (18)	28.6	40	500	Bussman	FWH 40B
30 (22)	34.0	45	500	Bussman	FWH 45B
40 (30)	44.8	60	500	Bussman	FWH 60B
50 (37)	56.0	80	500	Bussman	FWH 80B
60 (45)	66.8	90	500	Bussman	FWH 90B

(continued)

**Table 4-9—1100, 1105, and 1130 Fuse Specifications** *(continued)*

Rated Power	Input Current	Fuse Current	Fuse Voltage	Recommended Semiconductor Fuse	
				Manufacturer	Part Number
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>A<sub>rms</sub></i>	<i>V<sub>rms</sub></i>		
<b>460 V</b>					
75 (55)	83.4	125	500	Bussman	FWH 125B
100 (75)	109.4	150	500	Bussman	FWH 150B
125 (90)	137.2	200	500	Bussman	FWH 200B
150 (110)	161.4	225	500	Bussman	FWH 225A
200 (150)	215.2	300	500	Bussman	FWH 300A
250 (185)	269.1	350	500	Bussman	FWH 350A
300 (225)	322.9	450	500	Bussman	FWH 450A
350 (262)	376.7	500	500	Bussman	FWH 500A
400 (300)	430.5	600	500	Bussman	FWH 600A
500 (375)	538.1	700	500	Bussman	FWH 700A
600 (450)	645.7	1,000	500	Bussman	FWH 1000A
<b>575 V</b>					
1 1/2 (1.1)	1.7	3	700	Bussman	FWP 3A14F
2 (1.5)	2.0	3	700	Bussman	FWP 3A14F
3 (2.2)	3.0	4	700	Bussman	FWP 4A14F
5 (3.7)	4.9	10	700	Bussman	FWP 10A14F
7 1/2 (5.5)	7.2	10	700	Bussman	FWP 10A14F
10 (7.5)	9.2	15	700	Bussman	FWP 15A14F
15 (11)	14.0	20	700	Bussman	FWP 20A14F
20 (15)	18.4	25	700	Bussman	FWP 25A14F
25 (18)	22.8	30	700	Bussman	FWP 30A14F
30 (22)	27.2	40	700	Bussman	FWP 40B
40 (30)	35.6	50	700	Bussman	FWP 50B
50 (37)	44.8	60	700	Bussman	FWP 60B
60 (45)	53.6	70	700	Bussman	FWP 70B
75 (55)	66.8	90	700	Bussman	FWP 90B
100 (75)	87.4	125	700	Bussman	FWP 125B

*(continued)*

**Table 4-9—1100, 1105, and 1130 Fuse Specifications** *(continued)*

<b>Rated Power</b>	<b>Input Current</b>	<b>Fuse Current</b>	<b>Fuse Voltage</b>	<b>Recommended Semiconductor Fuse</b>	
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>A<sub>rms</sub></i>	<i>V<sub>rms</sub></i>	<i>Manufacturer</i>	<i>Part Number</i>
<b>575 V</b>					
125 (90)	109.8	150	700	Bussman	FWP 150B
150 (110)	129.1	175	700	Bussman	FWP 175B
200 (150)	172.2	225	700	Bussman	FWP 225A
250 (185)	215.2	300	700	Bussman	FWP 300A
300 (225)	258.3	350	700	Bussman	FWP 350A
350 (262)	301.3	400	700	Bussman	FWP 400A
400 (300)	344.4	450	700	Bussman	FWP 450A
500 (375)	430.5	600	700	Bussman	FWP 600A
600 (450)	516.6	700	700	Bussman	FWP 700A

**Table 4-10—1110 Fuse Specifications**

<b>Rated Power</b>	<b>Input Current</b>	<b>Fuse Current</b>	<b>Fuse Voltage</b>	<b>Recommended Semiconductor Fuse</b>	
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>A<sub>rms</sub></i>	<i>V<sub>rms</sub></i>	<i>Manufacturer</i>	<i>Part Number</i>
<b>230 V</b>					
1 1/2 (1.1)	8.2	15	250	Bussman	FWX 15A14F
2 (1.5)	10.1	15	250	Bussman	FWX 15A14F
3 (2.2)	14.7	20	250	Bussman	FWX 20A14F
5 (3.7)	23.8	35	250	Bussman	FWX 35A
7 1/2 (5.5)	35.1	50	250	Bussman	FWX 50A
10 (7.5)	45.7	70	250	Bussman	FWX 70A
15 (11)	68.5	100	250	Bussman	FWX 100A
20 (15)	89.7	150	250	Bussman	FWX 150A
25 (18)	112.6	175	250	Bussman	FWX 175A
30 (22)	133.8	200	250	Bussman	FWX 200A
40 (30)	176.1	250	250	Bussman	FWX 250A
50 (37)	220.2	350	250	Bussman	FWX 350A
<b>460 V</b>					
1 1/2 (1.1)	4.1	10	500	Bussman	FWH 10A14F
2 (1.5)	5.0	10	500	Bussman	FWX 10A14F
3 (2.2)	7.3	10	500	Bussman	FWX 10A14F
5 (3.7)	11.9	20	500	Bussman	FWX 20A14F
7 1/2 (5.5)	17.5	25	500	Bussman	FWX 25A14F
10 (7.5)	22.8	35	500	Bussman	FWH 35B
15 (11)	34.3	50	500	Bussman	FWH 50B
20 (15)	44.9	70	500	Bussman	FWH 70B
25 (18)	56.3	80	500	Bussman	FWH 80B
30 (22)	66.9	100	500	Bussman	FWH 100B
40 (30)	88.1	125	500	Bussman	FWH 125B
50 (37)	110.1	175	500	Bussman	FWH 175B
60 (45)	131.3	200	500	Bussman	FWH 200B
75 (55)	163.9	250	500	Bussman	FWH 250A
100 (75)	215.0	325	500	Bussman	FWH 325A

**Table 4-11—Isolation Transformer Ratings**

<b>Power</b>	<b>Single-Phase<sup>(†)</sup></b>	<b>Three- or Six-Phase</b>
<i>hp (kW)</i>	<i>kVA</i>	<i>kVA</i>
1 1/2 (1.1)	1 1/2	3
2 (1.5)	1 1/2	3
3 (2.2)	2	5
5 (3.7)	3	7 1/2
7 1/2 (5.5)	5	11
10 (7.5)	7 1/2	15
15 (11)	10	20
20 (15)	15	27
25 (18)	15	34
30 (22)	25	40
40 (30)	25	51
50 (37)	37 1/2	63
60 (45)	37 1/2	75
75 (55)	50	93
100 (75)	75	118
125 (90)	—	145
150 (110)	—	175
200 (150)	—	220
250 (185)	—	275
300 (225)	—	330
350 (262)	—	365
400 (300)	—	440
500 (375)	—	550
600 (450)	—	660

(†) Drive power rating is based upon use as a 230 V-to-460 V autotransformer.

**Table 4-12—Three-Phase Line Reactor Ratings (230 V)**

Power	Current	I n d u c t a n c e	
		3.0% Impedance	5.0% Impedance
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>mH</i>	<i>mH</i>
1 1/2 (1.1)	8	3.000	5.000
2 (1.5)	8	1.500	3.000
3 (2.2)	12	1.300	2.500
5 (3.7)	18	0.800	1.500
7 1/2 (5.5)	25	0.500	1.200
10 (7.5)	35	0.400	0.800
15 (11)	45 / 55	0.300	0.500
20 (15)	55	0.250	0.500
25 (18)	80	0.200	0.400
30 (22)	80	0.200	0.230
40 (30)	110	0.100	0.180
50 (37)	130 / 160	0.100	0.200
60 (45)	160	0.080	0.150
75 (55)	200	0.055	0.110

**Table 4-13—Three-Phase Line Reactor Ratings (460 V)**

Power	Current	I n d u c t a n c e	
		3.0% Impedance	5.0% Impedance
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>mH</i>	<i>mH</i>
1 1/2 (1.1)	2	9.100	12.000
2 (1.5)	4	6.500	12.000
3 (2.2)	8	5.000	7.500
5 (3.7)	8	3.000	5.000
7 1/2 (5.5)	12	2.500	4.200
10 (7.5)	18	1.500	2.500
15 (11)	25	1.200	2.000
20 (15)	35	0.800	1.700
25 (18)	35	0.800	1.200
30 (22)	45	0.700	1.200
40 (30)	55	0.500	0.850
50 (37)	80	0.400	0.700
60 (45)	80	0.400	0.700
75 (55)	110	0.300	0.450
100 (75)	130	0.200	0.300
125 (90)	160	0.150	0.230
150 (110)	200	0.110	0.240
200 (150)	250	0.090	0.150
250 (185)	320	0.075	0.130
300 (225)	400	0.061	0.110
350 (262)	500	0.050	0.085
400 (300)	500	0.050	0.085
500 (375)	600	0.040	0.065
600 (450)	750	0.031	0.050



**Table 4-14—Three-Phase Line Reactor Ratings (575 V)**

Power	Current	I n d u c t a n c e	
		3.0% Impedance	5.0% Impedance
<i>hp (kW)</i>	<i>A<sub>rms</sub></i>	<i>mH</i>	<i>mH</i>
1 1/2 (1.1)	2	12.000	20.000
2 (1.5)	4	12.000	22.000
3 (2.2)	4	9.100	12.000
5 (3.7)	8	5.000	7.500
7 1/2 (5.5)	12	3.100	5.100
10 (7.5)	12	2.500	4.200
15 (11)	18	1.500	2.500
20 (15)	25	1.200	2.000
25 (18)	35	1.200	1.700
30 (22)	35	0.800	1.700
40 (30)	45	0.700	1.200
50 (37)	55	0.500	0.850
60 (45)	80	0.400	0.700
75 (55)	80	0.400	0.700
100 (75)	110	0.300	0.450
125 (90)	130	0.200	0.370
150 (110)	160	0.230	0.320
200 (150)	200	0.190	0.240
250 (185)	250	0.150	0.190
300 (225)	320	0.096	0.160
350 (262)	400	0.082	0.140
400 (300)	400	0.082	0.140
500 (375)	500	0.057	0.096
600 (450)	600	0.048	0.080

**Table 4-15—Dynamic Braking Resistor Ratings**

Power	100% Braking			150% Braking			200% Braking			Duty Cycle / Power		
	230 V	460 V	575 V	230 V	460 V	575 V	230 V	460 V	575 V	5%	10%	20%
<i>hp (kW)</i>	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$	W	W	W
1 1/2 (1.1)	96.2	384.6	595.2	64.1	256.4	396.8	48.1	192.3	297.6	51	101	203
2 (1.5)	73.5	294.1	463.0	49.0	196.1	308.6	36.8	147.1	231.5	68	135	270
3 (2.2)	52.1	208.3	320.5	34.7	138.9	213.7	26.0	104.2	160.3	101	203	405
5 (3.7)	32.9	131.6	204.9	21.9	87.7	136.6	16.5	65.8	102.5	169	338	675
7 1/2 (5.5)	22.7	90.9	138.9	15.2	60.6	92.6	11.4	45.5	69.4	253	506	1013
10 (7.5)	17.9	71.4	113.6	11.9	47.6	75.8	8.9	35.7	56.8	338	675	1350
15 (11)	11.9	47.6	73.5	7.9	31.7	49.0	6.0	23.8	36.8	506	1013	2025
20 (15)	9.3	37.0	56.8	6.2	24.7	37.9	4.6	18.5	28.4	675	1350	2700
25 (18)	7.4	29.4	46.3	4.9	19.6	30.9	3.7	14.7	23.1	844	1688	3375
30 (22)	6.3	25.0	39.1	4.2	16.7	26.0	3.1	12.5	19.5	1013	2025	4050
40 (30)	4.8	19.2	30.5	3.2	12.8	20.3	2.4	9.6	15.2	1350	2700	5400
50 (37)	3.9	15.4	24.0	2.6	10.3	16.0	1.9	7.7	12.0	1688	3375	6750
60 (45)	3.3	13.0	20.2	2.2	8.7	13.4	1.6	6.5	10.1	2025	4050	8100
75 (55)	2.6	10.4	16.2	1.7	6.9	10.8	1.3	5.2	8.1	2531	5063	10125
100 (75)	—	8.1	12.6	—	5.4	8.4	—	4.0	6.3	3375	6750	13500
125 (90)	—	6.4	10.0	—	4.3	6.7	—	3.2	5.0	4219	8438	16875
150 (110)	—	5.6	8.7	—	3.7	5.8	—	2.8	4.3	5063	10125	20250
200 (150)	—	4.2	6.5	—	2.8	4.3	—	2.1	3.3	6750	13500	27000
250 (185)	—	3.3	5.2	—	2.2	3.5	—	1.7	2.6	8438	16875	33750
300 (225)	—	2.8	4.3	—	1.9	2.9	—	1.4	2.2	10125	20250	40500
350 (262)	—	2.4	2.5	—	1.6	2.5	—	1.2	1.9	11812	23625	47250
400 (300)	—	2.1	2.2	—	1.4	2.2	—	1.0	1.6	13500	27000	54000
500 (375)	—	1.7	1.7	—	1.1	1.7	—	0.83	1.3	16875	33750	67500
600 (450)	—	1.4	1.5	—	0.93	1.5	—	0.69	1.1	20250	40500	81000

Consult the factory for dynamic braking duty cycles greater than 20%.

**Table 4-16—Minimum Braking Resistance**

Power	1100 1105 (w/optional DB) 1110			1105 (w/integral DB)		
	CT	230 V	460 V	575 V	230 V	460 V
<i>hp (kW)</i>	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$	$\Omega$
1 1/2 (1.1)	48.1	192.3	297.6	48.1	192.3	297.6
2 (1.5)	36.8	147.1	231.5	40.0	147.1	231.5
3 (2.2)	26.0	104.2	160.3	40.0	104.2	160.3
5 (3.7)	16.5	65.8	102.5	26.7	80.0	102.5
7 1/2 (5.5)	11.4	45.5	69.4	13.3	53.3	69.4
10 (7.5)	8.9	35.7	56.8	13.3	53.3	56.8
15 (11)	6.0	23.8	36.8	8.0	32.0	36.8
20 (15)	5.3	18.5	28.4	8.0	18.5	28.4
25 (18)	5.3	16.0	23.1	—	16.0	23.1
30 (22)	5.3	12.5	19.5	—	16.0	19.5
40 (30)	2.4	10.7	15.2	—	16.0	15.2
50 (37)	2.0	10.7	13.3	—	10.7	13.3
60 (45)	2.0	6.5	10.1	—	6.5	10.1
75 (55)	—	5.2	8.1	—	5.2	8.1
100 (75)	—	4.0	6.3	—	4.0	6.3
125 (90)	—	4.0	5.0	—	4.0	5.0
150 (110)	—	2.8	4.3	—	2.8	4.3
200 (150)	—	2.7	3.3	—	—	3.3
250 (185)	—	2.0	2.6	—	—	—
300 (225)	—	2.0	2.5	—	—	—
350 (262)	—	1.3	1.9	—	—	—
400 (300)	—	1.3	1.7	—	—	—

## 4.9 Control Signal Connections

Each drive accepts one of several different types of control modules, and each control module accepts one of several associated option modules. The wiring of these modules is similar. Any differences are noted in the tables and figures below.

The drive accepts a variety of analog and digital inputs and outputs, synchronous and asynchronous serial communications, and optional encoder or resolver feedback. The 100 MHz control module also accommodates optional AnyBus<sup>®</sup> serial communications and MaxStream<sup>™</sup> wireless communications. These external signals are connected both to terminals and telephone-type jacks on the control module and to terminals on the optional encoder, resolver, AnyBus<sup>®</sup>, MaxStream<sup>™</sup>, and analog interface modules that mount on the control module. The general layout of external control connections is shown in Figure 4-7 through Figure 4-9. Control signal terminal specifications are given in Table 4-17. Refer to Section 4.2 for wiring requirements.

**Table 4-17—Control Signal Terminal Specifications**

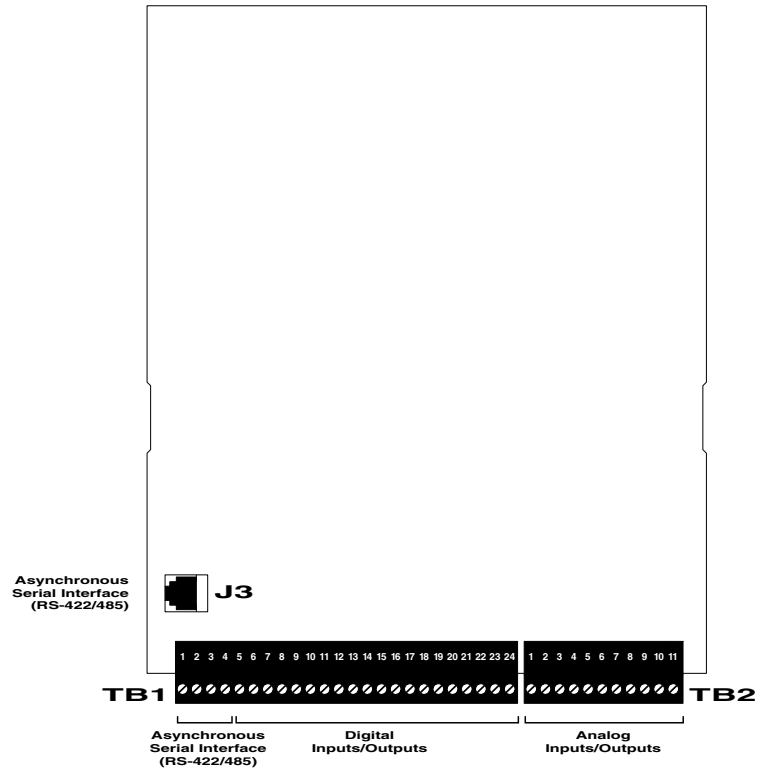
Connection	Maximum Wire Size	Tightening Torque
	AWG (mm <sup>2</sup> )	in•lb (Nm)
<b>Control Modules</b>		
TB1 and TB2	14 (2.1)	7.0 (0.79)
CON19 (optional on 100 MHz)	14 (2.1)	4.0 (0.45)
<b>Encoder Interface Modules (optional)</b>		
CON2 (single and dual), CON3 (dual)	14 (2.1)	4.5 (0.51)
<b>Resolver Interface Module with Encoder Emulation (optional)</b>		
CON2, CON3	16 (1.3)	4.5 (0.51)
<b>Analog Interface Module (optional)</b>		
CON2	16 (1.3)	2.2 (0.25)
<b>I/O Fanning Strip (optional)</b>		
CON3, CON4	14 (2.1)	7.0 (0.79)
<b>AnyBus<sup>®</sup> Serial Communication Module (optional)</b>		
<b>MaxStream<sup>™</sup> Wireless Communication Module (optional)</b>		
All connections	Refer to manufacturer's instruction manual	

### 4.9.1 Wiring Precautions

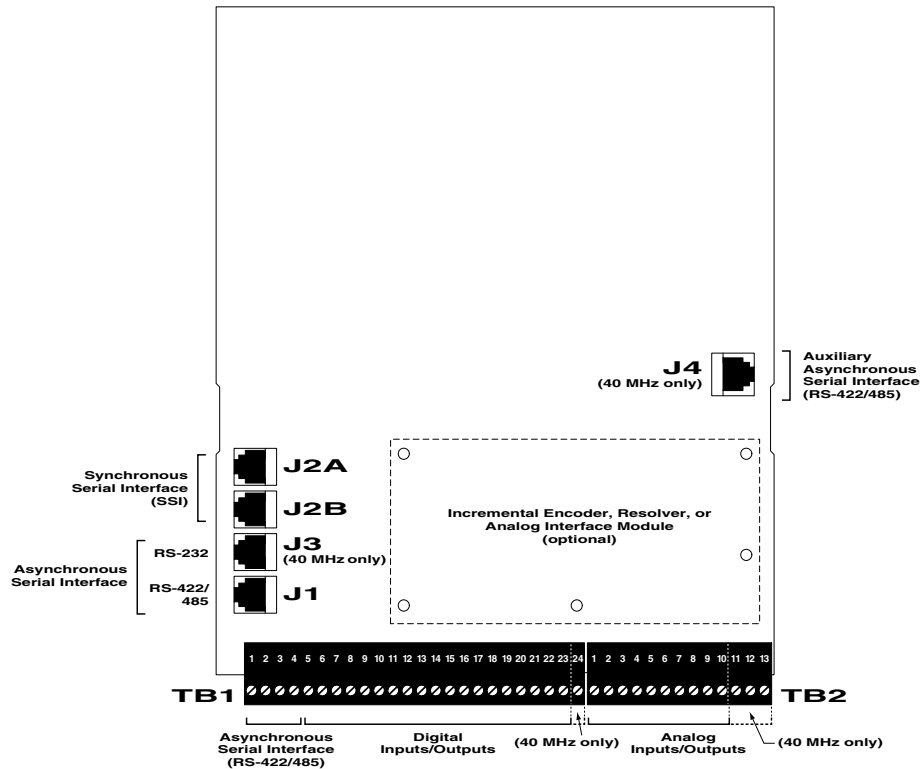
Observe the following precautions when wiring control signals:

- When disconnecting wires from the screw terminals, completely loosen the screws before pulling out the wires
- Tie shields to Logic Common at one end only
- Twist differential ( $\pm$ ) current input signals together

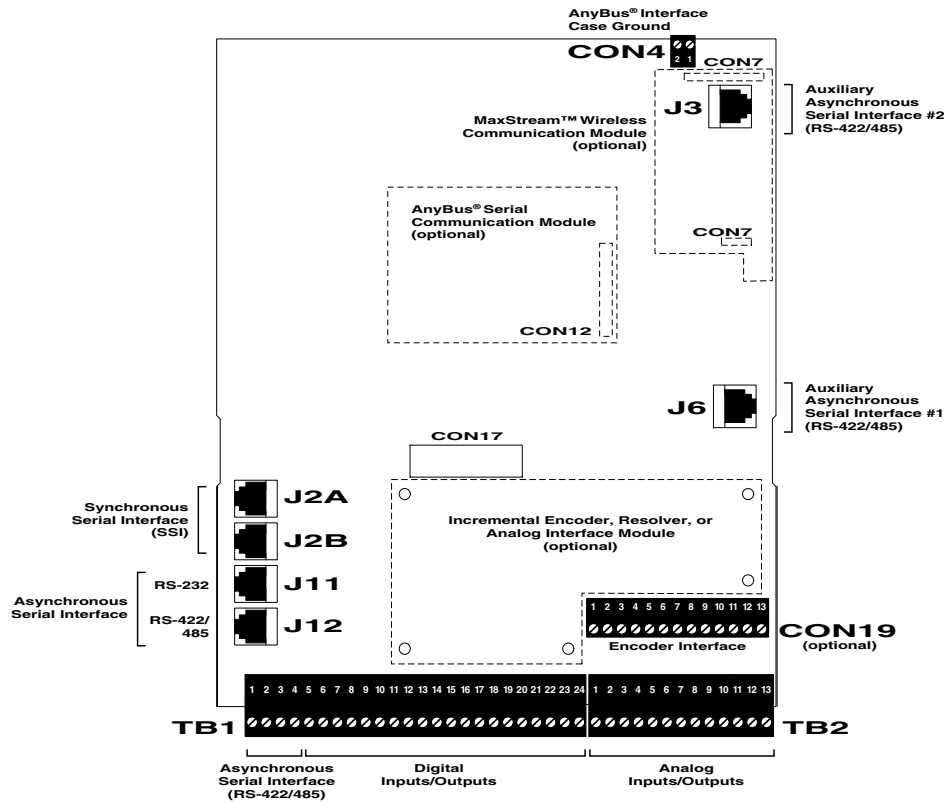
**Figure 4-7—Control Module Connectors (16 MHz)**



**Figure 4-8—Control Module Connectors (20 and 40 MHz)**



**Figure 4-9—Control Module Connectors (100 MHz)**



#### 4.9.2 Digital I/O Connections (TB1)

Digital inputs and outputs are connected at terminal block TB1 on the control module. Refer to Table 4-19 for general connection descriptions and specifications. The specific functionality of each input and output is determined by the application software. Refer to the application documentation for complete descriptions.

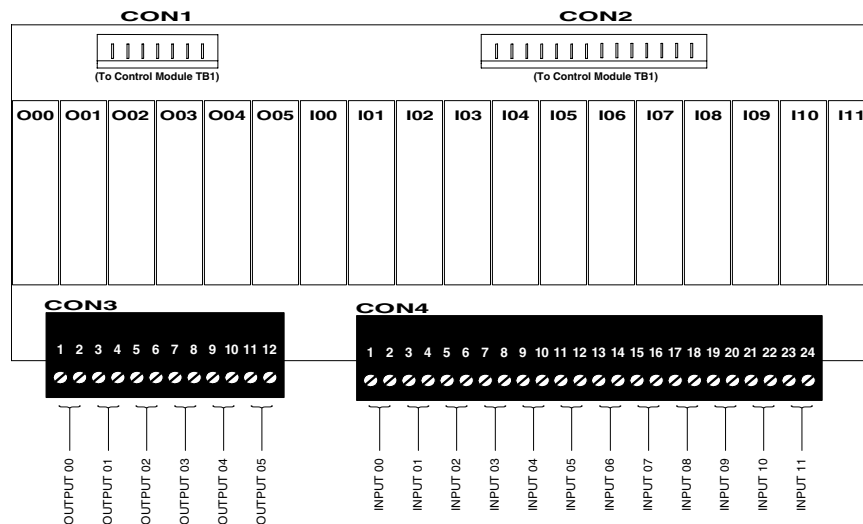
An optional I/O fanning strip and associated plug-in converter modules may be used to interface the drive's logic-type inputs and outputs with AC and DC circuits of various voltages. The fanning strip may be populated with up to 12 input converters and six output converters. Table 4-18 lists the converters that are available and their voltage ranges. Refer to Figure 4-10 for the fanning strip layout and connections. Jumpers supplied with the fanning strip may be used in lieu of converters to pass selected I/O directly from the drive to the fanning strip.

Connect the fanning strip to the control module using the 203-105 and 203-106 cables from CON1 and CON2 at the top of the fanning strip to TB1 of the controller.

**Table 4-18—I/O Converter Modules**

Part Number	Device	Voltage Range
912-688	Input converter	90 to 140 V AC
919-808	Input converter	180 to 280 V AC
913-108	Output converter	12 to 140 V AC
919-809	Output converter	180 to 280 V AC
913-109	Input converter	2.5 to 28 V DC
913-110	Output converter	5 to 60 V DC
915-282	Normally open relay	0 to 30 V DC, 0 to 250 V AC
921-332	Normally closed relay	0 to 30 V DC, 0 to 250 V AC
922-084	Pass-through jumper	—

**Figure 4-10—I/O Fanning Strip**



### 4.9.3 Analog I/O Connections (TB2, CON2)

Analog inputs and outputs are connected at terminal block TB2 on the control module. Refer to Table 4-20 for general connection descriptions and specifications. They may also be connected at terminal block CON2 on the optional Analog Interface Module (321-557). The Analog Interface Module mounts on the control module and provides eight additional inputs and four additional outputs. Analog Interface Module connections are shown in Figure 4-17 and Figure 4-18 and described in Table 4-28. Analog inputs and outputs are defined by the application. Refer to the application documentation for complete functional descriptions.

#### 4.9.4 Serial Connections (TB1, J1, J2, J3, J4, J6, J11, J12)

The drive provides both asynchronous and synchronous serial communication ports. The application software determines the functionality of these ports. Refer to the application documentation for any additional interconnection information specific to the application as well as a description of the communication protocol employed.

For AnyBus<sup>®</sup> and MaxStream<sup>™</sup> communication modules, please refer to the module manufacturers' instructions.

Asynchronous serial signals (RS-422/485) are connected either to terminals at block TB1 on the control module or to modular telephone-type jack J1 (40 MHz control module) and J12 (100 MHz control module). Jacks J3 (40 MHz) and J11 (100 MHz) provide an RS-232 connection that parallels the signals of J1 and J12. Jacks J4 (40 MHz) and J3 and J6 (100 MHz) provide auxiliary RS-422/485 connections independent from the other ports. Refer to Table 4-19 for TB1 terminal connections. Refer to Figure 4-11 and Table 4-21 for pinouts and descriptions of the modular telephone-type jack connectors.

The Synchronous Serial Interface (SSI), available with all but the 16 MHz controller, provides a means of slaving multiple drives together in real time. When supported by the application software, synchronous serial connections are made to jacks J2A and J2B using straight-through telephone cables. Refer to Figure 4-11 and Table 4-21 for pinouts and descriptions of the modular telephone-type jack connectors. Recommended synchronous serial cables are listed in Table 4-22.

When networking two or more drives for either synchronous or asynchronous communications, remove the terminating resistors in all drives *except* the last one. With a synchronous network, this is the slave drive furthest from the master. When using the 20 MHz or 40 MHz control modules, remove both the data *and* clock terminating resistors for a synchronous network.

Pull-up and pull-down resistors are generally required on the receive lines of the host computer to prevent the host from receiving garbage and to establish the ground reference for the serial port of the drive. The 16 MHz control module also provides pull-up and pull-down resistors on the transmit lines. In some networks, it may be necessary to remove the pull-up and pull-down resistors on the receive lines of the drive. Refer to the application documentation for any specific instructions.

Pull-up, pull-down, and terminating resistor locations are shown in Figure 4-12 and described in Table 4-23.



#### 4.9.5 Feedback Interface Connections

The drive can operate with or without a transducer, depending upon the requirements of the application. It can accept feedback from one or more incremental encoders (pulse generators) and/or from a resolver, depending upon the control and interface modules selected. The 20 and 40 MHz control modules can accommodate either a single incremental encoder, dual incremental encoders, or a resolver by adding the appropriate transducer interface. The 100 MHz control module has an on-board interface that accepts either an incremental encoder or an absolute/incremental encoder. It can also accommodate one or two additional incremental encoders or a resolver by adding the appropriate interface module.

##### 4.9.5.1 Encoder Connections (CON2, CON3)

The 100 MHz control module accommodates one encoder with optional marker pulses and reference inputs. It can also operate with an absolute/incremental encoder. Connections for the on-board interface are shown in Figure 4-13 and described in Table 4-24. The CON19 connections should be wired prior to installing the Dual Encoder, Resolver, or Analog interface modules since they will cover the terminal block. The pluggable connector can be removed to simplify wiring.

The Encoder Interface Module (316-887) accommodates one encoder with optional marker pulses. Connections for the single encoder interface are shown in Figure 4-14 and described in Table 4-25.

The Dual Encoder Interface Module (321-952) accommodates two encoders with optional marker pulses and reference inputs. Connections for the dual encoder interface are shown in Figure 4-15 and described in Table 4-26.

Use of a Unico incremental encoder cable (105-619) is recommended. This cable consists of one twisted pair of 14 AWG wire (for isolated +5 V and isolated Common), three twisted pairs of 18 AWG wire, an overall shield, and a PCV jacket. The cable measures about 9/16" in diameter. At 0.250 A, the cable is good for a maximum of 175' (53 m). When wiring directly, be sure to use wire of sufficient gauge for the isolated +5 V and isolated Common connections to keep the voltage drop at the encoder at 0.25 V or less.

The maximum encoder size that may be used with the interface module is dependent upon motor speed, as follows:

$$\text{maximum encoder size} = 12,000,000 / \text{maximum motor speed (rpm)}$$

For example, the maximum encoder size for an 1,800 rpm motor is 6,666 ppr. The formula allows maximum motor speed to be exceeded safely by 25% without exceeding the rating of the interface module.

##### 4.9.5.2 Resolver Connections (CON2, CON3)

The Resolver Interface Module with Encoder Emulation (322-096) accommodates feedback from a single resolver and echoes that feedback to another drive or device using encoder emulation. Connections for the resolver interface are shown in Figure 4-16 and described in Table 4-27.

Use of a Unico resolver cable (908-368) is recommended. This cable consists of three twisted pairs of 18 AWG wire, individually shielded, and a PCV jacket. If encoder emulation is used, the 105-619 incremental encoder described in the previous section is recommended.

**Table 4-19—TB1 Connection Descriptions**

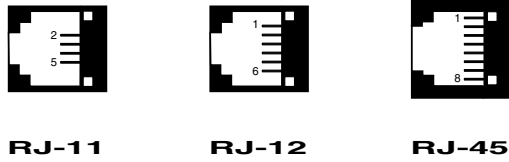
Terminal	Control Module / Description			
	<b>16 MHz</b> VFD (322-340) <b>40 MHz Mixed I/O</b> (322-100) <b>100 MHz Mixed I/O</b> (323-547 and 323-548)	<b>20 MHz</b> DCR (321-101) DSV (321-516)	<b>40 MHz Logic I/O</b> (322-157) <b>100 MHz Logic I/O</b> (323-397 and 323-546)	<b>40 MHz Contact I/O</b> (322-966)
<b>RS-422/485 Asynchronous Serial Communications (Isolated)</b>				
TB1-1	Transmit (+)	Transmit (+)	Transmit (+)	Transmit (+)
TB1-2	Transmit (-)	Transmit (-)	Transmit (-)	Transmit (-)
TB1-3	Receive (-)	Receive (-)	Receive (-)	Receive (-)
TB1-4	Receive (+)	Receive (+)	Receive (+)	Receive (+)
<b>Digital Outputs</b>				
	<i>Mixed I/O:</i>	<i>Mixed I/O:</i>	<i>Logic I/O:</i>	<i>Contact I/O:</i>
TB1-5	Relay 0 N.O.	Relay 0 N.O.	Open Collector 0	Relay 0 N.O.
TB1-6	Relay 0 N.C.	Relay 0 N.C.	Open Collector 1	Relay 0 N.C.
TB1-7	Relay 0 Common	Relay 0 Common	Open Collector 2	Relay 1 N.O.
TB1-8	Relay 1 N.O.	Relay 1 N.O.	Open Collector 3	Relay 1 N.C.
TB1-9	Relay 1 Common	Relay 1 Common	Open Collector 4	Relay 2 N.C.
TB1-10	Open Collector	Open Collector	Open Collector 5	Relay 2 N.O.
	<i>Relays contacts rated 125 V AC @ 5 A Open-collector output rated 24 V DC @ 500 mA</i>	<i>Relays contacts rated 125 V AC @ 5 A Open-collector output rated 24 V DC @ 500 mA</i>	<i>Rated 24 V DC @ 500 mA</i>	<i>Rated 125 V AC @ 5 A</i>
<b>Digital Inputs</b>				
TB1-11	Logic Common <i>Inputs need to sink 1 mA to Logic Common</i>	Logic Common <i>Inputs need to sink 1 mA to Logic Common</i>	Logic Common <i>Inputs need to sink 1 mA to Logic Common</i>	Logic Common <i>Inputs need to sink 1 mA to Logic Common</i>
TB1-12	Input 0	Input 0	Input 0	Input 0
TB1-13	Input 1	Input 1	Input 1	Input 1
TB1-14	Input 2	Input 2	Input 2	Input 2
TB1-15	Input 3	Input 3	Input 3	Input 3
TB1-16	Input 4	Input 4	Input 4	Input 4
TB1-17	Input 5	Input 5	Input 5	Input 5
TB1-18	Input 6	Input 6	Input 6	Input 6
TB1-19	Input 7	Input 7	Input 7	Input 7
TB1-20	Input 8	Input 8	Input 8	Input 8
TB1-21	Input 9	Logic Common	Input 9	Input 9
TB1-22	Input 10	Input 9	Input 10	Input 10
TB1-23	Input 11	Input 10	Input 11	Input 11
TB1-24	Logic Common (16 MHz)  +5 V DC (40 and 100 MHz) <i>Maximum output: 10 mA</i>	—	+5 V DC  <i>Maximum output: 10 mA</i>	+5 V DC  <i>Maximum output: 10 mA</i>

**Table 4-20—TB2 Connection Descriptions**

Terminal	Control Module / Description		
	<b>16 MHz</b> VFD (322-340)	<b>20 MHz</b> DCR (321-101) DSV (321-516)	<b>40 MHz Logic I/O</b> (322-157) <b>40 MHz Contact I/O</b> (322-966) <b>40 MHz Mixed I/O</b> (322-100)
			<b>100 MHz Logic I/O</b> (323-397 and 323-546) <b>100 MHz Mixed I/O</b> (323-547 and 323-548)
<b>DC Power Supply Output</b>			
TB2-1	+24 V DC <i>Unregulated</i> <i>Maximum output: 250 mA</i>	+24 V DC <i>Unregulated</i> <i>Maximum output: 250 mA</i>	+24 V DC <sup>(†)</sup> <i>Unregulated</i> <i>Maximum output: 250 mA</i>
<b>Analog Inputs</b>			
TB2-2	Analog Input 1 <i>0 to ±10 V DC</i> <i>Input impedance: 100 kΩ</i>	Analog Input 1 <i>0 to ±10 V DC</i> <i>Input impedance: 100 kΩ</i>	Analog Input 1 <i>0 to ±10 V DC or 0 to 20 mA</i> <i>Input impedance:</i> <i>400 kΩ or 500 Ω</i>
TB2-3	Analog Input 2 <i>0 to 10 V DC</i> <i>Input impedance: 100 kΩ</i>	Analog Input 2 <i>0 to 10 V DC</i> <i>Input impedance: 100 kΩ</i>	Analog Input 2 <i>0 to ±10 V DC or 0 to 20 mA</i> <i>Input impedance:</i> <i>400 kΩ or 500 Ω</i>
TB2-4	Analog Input 3 (+)	Analog Input 3 (+)	Analog Input 3 <i>0 to ±10 V DC or 0 to 20 mA</i> <i>Input impedance:</i> <i>400 kΩ or 500 Ω</i>
TB2-5	Analog Input 3 (–) <i>0 to 20 mA</i> <i>Input impedance: 150 Ω</i>	Analog Input 3 (–) <i>0 to 20 mA</i> <i>Input impedance: 150 kΩ</i>	Analog Input Common <sup>(†)</sup> <i>(for TB2-2, -3, and -4)</i> <i>To convert any input to 0 to 20 mA, install a 500 Ω resistor between the input and common (TB2-5)</i>
<b>DC Power Supply Outputs</b>			
TB2-6	Do not connect	Do not connect	Do not connect
TB2-7	+10 V DC <i>Maximum output: 10 mA</i>	+10 V DC <i>Maximum output: 10 mA</i>	+10 V DC <sup>(†)</sup> <i>Maximum output: 10 mA</i>
TB2-8	–10 V DC <i>Maximum output: 10 mA</i>	–10 V DC <i>Maximum output: 10 mA</i>	–10 V DC <sup>(†)</sup> <i>Maximum output: 10 mA</i>
<b>Analog Outputs</b>			
TB2-9	Analog Output 1 <i>0 to ±10 V DC</i> <i>Maximum output: 10 mA</i>	Analog Output 1 <i>0 to ±10 V DC</i> <i>Maximum output: 10 mA</i>	Analog Output 1 <i>0 to ±10 V DC</i> <i>Maximum output: 10 mA</i>
TB2-10	Analog Output 2 <i>0 to ±10 V DC</i> <i>Maximum output: 10 mA</i>	Analog Output 2 <i>0 to ±10 V DC</i> <i>Maximum output: 10 mA</i>	Analog Output 2 <i>0 to ±10 V DC</i> <i>Maximum output: 10 mA</i>
TB2-11	Do not connect	—	Do not connect
TB2-12	—	—	Analog Output 1 <i>0 to 20 mA</i> <i>Load impedance: 0 to 1000 Ω</i>
TB2-13	—	—	Analog Output 2 <i>0 to 20 mA</i> <i>Load impedance: 0 to 1000 Ω</i>

*(†) If the power supply outputs of the drive (TB2-1, TB2-7, or TB2-8) are used to power the analog inputs (TB2-2, TB2-3, or TB2-4), Logic Common (TB1-11) must be tied to Analog Input Common (TB2-5) to ensure proper signal reference.*

**Figure 4-11—Asynchronous Serial Connectors**



**Table 4-21—Serial Connector Pinouts**

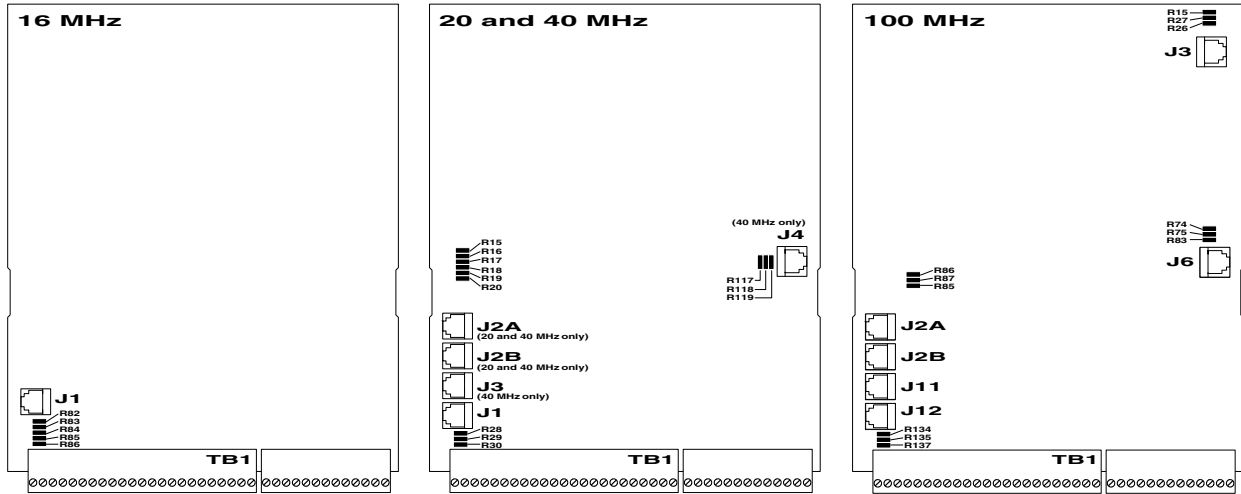
Pin	Connector / Description				
	<b>J1</b> (20 and 40 MHz) <b>J12</b> (100 MHz)	<b>J2A/J2B</b> (20, 40, and 100 MHz)	<b>J3</b> (16 MHz)	<b>J3</b> (40 MHz) <b>J11</b> (100 MHz)	<b>J4</b> (40 MHz) <b>J3 and J6</b> (100 MHz)
Port:	RS-422/485	SSI	RS-422/485	RS-232	RS-422/485
Jack:	6-position (RJ-12)	6-position (RJ-12)	6-position (RJ-11 or RJ-12)	6-position (RJ-11 or RJ-12)	8-position (RJ-45)
1	+5 V DC	Data (+)	No connection	No connection	+5 V DC
2	Receive (+)	Data (-)	Receive (+)	Receive (-)	+5 V DC
3	Receive (-)	Logic Common	Receive (-)	Common <sup>(†)</sup>	Receive (+)
4	Transmit (+)	Logic Common	Transmit (-)	Common <sup>(†)</sup>	Receive (-)
5	Transmit (-)	Clock (-)	Transmit (+)	Transmit (-)	Transmit (+)
6	Common <sup>(†)</sup>	Clock (+)	No connection	No connection	Transmit (-)
7	—	—	—	—	Logic Common
8	—	—	—	—	Logic Common

*(†) The commons of J1 and J3 on the 40 MHz controller and J11 and J12 on the 100 MHz controller are tied together but isolated from drive Logic Common.*

**Table 4-22—Synchronous Serial Cables**

Cable Length	Part Number
2 ft.	917-020
4 ft.	917-021
6 ft.	917-022
8 ft.	917-023
10 ft.	917-024
Longer than 10 ft.	Consult factory

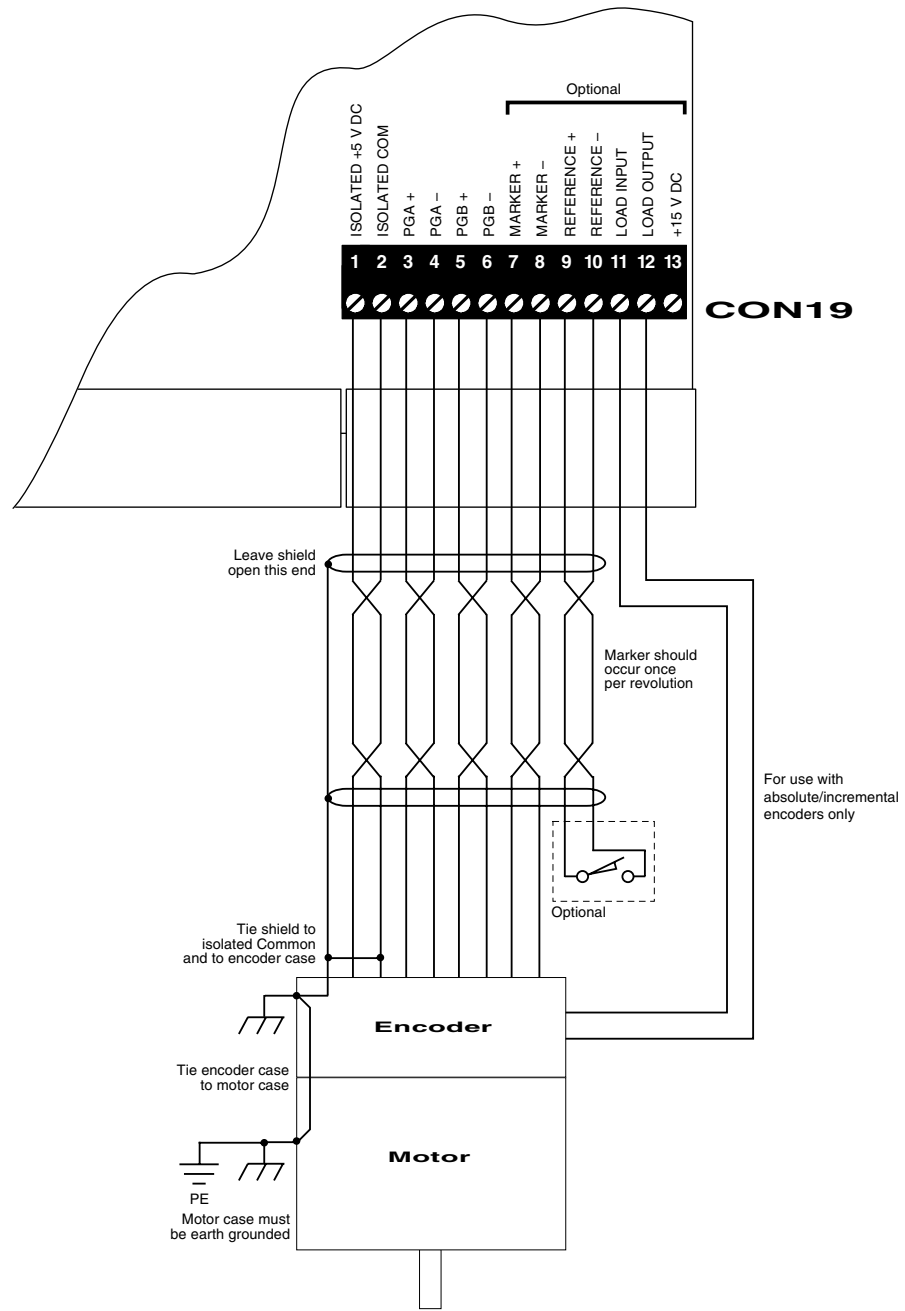
**Figure 4-12—Serial Communication Resistor Locations**



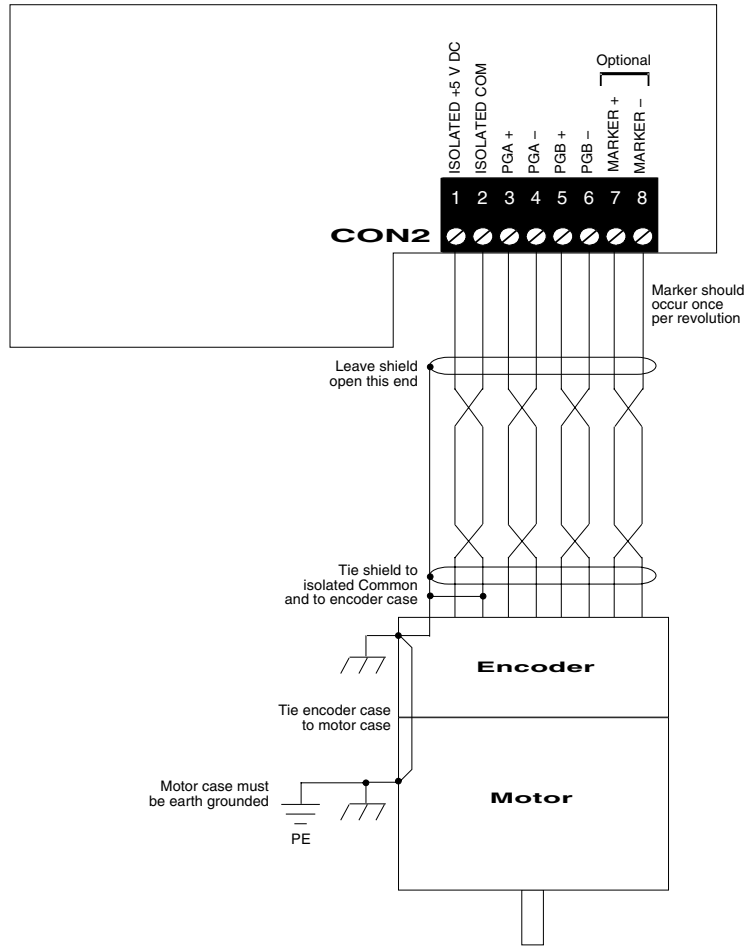
**Table 4-23—Serial Communication Resistors**

Signal	16, 20, and 40 MHz Controllers		100 MHz Controller		Description	Rating
	Connector	Resistor	Connector	Resistor		
Asynchronous receive	J1 and TB1 (20 and 40 MHz)	R29	J12 and TB1	R135	Terminating	121 Ω
		R28		R134	Pull-up	1.5 kΩ
		R30		R137	Pull-down	1.5 kΩ
	J3 and TB1 (16 MHz)	R83	—	—	Terminating	100 Ω
		R82			Receive pull-up	1.5 kΩ
		R84			Receive pull-down	1.5 kΩ
		R86			Transmit pull-up	10.0 kΩ
		R85			Transmit pull-down	10.0 kΩ
	J4 (40 MHz)	R118	J3	R27	Terminating	121 Ω
		R119		R15	Pull-up	1.5 kΩ
R117		R26		Pull-down	1.5 kΩ	
—	—	J6	R75	Terminating	121 Ω	
			R74	Pull-up	1.5 kΩ	
			R83	Pull-down	1.5 kΩ	
Synchronous data transmit/receive	J2A and J2B (20 and 40 MHz)	R16	J2A and J2B	R87	Terminating	121 Ω
		R15		R86	Pull-up	1.5 kΩ
		R17		R85	Pull-down	1.5 kΩ
Synchronous clock transmit/receive	J2A and J2B (20 and 40 MHz)	R19	<i>(Clock signal embedded in data signal)</i>		Terminating	121 Ω
		R18			Pull-up	1.5 kΩ
		R20			Pull-down	1.5 kΩ

**Figure 4-13—On-Board Encoder Interface Module Connections  
(100 MHz Controllers 323-397 and 323-547)**



**Figure 4-14—Encoder Interface Module Connections (316-887)**

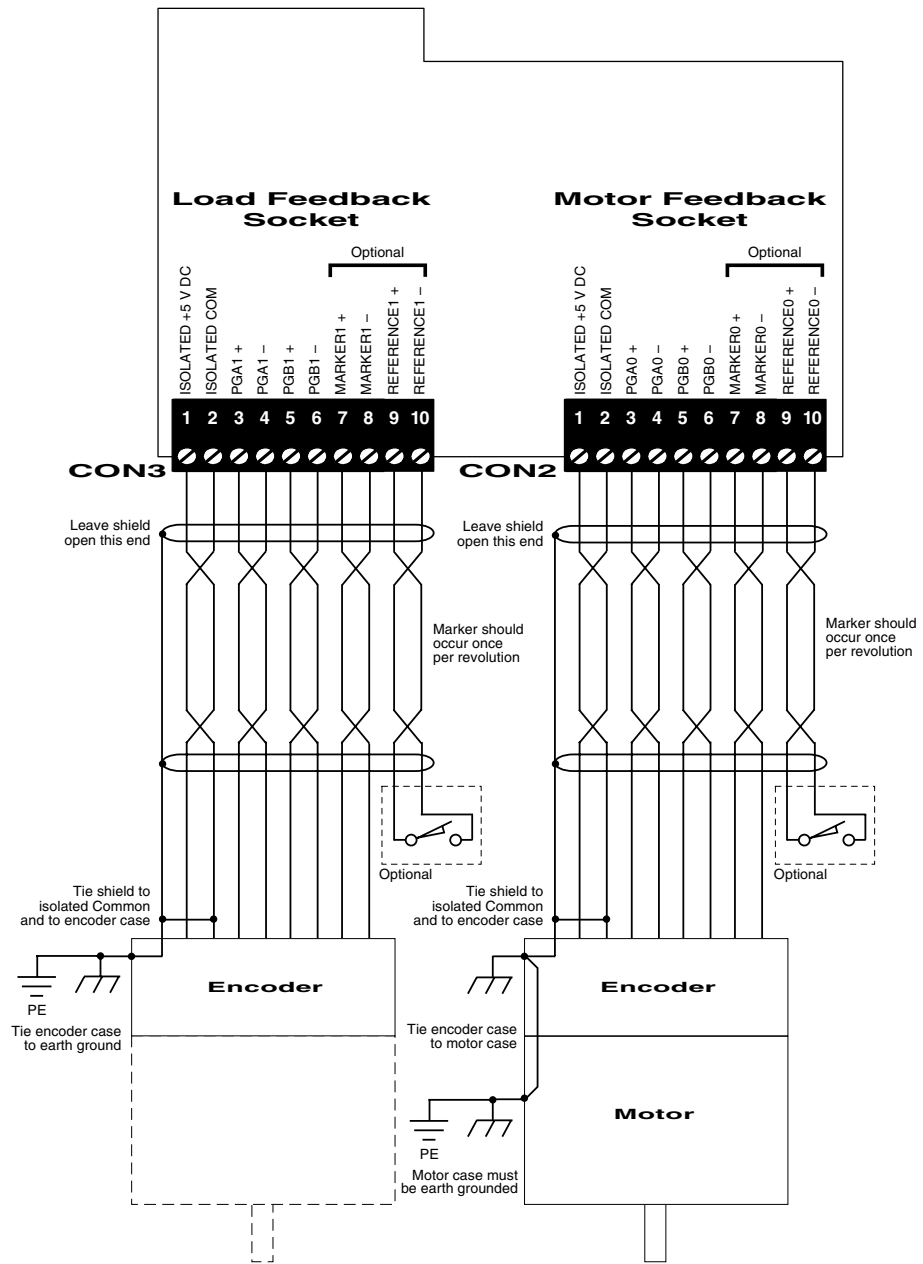


**Table 4-24—On-Board Encoder Interface Connections (CON19)**

Terminal	Description
<b>Power Supply Outputs (Isolated)</b>	
CON19-1	+5 V DC <i>Maximum output: 250 mA</i>
CON19-2	Common
<b>Encoder Channel Signals (Isolated)</b>	
CON19-3	PGA (+)
CON19-4	PGA (-) <i>0 to 5 V nominal</i>
CON19-5	PGB (+)
CON19-6	PGB (-) <i>0 to 5 V nominal</i>
<b>Marker Pulse Signals (Isolated)</b>	
CON19-7	Marker (+)
CON19-8	Marker (-) <i>0 to 5 V nominal</i>
CON19-9	Reference (+)
CON19-10	Reference (-) <i>0 to 5 V nominal</i>
<b>Incremental Serial Interface (Isolated)</b>	
CON19-11	Load Input +5 V DC
CON19-12	Load Output <i>0 to 5 V nominal</i>
<b>Power Supply Output (Isolated)</b>	
CON19-13	+15 V DC <i>Maximum output: 200 mA</i>



**Figure 4-15—Dual Encoder Interface Module Connections (321-952)**



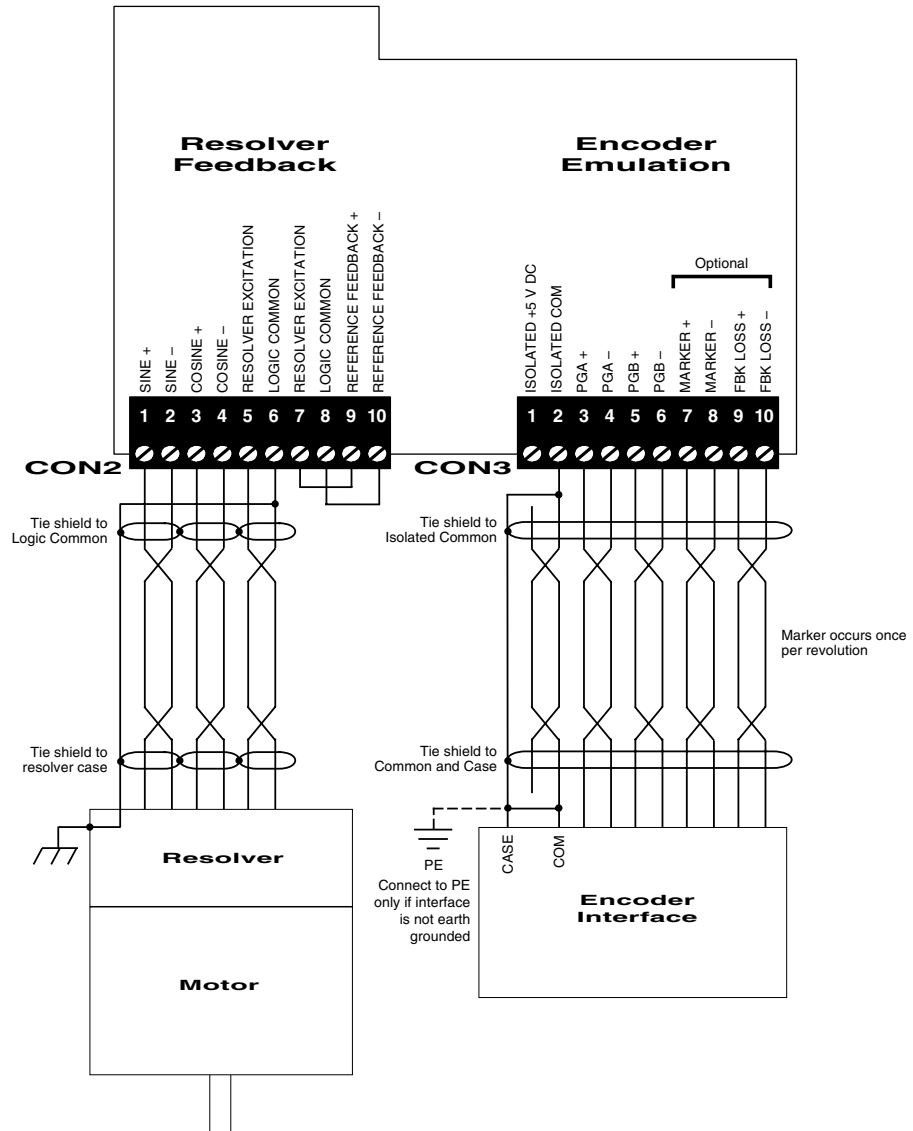
**Table 4-25—Encoder Interface Connections (CON2)**

Terminal	Description
<b>Power Supply Outputs (Isolated)</b>	
CON2-1	+5 V DC <i>Maximum output: 250 mA</i>
CON2-2	Common
<b>Encoder Channel Signals (Isolated)</b>	
CON2-3	PGA (+)
CON2-4	PGA (-) <i>0 to 5 V nominal</i>
CON2-5	PGB (+)
CON2-6	PGB (-) <i>0 to 5 V nominal</i>
<b>Marker Pulse Signals (Isolated)</b>	
CON2-7	Marker (+)
CON2-8	Marker (-) <i>0 to 5 V nominal</i>

**Table 4-26—Dual Encoder Interface Connections (CON2, CON3)**

Terminal	Description
<b>Power Supply Outputs (Isolated)</b>	
CON2-1	+5 V DC
CON3-1	<i>Maximum output: 250 mA</i>
CON2-2	Common
CON3-2	
<b>Encoder Channel Signals (Isolated)</b>	
CON2-3	PGA (+)
CON2-4	PGA (-)
CON3-3	PGA (+)
CON3-4	PGA (-) <i>0 to 5 V nominal</i>
CON2-5	PGB (+)
CON2-6	PGB (-)
CON3-5	PGB (+)
CON3-6	PGB (-) <i>0 to 5 V nominal</i>
<b>Marker Pulse Signals (Isolated)</b>	
CON2-7	Marker (+)
CON2-8	Marker (-)
CON3-7	Marker (+)
CON3-8	Marker (-) <i>0 to 5 V nominal</i>
<b>Reference Signals (Isolated)</b>	
CON2-9	Reference (+)
CON2-10	Reference (-)
CON3-9	Reference (+)
CON3-10	Reference (-) <i>0 to 5 V nominal</i>

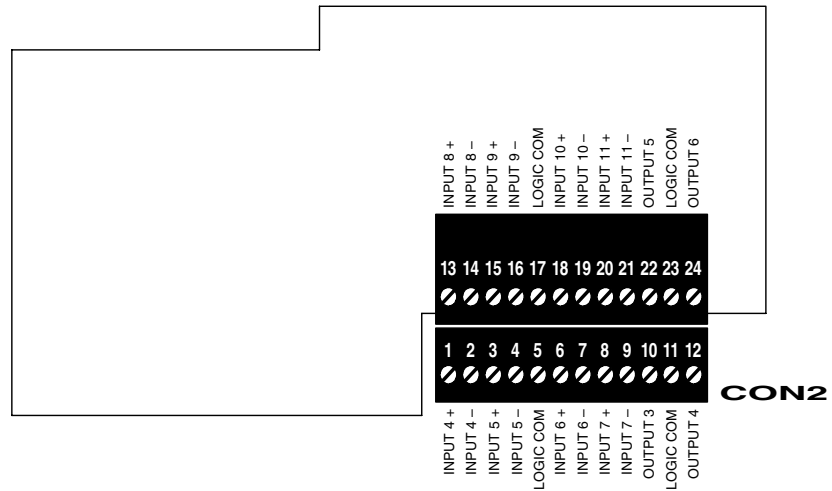
**Figure 4-16—Resolver Interface Module with Encoder Emulation Connections (322-096)**



**Table 4-27—Resolver Interface Module with Encoder Emulation Connections (CON2, CON3)**

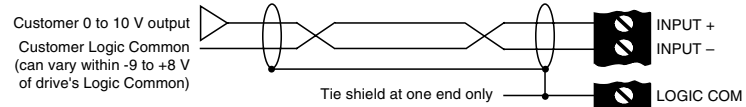
Terminal	Description
<b>Resolver</b>	
CON2-1	Sine (+)
CON2-2	Sine (–) <i>2 V<sub>rms</sub> peak-to-peak</i>
CON2-3	Cosine (+)
CON2-4	Cosine (–) <i>2 V<sub>rms</sub> peak-to-peak</i>
CON2-5	Resolver Excitation
CON2-6	Logic Common <i>4 V<sub>rms</sub> at 5 kHz</i>
CON2-7	Resolver Excitation
CON2-8	Logic Common <i>4 V<sub>rms</sub> at 5 kHz</i>
CON2-9	Reference Feedback (+)
CON2-10	Reference Feedback (–) <i>4 V<sub>rms</sub> at 5 kHz</i>
<b>Encoder Emulation</b>	
CON3-1	Isolated +5 V DC <i>Maximum output: 250 mA</i>
CON3-2	Isolated Common
CON3-3	PGA (+)
CON3-4	PGA (–) <i>0 to 5 V nominal</i>
CON3-5	PGB (+)
CON3-6	PGB (–) <i>0 to 5 V nominal</i>
CON3-7	Marker (+)
CON3-8	Marker (–) <i>0 to 5 V nominal</i>
CON3-9	Feedback Loss (+)
CON3-10	Feedback Loss (–) <i>0 to 5 V nominal</i>

**Figure 4-17—Analog Interface Module Connections (321-557)**

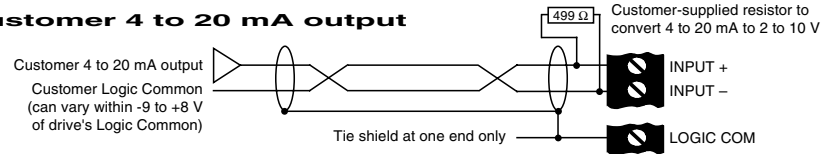


**Figure 4-18—Typical Analog Input Wiring**

**Customer 0 to 10 V output**

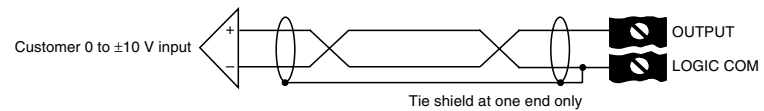


**Customer 4 to 20 mA output**



**Figure 4-19—Typical Analog Output Wiring**

**Customer 0 to ±10 V input**



**Table 4-28—Analog Interface Module Connections (CON2)**

Terminal	Description
<b>Bottom Row</b>	
CON2-1	Analog Input 4 (+)
CON2-2	Analog Input 4 (-)
CON2-3	Analog Input 5 (+)
CON2-4	Analog Input 5 (-)
CON2-5	Logic Common
CON2-6	Analog Input 6 (+)
CON2-7	Analog Input 6 (-)
CON2-8	Analog Input 7 (+)
CON2-9	Analog Input 7 (-)
CON2-10	Analog Output 3
CON2-11	Logic Common
CON2-12	Analog Output 4
<b>Top Row</b>	
CON2-13	Analog Input 8 (+)
CON2-14	Analog Input 8 (-)
CON2-15	Analog Input 9 (+)
CON2-16	Analog Input 9 (-)
CON2-17	Logic Common
CON2-18	Analog Input 10 (+)
CON2-19	Analog Input 10 (-)
CON2-20	Analog Input 11 (+)
CON2-21	Analog Input 11 (-)
CON2-22	Analog Output 5
CON2-23	Logic Common
CON2-24	Analog Output 6
<i>Inputs rated:</i>	<i>0 to 10 V DC or 0 to 20 mA</i>
	<i>Impedance: 200 k<math>\Omega</math> or 500 <math>\Omega</math></i>
<i>Outputs rated:</i>	<i>0 to <math>\pm</math>10 V DC</i>
	<i>Maximum output: 6 mA peak</i>
	<i>Short circuit: 25 mA</i>



# 5 Troubleshooting/Maintenance

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## 5.1 Overview

This chapter provides information useful in troubleshooting and maintaining the drive hardware. It presents the theory of operation, schematics, power electronics troubleshooting procedures, and general maintenance issues. It also provides a list of field-replaceable components.

## 5.2 Troubleshooting

This manual is not intended to provide in-depth service instructions. For service beyond that described in this manual, please contact Unico or your representative.

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### Attention

High voltage may be present even when all electrical power supplies are disconnected. After switching off electrical power, wait at least 15 minutes for bus circuit capacitors to discharge before working on the drive or associated equipment. Use an appropriate voltmeter to further verify that capacitors are discharged before beginning work. Do not rely exclusively on the bus voltage indicator. Dangerous voltage levels may remain even when the indicator is off.

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### 5.2.1 Theory of Operation

The general function of the drive is to convert a fixed voltage and frequency from an electrical power source into a variable voltage and frequency for controlling an AC motor. The block diagrams of the 1100, 1105, 1110, 1130, and 1150 drives are shown in Figure 5-1 through Figure 5-8.

A *rectifier section* is used on the 1100, 1105, and 1110 drives to convert the fixed AC line voltage into a DC bus voltage. The 1150 is a modular design intended for operating a number of units from a common DC bus. Low-power drives use a diode rectifier and resistors to charge the bus capacitors, which is then bypassed by a contact once the bus is up to full voltage. Medium- and high-power drives use silicon-controlled rectifiers (SCRs) to control the charging of the bus capacitors. High-power drives provide for optional twelve-pulse (six-phase) connection of the input to reduce harmonic currents. The 1110 drive is designed for single-phase operation using two, rather than three, AC line voltage terminals. A *rectifier control* coordinates the charging of the bus.

A *link choke* and *bus capacitors* in the 1100, 1105, and 1110 drives form a filter that smooths the output of the rectifier section into a steady DC voltage. An optional *dynamic brake* device on these units allows regenerative energy from the load to be dissipated in an external resistor when the drive is braking. The dynamic braking device turns on when the bus voltage exceeds a preset value, causing the braking current to flow



in the resistor. The link choke and dynamic brake device is normally part of the converter supplying the DC bus to 1150 units.

A *converter section* is used on the 1130 drive to regulate power flow between the AC line and DC bus. The converter uses an insulated gate bipolar transistor (IGBT) bridge to rectify the AC line voltage into a DC bus voltage. This section also regenerates energy from the DC bus to the AC line when the drive is braking. A *regen control* circuit turns on the input IGBTs in synchronism with the AC line to allow bidirectional power flow.

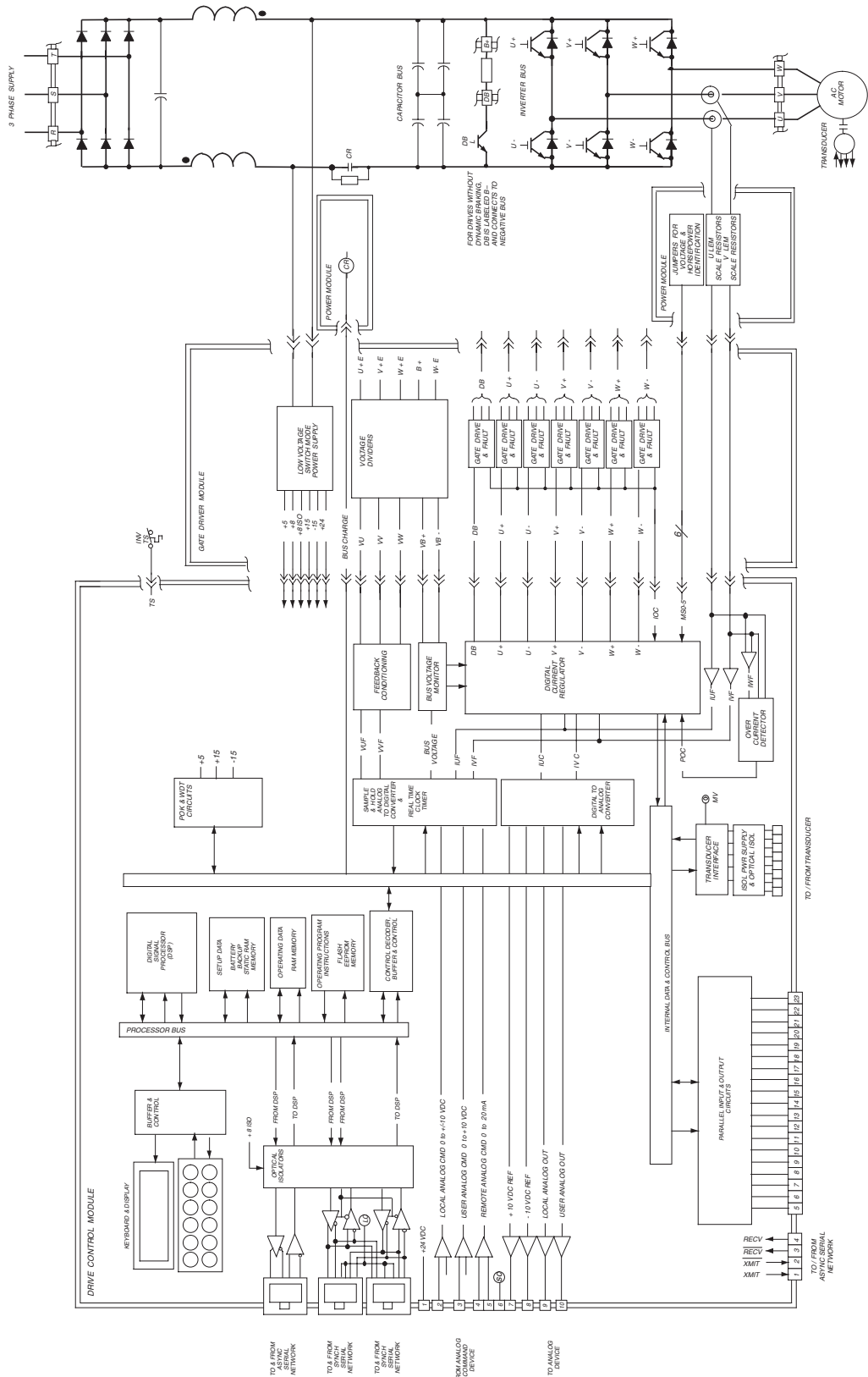
An *inverter section* consisting of six insulated gate bipolar transistors (IGBTs) is used to power an AC motor. This section can produce sine-wave motor voltages and currents of any desired amplitude by rapidly switching the IGBTs using a technique called pulse-width modulation (PWM). A *gate driver* is used to pass switching signals from the drive controller to the IGBTs.

Low-voltage power supplies provide the bias voltages for the control sections. Drives with constant-torque ratings up to 125 hp derive their control voltages from the DC bus using a bus-operated switching supply. Drives with constant-torque ratings greater than 125 hp use a step-down transformer and line-operated switching supply to generate the bias voltages.

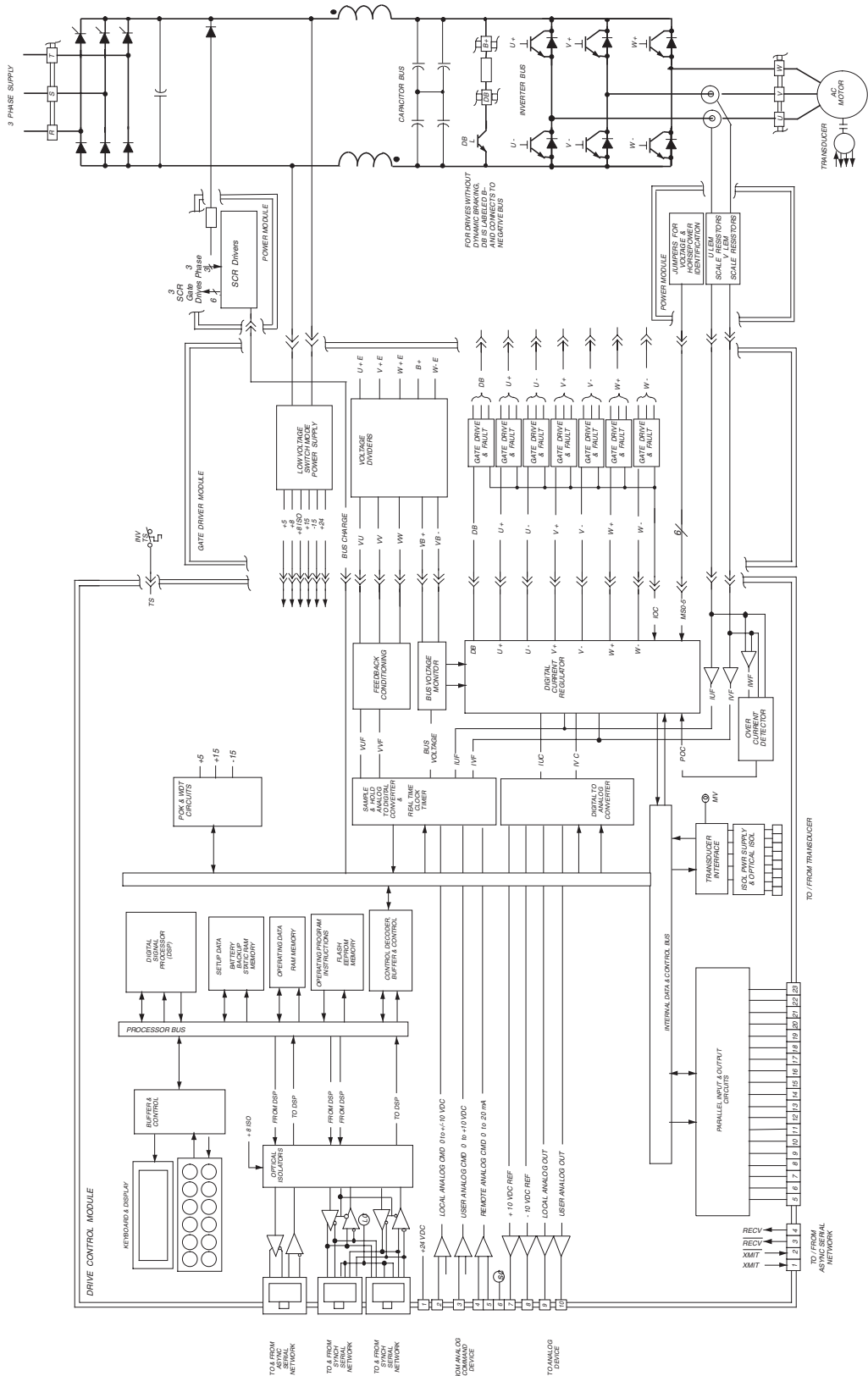
Overall operation of the unit is regulated by a *drive control* that incorporates a digital signal processor (DSP) and a digital current regulator (DCR) or digital space vector (DSV) control. This high-speed digital control uses both voltage and current feedback to regulate the output to the motor. Optional *encoder* and *resolver interfaces* are available to provide closed-loop control of motor velocity and/or position. A dual encoder option is available to slave the motor to other sections of a machine or to reduce machine resonance using dual transducer control. Variable-frequency drive (VFD) operation is an option for controlling AC motors in simple applications.

A *keypad* and *display* on the control module provide access to operating and setup parameters. The control module also provides a number of analog and digital inputs that can be used as input to and output from the drive. Serial communication channels are also available for connecting drives to process controllers, communication networks, programmable controllers, or personal computers. Refer to the application manual for a detailed description of the operation of the control as well as the associated keypad and display.

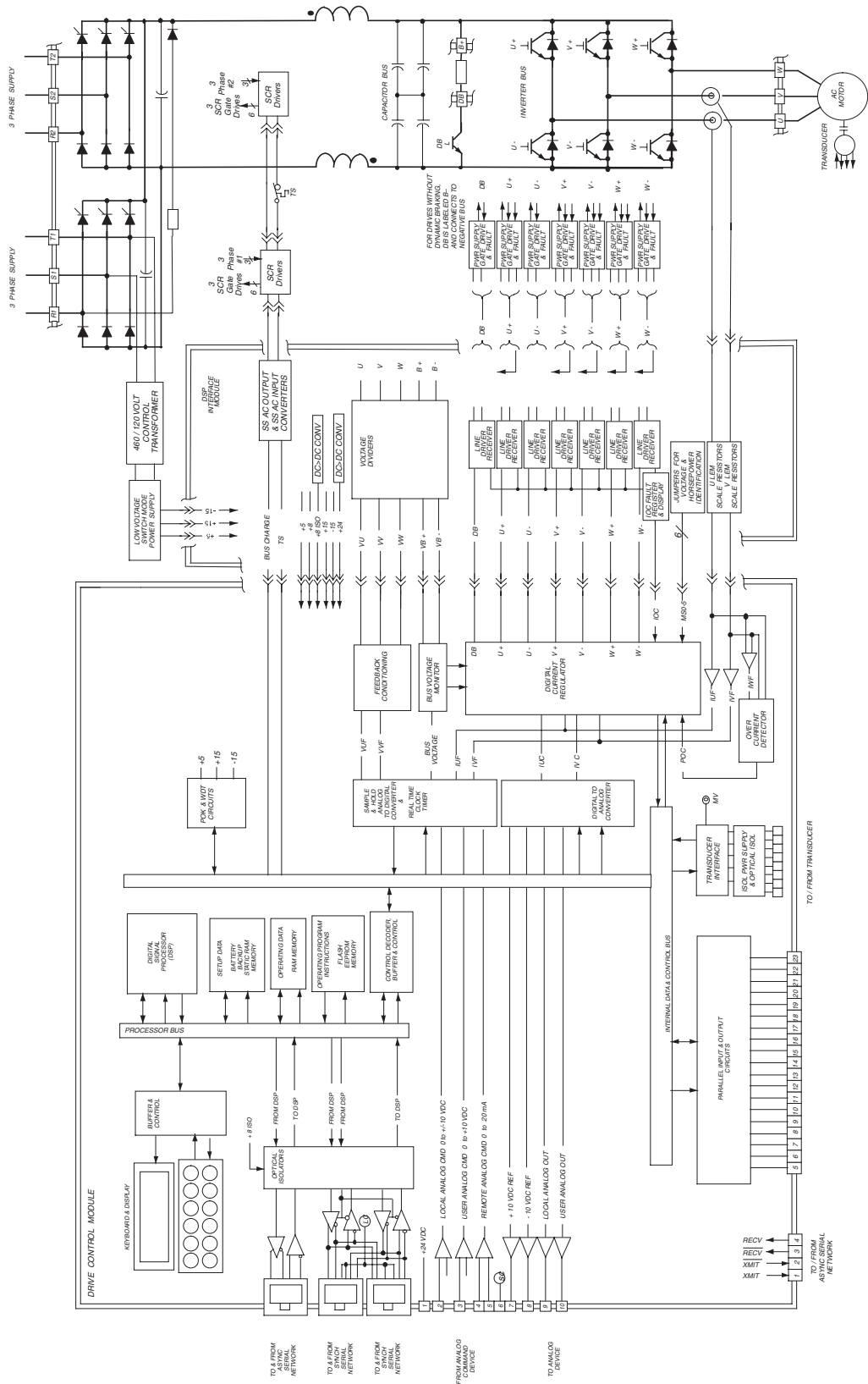
**Figure 5-1—1100 Block Diagram (Forms 1 and 2)**



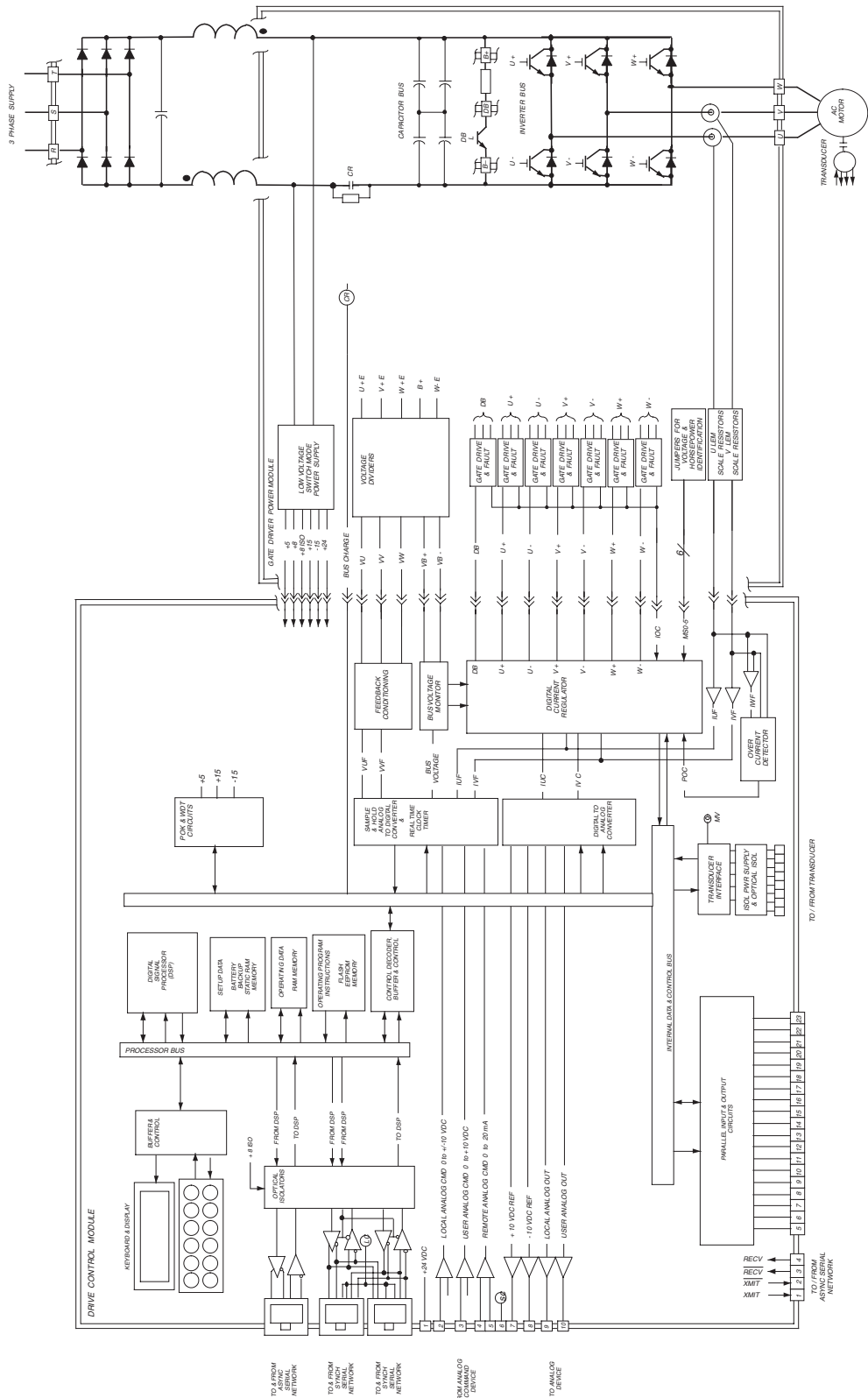
**Figure 5-2—1100 Block Diagram (Form 3)**



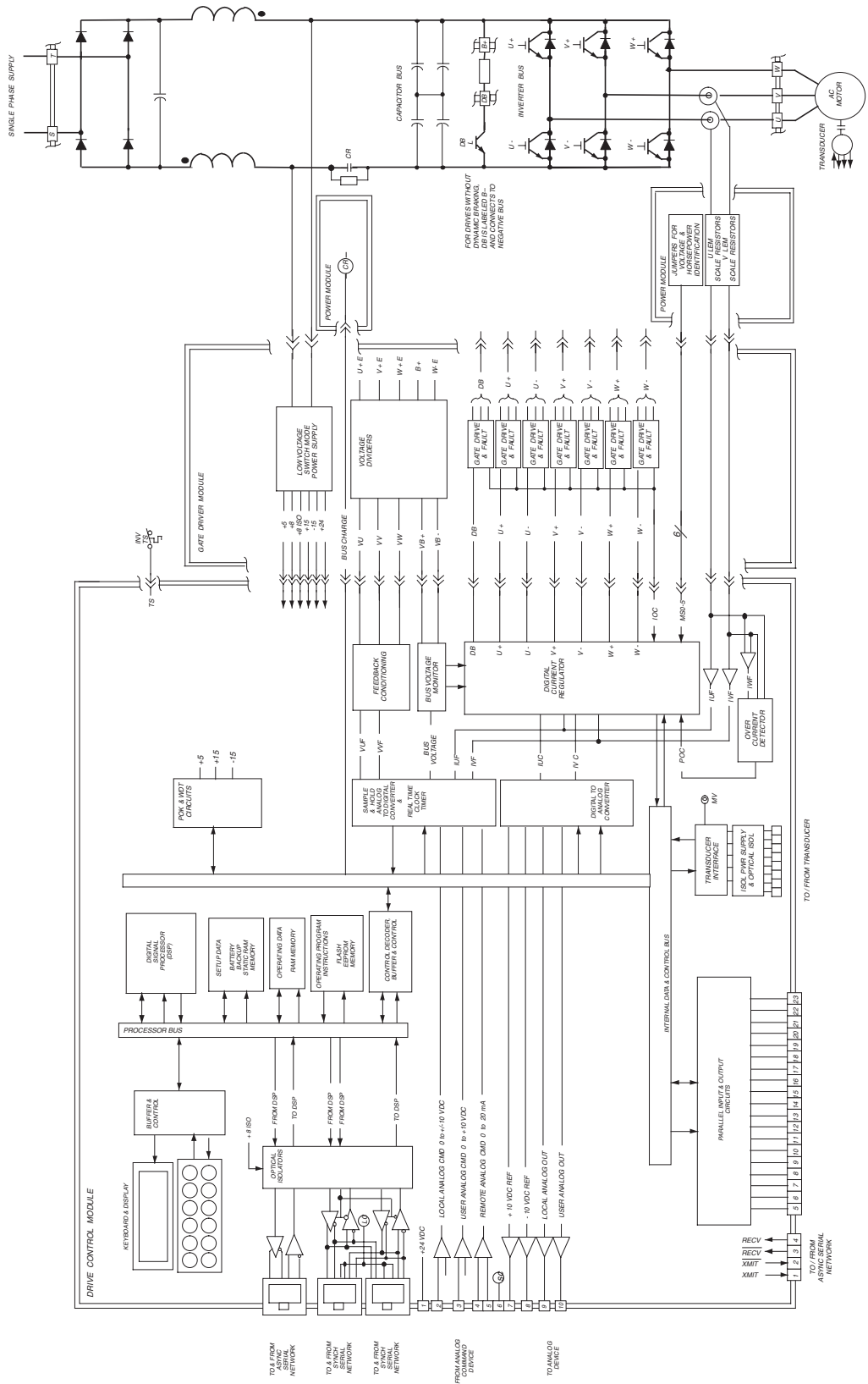
**Figure 5-3—1100 Block Diagram (Form 4)**



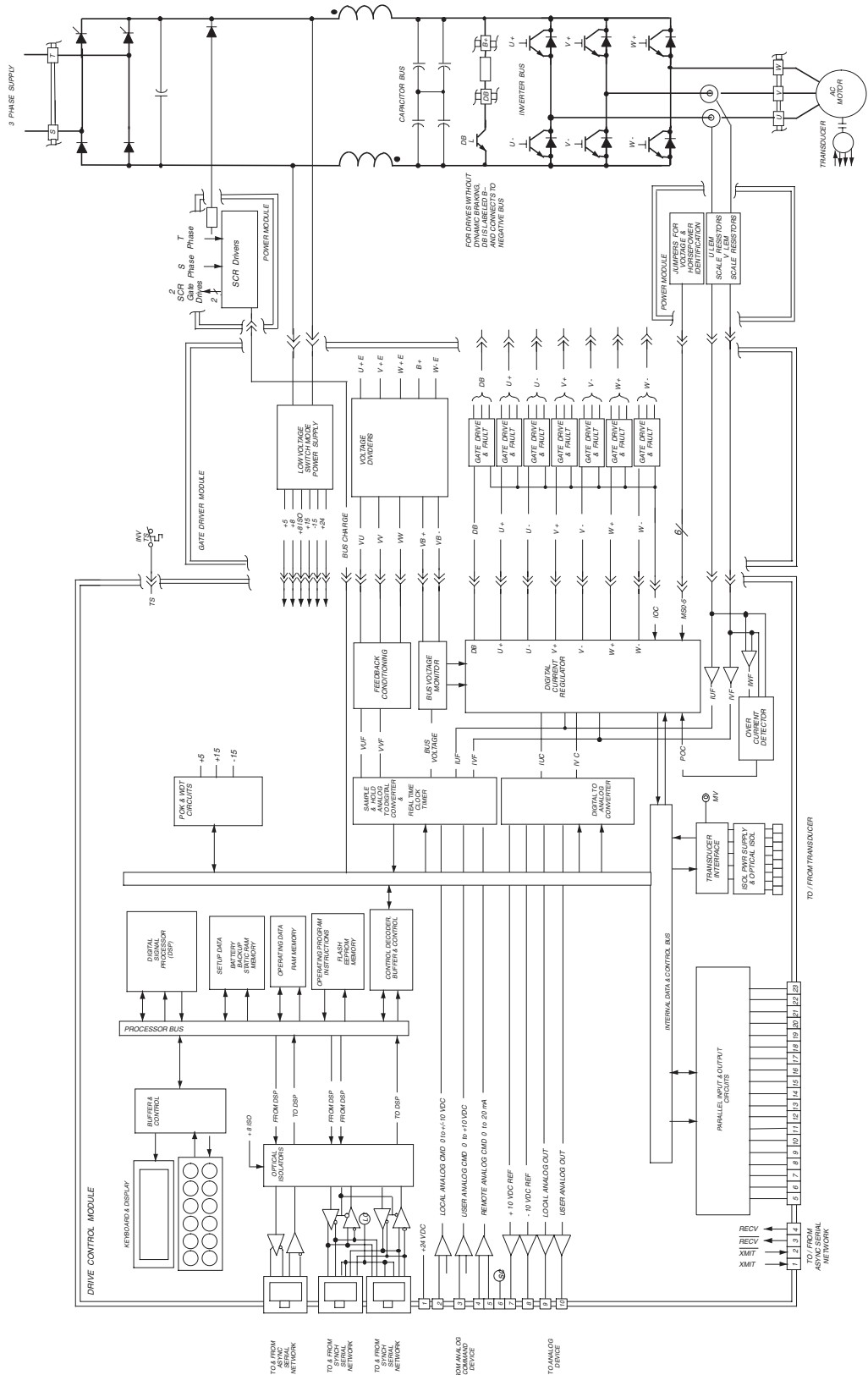
**Figure 5-4—1105 Block Diagram (Form 5 and 6)**



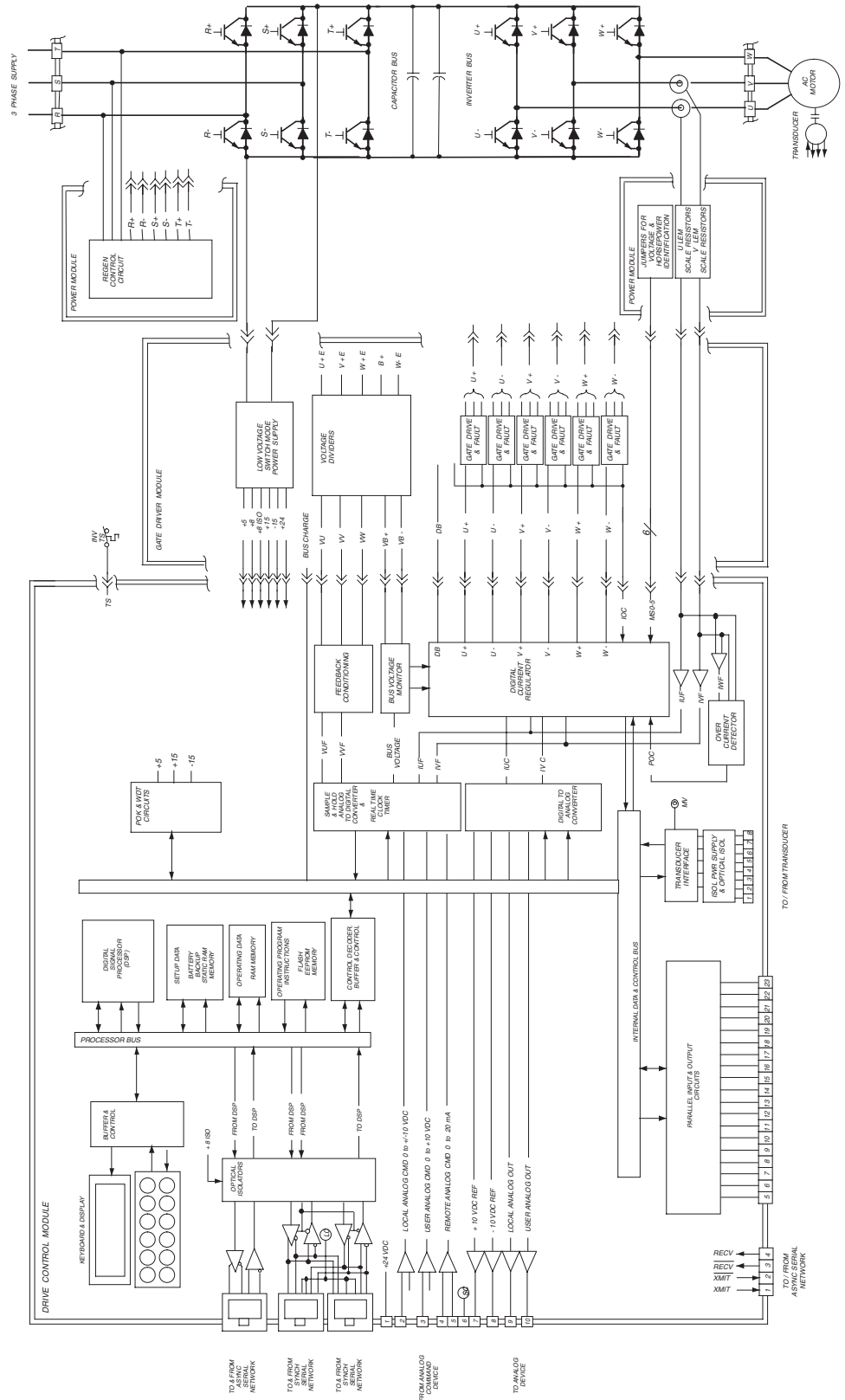
**Figure 5-5—1110 Block Diagram (Forms 1 and 2)**



**Figure 5-6—1110 Block Diagram (Form 3)**



**Figure 5-7—1130 Block Diagram**





**Figure 5-8—1150 Block Diagram**

## 5.2.2 Rectifier Checking Procedure

The rectifier bridge diodes or SCRs can be checked using a multimeter on the diode range by following the procedure outlined below.

---



### Attention

To avoid an electrical shock hazard and possible damage to the equipment, follow all safety instructions listed in the front of this manual, beginning on page i.

---

#### [1] Remove power

Lock off the incoming power at the main machine disconnect switch. Use an appropriate meter to verify that all DC bus capacitor banks have been discharged to zero volts before proceeding. Set the meter to DC voltage and read across terminals B+ and B-. The reading should be 0 V before any attempt is made to work on the drive.

#### [2] Disconnect power board

Disconnect all wires from terminals R, S, and T. Remove the three-phase fuses from the transformer or unplug the three-phase connector from the Power Board.

#### [3] Take readings

Using a multimeter on the diode range, take each of the readings indicated in Table 5-1 at the bridge rectifier terminals and check for the appropriate meter reading.

#### [4] Reconnect power board

Insert the three-phase fuses or plug in the three-phase connector on the Power Board.

#### [5] Take reading

With the meter, check B+ to the R1 terminal. It should read 0.25 to 0.40 V with (+) lead to R1 and open with (+) lead to B+.

#### [6] Replacement

Any meter reading other than that specified indicates a defective diode or SCR. Replace defective components or the entire drive.

#### [7] Reconnect

Replace all wires to terminals R, S, and T.

### 5.2.3 Transistor Checking Procedure

The inverter IGBTs can be checked using a multimeter on the diode range by following the procedure outlined below.

---



#### **Attention**

To avoid an electrical shock hazard and possible damage to the equipment, follow all safety instructions listed in the front of this manual, beginning on page i.

---

#### [1] **Remove power**

Lock off the incoming power at the main machine disconnect switch. Use an appropriate meter to verify that all DC bus capacitor banks have been discharged to zero volts before proceeding. Set the meter to DC voltage and read across terminals B+ and B-. The reading should be 0 V before any attempt is made to work on the inverter.

#### [2] **Disconnect wires**

Disconnect all wires from terminals B+, B-, U, V, and W.

#### [3] **Take readings**

Using a multimeter on the diode range, take each of the readings indicated in Table 5-2 and compare them with the proper values.

#### [4] **Replacement**

Any meter reading other than that specified indicates a defective transistor or diode. Replace defective components or the entire drive.

#### [5] **Reconnect**

Replace all wires to terminals B+, B-, U, V, and W.

**Table 5-1—Rectifier Checking Terminal Readings**

Ohmmeter (+) Lead	Ohmmeter (-) Lead	Proper Meter Reading	Transistor Checked
Bus +	R1, R2	Open	SCR R1+, R2+
Bus +	S1, S2	Open	SCR S1+, S2+
Bus +	T1, T2	Open	SCR T1+, T2+
R1, R2	Bus -	Open	DR1-, DR2-
S1, S2	Bus -	Open	DS1-, DS2-
T1, T2	Bus -	Open	DT1-, DT2-
R1, R2	Bus +	Open	SCR R1+, R2+
S1, S2	Bus +	Open	SCR S1+, S2+
T1, T2	Bus +	Open	SCR T1+, T2+
Bus -	R1, R2	0.25 V to 0.40 V	DR1-, DR2-
Bus -	S1, S2	0.25 V to 0.40 V	DS1-, DS2-
Bus -	T1, T2	0.25 V to 0.40 V	DT1-, DT2-

**Table 5-2—Transistor Checking Terminal Readings**

Ohmmeter (+) Lead	Ohmmeter (-) Lead	Proper Meter Reading	Transistor Checked
Bus +	B-	Open	Ddb flyback
Bus +	U	Open	QU+
Bus +	V	Open	QV+
Bus +	W	Open	QW+
B-	Bus -	Open	Qdb
U	Bus -	Open	QU-
V	Bus -	Open	QV-
W	Bus -	Open	QW-
B-	Bus +	0.25 V to 0.40 V	Ddb flyback
U	Bus +	0.25 V to 0.40 V	QU+
V	Bus +	0.25 V to 0.40 V	QV+
W	Bus +	0.25 V to 0.40 V	QW+
Bus -	B-	Forms 1 2 3: Open Form 4: 0.25 V to 0.40 V	Qdb
Bus -	U	0.25 V to 0.40 V	QU-
Bus -	V	0.25 V to 0.40 V	QV-
Bus -	W	0.25 V to 0.40 V	QW-

### **5.3 Maintenance**

The drive requires virtually no maintenance. Once the unit has been commissioned, an occasional routine inspection should be sufficient.

#### **5.3.1 Working Life**

Unico asserts that the working life of the product will be at least a five-year period from the date of purchase. Service, repair, and component replacement will be available from Unico to support the equipment for a minimum of five years.

#### **5.3.2 Battery Life**

Batteries supply nonvolatile memory while power is removed. Battery life is calculated at about ten years, but a typical installation is likely to operate for a longer period.

#### **5.3.3 Disposal**

Unico encourages proper recycling of this unit. Metal parts can be recycled. Plastic parts can either be recycled or burned under controlled conditions as regulated locally. If recycling is not feasible, all parts, except for the capacitors used in the DC bus circuit, can be taken to a refuse dump. The capacitors contain an electrolyte that is classified as hazardous waste. Contact local authorities for regulations and proper procedures for their disposal.

#### **5.3.4 Spare Parts**

Table 5-3 through

Table 5-14 list the field-replaceable components of the drive. Contact the factory or your value-added reseller for ordering information.

**Table 5-3—Control and Interface Modules**

Component	Order Code	Part Number
<b>Control Modules</b>		
16 MHz Control Module with VFD control	V00	322-340
20 MHz Control Module with DCR control	F00	321-101
20 MHz Control Module with DSV control	F20	321-516
40 MHz Control Module with logic I/O control	S00, S20	322-157
40 MHz Control Module with mixed I/O control	S10, S30	322-100
40 MHz Control Module with contact I/O control	S40	322-966
100 MHz Control Module with logic I/O control	J20	323-546
100 MHz Control Module with logic I/O control and encoder	J21	323-397
100 MHz Control Module with mixed I/O control	J30	323-548
100 MHz Control Module with mixed I/O control and encoder	J31	323-547
<b>I/O Fanning Strip</b>		
12-input/6-output fanning strip	—	708-295
<b>Keypad/Displays</b>		
12-key (2 x 6) keypad with 2 x 24 character display	—	203-045
16-key (4 x 4) keypad with 2 x 24 character display	—	203-046
16-key (4 x 4) keypad with graphic display	—	203-181
<b>Interface Modules</b>		
Encoder Interface Module (5 V)	xx1	316-887
Dual Encoder Interface Module (5 V)	xx2	321-952
Resolver Interface Module with Encoder Emulation	xx3	322-096
Analog Interface Module	xx9	321-557

**Table 5-4—I/O Converter Modules**

Device	Voltage Range	Order Code	Part Number
Input converter	90 to 140 V AC	AI1	912-688
Input converter	180 to 280 V AC	AI2	919-808
Output converter	12 to 140 V AC	AO1	913-108
Output converter	180 to 280 V AC	AO2	919-809
Input converter	2.5 to 28 V DC	DCI	913-109
Output converter	5 to 60 V DC	DCO	913-110
Normally open relay	0 to 30 V DC, 0 to 250 V AC	NOR	915-282
Normally closed relay	0 to 30 V DC, 0 to 250 V AC	NCR	921-332
Pass-through jumper	—	—	922-084

**Table 5-5—Drive Assemblies (1100 and 1105)**

Power CT <i>hp (kW)</i>	1100				1105			
	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB
<b>230 V</b>								
1 1/2 (1.1)	320-879	321-270	321-390	321-404	—	321-157	—	321-170
2 (1.5)	320-880	321-271	321-391	321-405	—	321-158	—	321-171
3 (2.2)	320-881	321-272	321-392	321-406	—	321-159	—	321-172
5 (3.7)	320-882	321-273	321-393	321-407	—	321-160	—	321-173
7 1/2 (5.5)	320-329	321-274	321-394	321-408	—	321-161	—	321-174
10 (7.5)	320-330	321-275	321-395	321-409	—	321-233	—	321-234
15 (11)	320-331	321-276	321-396	321-410	—	321-858	—	321-859
20 (15)	320-332	321-277	321-398	321-411	—	322-033	—	322-034
25 (18)	320-333	321-278	321-399	321-412	—	—	—	—
30 (22)	320-334	321-279	321-400	321-413	—	—	—	—
40 (30)	320-335	321-280	321-401	321-414	—	—	—	—
50 (37)	320-336	321-281	321-402	321-415	—	—	—	—
60 (45)	320-337	321-282	321-403	321-416	—	—	—	—
<b>460 V</b>								
1 1/2 (1.1)	320-883	321-283	321-417	321-438	—	321-162	—	321-175
2 (1.5)	320-884	321-284	321-418	321-439	—	321-163	—	321-176
3 (2.2)	320-885	321-285	321-419	321-440	—	321-164	—	321-177
5 (3.7)	320-886	321-316	321-420	321-441	—	321-165	—	321-178
7 1/2 (5.5)	320-887	321-287	321-421	321-442	—	321-166	—	321-179
10 (7.5)	320-888	321-288	321-422	321-443	—	321-167	—	321-180
15 (11)	320-338	321-289	321-423	321-444	—	321-168	—	321-181
20 (15)	320-339	321-290	321-424	321-445	—	321-169	—	321-182
25 (18)	320-340	321-291	321-425	321-446	—	323-084	—	323-085
30 (22)	320-341	321-292	321-426	321-447	—	322-363	—	322-364
40 (30)	320-342	321-293	321-427	321-448	—	322-365	—	322-366
50 (37)	320-343	321-294	321-428	321-449	323-125	323-119	323-137	323-130

*(continued)*



**Table 5-5—Drive Assemblies (1100 and 1105) (continued)**

Power CT <i>hp (kW)</i>	1100				1105			
	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB
<b>460 V</b>								
60 (45)	322-450	322-454	322-458	322-462	323-126	323-120	323-138	323-132
75 (55)	322-451	322-455	322-459	322-463	323-127	323-121	323-139	323-133
100 (75)	322-452	322-456	322-460	322-464	320-346	321-297	321-431	321-452
125 (90)	322-453	322-457	322-461	322-465	323-129	323-123	323-141	323-135
150 (110)	321-866	321-871	320-465	320-761	323-588	323-124	323-589	323-136
200 (150)	321-867	321-872	320-466	320-762	—	—	—	—
250 (185)	321-868	321-873	320-467	320-763	—	—	—	—
300 (225)	321-869	321-874	320-468	320-764	—	—	—	—
350 (262)	321-870	321-875	320-758	320-765	—	—	—	—
400 (300)	323-398	323-684	323-399	323-685	—	—	—	—
<b>575 V</b>								
1 1/2 (1.1)	321-138	321-299	321-459	321-480	—	322-919	—	322-904
2 (1.5)	321-139	321-300	321-460	321-481	—	322-920	—	322-905
3 (2.2)	321-140	321-301	321-461	321-482	—	322-921	—	322-906
5 (3.7)	321-141	321-302	321-462	321-483	—	322-922	—	322-907
7 1/2 (5.5)	321-142	321-303	321-463	321-484	—	322-923	—	322-908
10 (7.5)	321-143	321-304	321-464	321-485	—	322-924	—	322-909
15 (11)	321-144	321-305	321-465	321-486	—	322-925	—	322-910
20 (15)	321-145	321-306	321-466	321-487	—	322-926	—	322-911
25 (18)	321-146	321-307	321-467	321-488	—	322-927	—	322-996
30 (22)	321-147	321-308	321-468	321-489	—	322-928	—	322-997
40 (30)	321-148	321-309	321-469	321-490	—	323-142	—	323-154
50 (37)	321-149	321-310	321-470	321-491	323-151	323-143	323-163	323-155
60 (45)	321-150	321-311	321-471	321-492	323-152	323-144	323-164	323-156
75 (55)	321-151	321-312	321-472	321-493	323-153	323-145	323-165	323-157
100 (75)	321-152	321-313	321-473	321-494	323-750	323-146	323-754	323-158
125 (90)	321-153	321-314	321-474	321-495	323-751	323-147	323-755	323-159

*(continued)*

**Table 5-5—Drive Assemblies (1100 and 1105) (continued)**

Power CT hp (kW)	1100				1105			
	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB
<b>575 V</b>								
150 (110)	321-876	321-881	320-470	320-768	323-752	323-148	323-756	323-160
200 (150)	321-877	321-882	320-471	320-769	323-753	323-149	323-757	323-161
250 (185)	321-878	321-883	320-472	320-770	—	—	—	—
300 (225)	321-879	321-884	320-473	320-771	—	—	—	—
350 (262)	321-880	321-885	320-759	320-772	—	—	—	—
400 (300)	323-400	323-855	323-401	323-856	—	—	—	—

**Table 5-6—Drive Assemblies (1110, 1130, and 1150)**

Power CT hp (kW)	1110				1130		1150	
	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB	Chassis w/RB	Enclosed w/RB	Chassis	Enclosed
<b>230 V</b>								
1 1/2 (1.1)	319-261	321-566	321-589	321-612	—	—	323-895	—
2 (1.5)	319-262	321-567	321-590	321-613	—	—	323-896	—
3 (2.2)	319-263	321-568	321-591	321-614	—	—	323-897	—
5 (3.7)	319-264	321-569	321-592	321-615	—	—	323-898	—
7 1/2 (5.5)	319-265	321-570	321-593	321-616	323-353	320-698	323-899	—
10 (7.5)	319-266	321-571	321-594	321-617	323-354	320-289	323-900	—
15 (11)	319-267	321-572	321-595	321-618	323-355	320-290	323-901	—
20 (15)	319-268	321-573	321-596	321-619	323-356	320-291	323-902	—
25 (18)	319-269	321-574	321-597	321-620	323-357	320-292	323-903	—
30 (22)	319-270	321-575	321-598	321-621	323-358	320-293	323-904	—
40 (30)	322-102	322-103	322-104	322-105	323-359	320-294	323-905	—
50 (37)	—	—	—	—	323-360	320-295	323-906	—
60 (45)	—	—	—	—	323-361	320-296	323-907	—

(continued)

**Table 5-6—Drive Assemblies (1110, 1130, and 1150) (continued)**

Power CT <i>hp (kW)</i>	1110				1130		1150	
	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB	Chassis w/RB	Enclosed w/RB	Chassis	Enclosed
<b>460 V</b>								
1½ (1.1)	319-271	321-576	321-599	321-622	—	—	323-911	—
2 (1.5)	319-273	321-577	321-600	321-623	—	—	323-912	—
3 (2.2)	319-274	321-578	321-601	321-624	—	—	323-913	—
5 (3.7)	319-275	321-579	321-602	321-625	—	—	323-914	—
7½ (5.5)	319-276	321-580	321-603	321-626	323-362	320-718	322-990	—
10 (7.5)	319-277	321-581	321-604	321-627	323-363	320-719	322-991	—
15 (11)	319-278	321-582	321-605	321-628	323-364	320-720	322-788	—
20 (15)	319-279	321-583	321-606	321-629	323-365	320-297	322-992	—
25 (18)	319-280	321-584	321-607	321-630	323-366	320-298	323-910	—
30 (22)	319-281	321-585	321-608	321-631	323-367	320-299	319-959	—
40 (30)	319-282	321-586	321-609	321-632	323-368	320-300	319-960	—
50 (37)	319-283	321-587	321-610	321-633	323-369	320-301	319-961	—
60 (45)	319-284	321-588	321-611	321-634	323-370	320-302	319-962	—
75 (55)	322-106	322-107	322-108	322-109	323-371	320-303	319-963	—
100 (75)	—	—	—	—	323-372	320-304	319-964	—
125 (90)	—	—	—	—	323-373	321-361	323-908	—

*(continued)*

**Table 5-6—Drive Assemblies (1110, 1130, and 1150) (continued)**

Power CT <i>hp (kW)</i>	1110				1130		1150	
	Chassis w/o DB	Chassis w/DB	Enclosed w/o DB	Enclosed w/DB	Chassis w/RB	Enclosed w/RB	Chassis	Enclosed
<b>575 V</b>								
7 1/2 (5.5)	—	—	—	—	323-374	320-725	—	—
10 (7.5)	—	—	—	—	323-375	320-726	—	—
15 (11)	—	—	—	—	323-376	320-727	—	—
20 (15)	—	—	—	—	323-377	320-728	—	—
25 (18)	—	—	—	—	323-378	320-729	—	—
30 (22)	—	—	—	—	323-379	320-730	—	—
40 (30)	—	—	—	—	323-380	320-731	—	—
50 (37)	—	—	—	—	323-381	320-732	—	—
60 (45)	—	—	—	—	323-382	320-733	—	—
75 (55)	—	—	—	—	323-383	320-734	—	—
100 (75)	—	—	—	—	323-384	320-735	—	—
125 (90)	—	—	—	—	323-385	321-362	—	—

**Table 5-7—1100 and 1110 Field-Replaceable Components (Forms ①, ②, and ③)**

Power CT <i>hp (kW)</i>	Power Control Module	Gate Drive w/o DB	Gate Drive w/DB	Diode/ SCR Bridge	Bus Capacitor Module	Brake IGBT Assembly	Inverter IGBT Assembly	Internal Cooling Fan	External Cooling Fan
<b>230 V</b>									
1½ (1.1)	321-665	320-798	320-799	708-373	318-918	708-387	707-845	913-282	—
2 (1.5)	321-666	320-798	320-799	708-373	318-918	708-387	707-846	913-282	—
3 (2.2)	321-667	320-798	320-799	708-374	318-918	708-387	707-850	913-282	—
5 (3.7)	321-668	320-798	320-799	708-374	318-918	708-387	707-850	913-282	—
7½ (5.5)	321-669	320-798	320-799	708-374	318-917	708-388	707-851	913-282	—
10 (7.5)	321-670	320-798	320-799	708-375	318-920	708-388	707-857	913-282	—
15 (11)	321-671	320-798	320-799	708-375	318-919	708-390	707-858 (3)	913-282	914-338
20 (15)	321-672	320-798	320-799	708-376 (3)	318-920	708-390	707-858 (3)	913-282	914-338
25 (18)	321-673	320-798	320-799	708-376 (3)	318-920	708-390	707-864 (3)	913-282	914-338
30 (22)	321-674	320-798	320-799	708-376 (3)	318-923	708-391	707-860 (3)	913-282	914-338
40 (30)	321-675	320-798	320-799	708-056 (6)	320-577	707-886	707-882 (6)	913-282	914-338
50 (37)	321-676	320-798	320-799	708-057 (6)	320-577	707-886	707-883 (6)	913-282	914-338
60 (45)	321-677	320-798	320-799	708-060 (6)	320-577	707-886	707-883 (6)	913-282	914-338
<b>460 V</b>									
1½ (1.1)	321-678	320-604	320-605	708-378	315-741	708-387	707-847	913-282	—
2 (1.5)	321-679	320-604	320-605	708-378	315-741	708-387	707-848	913-282	—
3 (2.2)	321-680	320-604	320-605	708-378	315-741	708-387	707-848	913-282	—
5 (3.7)	321-681	320-604	320-605	708-378	315-741	708-387	707-849	913-282	—
7½ (5.5)	321-682	320-604	320-605	708-378	316-202	708-388	707-852	913-282	—
10 (7.5)	321-683	320-604	320-605	708-379	316-202	708-388	707-852	913-282	—
15 (11)	321-684	320-604	320-605	708-379	316-202	708-388	707-866	913-282	—
20 (15)	321-685	320-604	320-605	708-379	318-925	708-388	707-867	913-282	—
25 (18)	321-686	320-604	320-605	708-380	318-925	708-389	707-868 (3)	913-282	914-338
30 (22)	321-687	320-604	320-605	708-381	318-925	708-389	707-868 (3)	913-282	914-338
40 (30)	321-688	320-604	320-605	708-381	318-926	708-389	707-869 (3)	913-282	914-338
50 (37)	321-689	320-604	320-605	708-381	318-926	708-389	707-869 (3)	913-282	914-338

*(continued)*

**Table 5-7—1100 and 1110 Field-Replaceable Components (Forms , , and )**  
(continued)

Power CT <i>hp (kW)</i>	Power Control Module	Gate Drive w/o DB	Gate Drive w/DB	Diode/ SCR Bridge	Bus Capacitor Module	Brake IGBT Assembly	Inverter IGBT Assembly	Internal Cooling Fan	External Cooling Fan
60 (45)	321-690	318-622	317-229	708-056 (6)	318-914	707-886	707-884 (6)	913-282	914-338
75 (55)	321-691	318-622	317-229	708-057 (6)	318-915	707-886	707-885 (6)	913-282	914-338
100 (75)	321-692	318-622	317-229	708-059 (6)	318-916	707-886	707-888 (6)	913-282	914-338
125 (90)	321-693	318-622	317-229	708-060 (6)	318-916	707-886	707-888 (6)	913-282	914-338
<b>575 V</b>									
1 1/2 (1.1)	321-694	319-824	317-834	708-378	319-974	708-387	707-854	913-282	—
2 (1.5)	321-695	319-824	317-834	708-378	319-974	708-387	707-854	913-282	—
3 (2.2)	321-696	319-824	317-834	708-378	319-974	708-387	707-854	913-282	—
5 (3.7)	321-697	319-824	317-834	708-378	319-974	708-387	707-854	913-282	—
7 1/2 (5.5)	321-698	319-824	317-834	708-378	319-975	708-388	707-854	913-282	—
10 (7.5)	321-699	319-824	317-834	708-379	319-975	708-388	707-854	913-282	—
15 (11)	321-700	319-824	317-834	708-379	319-975	708-388	707-855	913-282	—
20 (15)	321-701	319-824	317-834	708-379	319-975	708-388	707-855	913-282	—
25 (18)	321-702	319-824	317-834	708-380	319-975	708-388	707-876	913-282	—
30 (22)	321-703	319-824	317-834	708-380	319-976	708-389	707-877 (3)	913-282	914-338
40 (30)	321-704	319-824	317-834	708-381 (3)	319-976	708-389	707-878 (3)	913-282	914-338
50 (37)	321-705	319-824	317-834	708-381 (3)	319-977	708-389	707-878 (3)	913-282	914-338
60 (45)	321-706	317-835	317-834	708-056 (6)	319-978	707-889	707-889 (6)	913-282	914-338
75 (55)	321-707	317-835	317-834	708-056 (6)	319-978	707-889	707-889 (6)	913-282	914-338
100 (75)	321-708	317-835	317-834	708-057 (6)	319-980	707-889	707-889 (6)	913-282	914-338
125 (90)	321-709	317-835	317-834	708-059 (6)	319-980	707-889	707-890 (6)	913-282	914-338

**Table 5-8—1100 Field-Replaceable Components (Form ④)**

Power CT <i>hp (kW)</i>	Power Control Module	Control Interface Module	Control Power Supply	Diode/ SCR Bridge	Bus Capacitor	Brake IGBT Assembly	Inverter IGBT Assembly	Internal Cooling Fan	External Cooling Fan
<b>460 V</b>									
150 (110)	319-317	320-819	916-403	708-060 (6)	918-771 (10)	707-892	708-030 (6)	901-991 (4)	909-832 (4)
200 (150)	319-317	320-820	916-403	708-060 (6)	918-771 (12)	708-034	708-031 (6)	901-991 (4)	909-832 (8)
250 (185)	319-317	320-821	916-403	708-062 (6)	918-771 (14)	708-034	708-031 (6)	901-991 (4)	909-832 (8)
300 (225)	319-317	320-774	916-403	708-063 (6)	918-771 (16)	708-030	708-032 (6)	901-991 (4)	909-832 (8)
350 (262)	319-317	320-775	916-403	708-065 (6)	918-771 (18)	708-030	708-032 (6)	901-991 (4)	909-832 (8)
400 (300)	319-317 919-666	320-776	916-403	708-065 (6)	918-771 (18)	708-030	708-033 (6)	901-991 (4)	909-832 (8)
<b>575 V</b>									
150 (110)	319-317	320-822	916-403	708-057 (6)	917-948 (8)	708-034	708-034 (6)	901-991 (4)	909-832 (4)
200 (150)	319-317	320-823	916-403	708-060 (6)	917-948 (10)	708-034	708-035 (6)	901-991 (4)	909-832 (8)
250 (185)	319-317	320-824	916-403	708-060 (6)	917-948 (12)	708-034	708-036 (6)	901-991 (4)	909-832 (8)
300 (225)	319-317	320-777	916-403	708-062 (6)	917-948 (14)	708-035	708-037 (6)	901-991 (4)	909-832 (8)
350 (262)	319-317	320-778	916-403	708-063 (6)	917-948 (16)	708-035	708-037 (6)	901-991 (4)	909-832 (8)
400 (300)	319-317 919-666	320-779	916-403	708-065 (6)	917-948 (18)	708-035	711-843 (6)	901-991 (4)	909-832 (8)

**Table 5-9—1100 Field-Replaceable Components (Form ④)**

<b>Power</b>			
<b>CT</b> <i>hp (kW)</i>	<b>Current Sensors</b>	<b>Clamp Module</b>	<b>Snubber Module</b>
<b>460 V</b>			
150 (110)	918-689 (2)	103-210 (3)	—
200 (150)	918-690 (2)	103-210 (3)	—
250 (185)	918-690 (2)	103-210 (3)	—
300 (225)	918-691 (2)	103-210 (3)	—
350 (262)	918-691 (2)	103-210 (3)	318-876 (3)
400 (300)	922-472	103-210 (3)	318-876 (3)
<b>575 V</b>			
150 (110)	918-689 (2)	103-210 (3)	—
200 (150)	918-690 (2)	103-210 (3)	—
250 (185)	918-690 (2)	103-210 (3)	—
300 (225)	918-691 (2)	103-210 (3)	—
350 (262)	918-691 (2)	103-210 (3)	318-876 (3)
400 (300)	922-472	103-210 (3)	318-876 (3)



**Table 5-10—1105 Field-Replaceable Components  
(Forms 5, 6, and 7)**

<b>Power CT hp (kW)</b>	<b>Power Control Module</b>	<b>External Cooling Fan</b>	<b>Internal Cooling Fan</b>	<b>External Choke Fan (Chassis)</b>	<b>External Cooling Fan (Enclosed)</b>
<b>230 V</b>					
1 1/2 (1.1)	321-656	—	920-596	—	—
2 (1.5)	321-657	—	920-596	—	—
3 (2.2)	321-658	920-458	920-596	—	—
5 (3.7)	321-659	920-458	920-596	—	—
7 1/2 (5.5)	321-660	920-458	920-596	921-541	920-541
10 (7.5)	321-661	920-458	920-596	921-541	920-541
15 (11)	321-793	920-458	—	921-541	920-458
20 (15)	322-082	920-458	—	921-541	920-458
<b>460 V</b>					
1 1/2 (1.1)	321-510	—	920-596	—	—
2 (1.5)	321-511	—	920-596	—	—
3 (2.2)	321-512	920-458	920-596	—	—
5 (3.7)	321-513	920-458	920-596	—	—
7 1/2 (5.5)	321-652	920-458	920-596	921-541	921-541
10 (7.5)	321-653	920-458	920-596	921-541	921-541
15 (11)	321-654	920-458	—	921-541	920-458
20 (15)	321-655	920-458	—	921-541	920-458
25 (18)	321-655	920-458	—	921-541	920-458
30 (22)	322-383	914-338	914-338	—	914-338
40 (30)	322-384	914-338	914-338	—	914-338

**Table 5-11—1105 Field-Replaceable Components (Form ③)**

Power CT <i>hp (kW)</i>	Power Control Module	Gate Drive w/o DB	Gate Drive w/DB	Diode/ SCR Bridge	Bus Capacitor Module	Brake IGBT Assembly	Inverter IGBT Assembly	Internal Cooling Fan	External Cooling Fan
<b>460 V</b>									
50 (37)	319-856	318-662	317-229	708-056 (6)					
60 (45)	319-857	318-662	317-229	708-057 (6)					
75 (55)	319-858	318-662	317-229	708-059 (6)					
100 (75)	319-859	318-662	317-229	708-061 (6)					
125 (90)	319-860	318-662	317-229	708-061 (6)					
150 (110)	323-251	318-662	317-229	708-062 (6)					
<b>575 V</b>									
50 (37)	319-861	<i>C o n s u l t f a c t o r y</i>				<i>C o n s u l t f a c t o r y</i>			
60 (45)	319-862								
75 (55)	319-863	<i>C o n s u l t f a c t o r y</i>				<i>C o n s u l t f a c t o r y</i>			
100 (75)	319-864								
125 (90)	319-865	<i>C o n s u l t f a c t o r y</i>				<i>C o n s u l t f a c t o r y</i>			
150 (110)	323-253								
200 (150)	323-254								

**Table 5-12—1105 Field-Replaceable Components (Form ③)**

Power CT <i>hp (kW)</i>	Power Control Module	Gate Driver Module	Diode/ SCR Bridge	Bus Capacitor	Brake IGBT Assembly	Brake Clamp Diode Assembly	Inverter IGBT Assembly	Internal Cooling Fan	External Cooling Fan
<b>460 V</b>									
125 (90)	323-250	323-035	708-061 (6)	918-771 (12)	711-608	711-541	710-663 (6)	901-991 (2)	909-832 (3)
150 (110)	323-251	323-035	708-062 (6)	918-771 (16)	711-845	711-541	710-664 (6)	901-991 (2)	909-832 (6)
<b>575 V</b>									
125 (90)	323-252	323-036	708-060 (6)	917-948 (12)	711-533	711-540	710-665 (6)	901-991 (2)	909-832 (3)
150 (110)	323-253	323-036	708-061 (6)	917-948 (14)	711-533	711-540	710-665 (6)	901-991 (2)	909-832 (3)
200 (150)	323-254	323-036	708-062 (6)	917-948 (16)	711-533	711-540	710-666 (6)	901-991 (2)	909-832 (6)

**Table 5-13—1105 Field-Replaceable Components (Form ③)**

Power CT <i>hp (kW)</i>	Current Sensors	Clamp Module
<b>460 V</b>		
125 (90)	918-689 (2)	316-465
150 (110)	918-690 (2)	316-465
<b>575 V</b>		
125 (90)	918-689 (2)	319-817
150 (110)	918-689 (2)	319-817
200 (150)	918-690 (2)	319-817

**Table 5-14—1130 Field-Replaceable Components**

<b>Power CT</b> <i>hp (kW)</i>	<b>Power Control Module</b>	<b>Gate Drive Module</b>	<b>Current Sensor</b>	<b>In/Out IGBT Assembly</b>	<b>Bus Capacitor Assembly</b>	<b>Internal Cooling Fan</b>	<b>External Cooling Fan</b>
<b>230 V</b>							
7½ (5.5)	321-717	320-842	—	707-913 (2)	321-380	913-282	914-338
10 (7.5)	321-718	320-842	—	707-914 (2)	321-380	913-282	914-338
15 (11)	321-719	320-842	—	707-915 (2)	321-380	913-282	914-338
20 (15)	321-720	320-842	—	707-915 (2)	321-380	913-282	914-338
25 (18)	321-721	320-842	—	707-859 (6)	321-380	913-282	914-338
30 (22)	321-722	320-842	918-689 (2)	707-882 (6)	321-380	913-282	914-338
40 (30)	321-723	320-842	918-689 (2)	707-883 (12)	321-380 (2)	913-282	914-338
50 (37)	321-724	320-842	918-689 (2)	707-883 (12)	321-380 (2)	913-282	914-338
60 (45)	321-725	320-842	918-689 (2)	707-883 (12)	321-380 (2)	913-282	914-338
<b>460 V</b>							
7½ (5.5)	321-737	320-843	—	707-916 (2)	321-382	913-282	914-338
10 (7.5)	321-738	320-843	—	707-916 (2)	321-382	913-282	914-338
15 (11)	321-739	320-843	—	707-917 (2)	321-382	913-282	914-338
20 (15)	321-740	320-843	—	707-917 (2)	321-382	913-282	914-338
25 (18)	321-741	320-843	—	707-918 (2)	321-382	913-282	914-338
30 (22)	321-742	320-843	—	707-868 (6)	321-382	913-282	914-338
40 (30)	321-743	320-843	—	707-868 (6)	321-382	913-282	914-338
50 (37)	321-744	320-843	—	707-869 (6)	321-382	913-282	914-338
60 (45)	321-745	320-843	918-689 (2)	707-887 (12)	321-382 (2)	913-282	914-338
75 (55)	321-746	320-843	918-689 (2)	707-887 (12)	321-382 (2)	913-282	914-338
100 (75)	321-747	320-843	918-689 (2)	707-888 (12)	321-382 (2)	913-282	914-338
125 (90)	321-748	320-843	918-689 (2)	707-888 (12)	321-382 (2)	913-282	914-338

*(continued)*

**Table 5-14—1130 Field-Replaceable Components** *(continued)*

<b>Power CT <i>hp (kW)</i></b>	<b>Power Control Module</b>	<b>Gate Drive Module</b>	<b>Current Sensor</b>	<b>In/Out IGBT Assembly</b>	<b>Bus Capacitor Assembly</b>	<b>Internal Cooling Fan</b>	<b>External Cooling Fan</b>
<b>575 V</b>							
7½ (5.5)	321-749	320-844	—	707-854	321-383	913-282	914-338
10 (7.5)	321-750	320-844	—	707-854	321-383	913-282	914-338
15 (11)	321-751	320-844	—	707-854	321-383	913-282	914-338
20 (15)	321-752	320-844	—	707-855	321-383	913-282	914-338
25 (18)	321-753	320-844	—	707-856	321-383	913-282	914-338
30 (22)	321-754	320-844	—	707-878 (6)	321-383	913-282	914-338
40 (30)	321-755	320-844	—	707-878 (6)	321-383	913-282	914-338
50 (37)	321-756	320-844	—	707-890 (12)	321-383	913-282	914-338
60 (45)	321-757	320-844	918-689 (2)	707-890 (12)	321-383 (2)	913-282	914-338
75 (55)	321-758	320-844	918-689 (2)	707-890 (12)	321-383 (2)	913-282	914-338
100 (75)	321-759	320-844	918-689 (2)	707-890 (12)	321-383 (2)	913-282	914-338
125 (90)	321-760	320-844	918-689 (2)	707-890 (12)	321-383 (2)	913-282	914-338



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86.10.6218.6365

```
/* EHWD2005 Program => Round Robin RTOS for ICECUBE EHWD Refurbished Drill Only */
```

```
// PICO Program: reworked for use in the BL1700
// extensive changes, removal of costatement proliferation, removed sonar, removed flowrate
// 9/8/99 djw
//
// EHWD Program: reworked for use in ICECUBE Program using BL1700
// Version 01:
// 7/23/2003 jra
//
//
// Version 02:
// 8/07/2003 jra V20030807
//
// 1. Changed drill_id to R
// 2. Modified ADC Channel Assignment to Fit ICECUBE EHWD Hardware
// 3. Modified ADC Channel Message Structure to Fit ICECUBE EHWD Data
// 4. Changed srk routine calling format - to avoid compile error
// 5. Changed Bad Data from XXXX to ---
// 6. Changed mark output from long integer to string
//
// 8/08/2003 jra V20030808
//
// 1. Convert mark value to string (smark).
// 2. Set size of smark string (smark).
// 3. Fill smark with leading zeros so size is constant 10 characters
// 4. Add code to select mux channel
// 5. Add Va and Vb read
//
// 8/12/2003 jra V20030812
//
// 1. Removed 8/08/2003 changes and retyped in effort to fix Dynamic C
//      problem.
//
// 8/26/2003 jra V20030826
//
// Note: Problem with Dynamic C not reentering debug mode after compiling to
//      target was due to pathname that was too long
//
// 1. Complete Paroscientific Serial Port Polling Code
//
//
// 8/27/2003 jra V20030827
//
// 1. Remove LF or CR from Paroscientific Data Sent Out Port
//
// 9/7/2003 jra V20030907
//
// 1. Change Paroscientific default data format (used when Paroscientific is offline and
//      does not answer commands) to match fixed data format returned by Paroscientific
//      when it is on line
//
//
//
```



```
// 5/26/2005 jra V20050526R
//
// Extensive Modifications for 2005-2006 Drilling Season to Accomodate addition of
// Daughter Board and two new sensors: Hose Water Pressure Sensor and Accelerometer.
// In addition, code was modified to read Accelerometer multiple times during each
// logging interval to increase the sample rate
//
// 1. Add code to multiplex Channel 8: with addition of daughter board, Channel 8
// is the output of the daughter board multiplexer. The inputs to the multiplexer are
// the following signals:
// - MLDT2
// - Accelerometer Output
// - Filtered Accelerometer Output
// - Hose Water Pressure Sensor Output
// - HiLevel3 Output (Undedicated Input - Available for Expansion)
// - HiLevel4 Output = Reference Level for Schmitt Trigger
// - LowLevel1 Output (Undedicated Input - Available for Expansion)
// - LowLevel2 Output (Undedicated Input - Available for Expansion)
// 2. Add code to Trigger unused logic outputs from ZWorld that are connected
// to Bridge Board. Triggers used to determine timing sequence of
// all analog inputs during one logging interval
// 3. Add additional code to read Accelerometer inputs multiple times during
// single logging interval
// 4. Add additional variables to accomodate the Hose Water Pressure Sensor
// variable and the multiple accelerometer and filtered accelerometer
// readings
// 5. Modify output data string in include all new readings
//
//
// 6/19/2005 jra V20050619R
//
// 1. Reset LO_Level2 data and status
// 2. Invert all MUX Select signals to compensate for Daughter Board Schmitt
// Trigger Circuit Inversion.
//
//
// 6/20/2005 jra V20050620R
//
// 1. Move all new variables in output stream to end (after the Nav Pak Variables).
// In previous versions they were placed before the Paro Data. This position does
// not fit the positions as specified in the spec and as assumed by the EHWD2005
// VB Test Software
//
//
//
// 6/28/2005 jra V20050628R Round Robin Operating System
//
// Redid basic structure of program - replacing multitasking RTOS with
// round robin RTOS:
//
//
// 1. Remove all costates in main endless loop
// 2. Replace Delays with call to timer1 to do timing functions
```



```
#define ADOUT_SIZE 5 // A/D channel dataout string size
#define GOOD_SIZE 2 // good data status bit size

#define AVERAGE 10 // # of load/temp/pres samples

// Digital IO Definitions

#define INS 1
#define OUTS 0
#define BANK_A INS //bank A inputs
#define BANK_B OUTS //bank B outputs
#define TURNON 1
#define TURNOFF 0

#define HVAL 0x4110 // Header H9
#define HVAH 0x4118 // Header H6
#define HVBL 0x4100 // Header H10
#define HVBH 0x4108 // Header H7

// HVBL Channel On/Off Values (Header H10)

#define HVBLCH0_OFF 0
#define HVBLCH0_ON 1
#define HVBLCH1_OFF 2
#define HVBLCH1_ON 3
#define HVBLCH2_OFF 4
#define HVBLCH2_ON 5
#define HVBLCH3_OFF 6
#define HVBLCH3_ON 7

// HVBH Channel On/Off Values (Header H11)

#define HVBHCH0_OFF 0
#define HVBHCH0_ON 1
#define HVBHCH1_OFF 2
#define HVBHCH1_ON 3
#define HVBHCH2_OFF 4
#define HVBHCH2_ON 5
#define HVBHCH3_OFF 6
#define HVBHCH3_ON 7

// EHWD ADC Channel Assignments

#define ZERO_CHAN 16 // TSEAL2 channel 0, unipolar, SEAL2 Pressure
#define ONE_CHAN 17 // MLDT1 channel 1, unipolar, spring calipers
#define TWO_CHAN 18 // Cavity channel 2, unipolar, Cavity Air Pressure
#define THREE_CHAN 19 // system channel 3, unipolar, Heat Sink Temperature
#define FOUR_CHAN 20 // load channel 4, unipolar, Drill Weight Sensor
```

```

#define FIVE_CHAN  21          // HoleTemp channel 5, unipolar, Drill Hole Water Temp
#define SIX_CHAN   22          // HoseTemp channel 6, unipolar, Hose Water Temp
#define SEVEN_CHAN 23          // TSEAL1 channel 7, unipolar, SEAL1 Pressure
#define EIGHT_CHAN 24          // MUX2 channel 8, unipolar, Multiplexed Channels:
                                //
                                // MuxCH0 = MLDT2
                                // MuxCH1 =
Accelerometer Output
                                // MuxCH2 = Filtered
Accelerometer Output
                                // MuxCH3 = Hose
Water Pressure Sensor Output
                                // MuxCH4 = HiLevel3
Output (Undedicated Input - Available for Expansion)
                                // MuxCH5 = HiLevel4
Output = Reference Level for Schmitt Trigger
                                // MuxCH6 =
LowLevel1 Output (Undedicated Input - Available for Expansion)
                                // MuxCH7 =
LowLevel2 Output (Undedicated Input - Available for Expansion)

#define NINE_CHAN  25          // MUX channel 9, unipolar, Multiplexed Input/Output Voltage

// Amanda Drill ADC Channel Assignments

// #define ZERO_CHAN  16          // Load Cell channel 0, unipolar, load cell
// #define ONE_CHAN   17          // Mlgt channel 1, unipolar, spring calipers
// #define TWO_CHAN   18          // Old FLOW channel 2, bipolar
// #define THREE_CHAN 19          // Hole Temp channel 3, unipolar, exterior temp
// #define FOUR_CHAN  20          // Hose Temp channel 4, unipolar, interior temp
// #define FIVE_CHAN  21          // Hole Pres channel 5, unipolar, exterior pressure
// #define SIX_CHAN   22          // Hose Pres chnnel 6, unipolar, interior pressure
// #define SEVEN_CHAN 23          // Board channel 7, unipolar, board temp
// #define EIGHT_CHAN 24          //
// #define NINE_CHAN  25          //

#define BUFSIZE 256          // I/O Circular buffer(s) size

shared struct _Channel *uplink;
shared struct _Channel *navpack;
shared struct _Channel *paropsense;

shared char UPLINKreadBuffer[BUFSIZE],UPLINKwriteBuffer[BUFSIZE];
shared char NAVPACKreadBuffer[BUFSIZE],NAVPACKwriteBuffer[BUFSIZE];
shared char PAROPSENSEreadBuffer[BUFSIZE],PAROPSENSEwriteBuffer[BUFSIZE];

//function prototypes
void startup();
void dataout(void);
void simple_ad(int, char *, char *);

char good[]="G";          // good string
char bad[]="I";          // invalid string

```

```

char blank[]="---";           // 3 char bad data string
char summer;                 // checksum value

/* SYS */
shared unsigned long mark;   // 25ms counter
shared unsigned long msmark; // ms counter
shared char check[5];        // checksum word
shared char ps_status[GOOD_SIZE]; // inverter good signal (low=bad)
shared char drill_id[2];     // drill identifier, init to U means un-initialized

// Amanda Drills: P = Primary Drill, S = Secondary Drill
// ICECUBE Drills: R = Refurbished Amanda Secondary Drill
//
//
Z = Primary ICECUBE Drill
Y = Secondary ICECUBE Drill

// Note: This program is for the ICECUBE Refurbished
// Amanda Drill Only

/* UPLINK */
shared char buildbuf[DAT_SIZE]; // buffer to build data out string

/* NAVIGATION */
char NavCMD[] = "G\r";
shared char nav_data[NAV_SIZE+4];
shared char nav_status[GOOD_SIZE];

/* Paroscientific Pressure Sensor */
char ParoGetPressureCMD[] = "*0100P3\r\n";
char ParoSetIntTimeCMD[] = "*0100EW*0100PI=50\r\n";
char ParoSetFixedCMD[] = "*0100EW*0100DL=1\r\n";
shared char paro_data[PARO_SIZE];
shared char paro_status[GOOD_SIZE];

/* Unscaled ADC Values for analog sensors: */
/* LOAD CELL, MLDTs, TEMP SENSORS, PRESSURE SENSORS, VOLTAGE SENSORS, Accelerometer */
shared char mux2[ADOUT_SIZE];
shared char mldt2[ADOUT_SIZE];
shared char accel1[ADOUT_SIZE];
shared char accel2[ADOUT_SIZE];
shared char accel3[ADOUT_SIZE];
shared char accel4[ADOUT_SIZE];
shared char accel5[ADOUT_SIZE];
shared char accelf[ADOUT_SIZE];
shared char hose_pressure[ADOUT_SIZE];
shared char HI_Level3[ADOUT_SIZE];
shared char HI_Level4[ADOUT_SIZE];
shared char LO_Level1[ADOUT_SIZE];
shared char LO_Level2[ADOUT_SIZE];
shared char mux[ADOUT_SIZE];
shared char va[ADOUT_SIZE];
shared char vb[ADOUT_SIZE];
shared char load[ADOUT_SIZE];
shared char mldt1[ADOUT_SIZE];

```

```

shared char hole_temp[ADOUT_SIZE];
shared char hose_temp[ADOUT_SIZE];
shared char sys_temp[ADOUT_SIZE];
shared char tseal1[ADOUT_SIZE];
shared char tseal2[ADOUT_SIZE];
shared char cavity[ADOUT_SIZE];

```

```

shared char mux_status[GOOD_SIZE];
shared char va_status[GOOD_SIZE]; // status strings
shared char vb_status[GOOD_SIZE];
shared char mux2_status[GOOD_SIZE];
shared char mldt2_status[GOOD_SIZE];
shared char accel1_status[GOOD_SIZE];
shared char accel2_status[GOOD_SIZE];
shared char accel3_status[GOOD_SIZE];
shared char accel4_status[GOOD_SIZE];
shared char accel5_status[GOOD_SIZE];
shared char accel_status[GOOD_SIZE];
shared char hose_pressure_status[GOOD_SIZE];
shared char HI_Level3_status[GOOD_SIZE];
shared char HI_Level4_status[GOOD_SIZE];
shared char LO_Level1_status[GOOD_SIZE];
shared char LO_Level2_status[GOOD_SIZE];
shared char load_status[GOOD_SIZE]; // status strings
shared char mldt1_status[GOOD_SIZE];
shared char holet_status[GOOD_SIZE];
shared char hoset_status[GOOD_SIZE];
shared char syst_status[GOOD_SIZE];
shared char tseal1_status[GOOD_SIZE];
shared char tseal2_status[GOOD_SIZE];
shared char cavity_status[GOOD_SIZE];

```

```
main () {
```

```

int num, freecnt;
int waittime;
unsigned port;
unsigned portvalue;
unsigned stport;

```

```
//djw reload_vec(14, Dz0_circ_int); // disable programming port interrupt
```

```

VdInit(); // initial virtual driver
init_srtkernel(); // initialize the SRTK
startup(); // startup tasks

```

```

port = HVBL; // Shared address port for Multiplexers = BL1700 lower byte of port B
stport = HVBH; // Scope Trigger Port

```

```

while (1) {
    // forever background tasks

    portvalue = HVBHCH0_OFF;
    outport(stport, portvalue);
    portvalue = HVBHCH1_OFF;
    outport(stport, portvalue);
    portvalue = HVBHCH2_OFF;
    outport(stport, portvalue);

    // Initialize Scope Trigger Port

    // Sensor Inputs

    // EHWD Analog to Digital Conversions

    simple_ad(FOUR_CHAN, load, load_status);
    simple_ad(ONE_CHAN, mldt1, mldt1_status);
    simple_ad(TWO_CHAN, cavity, cavity_status);
    simple_ad(FIVE_CHAN, hole_temp, holet_status);
    simple_ad(SIX_CHAN, hose_temp, holet_status);
    simple_ad(ZERO_CHAN, tseal2, tseal2_status);
    simple_ad(SEVEN_CHAN, tseal1, tseal1_status);
    simple_ad(THREE_CHAN, sys_temp, syst_status);

    // Channel 8: Multiplexer2 Inputs

    portvalue = HVBLCH0_OFF;

    // Select Mux2 Channel 0 = mldt2
    outport(port, portvalue);
    portvalue = HVBLCH1_OFF;

    outport(port, portvalue);
    portvalue = HVBLCH2_OFF;

    outport(port, portvalue);
    simple_ad(EIGHT_CHAN, mux2, mux2_status);
    strcpy(mldt2, mux2);
    strcpy(mldt2_status, mux2_status);

    portvalue = HVBLCH0_ON;

    // Select Mux2 Channel 1 = Accelerometer
    outport(port, portvalue);
    portvalue = HVBLCH1_OFF;

    outport(port, portvalue);
    portvalue = HVBLCH2_OFF;

    outport(port, portvalue);
    simple_ad(EIGHT_CHAN, mux2, mux2_status);
    strcpy(accel1, mux2);

```

```
        strcpy(accel1_status,mux2_status);
        portvalue = HVBLCH0_OFF;
// Select Mux2 Channel 2 = Filtered Accelerometer
        outport(port, portvalue);
        portvalue = HVBLCH1_ON;

        outport(port, portvalue);
        portvalue = HVBLCH2_OFF;

        outport(port, portvalue);
        simple_ad(EIGHT_CHAN, mux2, mux2_status);
        strcpy(accelf,mux2);
        strcpy(accelf_status,mux2_status);

// Select Mux2 Channel 3 = Hose Pressure
        portvalue = HVBLCH0_ON;

        outport(port, portvalue);
        portvalue = HVBLCH1_ON;

        outport(port, portvalue);
        portvalue = HVBLCH2_OFF;

        outport(port, portvalue);
        simple_ad(EIGHT_CHAN, mux2, mux2_status);
        strcpy(hose_pressure,mux2);
        strcpy(hose_pressure_status,mux2_status);

// Select Mux2 Channel 4 = HI Level 3
        portvalue = HVBLCH0_OFF;

        outport(port, portvalue);
        portvalue = HVBLCH1_OFF;

        outport(port, portvalue);
        portvalue = HVBLCH2_ON;

        outport(port, portvalue);
        simple_ad(EIGHT_CHAN, mux2, mux2_status);
        strcpy(HI_Level3,mux2);
        strcpy(HI_Level3_status,mux2_status);

// Select Mux2 Channel 5 = HI Level 4
        portvalue = HVBLCH0_ON;

// (Reference for Schmitt Trigger)
        outport(port, portvalue);

        portvalue = HVBLCH1_OFF;

        outport(port, portvalue);
        portvalue = HVBLCH2_ON;

        outport(port, portvalue);
        simple_ad(EIGHT_CHAN, mux2, mux2_status);
        strcpy(HI_Level4,mux2);
```



```
strcpy(HL_Level4_status,mux2_status);

// Select Mux2 Channel 6 = LO Level 1
portvalue = HVBLCH0_OFF;
outputport(port, portvalue);

portvalue = HVBLCH1_ON;
outputport(port, portvalue);
portvalue = HVBLCH2_ON;
outputport(port, portvalue);
simple_ad(EIGHT_CHAN, mux2, mux2_status);
strcpy(LO_Level1,mux2);
strcpy(LO_Level1_status,mux2_status);

// Select Mux2 Channel 7 = LO Level 2
portvalue = HVBLCH0_ON;
outputport(port, portvalue);

portvalue = HVBLCH1_ON;
outputport(port, portvalue);
portvalue = HVBLCH2_ON;
outputport(port, portvalue);
simple_ad(EIGHT_CHAN, mux2, mux2_status);
strcpy(LO_Level2,mux2);
strcpy(LO_Level2_status,mux2_status);

// Channel 9: Multiplexer 1 Inputs

// Select Mux Channel 0 = Va = Input Voltage
portvalue = HVBLCH0_OFF;
outputport(port, portvalue);
portvalue = HVBLCH1_OFF;
outputport(port, portvalue);
portvalue = HVBLCH2_OFF;
outputport(port, portvalue);
simple_ad(NINE_CHAN, mux, mux_status);
strcpy(va,mux);
strcpy(va_status,mux_status);

// Select Mux Channel 1 = Vb = Output Voltage
portvalue = HVBLCH0_ON;
outputport(port, portvalue);
portvalue = HVBLCH1_OFF;
outputport(port, portvalue);
```

```

        portvalue = HVBLSCH2_OFF;

        outputport(port, portvalue);
        simple_ad(NINE_CHAN, mux,    mux_status);
        strcpy(vb,mux);
        strcpy(vb_status,mux_status);

        // Indicate First Accelerometer Reading Taken

        portvalue = HVBHCH0_ON;
        outputport(stport, portvalue);
        portvalue = HVBHCH1_OFF;

        outputport(stport, portvalue);
        portvalue = HVBHCH2_OFF;

        outputport(stport, portvalue);

// Amanda Drill Analog to Digital Conversions

//          simple_ad(ZERO_CHAN, load,    load_status);
//          simple_ad(ONE_CHAN,  mldt,    mldt_status);
/////      simple_ad(TWO_CHAN,  , );
//          simple_ad(THREE_CHAN, hole_temp, holet_status);
//          simple_ad(FOUR_CHAN, hose_temp, holet_status);
//          simple_ad(FIVE_CHAN,  hole_pres, holep_status);
//          simple_ad(SIX_CHAN,   hose_pres, hosep_status);
//          simple_ad(SEVEN_CHAN, sys_temp, syst_status);
//          simple_ad(EIGHT_CHAN, va,    va_status);
//          simple_ad(NINE_CHAN, vb,    vb_status);

// end SENSORS

// Get Paroscientific Pressure Sensor Data

        aascWriteBlk(parosense, ParoGetPressureCMD,sizeof(ParoGetPressureCMD),0); // Send command to Paroscientific

// 40 ms wait time

        tdelay(waittime);

        portvalue = HVBLSCH0_ON;

// Select Mux2 Channel 1 = Accelerometer

        outputport(port, portvalue);

```

```
portvalue = HVBLCH1_OFF;

outport(port, portvalue);
portvalue = HVBLCH2_OFF;

outport(port, portvalue);
simple_ad(EIGHT_CHAN, mux2, mux2_status);
strcpy(accel2,mux2);
strcpy(accel2_status,mux2_status);

// Indicate Second Accelerometer Reading Taken

portvalue = HVBHCH0_OFF;
outport(stport, portvalue);
portvalue = HVBHCH1_ON;

outport(stport, portvalue);
portvalue = HVBHCH2_OFF;

outport(stport, portvalue);

// 40 ms wait time
waittime = 40;
tdelay(waittime);

// Select Mux2 Channel 1 = Accelerometer
portvalue = HVBLCH0_ON;

outport(port, portvalue);
portvalue = HVBLCH1_OFF;

outport(port, portvalue);
portvalue = HVBLCH2_OFF;

outport(port, portvalue);
simple_ad(EIGHT_CHAN, mux2, mux2_status);
strcpy(accel3,mux2);
strcpy(accel3_status,mux2_status);

// Indicate Third Accelerometer Reading Taken

portvalue = HVBHCH0_ON;
outport(stport, portvalue);
portvalue = HVBHCH1_ON;

outport(stport, portvalue);
portvalue = HVBHCH2_OFF;

outport(stport, portvalue);

freecnt = aascReadBufLeft(paropsense);
```

```

num = aascReadBlk( parosense, paro_data, freecnt, 0);
//
num = 0;          // Temporary bypass
if (num == PARO_SIZE) {
    strcpy(&paro_data[num-2],"\0");
    strcpy(paro_status, good);
}
else {
    strcpy(paro_status, bad);          // nav problem
    strcpy(paro_data,"*0001+000000.000");
}

// paroscientific pressure data complete

// Get Navigation Data

aascWriteBlk(navpack, NavCMD,sizeof(NavCMD),0); // Send "G\r" to NavPack

waittime = 40;
// 40 ms wait time
tdelay(waittime);

portvalue = HVBLCH0_ON;
// Select Mux2 Channel 1 = Accelerometer
outport(port, portvalue);
portvalue = HVBLCH1_OFF;

outport(port, portvalue);
portvalue = HVBLCH2_OFF;

outport(port, portvalue);
simple_ad(EIGHT_CHAN, mux2, mux2_status);
strcpy(accel4,mux2);
strcpy(accel4_status,mux2_status);

// Indicate Fourth Accelerometer Reading Taken

portvalue = HVBHCH0_OFF;
outport(stport, portvalue);
portvalue = HVBHCH1_OFF;

outport(stport, portvalue);
portvalue = HVBHCH2_ON;

outport(stport, portvalue);

```

```
waittime = 40;
// 40 ms wait time
tdelay(waittime);

portvalue = HVBLSCH0_ON;
// Select Mux2 Channel 1 = Accelerometer
outport(port, portvalue);
portvalue = HVBLSCH1_OFF;

outport(port, portvalue);
portvalue = HVBLSCH2_OFF;

outport(port, portvalue);
simple_ad(EIGHT_CHAN, mux2, mux2_status);
strcpy(accel5, mux2);
strcpy(accel5_status, mux2_status);

// Indicate Fifth Accelerometer Reading Taken

portvalue = HVBHCH0_ON;
outport(stport, portvalue);
portvalue = HVBHCH1_OFF;

outport(stport, portvalue);
portvalue = HVBHCH2_ON;

outport(stport, portvalue);

freecnt = aascReadBufLeft(navpack);
num = aascReadBlk( navpack, nav_data, freecnt, 0);

if (num == NAV_SIZE) {
    strcpy(&nav_data[num-1], "\0");
    strcpy(nav_status, good);
}
else {
    strcpy(nav_status, bad); // nav problem
    strcpy(nav_data, "N +0.00 +0.00 000.0 +000.0 +000.0 +000.0 +00.0");
}

// navigation data complete

// Send out Data
dataout(); // send data uphole

// Indicate Data Acq Complete
portvalue = HVBHCH0_OFF;
outport(stport, portvalue);
portvalue = HVBHCH1_ON;
```

```

        outputport(stport, portvalue);
        portvalue = HVBHCH2_ON;
        outputport(stport, portvalue);

//          waittime = 40;
//          // 40 ms wait time - Not needed so disabled
//          tdelay(waittime);

    }          // while main running
}

#funcchain _srtk_hightask srtk_hightask
void srtk_hightask() { mark++; }          // hightask

#funcchain _srtk_lowtask srtk_lowtask
void srtk_lowtask() { runwatch(); } // lowtask

void startup(void) {
    unsigned IDbits;

    eioBrdInit(0);          // digital and analog io init
    eioBrdAdcMode(0,0,0);    // 12 bit, MSB first, Unipolar

    // setup NAVIGATION RS232 serial port
    // Open a channel to the SCC ( scc channel A at 8N1 with rs232 driver ).
    navpack = aascOpen( DEV_SCC, 0, SCC_A | SCC_8N1 | SCC_1200*8, NULL);

    // setup PAROSCIENTIFIC RS232 serial port
    // Open a channel to the SCC ( scc channel B at 8N1 with rs232 driver ).
    paropsense = aascOpen(DEV_SCC, 0, SCC_B | SCC_8N1 | SCC_1200*8, NULL);

    // Get Drill ID
    IDbits = inport(0x4042);
    IDbits &= 0x1; // bit zero only
    if(IDbits == 0) { strcpy(drill_id,"R"); }; // Intended to notify the UpHole Cockpit program
    if(IDbits == 1) { strcpy(drill_id,"R"); }; // of which set of calibration coefficients to use.

the ICECUBE Refurbished          // However, this program is for
                                   // Amanda Drill Only

    // setup DATA OUT RS485 serial port

```

```

// Open channel Z1 at 8N1

uplink = aascOpen(DEV_Z1, 0, ASCL_PARAM_8N1+ASCL_PARAM_1200*8,NULL);

aascSetReadBuf( navpack, NAVPACKreadBuffer, sizeof( NAVPACKreadBuffer));
aascSetWriteBuf( navpack, NAVPACKwriteBuffer, sizeof( NAVPACKwriteBuffer));
aascSetReadBuf( paropsense, PAROPSENSEreadBuffer, sizeof( PAROPSENSEreadBuffer));
aascSetWriteBuf( paropsense, PAROPSENSEwriteBuffer, sizeof( PAROPSENSEwriteBuffer));
aascSetReadBuf( uplink, UPLINKreadBuffer, sizeof( UPLINKreadBuffer));
aascSetWriteBuf( uplink, UPLINKwriteBuffer, sizeof( UPLINKwriteBuffer));

aascTxSwitch(navpack,1); //Tx on
aascRxSwitch(navpack,1); //Rx on
aascTxSwitch(paropsense,1); //Tx on
aascRxSwitch(paropsense,1); //Rx on
aascTxSwitch(uplink,1); //Tx on
aascRxSwitch(uplink,0); //Rx off

sccSw485(SCC_A,0); // turn off RS485 for NavPack
sccSw485(SCC_B,0); // turn off RS485 for Paroscientific
z1Sw485(1); // turn on RS485 for uplink

//-----

// setup PAROSCIENTIFIC Integration Time

// aascWriteBlk(paropsense, ParoSetIntTimeCMD,sizeof(ParoSetIntTimeCMD),0); // Send Set Integration Time CMD
// waitFor( DelayMs(50L) );
// freecnt = aascReadBufLeft(paropsense);
// num = aascReadBlk( paropsense, paro_data, freecnt, 0);

// setup PAROSCIENTIFIC Data Format = Fixed

// aascWriteBlk(paropsense, ParoSetFixedCMD,sizeof(ParoSetFixedCMD),0); // Send Set Fixed Data CMD
// waitFor( DelayMs(50L) );
// freecnt = aascReadBufLeft(paropsense);
// num = aascReadBlk( paropsense, paro_data, freecnt, 0);

//-----

mark = 0UL; // reset string variables
msmark = 0UL;
strcpy(buildbuf,"");
//
strcpy(ps_status,good);
strcpy(nav_status, bad);
strcpy(nav_data, "N +0.00 +0.00 000.0 +000.0 +000.0 +000.0 +00.0"); //
strcpy(paro_status, bad);

```

```
strcpy(paro_data, "*0001+000000.000"); //
strcpy(load_status, bad);
strcpy(load, blank);
strcpy(mldt1_status, bad);
strcpy(mldt1, blank);
strcpy(holet_status, bad);
strcpy(hole_temp, blank);
strcpy(hoset_status, bad);
strcpy(hose_temp, blank);
//
//
//
//
strcpy(holep_status, bad);
strcpy(hole_pres, blank);
strcpy(hosep_status, bad);
strcpy(hose_pres, blank);
strcpy(syst_status, bad);
strcpy(sys_temp, blank);
strcpy(tseal1_status, bad);
strcpy(tseal1, blank);
strcpy(tseal2_status, bad);
strcpy(tseal2, blank);
strcpy(cavity_status, bad);
strcpy(cavity, blank);
strcpy(mux_status, bad);
strcpy(mux, blank);
strcpy(va_status, bad);
strcpy(vb_status, bad);
strcpy(va, blank);
strcpy(vb, blank);
strcpy(mux2_status, bad);
strcpy(mux2, blank);
strcpy(mldt2_status, bad);
strcpy(mldt2, blank);
strcpy(accel1_status, bad);
strcpy(accel1, blank);
strcpy(accel2_status, bad);
strcpy(accel2, blank);
strcpy(accel3_status, bad);
strcpy(accel3, blank);
strcpy(accel4_status, bad);
strcpy(accel4, blank);
strcpy(accel5_status, bad);
strcpy(accel5, blank);
strcpy(accelf_status, bad);
strcpy(accelf, blank);
strcpy(hose_pressure_status, bad);
strcpy(hose_pressure, blank);
strcpy(HI_Level3_status, bad);
strcpy(HI_Level3, blank);
strcpy(HI_Level4_status, bad);
strcpy(HI_Level4, blank);
strcpy(LO_Level1_status, bad);
strcpy(LO_Level1, blank);
strcpy(LO_Level2_status, bad);
strcpy(LO_Level2, blank);
```



```

}          // setup

void dataout(void) {
    int count, csun, datsize, freecnt, strcount;
    char smark[11];
    char basemark[11];
    char smsmark[11];
    char msbasemark[11];

    freecnt = aaseWriteBufLeft(uplink);
    if(freecnt != 0) return;

    // Convert 25 ms tick count to String
    ltoa(mark, smark);
    strcpy(basemark, "");
    for(strcount = 0; strcount < (10-strlen(smark)); strcount++)
    {
        strcat(basemark, "0");
    }
    strcat(basemark, smark);
    strcpy(smark, basemark);

    // Get ms count and convert to string
    msmark = MS_TIMER;
    ltoa(msmark, smsmark);
    strcpy(msbasemark, "");
    for(strcount = 0; strcount < (10-strlen(smsmark)); strcount++)
    {
        strcat(msbasemark, "0");
    }
    strcat(msbasemark, smsmark);
    strcpy(smsmark, msbasemark);

    sprintf(buildbuf, "%s/%s/%s/%s/%s/%s/%s/%s/%s/%s/%s/%s/%s/%s/%s/%s",
        drill_id,
        smsmark,
        ps_status,
        syst_status, sys_temp,
        mldt1_status, mldt1,
        mldt2_status, mldt2,
        load_status, load,
        holet_status, hole_temp,
        hose_status, hose_temp,
        va_status, va,
        vb_status, vb,
        cavity_status, cavity,

```

```
        tseal1_status,tseal1);

    strcat(buildbuf,tseal2_status);
    strcat(buildbuf,tseal2);
    strcat(buildbuf,paro_status);
    strcat(buildbuf,paro_data);
    strcat(buildbuf,nav_status);
    strcat(buildbuf,nav_data);
    strcat(buildbuf,accel1_status);
    strcat(buildbuf,accel1);
    strcat(buildbuf,accel2_status);
    strcat(buildbuf,accel2);
    strcat(buildbuf,accel3_status);
    strcat(buildbuf,accel3);
    strcat(buildbuf,accel4_status);
    strcat(buildbuf,accel4);
    strcat(buildbuf,accel5_status);
    strcat(buildbuf,accel5);
    strcat(buildbuf,accelf_status);
    strcat(buildbuf,accelf);
    strcat(buildbuf,hose_pressure_status);
    strcat(buildbuf,hose_pressure);
    strcat(buildbuf,HI_Level3_status);
    strcat(buildbuf,HI_Level3);
    strcat(buildbuf,HI_Level4_status);
    strcat(buildbuf,HI_Level4);
    strcat(buildbuf,LO_Level1_status);
    strcat(buildbuf,LO_Level1);
    strcat(buildbuf,LO_Level2_status);
    strcat(buildbuf,LO_Level2);
    strcat(buildbuf,"K");

//          holep_status,hole_pres,
//          hosep_status,hose_pres,

    strcpy(syst_status, bad);          // reset status
    strcpy(mldt1_status, bad);
    strcpy(mldt2_status, bad);
    strcpy(load_status, bad);
    strcpy(holet_status, bad);
    strcpy(hoset_status, bad);
//    strcpy(holep_status, bad);
//    strcpy(hosep_status, bad);
    strcpy(va_status, bad);
    strcpy(vb_status, bad);
    strcpy(cavity_status, bad);
    strcpy(tseal1_status, bad);
    strcpy(tseal2_status, bad);

    strcpy(accel1_status, bad);
```

```

strcpy(accel2_status, bad);
strcpy(accel3_status, bad);
strcpy(accel4_status, bad);
strcpy(accel5_status, bad);
strcpy(accelf_status, bad);
strcpy(hose_pressure_status, bad);
strcpy(HI_Level3_status, bad);
strcpy(HI_Level4_status, bad);
strcpy(LO_Level1_status, bad);
strcpy(LO_Level2_status, bad);

strcpy(paro_status, bad);
strcpy(nav_status, bad);

count = strlen(buildbuf);
csum = checksum(buildbuf, count); // calculate checksum of data so far
csum &= 0x00ff;
sprintf(check, "%02x", csum);

strcat(buildbuf, check); // just send last two bytes
strcat(buildbuf, "\r"); // Carriage Return
strcat(buildbuf, "\n"); // Line Feed

datsize = strlen(buildbuf);

aascWriteBlk(uplink, buildbuf, datsize, 0);

// else { return ; }

return ;
// dataout
}

void simple_ad(int channel, char *string, char *status) {
    auto int i; // loop counter
    auto unsigned samp; // each sample value
    auto unsigned long ff; // running sample total
    auto unsigned int num; // average sample value
    auto int length; // length of string
    auto char temp_str[ADOUT_SIZE]; // temp string to build into
    auto char num_str[ADOUT_SIZE]; // temp num to char string

    ff = 0;
    for (i=0; i<AVERAGE; i++) { // get channel values
        samp = eioBrdAI(channel);
        ff = ff + samp; // if good...save
    }

    num = ff/AVERAGE; // average

    num &= 0x0FFF; // 0.0volts at the A/D input == 000 hex
                // 2.5volts at the A/D input == FFF hex

```

```

                                                                    // note chans 0->7 have an inverting buffer
                                                                    //   chans 8, 9 are straight through

sprintf(num_str,"%03x",num);// convert A/D value to string

strcpy(string,      num_str);      // stuff into string variable above
strcpy(status,good);
}

#asm nodebug
checksum:
  pop bc  ; return address
  pop hl  ; first arg
  pop de  ; second arg
  push de
  push hl
  push bc
  inc d   ; false high
  xor a
chk1:
  add a,(hl)
  inc hl
  dec e
  jr nz,chk1
  dec d
  jr nz,chk1
  ld (summer),a ; save
  ld l,a
  ld h,0
  ret    ; result in hl
#endasm
```

```

/* EHWD Program => Modified Amanda drill program for ICECUBE New Drill Head 01 (ID = X)*/

// PICO Program: reworked for use in the BL1700
// extensive changes, removal of costatement proliferation, removed sonar, removed
flowrate
// 9/8/99 djw
//
// EHWD Program: reworked for use in ICECUBE Program using BL1700
// Version 01:
// 7/23/2003 jra
//
//
// Version 02:
// 8/07/2003 jra V20030807
//
// 1. Changed drill_id to R
// 2. Modified ADC Channel Assignment to Fit ICECUBE EHWD Hardware
// 3. Modified ADC Channel Message Structure to Fit ICECUBE EHWD Data
// 4. Changed srtk routine calling format - to avoid compile error
// 5. Changed Bad Data from XXXX to ---
// 6. Changed mark output from long integer to string
//
// 8/08/2003 jra V20030808
//
// 1. Convert mark value to string (smark).
// 2. Set size of smark string (smark).
// 3. Fill smark with leading zeros so size is constant 10 characters
// 4. Add code to select mux channel
// 5. Add Va and Vb read
//
// 8/12/2003 jra V20030812
//
// 1. Removed 8/08/2003 changes and retyped in effort to fix Dynamic C
//      problem.
//
// 8/26/2003 jra V20030826
//
// Note: Problem with Dynamic C not reentering debug mode after compiling to
//      target was due to pathname that was too long
//
// 1. Complete Paroscientific Serial Port Polling Code
//
//
// 8/27/2003 jra V20030827
//
// 1. Remove LF or CR from Paroscientific Data Sent Out Port
//
// 9/7/2003 jra V20030907
//
// 1. Change Paroscientific default data format (used when Paroscientific is offline and
//      does not answer commands) to match fixed data format returned by Paroscientific
//      when it is on line
//
//
// 9/19/2004 jra V20030907X
//
// 1. Copied V20030907 for EHWD Refurbished Amanda Drill Head and changed the Drill Head
//      ID from R to X - for use with the EHWD New Drill Head Number 01 (ID = X)
//
//
////

#define MAX_CHAN 5 // This needs to be here above the libraries
//
#use vdriver.lib
#use srtk.lib

#use eziobl17.lib
#use aasc.lib
#use aascz0.lib
#use aascz1.lib
#use aascsc.lib
#use bios.lib

```

```

#nointerleave

#define RUNKERNEL 1 // use the simplified real-
time kernel

#define NAV_SIZE 47 // navigation data message
size
#define PARO_SIZE 18 // paroscientific pressure
transmitter data message size
#define DAT_SIZE 256 // data out data word size
#define ADOUT_SIZE 5 // A/D channel dataout string
size
#define GOOD_SIZE 2 // good data status bit size

#define AVERAGE 10 // # of load/temp/pres samples

// Digital IO Definitions

#define INS 1
#define OUTS 0
#define BANK_A INS //bank A inputs
#define BANK_B OUTS //bank B outputs
#define TURNON 1
#define TURNOFF 0

#define HVAL 0x4110
#define HVAH 0x4118
#define HVBL 0x4100
#define HVBH 0x4108

// HVBL Channel On/Off Values

#define HVBLCH0_OFF 0
#define HVBLCH0_ON 1
#define HVBLCH1_OFF 2
#define HVBLCH1_ON 3
#define HVBLCH2_OFF 4
#define HVBLCH2_ON 5
#define HVBLCH3_OFF 6
#define HVBLCH3_ON 7

// EHWD ADC Channel Assignments

#define ZERO_CHAN 16 // TSEAL2 channel 0, unipolar,
SEAL2 Pressure
#define ONE_CHAN 17 // MLDT1 channel 1, unipolar,
spring calipers
#define TWO_CHAN 18 // Cavity channel 2, unipolar,
Cavity Air Pressure
#define THREE_CHAN 19 // systemp channel 3, unipolar,
Heat Sink Temperature
#define FOUR_CHAN 20 // load channel 4, unipolar,
Drill Weight Sensor
#define FIVE_CHAN 21 // HoleTemp channel 5, unipolar,
Drill Hole Water Temp
#define SIX_CHAN 22 // HoseTemp channel 6, unipolar,
Hose Water Temp
#define SEVEN_CHAN 23 // TSEAL1 channel 7, unipolar,
SEAL1 Pressure
#define EIGHT_CHAN 24 // MLDT2 channel 8,
unipolar, spring calipers
#define NINE_CHAN 25 // MUX channel 9, unipolar,
Multiplexed Input/Output Voltage

// Amanda Drill ADC Channel Assignments

// #define ZERO_CHAN 16 // Load Cell channel 0,
unipolar, load cell

```

```

// #define ONE_CHAN    17                // Mlgt      channel 1,
unipolar, spring calipers
// #define TWO_CHAN   18                // Old FLOW  channel 2,
bipolar
// #define THREE_CHAN 19                // Hole Temp channel 3,
unipolar, exterior temp
// #define FOUR_CHAN  20                // Hose Temp channel 4,
unipolar, interior temp
// #define FIVE_CHAN  21                // Hole Pres channel 5,
unipolar, exterior pressure
// #define SIX_CHAN   22                // Hose Pres channel 6,
unipolar, interior pressure
// #define SEVEN_CHAN 23                // Board    channel 7,
unipolar, board temp
// #define EIGHT_CHAN 24                //
// #define NINE_CHAN  25                //

#define BUFSIZE 256                    // I/O Circular buffer(s) size

shared struct _Channel *uplink;
shared struct _Channel *navpack;
shared struct _Channel *paropsense;

shared char UPLINKreadBuffer[BUFSIZE],UPLINKwriteBuffer[BUFSIZE];
shared char NAVPACKreadBuffer[BUFSIZE],NAVPACKwriteBuffer[BUFSIZE];
shared char PAROPSENSEreadBuffer[BUFSIZE],PAROPSENSEwriteBuffer[BUFSIZE];

//function prototypes
void startup();
void dataout(void);
void simple_ad(int, char *, char *);

char good[]="G";                        // good string
char bad[]="B";                          // bad string
char blank[]="---";                      // 3 char bad data string
char summer;                             // checksum value

/* SYS */
shared unsigned long mark;                // 25ms counter
shared char check[5];                    // checksum word
shared char ps_status[GOOD_SIZE];        // inverter good signal (low=bad)
shared char drill_id[2];                 // drill identifier, init to U means
un-initialized

// Amanda Drills: P = Primary Drill, S = Secondary Drill
// ICECUBE Drills: R = Refurbished Amanda Secondary Drill

// X = ICECUBE Drill Head #01
// Y = ICECUBE Drill Head #02

// Note: This program is for the ICECUBE New Drill Head
// Number 01 (ID = X) only

/* UPLINK */
shared char buildbuf[DAT_SIZE];          // buffer to build data out string

/* NAVIGATION */
char NavCMD[] = "G\r";
shared char nav_data[NAV_SIZE+4];
shared char nav_status[GOOD_SIZE];

/* Paroscientific Pressure Sensor */
char ParoGetPressureCMD[] = "*0100P3\r\n";
char ParoSetIntTimeCMD[] = "*0100EW*0100PI=50\r\n";
char ParoSetFixedCMD[] = "*0100EW*0100DL=1\r\n";
shared char paro_data[PARO_SIZE];
shared char paro_status[GOOD_SIZE];

/* LOAD CELL, MLDTs, TEMP SENSORS, PRESSURE SENSORS, VOLTAGE SENSORS */
shared char va[ADOUT_SIZE];              // data strings
shared char vb[ADOUT_SIZE];
shared char load[ADOUT_SIZE];            // data strings
shared char mldt1[ADOUT_SIZE];

```

```

shared char mldt2[ADOUT_SIZE];
shared char hole_temp[ADOUT_SIZE];
shared char hose_temp[ADOUT_SIZE];
shared char sys_temp[ADOUT_SIZE];
shared char tseal1[ADOUT_SIZE];
shared char tseal2[ADOUT_SIZE];
shared char cavity[ADOUT_SIZE];
shared char mux[ADOUT_SIZE];
// shared char hole_pres[ADOUT_SIZE];
// shared char hose_pres[ADOUT_SIZE];

shared char va_status[GOOD_SIZE]; // status strings
shared char vb_status[GOOD_SIZE];
shared char load_status[GOOD_SIZE]; // status strings
shared char mldt1_status[GOOD_SIZE];
shared char mldt2_status[GOOD_SIZE];
shared char holet_status[GOOD_SIZE];
shared char hoset_status[GOOD_SIZE];
shared char syst_status[GOOD_SIZE];
shared char tseal1_status[GOOD_SIZE];
shared char tseal2_status[GOOD_SIZE];
shared char cavity_status[GOOD_SIZE];
shared char mux_status[GOOD_SIZE];
// shared char holep_status[GOOD_SIZE];
// shared char hosep_status[GOOD_SIZE];

main () {

int num, freecnt;
unsigned port;
unsigned portvalue;

//djw reload_vec(14, Dz0_circ_int); // disable programming port interrupt

VdInit(); // initial
virtual driver
init_srtkernel(); // initialize the SRTK
startup(); // startup
tasks

port = HVBL; // Mux address port =
BL1700 lower byte of port B

while (1) { // forever
background tasks
costate {

// EHWD Analog to Digital Conversions

simple_ad(FOUR_CHAN, load,
load_status);
simple_ad(ONE_CHAN, mldt1,
mldt1_status);
simple_ad(TWO_CHAN, cavity,
cavity_status);
simple_ad(FIVE_CHAN, hole_temp,
holet_status);
simple_ad(SIX_CHAN, hose_temp,
hoset_status);
simple_ad(ZERO_CHAN, tseal2,
tseal2_status);
simple_ad(SEVEN_CHAN, tseal1,
tseal1_status);
simple_ad(THREE_CHAN, sys_temp,
syst_status);
simple_ad(EIGHT_CHAN, mldt2,
mldt2_status);

portvalue = HVBLCH0_ON;
// Select Mux Channel 0 = Va
= Input Voltage

```



```

        outport(port, portvalue);
        portvalue = HVBLCH1_ON;

        outport(port, portvalue);
        portvalue = HVBLCH2_ON;

        outport(port, portvalue);
        simple_ad(NINE_CHAN, mux, mux_status);
        strcpy(va,mux);
        strcpy(va_status,mux_status);

        portvalue = HVBLCH0_OFF;
        // Select Mux Channel 1 = Vb =

        outport(port, portvalue);
        portvalue = HVBLCH1_ON;

        outport(port, portvalue);
        portvalue = HVBLCH2_ON;

        outport(port, portvalue);
        simple_ad(NINE_CHAN, mux, mux_status);
        strcpy(vb,mux);
        strcpy(vb_status,mux_status);

        // Amanda Drill Analog to Digital Conversions
        //
        // simple_ad(ZERO_CHAN, load,
load_status);
        //
        // simple_ad(ONE_CHAN, mldt,
mldt_status);
        //
        // simple_ad(TWO_CHAN, , );
        // simple_ad(THREE_CHAN, hole_temp,
holet_status);
        //
        // simple_ad(FOUR_CHAN, hose_temp,
hoset_status);
        //
        // simple_ad(FIVE_CHAN, hole_pres,
holep_status);
        //
        // simple_ad(SIX_CHAN, hose_pres,
hosep_status);
        //
        // simple_ad(SEVEN_CHAN, sys_temp,
syst_status);
        //
        // simple_ad(EIGHT_CHAN, va, va_status);
        // simple_ad(NINE_CHAN, vb, vb_status);

    } // end SENSORS

    costate {
        dataout(); // send data uphole

        // Get Paroscientific Pressure Sensor Data
        costate {
            aascWriteBlk(paropsense,
ParoGetPressureCMD,sizeof(ParoGetPressureCMD),0); // Send command to Paroscientific
            waitfor( DelayMs(80L) );
            freecnt = aascReadBufLeft(paropsense);

            num = aascReadBlk( paropsense, paro_data,
freecnt, 0);

            //
            num = 0; // Temporary bypass

            if (num == PARO_SIZE) {
                strcpy(&paro_data[num-2],"\0");
                strcpy(paro_status, good);
            }
            else {
                strcpy(paro_status, bad);
            }

            // nav problem
            strcpy(paro_data,"*0001+000000.000");
        } // paroscientific pressure data
    }

```

```

// Get Navigation Data

costate {
NavCMD,sizeof(NavCMD),0); // Send "G\r" to NavPack
aascWriteBlk(navpack,
waitfor( DelayMs(80L) );
freecnt = aascReadBufLeft(navpack);

num = aascReadBlk( navpack, nav_data,
freecnt, 0);

if (num == NAV_SIZE) {
strcpy(&nav_data[num-1],"\0");
strcpy(nav_status, good);
}
else {
strcpy(nav_status, bad);
strcpy(nav_data,"N +0.00 +0.00
000.0 +000.0 +000.0 +000.0 +00.0");
}
// navigation data
} // while main running
}

#funcchain _srtk_hightask srtk_hightask
void srtk_hightask(){ mark++; } // hightask

#funcchain _srtk_lowtask srtk_lowtask
void srtk_lowtask(){ runwatch(); } // lowtask

void startup(void) {
unsigned IDbits;

eioBrdInit(0); // digital and analog io init
eioBrdAdcMode(0,0,0); // 12 bit, MSB first, Unipolar

// setup NAVIGATION RS232 serial port
// Open a channel to the SCC ( scc channel A at 8N1 with rs232 driver ).
navpack = aascOpen( DEV_SCC, 0, SCC_A | SCC_8N1 | SCC_1200*8, NULL);

// setup PAROSCIENTIFIC RS232 serial port
// Open a channel to the SCC ( scc channel B at 8N1 with rs232 driver ).
paropsense = aascOpen( DEV_SCC, 0, SCC_B | SCC_8N1 | SCC_1200*8, NULL);

// Get Drill ID

IDbits = inport(0x4042);
IDbits &= 0x1; // bit zero only
if(IDbits == 0){ strcpy(drill_id,"X"); }; // Intended to notify the UpHole Cockpit
program
if(IDbits == 1){ strcpy(drill_id,"X"); }; // of which set of calibration
coefficients to use.
// However, this program is
for the ICECUBE New Drill Head // Number 01 (ID = X) only

// setup DATA OUT RS485 serial port
// Open channel Z1 at 8N1

uplink = aascOpen(DEV_Z1, 0, ASCII_PARAM_8N1+ASCII_PARAM_1200*8,NULL);

aascSetReadBuf( navpack, NAVPACKreadBuffer, sizeof( NAVPACKreadBuffer));
aascSetWriteBuf( navpack, NAVPACKwriteBuffer, sizeof( NAVPACKwriteBuffer));
aascSetReadBuf( paropsense, PAROPSENSEreadBuffer, sizeof( PAROPSENSEreadBuffer));

```

```

    aascSetWriteBuf( paropsense, PAROPSENSEwriteBuffer, sizeof(
PAROPSENSEwriteBuffer));
    aascSetReadBuf( uplink, UPLINKreadBuffer, sizeof( UPLINKreadBuffer));
    aascSetWriteBuf( uplink, UPLINKwriteBuffer, sizeof( UPLINKwriteBuffer));

    aascTxSwitch(navpack,1); //Tx on
    aascRxSwitch(navpack,1); //Rx on
    aascTxSwitch(paropsense,1); //Tx on
    aascRxSwitch(paropsense,1); //Rx on
    aascTxSwitch(uplink,1); //Tx on
    aascRxSwitch(uplink,0); //Rx off

    sccSw485(SCC_A,0); // turn off RS485 for NavPack
    sccSw485(SCC_B,0); // turn off RS485 for Paroscientific
    z1Sw485(1); // turn on RS485 for uplink

//-----

// setup PAROSCIENTIFIC Integration Time

// aascWriteBlk(paropsense, ParoSetIntTimeCMD,sizeof(ParoSetIntTimeCMD),0); // Send
Set Integration Time CMD
// waitfor( DelayMs(50L) );
// freecnt = aascReadBufLeft(paropsense);
// num = aascReadBlk( paropsense, paro_data, freecnt, 0);

// setup PAROSCIENTIFIC Data Format = Fixed

// aascWriteBlk(paropsense, ParoSetFixedCMD,sizeof(ParoSetFixedCMD),0); // Send Set
Fixed Data CMD
// waitfor( DelayMs(50L) );
// freecnt = aascReadBufLeft(paropsense);
// num = aascReadBlk( paropsense, paro_data, freecnt, 0);

//-----

mark = 0UL; //
reset string variables
strcpy(buildbuf,"");
//
strcpy(ps_status,good);
strcpy(nav_status, bad);
strcpy(nav_data, "N +0.00 +0.00 000.0 +000.0 +000.0 +000.0 +00.0"); //
strcpy(paros_status, bad);
strcpy(paros_data, "*0001+000000.000"); //
strcpy(load_status, bad);
strcpy(load, blank);
strcpy(mldt1_status, bad);
strcpy(mldt1, blank);
strcpy(holet_status, bad);
strcpy(hole_temp, blank);
strcpy(hoset_status, bad);
strcpy(hose_temp, blank);
// strcpy(holep_status, bad);
// strcpy(hole_pres, blank);
// strcpy(hosep_status, bad);
// strcpy(hose_pres, blank);
strcpy(syst_status, bad);
strcpy(sys_temp, blank);
strcpy(va_status, bad);
strcpy(vb_status, bad);
strcpy(va, blank);
strcpy(vb, blank);
strcpy(mldt2_status, bad);
strcpy(mldt2, blank);
strcpy(mux_status, bad);
strcpy(mux, blank);
strcpy(tseal1_status, bad);
strcpy(tseal1, blank);
strcpy(tseal2_status, bad);
strcpy(tseal2, blank);

```

```

strcpy(cavity_status, bad);
strcpy(cavity, blank);

} // setup

void dataout(void) {
int count, csum, datsize, freecnt, strcount;
char smark[11];
char basemark[11];

freecnt = aascWriteBufLeft(uptlink);
if(freecnt != 0)return;

ltoa(mark, smark);
strcpy(basemark, "");
for(strcount = 0; strcount < (10-strlen(smark)); strcount++ )
{
strcat(basemark, "0");
}
strcat(basemark, smark);
strcpy(smark, basemark);

sprintf(buildbuf, "%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s",
drill_id,
smark,
ps_status,
syst_status, sys_temp,
mldt1_status, mldt1,
mldt2_status, mldt2,
load_status, load,
holet_status, hole_temp,
hoset_status, hose_temp,
va_status, va,
vb_status, vb,
cavity_status, cavity,
tseal1_status, tseal1);

strcat(buildbuf, tseal2_status);
strcat(buildbuf, tseal2);
strcat(buildbuf, paro_status);
strcat(buildbuf, paro_data);
strcat(buildbuf, nav_status);
strcat(buildbuf, nav_data);
strcat(buildbuf, "K");

// holep_status, hole_pres,
// hosep_status, hose_pres,

strcpy(syst_status, bad); // reset status
strcpy(mldt1_status, bad);
strcpy(mldt2_status, bad);
strcpy(load_status, bad);
strcpy(holet_status, bad);
strcpy(hoset_status, bad);
// strcpy(holep_status, bad);
// strcpy(hosep_status, bad);
strcpy(va_status, bad);
strcpy(vb_status, bad);
strcpy(cavity_status, bad);
strcpy(tseal1_status, bad);
strcpy(tseal2_status, bad);

strcpy(paro_status, bad);
strcpy(nav_status, bad);

count = strlen(buildbuf);
csum = checksum(buildbuf, count); // calculate checksum of data so far
csum &= 0x00ff;
sprintf(check, "%02x", csum);

```

```

        strcat(buildbuf, check); // just send last two bytes
        strcat(buildbuf, "\r"); // Carriage Return
        strcat(buildbuf, "\n"); // Line Feed

        datsize = strlen(buildbuf);

        aascWriteBlk(uplink, buildbuf, datsize, 0);

//      else { return ; }

        return ;
    } // dataout

void simple_ad(int channel, char *string, char *status) { // loop
    auto int i;
    counter // each sample value
        auto unsigned samp; // running sample total
        auto unsigned long ff; // average sample value
        auto unsigned int num; // length of
        auto int length;

    string
        auto char temp_str[ADOUT_SIZE]; // temp string to build into
        auto char num_str[ADOUT_SIZE]; // temp num to char string

        ff = 0;
        for (i=0; i<AVERAGE; i++) { // get channel values
            samp = eioBrdAI(channel);
            ff = ff + samp; // if good...save
        }

        num = ff/AVERAGE; // average

        num &= 0x0FFF; // 0.0volts at the A/D input == 000 hex
        // 2.5volts at the A/D input
        == FFF hex // note chans 0->7 have an
        inverting buffer // chans 8, 9 are
        straight through

        sprintf(num_str, "%03x", num); // convert A/D value to string

        strcpy(string, num_str); // stuff into string variable above
        strcpy(status, good);
    }

#asm nodebug
checksum:
    pop bc ; return address
    pop hl ; first arg
    pop de ; second arg
    push de
    push hl
    push bc
    inc d ; false high
    xor a
chk1:
    add a, (hl)
    inc hl
    dec e
    jr nz, chk1
    dec d
    jr nz, chk1
    ld (summer), a ; save
    ld l, a
    ld h, 0
    ret ; result in hl
#endasm

```



```

#define MAX_CHAN 5      // This needs to be here above the libraries
//
#use vdriver.lib
#use srtk.lib

#use eziobl17.lib
#use aasc.lib
#use aascz0.lib
#use aascz1.lib
#use aascsc.lib
#use bios.lib

#nointerleave

#define RUNKERNEL 1    // use the simplified real-time kernel

#define NAV_SIZE 47    // navigation data message size
#define PARO_SIZE 18  // paroscientific pressure transmitter
data message size
#define DAT_SIZE 256   // data out data word size
#define ADOUT_SIZE 5  // A/D channel dataout string size
#define GOOD_SIZE 2    // good data status bit size

#define AVERAGE 10    // # of load/temp/pres samples

// Digital IO Definitions

#define INS 1
#define OUTS 0
#define BANK_A INS     //bank A inputs
#define BANK_B OUTS    //bank B outputs
#define TURNON 1
#define TURNOFF 0

#define HVAL 0x4110
#define HVAH 0x4118
#define HVBL 0x4100
#define HVBH 0x4108

// HVBL Channel On/Off Values

#define HVBLCH0_OFF 0
#define HVBLCH0_ON  1
#define HVBLCH1_OFF 2
#define HVBLCH1_ON  3
#define HVBLCH2_OFF 4
#define HVBLCH2_ON  5
#define HVBLCH3_OFF 6
#define HVBLCH3_ON  7

// EHWD ADC Channel Assignments

#define ZERO_CHAN 16    // TSEAL2    channel 0, unipolar, SEAL2
Pressure
#define ONE_CHAN 17    // MLDT1    channel 1, unipolar, spring
calipers
#define TWO_CHAN 18    // Cavity    channel 2, unipolar, Cavity Air
Pressure
#define THREE_CHAN 19  // systemp   channel 3, unipolar, Heat Sink
Temperature
#define FOUR_CHAN 20   // load      channel 4, unipolar, Drill Weight
Sensor
#define FIVE_CHAN 21   // HoleTemp  channel 5, unipolar, Drill Hole
Water Temp

```

```

#define SIX_CHAN    22                // HoseTemp  channel 6, unipolar, Hose Water
Temp
#define SEVEN_CHAN  23                // TSEAL1   channel 7, unipolar, SEAL1
Pressure
#define EIGHT_CHAN  24                // MLDT2    channel 8, unipolar,
spring calipers
#define NINE_CHAN   25                // MUX      channel 9, unipolar, Multiplexed
Input/Output Voltage

// Amanda Drill ADC Channel Assignments

// #define ZERO_CHAN  16                // Load Cell channel 0, unipolar, load
cell
// #define ONE_CHAN   17                // Mlgt     channel 1, unipolar, spring
calipers
// #define TWO_CHAN   18                // Old FLow channel 2, bipolar
// #define THREE_CHAN 19                // Hole Temp channel 3, unipolar,
exterior temp
// #define FOUR_CHAN  20                // Hose Temp channel 4, unipolar,
interior temp
// #define FIVE_CHAN  21                // Hole Pres channel 5, unipolar,
exterior pressure
// #define SIX_CHAN   22                // Hose Pres chnnel 6, unipolar,
interior pressure
// #define SEVEN_CHAN 23                // Board   channel 7, unipolar, board
temp
// #define EIGHT_CHAN 24                //
// #define NINE_CHAN  25                //

#define BUFSIZE 256                    // I/O Circular buffer(s) size

shared struct _Channel *uplink;
shared struct _Channel *navpack;
shared struct _Channel *paropsense;

shared char UPLINKreadBuffer[BUFSIZE],UPLINKwriteBuffer[BUFSIZE];
shared char NAVPACKreadBuffer[BUFSIZE],NAVPACKwriteBuffer[BUFSIZE];
shared char PAROPSENSEreadBuffer[BUFSIZE],PAROPSENSEwriteBuffer[BUFSIZE];

//function prototypes
void startup();
void dataout(void);
void simple_ad(int, char *, char *);

char good[]="G";                        // good string
char bad[]="B";                          // bad string
char blank[]="---";                      // 3 char bad data string
char summer;                             // checksum value

/* SYS */
shared unsigned long mark;                // 25ms counter
shared char check[5];                    // checksum word
shared char ps_status[GOOD_SIZE];        // inverter good signal (low=bad)
shared char drill_id[2];                  // drill identifier, init to U means un-
initialized

// Amanda
Drills: P = Primary Drill, S = Secondary Drill
// ICECUBE
Drills: R = Refurbished Amanda Secondary Drill
//
x = ICECUBE Drill Head #01
//
Y = ICECUBE Drill Head #02
// Note:
This program is for the ICECUBE New Drill Head
//
Number 02 (ID = Y) only

/* UPLINK */
shared char buildbuf[DAT_SIZE];          // buffer to build data out string

```



```

/* NAVIGATION */
char NavCMD[] = "G\r";
shared char nav_data[NAV_SIZE+4];
shared char nav_status[GOOD_SIZE];

/* Paroscientific Pressure Sensor */
char ParoGetPressureCMD[] = "*0100P3\r\n";
char ParoSetIntTimeCMD[] = "*0100EW*0100PI=50\r\n";
char ParoSetFixedCMD[] = "*0100EW*0100DL=1\r\n";
shared char paro_data[PARO_SIZE];
shared char paro_status[GOOD_SIZE];

/* LOAD CELL, MLDTs, TEMP SENSORS, PRESSURE SENSORS, VOLTAGE SENSORS */
shared char va[ADOUT_SIZE]; // data strings
shared char vb[ADOUT_SIZE];
shared char load[ADOUT_SIZE]; // data strings
shared char mldt1[ADOUT_SIZE];
shared char mldt2[ADOUT_SIZE];
shared char hole_temp[ADOUT_SIZE];
shared char hose_temp[ADOUT_SIZE];
shared char sys_temp[ADOUT_SIZE];
shared char tseal1[ADOUT_SIZE];
shared char tseal2[ADOUT_SIZE];
shared char cavity[ADOUT_SIZE];
shared char mux[ADOUT_SIZE];
// shared char hole_pres[ADOUT_SIZE];
// shared char hose_pres[ADOUT_SIZE];

shared char va_status[GOOD_SIZE]; // status strings
shared char vb_status[GOOD_SIZE];
shared char load_status[GOOD_SIZE]; // status strings
shared char mldt1_status[GOOD_SIZE];
shared char mldt2_status[GOOD_SIZE];
shared char holet_status[GOOD_SIZE];
shared char hosed_status[GOOD_SIZE];
shared char syst_status[GOOD_SIZE];
shared char tseal1_status[GOOD_SIZE];
shared char tseal2_status[GOOD_SIZE];
shared char cavity_status[GOOD_SIZE];
shared char mux_status[GOOD_SIZE];
// shared char holep_status[GOOD_SIZE];
// shared char hosep_status[GOOD_SIZE];

main () {

int num, freecnt;
unsigned port;
unsigned portvalue;

//djw reload_vec(14, Dz0_circ_int); // disable programming port interrupt

VdInit(); // initial virtual driver
init_srtkernel(); // initialize the SRTK
startup(); // startup tasks

port = HVBL; // Mux address port = BL1700
lower byte of port B

while (1) { // forever background
tasks
costate {

// EHWD Analog to Digital Conversions

```

```

simple_ad(FOUR_CHAN, load, load_status);

simple_ad(ONE_CHAN, mldt1, mldt1_status);
simple_ad(TWO_CHAN, cavity, cavity_status);
simple_ad(FIVE_CHAN, hole_temp, holet_status);
simple_ad(SIX_CHAN, hose_temp, hoset_status);
simple_ad(ZERO_CHAN, tseal2, tseal2_status);

simple_ad(SEVEN_CHAN, tseal1, tseal1_status);
simple_ad(THREE_CHAN, sys_temp, syst_status);

simple_ad(EIGHT_CHAN, mldt2, mldt2_status);

portvalue = HVBLCH0_ON;
// Select Mux Channel 0 = Va = Input Voltage
outport(port, portvalue);
portvalue = HVBLCH1_ON;

outport(port, portvalue);
portvalue = HVBLCH2_ON;

outport(port, portvalue);
simple_ad(NINE_CHAN, mux, mux_status);
strcpy(va, mux);
strcpy(va_status, mux_status);

portvalue = HVBLCH0_OFF;
// Select Mux Channel 1 = Vb = Output Voltage
outport(port, portvalue);
portvalue = HVBLCH1_ON;

outport(port, portvalue);
portvalue = HVBLCH2_ON;

outport(port, portvalue);
simple_ad(NINE_CHAN, mux, mux_status);
strcpy(vb, mux);
strcpy(vb_status, mux_status);

// Amanda Drill Analog to Digital Conversions

// simple_ad(ZERO_CHAN, load, load_status);

// simple_ad(ONE_CHAN, mldt, mldt_status);
//// simple_ad(TWO_CHAN, , );
// simple_ad(THREE_CHAN, hole_temp, holet_status);
// simple_ad(FOUR_CHAN, hose_temp, hoset_status);
// simple_ad(FIVE_CHAN, hole_pres, holep_status);

// simple_ad(SIX_CHAN, hose_pres, hosep_status);
// simple_ad(SEVEN_CHAN, sys_temp, syst_status);

// simple_ad(EIGHT_CHAN, va, va_status);
// simple_ad(NINE_CHAN, vb, vb_status);

} // end SENSORS

costate { dataout(); } // send data uphole

// Get Paroscientific Pressure Sensor Data

costate {
aascWriteBlk(paropsense,
ParoGetPressureCMD, sizeof(ParoGetPressureCMD), 0); // Send command to Paroscientific
waitfor( DelayMs(80L) );
freecnt = aascReadBufLeft(paropsense);

num = aascReadBlk( paropsense, paro_data, freecnt, 0);

```

```

//                                     num = 0;                                     // Temporary bypass

                                     if (num == PARO_SIZE) {
                                         strcpy(&paro_data[num-2], "\0");
                                         strcpy(paro_status, good);
                                     }
                                     else {
                                         strcpy(paro_status, bad);

// nav problem
                                         strcpy(paro_data, "*0001+000000.000");
                                     }
                                     } // paroscientific pressure data

// Get Navigation Data
costate {
    aascWriteBlk(navpack, NavCMD, sizeof(NavCMD), 0); // Send
"G\r" to NavPack
    waitFor( DelayMs(80L) );
    freecnt = aascReadBufLeft(navpack);
    num = aascReadBlk( navpack, nav_data, freecnt, 0);

    if (num == NAV_SIZE) {
        strcpy(&nav_data[num-1], "\0");
        strcpy(nav_status, good);
    }
    else {
        strcpy(nav_status, bad);

// nav problem
        strcpy(nav_data, "N +0.00 +0.00 000.0
+000.0 +000.0 +000.0 +00.0");
    }
    } // navigation data

} // while main running

#funcchain _srthightask srthightask
void srthightask(){ mark++; } // hightask

#funcchain _srthightask srthightask
void srthightask(){ runwatch(); } // lowtask

void startup(void) {
    unsigned IDbits;

    eioBrdInit(0); // digital and analog io init
    eioBrdAdcMode(0,0,0); // 12 bit, MSB first, Unipolar

    // setup NAVIGATION RS232 serial port
    // Open a channel to the SCC ( scc channel A at 8N1 with rs232 driver ).
    navpack = aascOpen( DEV_SCC, 0, SCC_A | SCC_8N1 | SCC_1200*8, NULL);

    // setup PAROSCIENTIFIC RS232 serial port
    // Open a channel to the SCC ( scc channel B at 8N1 with rs232 driver ).
    paropsense = aascOpen( DEV_SCC, 0, SCC_B | SCC_8N1 | SCC_1200*8, NULL);

    // Get Drill ID

    IDbits = inport(0x4042);
    IDbits &= 0x1; // bit zero only
    if(IDbits == 0){ strcpy(drill_id, "Y"); }; // Intended to notify the UpHole Cockpit program
    if(IDbits == 1){ strcpy(drill_id, "Y"); }; // of which set of calibration coefficients to
use.

```

```

// However, this program is for the ICECUBE New Drill Head

// Number 0Y (ID = Y) only

// setup DATA OUT RS485 serial port
// Open channel Z1 at 8N1

uplink = aascOpen(DEV_Z1, 0, ASCI_PARAM_8N1+ASCI_PARAM_1200*8,NULL);

aascSetReadBuf( navpack, NAVPACKreadBuffer, sizeof( NAVPACKreadBuffer));
aascSetWriteBuf( navpack, NAVPACKwriteBuffer, sizeof( NAVPACKwriteBuffer));
aascSetReadBuf( paropsense, PAROPSENSEreadBuffer, sizeof( PAROPSENSEreadBuffer));
aascSetWriteBuf( paropsense, PAROPSENSEwriteBuffer, sizeof( PAROPSENSEwriteBuffer));
aascSetReadBuf( uplink, UPLINKreadBuffer, sizeof( UPLINKreadBuffer));
aascSetWriteBuf( uplink, UPLINKwriteBuffer, sizeof( UPLINKwriteBuffer));

aascTxSwitch(navpack,1); //Tx on
aascRxSwitch(navpack,1); //Rx on
aascTxSwitch(paropsense,1); //Tx on
aascRxSwitch(paropsense,1); //Rx on
aascTxSwitch(uplink,1); //Tx on
aascRxSwitch(uplink,0); //Rx off

sccSw485(SCC_A,0); // turn off RS485 for NavPack
sccSw485(SCC_B,0); // turn off RS485 for Paroscientific
z1Sw485(1); // turn on RS485 for uplink

//-----

// setup PAROSCIENTIFIC Integration Time

// aascWriteBlk(paropsense, ParoSetIntTimeCMD,sizeof(ParoSetIntTimeCMD),0); // Send Set
Integration Time CMD
// waitfor( DelayMs(50L) );
// freecnt = aascReadBufLeft(paropsense);
// num = aascReadBlk( paropsense, paro_data, freecnt, 0);

// setup PAROSCIENTIFIC Data Format = Fixed

// aascWriteBlk(paropsense, ParoSetFixedCMD,sizeof(ParoSetFixedCMD),0); // Send Set Fixed Data
CMD
// waitfor( DelayMs(50L) );
// freecnt = aascReadBufLeft(paropsense);
// num = aascReadBlk( paropsense, paro_data, freecnt, 0);

//-----

mark = 0UL; // reset string
variables
strcpy(buildbuf,"");
//
strcpy(ps_status,good);
strcpy(nav_status, bad);
strcpy(nav_data, "N +0.00 +0.00 000.0 +000.0 +000.0 +000.0 +00.0"); //
strcpy(paro_status, bad);
strcpy(paro_data, "*0001+000000.000"); //
strcpy(load_status, bad);
strcpy(load, blank);
strcpy(mldt1_status, bad);
strcpy(mldt1, blank);
strcpy(holet_status, bad);
strcpy(hole_temp, blank);
strcpy(hoset_status, bad);

```

```

strcpy(hose_temp, blank);
// strcpy(holep_status, bad);
// strcpy(hole_pres, blank);
// strcpy(hosep_status, bad);
// strcpy(hose_pres, blank);
strcpy(syst_status, bad);
strcpy(sys_temp, blank);
strcpy(va_status, bad);
strcpy(vb_status, bad);
strcpy(va, blank);
strcpy(vb, blank);
strcpy(mldt2_status, bad);
strcpy(mldt2, blank);
strcpy(mux_status, bad);
strcpy(mux, blank);
strcpy(tseal1_status, bad);
strcpy(tseal1, blank);
strcpy(tseal2_status, bad);
strcpy(tseal2, blank);
strcpy(cavity_status, bad);
strcpy(cavity, blank);

} // setup

void dataout(void) {
int count, csum, datsize, freecnt, strcount;
char smark[11];
char basemark[11];

freecnt = aascWriteBufLeft(uplink);
if(freecnt != 0)return;

ltoa(mark, smark);
strcpy(basemark, "");
for(strcount = 0; strcount < (10-strlen(smark)); strcount++ )
{
strcat(basemark, "0");
}
strcat(basemark, smark);
strcpy(smark, basemark);

sprintf(buildbuf, "%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s",
drill_id,
smark,
ps_status,
syst_status, sys_temp,
mldt1_status, mldt1,
mldt2_status, mldt2,
load_status, load,
holet_status, hole_temp,
hoset_status, hose_temp,
va_status, va,
vb_status, vb,
cavity_status, cavity,
tseal1_status, tseal1);

strcat(buildbuf, tseal2_status);
strcat(buildbuf, tseal2);
strcat(buildbuf, paro_status);
strcat(buildbuf, paro_data);
strcat(buildbuf, nav_status);
strcat(buildbuf, nav_data);
strcat(buildbuf, "K");

// holep_status, hole_pres,
// hosep_status, hose_pres,

```

```

strcpy(syst_status, bad); // reset status
strcpy(mldtl_status, bad);
strcpy(mldtl_status, bad);
strcpy(load_status, bad);
strcpy(holet_status, bad);
strcpy(hoset_status, bad);
// strcpy(holep_status, bad);
// strcpy(hosep_status, bad);
strcpy(va_status, bad);
strcpy(vb_status, bad);
strcpy(cavity_status, bad);
strcpy(tseal1_status, bad);
strcpy(tseal2_status, bad);

strcpy(paro_status, bad);
strcpy(nav_status, bad);

count = strlen(buildbuf);
csum = checksum(buildbuf, count); // calculate checksum of data so far
csum &= 0x00ff;
sprintf(check, "%02x", csum);

strcat(buildbuf, check); // just send last two bytes
strcat(buildbuf, "\r"); // Carriage Return
strcat(buildbuf, "\n"); // Line Feed

datsize = strlen(buildbuf);

aascWriteBlk(uplink, buildbuf, datsize, 0);

// else { return ; }

return ;
} // dataout

void simple_ad(int channel, char *string, char *status) {
    auto int i; // loop counter
    auto unsigned samp; // each sample value
    auto unsigned long ff; // running sample total
    auto unsigned int num; // average sample value
    auto int length; // length of string
    auto char temp_str[ADOUT_SIZE]; // temp string to build into
    auto char num_str[ADOUT_SIZE]; // temp num to char string

    ff = 0;
    for (i=0; i<AVERAGE; i++) { // get channel values
        samp = eioBrdAI(channel);
        ff = ff + samp; // if good...save
    }

    num = ff/AVERAGE; // average

    num &= 0x0FFF; // 0.0volts at the A/D input == 000 hex
    // 2.5volts at the A/D input == FFF hex
    // note chans 0->7 have an inverting
    // chans 8, 9 are straight through

    sprintf(num_str, "%03x", num); // convert A/D value to string

    strcpy(string, num_str); // stuff into string variable above
    strcpy(status, good);
}

#asm nodebug
checksum::
    pop bc ; return address

```

```
pop    hl    ; first arg
pop    de    ; second arg
push   de
push   hl
push   bc
inc    d     ; false high
xor    a
chk1:
add    a,(hl)
inc    hl
dec    e
jr    nz,chk1
dec    d
jr    nz,chk1
ld    (summer),a ; save
ld    l,a
ld    h,0
ret    ; result in hl
#endasm
```

**Hot Water Drill Control System I/O**  
**High Pressure Pump (HPP)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Op Range	Measurement Range	Function	Local Display
High Pressure Pump (HPP) Ports: 2 DGH Modules: 18 DGH I/O D1252: 14 D1412: 3 D1632: 7 D1712: 3 Motor Drives 8	HPP-V1	Electrical closet / Water Tank #2	Vector Drive	Primer Pump #1 motor torque	Unico	1105	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V2	Electrical closet / Water Tank #2	Vector Drive	Primer Pump #2 motor torque	Unico	1105	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V3	Electrical closet / Water Tank #2	Vector Drive	Primer Pump #3 motor torque	Unico	1105	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V4	Electrical closet / Water Tank #2	Vector Drive	Primer Pump #4 motor torque	Unico	1105	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V5	Electrical closet	Vector Drive	HP Pump #1 motor velocity	Unico	1100	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V6	Electrical closet	Vector Drive	HP Pump #2 motor velocity	Unico	1100	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V7	Electrical closet	Vector Drive	HP Pump #3 motor velocity	Unico	1100	-	-	-	D	12		-	-	-	-	-	-	-	-
	HPP-V8	Electrical closet	Vector Drive	HP Pump #4 motor velocity	Unico	1100	-	-	-	D	12		-	-	-	-	-	-	-	-
HPP1-PI	HPP1 Inlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	1 (31)	-	D1252	4-20 mA	psig	0 - 100 psia	(-10) - 30 psig	mA to 85 psig	Yes	
HPP2-PI	HPP2 Inlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	2 (32)	-	D1252	4-20 mA	psig	0 - 100 psia	(-10) - 30 psig	mA to 85 psig	Yes	
HPP3-PI	HPP3 Inlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	3 (33)	-	D1252	4-20 mA	psig	0 - 100 psia	(-10) - 30 psig	mA to 85 psig	Yes	
HPP4-PI	HPP4 Inlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	4 (34)	-	D1252	4-20 mA	psig	0 - 100 psia	(-10) - 30 psig	mA to 85 psig	Yes	
HPP-F1	HPP1 Outlet	Flow	Water flow rate	Hydro Flo	LPL15056NN-65	-	+/- 1%	16-30 VDC	S	DCC:15	A (41)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
		Pressure	Differential Pressure drop across venturi	Setra	2351-002PD-11-06-L-1	Infinite	0.5% FS	16-30 VDC	S	DCC:15	B (42)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
HPP-F2	HPP2 Outlet	Flow	Water flow rate	Hydro Flo	LPL15056NN-65	-	+/- 1%	16-30 VDC	S	DCC:15	C (43)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
		Pressure	Differential Pressure drop across venturi	Setra	2351-002PD-11-06-L-1	Infinite	0.5% FS	16-30 VDC	S	DCC:15	D (44)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
HPP-F3	HPP3 Outlet	Flow	Water flow rate	Hydro Flo	LPL15056NN-65	-	+/- 1%	16-30 VDC	S	DCC:15	E (45)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
		Pressure	Differential Pressure drop across venturi	Setra	2351-002PD-11-06-L-1	Infinite	0.5% FS	16-30 VDC	S	DCC:15	F (46)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
HPP-F4	HPP4 Outlet	Flow	Water flow rate	Hydro Flo	LPL15056NN-65	-	+/- 1%	16-30 VDC	S	DCC:15	G (47)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
		Pressure	Differential Pressure drop across venturi	Setra	2351-002PD-11-06-L-1	Infinite	0.5% FS	16-30 VDC	S	DCC:15	H (48)	-	D1252	4-20 mA	GPM	35-60 GPM	0 - 60 GPM	mA to 60 GPM	Yes	
HPP1-PO	HPP1 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	I (49)	-	D1252	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3000 psig	Yes	
HPP2-PO	HPP2 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	J (4A)	1	D1712	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3000 psig	Yes	
HPP3-PO	HPP3 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	K (4B)	2	D1712	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3000 psig	Yes	
HPP4-PO	HPP4 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	L (4C)	3	D1712	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3000 psig	Yes	
HPP-TO	HPP MDS outlet manifold	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:15	M (4D)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No	
HPPR-P	Return from MHP	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:15	N (4E)	-	D1252	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3000 psig	Yes	
HPPR-T	Return from MHP	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:15	O (4F)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No	
		Flow	Water flow rate	Hydro Flo	LPL15056NN-65	N/A	+/- 1%	16-30 VDC	S	DCC:15	P (4G)	-	D1252	4-20 mA	GPM	140-260 GPM	0 - 260 GPM	mA to 260 GPM	Yes	
HPPR-F	Return from MHP	Pressure	Differential Pressure drop across venturi	Setra	2351-005PD-11-06-L-1	Infinite	0.5% FS	16-30 VDC	S	DCC:15	Q (4H)	-	D1252	4-20 mA	GPM	140-260 GPM	0 - 260 GPM	mA to 260 GPM	Yes	
		Flow	Water flow rate	Hydro Flo	LPL15056NN-65	N/A	+/- 1%	16-30 VDC	S	DCC:15	R (4I)	-	D1252	4-20 mA	GPM	140-260 GPM	0 - 260 GPM	mA to 260 GPM	Yes	
HPP-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	DCC:15	S (4J)	1	D1712	digital	Safe / Estop Location	-	-	estop	No	
HPP-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	DCC:15	T (4K)	2	D1712	digital	Safe / Estop Location	-	-	estop	No	
HPP-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	DCC:15	U (4L)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No	
HPP-W	MDS main room	Water detector	Water leak	Dorien Products	XSS-5, SC-24	-	-	+24V	S	DCC:15	V (4M)	3	D1712	digital	Leak / No Leak Location (MDS)	-	-	water	No	
HPP-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	DCC:15	W (4N)	4	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No	
HPP-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	DCC:15	X (4O)	5	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No	
HPP-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal	Detect A: Fire	12-X27120-000-225	-	-	+24V	S	DCC:15	Y (4P)	6	D1712	digital	Safe / Estop Location	-	-	estop	No
HPP-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal	Detect A: Fire	12-X27120-000-225	-	-	+24V	S	DCC:15	Z (4Q)	7	D1712	digital	Safe / Estop Location	-	-	estop	No



**Hot Water Drill Control System I/O**  
**PreHeat System (PHS)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Op Range	Measurement Range	Function	Local Display
PreHeat System (PHS) Parts: 3 DGH Modules: 34 DGH I/O D1252: 13 D1412: 16 D1632: 1 D1712: 47 Motor Drives: 4	PHS-V1	Electrical closet / Small heater pump	Vector Drive	Small Heater Pump	Unico	1105	-	-	-	D	6	41	-	-	-	-	-	-	-	No
	PHS-V2	Electrical closet / Large heater pump	Vector Drive	Large Heater Pump	Unico	1105	-	-	-	D	6	42	-	-	-	-	-	-	-	No
	PHS-V3	Electrical closet / Tank 1	Vector Drive	WT1 Transfer Pump	Unico	1105	-	-	-	D	6	43	-	-	-	-	-	-	-	No
	PHS-V4	Electrical closet / Tank 1	Vector Drive	WT2 Transfer Pump	Unico	1105	-	-	-	D	6	44	-	-	-	-	-	-	-	No
	PHS-PR1	Electrical Closet Heater #1	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	1	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR2	Electrical Closet Heater #2	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	2	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR3	Electrical Closet Heater #3	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	3	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR4	Electrical Closet Heater #4	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	4	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR5	Electrical Closet Heater #5	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	5	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR6	Electrical Closet Heater #6	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	6	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR7	Electrical Closet Heater #7	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	7	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR8	Electrical Closet Heater #8	Power relay	Water Heater Starter	Stinger Modification	-	-	-	-	A	5	A (41)	8	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	PHS-PR9	Electrical Closet Heater #9	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	5	A (41)	9	D1712	Digital	Fired / Unfired	-	-	heater relay	No
PHS-PR10	Electrical Closet Heater #10	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	5	A (41)	10	D1712	Digital	Fired / Unfired	-	-	heater relay	No	
PHS-PR11	Electrical Closet Heater #11	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	5	A (41)	11	D1712	Digital	Fired / Unfired	-	-	heater relay	No	
PHS-PR12	Electrical Closet Heater #12	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	5	A (41)	12	D1712	Digital	Fired / Unfired	-	-	heater relay	No	
PHS-PR13	Electrical Closet Heater #13	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	5	A (41)	13	D1712	Digital	Fired / Unfired	-	-	heater relay	No	
PHS-P11	Heater Pump 1 Inlet	Pressure	Absolute Water Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	B (42)	-	D1252	4-20 mA	psig	0-100 psia	(-10) - 30 psig	mA to 85 psig	Yes	
PHS-P12	Heater Pump 2 Inlet	Pressure	Absolute Water Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	C (43)	-	D1252	4-20 mA	psig	0-100 psia	(-10) - 30 psig	mA to 85 psig	Yes	
PHS-F1	Supply Manifold 1	Flow	Water flow rate	Hydro Flo	LPL15056NN-38	Infinite	1 %	16-30 VDC	S	4	D (44)	-	D1252	4-20 mA	GPM	18-80 GPM	0 - 80 GPM	mA to 80 GPM	Yes	
		Pressure	Differential Pressure drop across venturi	Setra	2351-010PD-11-06-L-1		0.18% FS													
PHS-F2	Supply Manifold 2	Flow	Water flow rate	Hydro Flo	LPL15056NN-38	Infinite	1 %	16-30 VDC	S	4	E (45)	-	D1252	4-20 mA	GPM	18-80 GPM	0 - 80 GPM	mA to 80 GPM	Yes	
		Pressure	Differential Pressure drop across venturi	Setra	2351-010PD-11-06-L-1		0.18% FS													
PHS-PO1	Heater Pump 1 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	F (46)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes	
PHS-PO2	Heater Pump 2 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	G (47)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes	
PHS-PM1	Inlet Manifold 1	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	H (48)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes	
PHS-PM2	Inlet Manifold 2	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	I (49)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes	
PHS-SH1	Inlet Manifold 1 Heater #1	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	1	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH2	Inlet Manifold 1 Heater #2	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	2	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH3	Inlet Manifold 1 Heater #3	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	3	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH4	Inlet Manifold 1 Heater #4	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	4	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH5	Inlet Manifold 1 Heater #5	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	5	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH6	Inlet Manifold 1 Heater #6	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	6	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH7	Inlet Manifold 1 Heater #7	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	7	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH8	Inlet Manifold 2 Heater #8	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	8	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH9	Inlet Manifold 2 Heater #9	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	9	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH10	Inlet Manifold 2 Heater #10	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	10	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH11	Inlet Manifold 2 Heater #11	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	11	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH12	Inlet Manifold 1 Heater #12	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	12	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-SH13	Inlet Manifold 1 Heater #13	Normally Open Solenoid	Water Flow	Snapitite	242AV6NBAJG1	-	-	120 VAC	A	5	J (4A)	13	D1712	-	Open / Closed	-	-	solenoid n/o	No	
PHS-PSH1	Outlet Manifold 1 Heater #1	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	1	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH2	Outlet Manifold 1 Heater #2	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	2	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH3	Outlet Manifold 1 Heater #3	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	3	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH4	Outlet Manifold 1 Heater #4	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	4	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH5	Outlet Manifold 1 Heater #5	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	5	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH6	Outlet Manifold 1 Heater #6	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	6	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH7	Outlet Manifold 1 Heater #7	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	7	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH8	Outlet Manifold 2 Heater #8	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	8	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH9	Outlet Manifold 2 Heater #9	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	9	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH10	Outlet Manifold 2 Heater #10	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	10	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH11	Outlet Manifold 2 Heater #11	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	11	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH12	Outlet Manifold 1 Heater #12	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	12	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-PSH13	Outlet Manifold 1 Heater #13	Pressure Switch	Pressure switch on a balancing valve	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	5	K (4B)	13	D1712	SPDT	Open / Closed	4-45 psid	-	solenoid n/o	No	
PHS-TH1	Outlet Manifold 1 Heater #1	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	L (4C)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes	
PHS-TH2	Outlet Manifold 1 Heater #2	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	M (4D)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes	
PHS-TH3	Outlet Manifold 1 Heater #3	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	O (4E)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes	

PreHeat System (PHS)

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Op Range	Measurement Range	Function	Local Display
	PHS-TH4	Outlet Manifold 1 Heater #4	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	P (4F)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH5	Outlet Manifold 1 Heater #5	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	Q (50)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH6	Outlet Manifold 1 Heater #6	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	R (51)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH7	Outlet Manifold 1 Heater #7	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	S (52)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH8	Outlet Manifold 2 Heater #8	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	T (53)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH9	Outlet Manifold 2 Heater #9	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	U (54)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH10	Outlet Manifold 2 Heater #10	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	V (55)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH11	Outlet Manifold 2 Heater #11	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	W (56)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH12	Outlet Manifold 1 Heater #12	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	X (57)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TH13	Outlet Manifold 1 Heater #13	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	Y (58)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TMO1	Outlet Manifold 1	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	a (61)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-TMO2	Outlet Manifold 2	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	b (62)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	PHS-PMO1	Outlet Manifold 1	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	c (63)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes
	PHS-PMO2	Outlet Manifold 1	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	4	d (64)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes
	WT2-WL	Electrical closet / Water Tank #2	Pressure	Water level	Setra	5261-030-A-W2-UA-S-A	Infinite	0.15% FS	24 VDC	S	5	e (65)	-	D1252	4-20 mA	in H2O	0-830 in H2O	0-84 in H2O	mA to 830 inH2O	No
	WT2-T1	Electrical closet / Water Tank #2	RTD	Water temperature	Global Water	WQ101	0.2 °F	0.1 °F	10-36 VDC	S	5	f (66)	-	D1252	4-20 mA	F	(-58°) - 212° F	(-58°) - 122° F	temperature	No
Not Needed on List	WT2-T2	Electrical closet / Water Tank #2	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	4	g (67)	-	D1252	4-20 mA	F	32 - 250 °F	32 - 200° F	temperature	No
	PHS-FF	MDS fuel inlet	Flow	Fuel flow	Exact Flow	EFM84SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	4	h (68)	-	D1632	0-5 V TTL Square Wave	GPH	7.8 - 180 GPH	0 - 30 GPH	PULSE	No
	PHS-FS	MDS main room	Pressure	Fire suppression system dump	Kidde	486536	-	-	+24V	S	5	i (69)	1	D1712	Digital	Safe / Estop Location	-	-	estop	No
	PHS-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	5	i (69)	2	D1712	digital	Safe / Estop Location	-	-	estop	No
	PHS-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	5	i (69)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
	PHS-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	4	j (6A)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	PHS-W	MDS main room	Water detector	Water leak	Dorken Products Water Alert	XSS-5, SC-24	-	-	+24V	S	5	i (69)	4	D1712	digital	Leak / No Leak Location (MDS)	-	-	water	No
	PHS-CO1	MDS main room	Environment sensor	Carbon Monoxide	Kidde	KN-COSM-IB	-	-	+24V	S	5	i (69)	5	D1712	digital	Condition & MDS Location	-	-	Carbon Monoxide Detection	No
	PHS-CO2	MDS main room	Environment sensor	Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	5	i (69)	6	D1712	digital	Condition & MDS Location	-	-	Fire and Smoke Detection	No
	PHS-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	5	i (69)	7	D1712	digital	Safe / Estop Location	-	-	estop	No
	PHS-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	5	i (69)	8	D1712	digital	Safe / Estop Location	-	-	estop	No

Hot Water Drill Control System I/O

Rodriguez Well System (RWS)

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensord Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Rodriguez Well System (RWS)	<b>UTILITY CLOSET EQUIPMENT</b>																			
3	RWS-V1	Electrical closet / Heaters 1-5	Vector Drive	Vane pump	Unico	1105	-	-	-	D	9	51	-	-	-	-	-	-	-	No
	RWS-V2	Electrical closet / Heaters 6-10	Vector Drive	Vane pump	Unico	1105	-	-	-	D	9	52	-	-	-	-	-	-	-	No
DGH Modules:	RWS-V3	Electrical closet / Rod Well Hose Reel	Vector Drive	Rodriguez well hose reel drum	Unico	1105	-	-	-	D	9	53	-	-	-	-	-	-	-	No
	RWS-V4	Electrical closet / Subpump Water Well	Vector Drive	Submersible water well pump	Unico	1105	-	-	-	D	9	54	-	-	-	-	-	-	-	No
DGH I/O	RWS-PR1	Electrical Closet Heater #1	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	1	D1712	Digital	Fired / Unfired	-	-	heater relay	No
D1252:	RWS-PR2	Electrical Closet Heater #2	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	2	D1712	Digital	Fired / Unfired	-	-	heater relay	No
10:	RWS-PR3	Electrical Closet Heater #3	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	3	D1712	Digital	Fired / Unfired	-	-	heater relay	No
D1412:	RWS-PR4	Electrical Closet Heater #4	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	4	D1712	Digital	Fired / Unfired	-	-	heater relay	No
14:	RWS-PR5	Electrical Closet Heater #5	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	5	D1712	Digital	Fired / Unfired	-	-	heater relay	No
D1632:	RWS-PR6	Electrical Closet Heater #6	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	6	D1712	Digital	Fired / Unfired	-	-	heater relay	No
3:	RWS-PR7	Electrical Closet Heater #7	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	7	D1712	Digital	Fired / Unfired	-	-	heater relay	No
D1712:	RWS-PR8	Electrical Closet Heater #8	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	8	D1712	Digital	Fired / Unfired	-	-	heater relay	No
61:	RWS-PR9	Electrical Closet Heater #9	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	9	D1712	Digital	Fired / Unfired	-	-	heater relay	No
Motor Drives	RWS-PR10	Electrical Closet Heater #10	Power relay	Water Heater Starter	Singer Modification	-	-	-	-	A	8	A (41)	10	D1712	Digital	Fired / Unfired	-	-	heater relay	No
4	<b>HOT WATER SUPPLY TO THE ROD WELL</b>																			
	RWS-FRWRI	Hot Water Supply to Rod Well	Flow	Water flow rate	Hydro Flo	LPL15056NN-10	Infinite	1 %	16-30 VDC	S	7	B (42)	-	D1252	4-20 mA	GPM	10-30 GPM	0 - 30 GPM	mA to 30 GPM	Yes
			Pressure	Differential Pressure drop across venturi	Setra	2351-015PD-11-06-L-1		0.18% FS									1-15 PSID			
	RWS-TRWRI	Hot Water to Rod Well	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F		S	7	C (43)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	RWS-PRWRI	Hot Water to Rod Well	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	7	D (44)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes
	<b>INLET MANIFOLD &amp; COLD WATER SUPPLY</b>																			
	RWS-P1	Heater Pump Inlet	Pressure	Absolute Water Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	7		-	D1252	4-20 mA	psig	0-100 psia	(-10) - 30 psig	mA to 85 psig	Yes
	RWS-P11	Heater Pump 1 Inlet	Pressure	Absolute Water Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	7	E (45)	-	D1252	4-20 mA	psig	0-100 psia	(-10) - 30 psig	mA to 85 psig	Yes
	RWS-P12	Heater Pump 2 Inlet	Pressure	Absolute Water Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	7	F (46)	-	D1252	4-20 mA	psig	0-100 psia	(-10) - 30 psig	mA to 85 psig	Yes
	RWS-F2	Cold Water Supply from Pumps	Flow	Water flow rate	Hydro Flo	LPL15056NN-38	Infinite	1 %	16-30 VDC	S	7	G (47)	-	D1252	4-20 mA	GPM	18-80 GPM	0 - 80 GPM	mA to 80 GPM	Yes
			Pressure	Differential Pressure drop across venturi	Setra	2351-010PD-11-06-L-1		0.18% FS									1-10 PSID			
	RWS-PMI	Pump Cold Water Supply	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	7	H (48)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes
	RWS-TMI	Pump Cold Water Supply	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F		S	7	I (49)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	RWS-NOS11	Flow to Genset	Normally Open Solenoid	Water Flow	Snaptite	242AV-BNB-AMG1	-	-	120 VAC	A	8	I(6C)	7	D1710	Digital	Open / Closed	-	-	solenoid n/o	No
	<b>HEATER INPUT AND OUTPUT PLUMBING</b>																			
	RWS-3V1	Input Manifold Heater #1	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	00 01	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V2	Input Manifold Heater #2	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	02 03	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V3	Input Manifold Heater #3	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	04 05	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V4	Input Manifold Heater #4	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	06 07	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V5	Input Manifold Heater #5	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	08 09	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V6	Input Manifold Heater #6	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	10 11	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V7	Input Manifold Heater #7	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(69)	12 13	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V8	Input Manifold Heater #8	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	I(6C)	8 9	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V9	Input Manifold Heater #9	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	01 02	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-3V10	Input Manifold Heater #10	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	03 04	D1712	Digital	WT1 / Rod Well	-	-		No
	RWS-NOS1	Input Manifold Heater #1	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	K(6B)	12	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS2	Input Manifold Heater #2	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	K(6B)	13	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS3	Input Manifold Heater #3	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	K(6B)	14	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS4	Input Manifold Heater #4	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	0'	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS5	Input Manifold Heater #5	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	1	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS6	Input Manifold Heater #6	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	2	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS7	Input Manifold Heater #7	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	3	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS8	Input Manifold Heater #8	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	4	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS9	Input Manifold Heater #9	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	5	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-NOS10	Input Manifold Heater #10	Normally Open Solenoid	Water Flow	Snaptite	242AV6NBAJG1	-	-	120 VAC	A	8	I(6C)	6	D1712	Digital	Open / Closed	-	-	solenoid n/o	No
	RWS-PSH1	Output Manifold Heater #1	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	0'	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH2	Output Manifold Heater #2	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	1	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH3	Output Manifold Heater #3	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	2	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH4	Output Manifold Heater #4	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	3	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH5	Output Manifold Heater #5	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	4	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH6	Output Manifold Heater #6	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	5	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH7	Output Manifold Heater #7	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	6	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH8	Output Manifold Heater #8	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	7	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH9	Output Manifold Heater #9	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	8	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-PSH10	Output Manifold Heater #10	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	8	H(68)	9	D1712	Digital	Open / Closed	4-45 psid	-	solenoid n/o	No
	RWS-TH1	Outlet Manifold Heater #1	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F		S	7	J (4A)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes

Rodriguez Well System (RWS)

Mobile Drilling Structure	Name	Location	Sensor/ Actuator Type	Controlled or Sensored Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
	RWS-TH2	Outlet Manifold Heater #2	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	K (4B)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH3	Outlet Manifold Heater #3	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	L (4C)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH4	Outlet Manifold Heater #4	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	M (4D)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH5	Outlet Manifold Heater #5	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	N (4E)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH6	Outlet Manifold Heater #6	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	O (4F)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH7	Outlet Manifold Heater #7	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	P (50)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH8	Outlet Manifold Heater #8	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	Q (51)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH9	Outlet Manifold Heater #9	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	R (52)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-TH10	Outlet Manifold Heater #10	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	S (53)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	Yes
	RWS-3V01	Outlet Manifold Heater #1	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	05 06	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V02	Outlet Manifold Heater #2	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	07 08	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V03	Outlet Manifold Heater #3	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	09 10	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V04	Outlet Manifold Heater #4	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	11 12	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V05	Outlet Manifold Heater #5	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	J(6A)	13 14	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V06	Outlet Manifold Heater #6	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	K(6B)	00 01	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V07	Outlet Manifold Heater #7	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	K(6B)	02 03	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V08	Outlet Manifold Heater #8	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	K(6B)	04 05	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V09	Outlet Manifold Heater #9	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	K(6B)	06 07	D1712	Digital	WT1 / Rod Well	-	-	-	-
	RWS-3V010	Outlet Manifold Heater #10	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	K(6B)	08 09	D1712	Digital	WT1 / Rod Well	-	-	-	-
<b>HEATER INPUT &amp; OUTPUT MANIFOLD BYPASS / OVERFLOW PLUMBING</b>																				
	RWS-PPS1	Output Manifold Seals #1	Flow	Pressure switch on a flow regulator	Durable Controls	24-014-M900	-	-	5A res/ind @ 125 VAC	S	-	-	-	D1712	Digital	Open / Closed	4-45 psid	-	-	-
	RWS-F2	Rod Well - WT1R Manifold	Flow	Water heater output flow	Omega	#FTB792-ND & FJ SC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	7	T (54)	-	D1632	0 - 750 Hz	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
	RWS-F3	WT1S-WT1R/Reek Manifold	Flow	Water heater output flow	Omega	#FTB792-ND & FJ SC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	7	U (55)	-	D1632	0 - 750 Hz	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
	RWS-3V011	Outlet Manifold WT2	3-way valve	Water source via valve position	DuraValve	EA5603-3/4"	-	-	120 VAC	A	8	K(6B)	10 11	D1712	Digital	-	-	-	-	-
<b>ROD WELL COLD WATER SUPPLY MANIFOLD</b>																				
	RWS-FRWRO	Rod Well Cold Water Supply	Flow	Water flow rate	Hydro Flo	LPL15056NN-10	Infinite	1 %	16-30 VDC	S	7	V (56)	-	D1252	4-20 mA	GPM	10-30 GPM	0 - 30 GPM	mA to 30 GPM	Yes
			Pressure	Differential Pressure drop across venturi	Sotra	2351-01SPD-11-06-L-1	-	0.18% FS	-	-	-	-	-	-	-	-	1-15 PSID	-	-	-
	RWS-TRWRO	Rod Well Cold Supply	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	7	W (57)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	RWS-PRWRO	Rod Well Cold Supply	Pressure	Gage water pressure	Sotra	C204-644	Infinite	0.11% FS	17-42 VDC	S	7	X (58)	-	D1252	4-20 mA	psig	0-250 psig	0-75 psig	mA to 250 psig	Yes
<b>WATER TANK 1 SENSORS</b>																				
	WT1-WL	Electrical closet / Water Tank #1	Pressure	Water level	Sotra	5261-030-A-W2-UA-S-A	Infinite	0.15% FS	24 VDC	S	8	Y (59)	-	D1252	4-20 mA	in H2O	0-830 in H2O	0-84 in H2O	mA to 830 inH2O	No
	WT1-T	Electrical closet / Water Tank #1	RTD	Water temperature	Global Water	WG101	-	+/- 0.2° F	10-36 V	S	8	Z (5A)	-	D1251	4-20 mA	F	-58 - 122 F	32 - 70° F	temperature	No
<b>ENVIRONMENTAL SENSORS</b>																				
	RWS-FF	MDS fuel inlet	Flow	Fuel flow	Exact Flow	EFM84SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	7	d (64)	-	D1632	0-5 V TTL Square Wave	GPH	7.8 - 180 GPH	0 - 30 GPH	-	No
	RWS-FS	MDS main room	Pressure	Fire suppression system dump	Kidde	48653d	-	-	+24V	S	8	f(66)	0'	D1712	Digital	Safe / E-stop Location	-	-	estop	No
	RWS-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	8	f(66)	1	D1712	Digital	Safe / E-stop Location	-	-	estop	No
	RWS-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	8	f(66)	2	D1712	Digital	Safe / E-stop Location	-	-	estop	No
	RWS-E3	Rodriguez well hose reel	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	8	f(66)	3	D1712	Digital	Safe / E-stop Location	-	-	estop	No
	RWS-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	7	a (65)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	RWS-W	MDS main room	Water detector	Water leak	Dorlen Products Water Alert	XSS-5, SC-24	-	-	+24V	S	8	f(66)	4	D1712	Digital	Leak / No Leak Location (MDS)	-	-	water	No
	RWS-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	8	f(66)	5	D1712	Digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	RWS-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	8	f(66)	6	D1712	Digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	RWS-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	8	f(66)	7	D1712	Digital	Safe / E-stop Location	-	-	estop	No
	RWS-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	8	f(66)	8	D1712	Digital	Safe / E-stop Location	-	-	estop	No

**Hot Water Drill Control System I/O**  
**Main Heating Plant 1 (MHP1)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator Type	Controlled or Sensing Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Main Heating Plant 1 (MHP1) Ports: 2 28 DGH I/O D1252: 4 D1412: 12 D1632: 10 D1712: 17 Motor Drives	MHP1-PR1	Electrical Closet Heater #1	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	1	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR2	Electrical Closet Heater #2	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	2	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR3	Electrical Closet Heater #3	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	3	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR4	Electrical Closet Heater #4	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	4	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR5	Electrical Closet Heater #5	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	5	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR6	Electrical Closet Heater #6	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	6	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR7	Electrical Closet Heater #7	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	7	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR8	Electrical Closet Heater #8	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	8	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP1-PR9	Electrical Closet Heater #9	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:17	A (41)	9	D1712	Digital	Fired / Unfired	-	-	heater relay	No
MHP1-P1MI	Inlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	-	S	DCC:17	B (42)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
MHP1-P2MI	Inlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	-	S	DCC:17	C (43)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
MHP1-TH1	Outlet Heater #1	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	D (44)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH2	Outlet Heater #2	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	E (45)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH3	Outlet Heater #3	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	F (46)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH4	Outlet Heater #4	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	G (47)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH5	Outlet Heater #5	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	H (48)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH6	Outlet Heater #6	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	I (49)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH7	Outlet Heater #7	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	J (4A)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH8	Outlet Heater #8	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	K (4B)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-TH9	Outlet Heater #9	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	L (4C)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-FH1	Outlet Heater #1	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	M (4D)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH2	Outlet Heater #2	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	N (4E)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH3	Outlet Heater #3	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	O (4F)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH4	Outlet Heater #4	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	P (50)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH5	Outlet Heater #5	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	Q (51)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH6	Outlet Heater #6	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	R (52)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH7	Outlet Heater #7	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	S (53)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH8	Outlet Heater #8	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	T (54)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-FH9	Outlet Heater #9	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	-	S	DCC:17	U (55)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	Hz to 10 GPM	No
MHP1-T1MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	V (56)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-T2MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	-	S	DCC:17	W (57)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-P1MO	Outlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	-	S	DCC:17	X (58)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
MHP1-P2MO	Outlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	-	S	DCC:17	Y (59)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
MHP1-FF	MDS fuel inlet	Flow	Fuel flow	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	-	S	DCC:17	Z (5A)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH		No
MHP1-FS	MDS main room	Pressure	Fire suppression system dump	Kidde	486536	-	-	+24V	-	S	DCC:17	a (61)	1	D1712	Digital	Safe / Estop Location	-	-	estop	No
MHP1-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	-	S	DCC:17	a (61)	2	D1712	digital	Safe / Estop Location	-	-	estop	No
MHP1-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	-	S	DCC:17	a (61)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
MHP1-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	-	S	DCC:17	b (62)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
MHP1-W	MDS main room	Water detector	Water leak	Dorion Products	XSS-5, SC-24	-	-	+24V	-	S	DCC:17	a (61)	4	D1712	digital	Leak / No Leak Location (MDS)	-	-	water	No
MHP1-CO1	MDS main room	Environment sensor	CO	Kidde	KN-COSM-IB	-	-	+24V	-	S	DCC:17	a (61)	5	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
MHP1-CO2	MDS main room	Environment sensor	Smoke	Kidde	KN-COSM-IB	-	-	+24V	-	S	DCC:17	a (61)	6	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
MHP1-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	-	S	DCC:17	a (61)	7	D1712	digital	Safe / Estop Location	-	-	estop	No
MHP1-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	-	S	DCC:17	a (61)	8	D1712	digital	Safe / Estop Location	-	-	estop	No

**Hot Water Drill Control System I/O**  
**Main Heating Plant 2 (MHP 2)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator Type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Main Heating Plant 2 (MHP 2) Ports:	MHP2-PR1	Electrical Closet Heater #1	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	1	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR2	Electrical Closet Heater #2	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	2	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR3	Electrical Closet Heater #3	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	3	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR4	Electrical Closet Heater #4	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	4	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR5	Electrical Closet Heater #5	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	5	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR6	Electrical Closet Heater #6	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	6	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR7	Electrical Closet Heater #7	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	7	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR8	Electrical Closet Heater #8	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	8	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP2-PR9	Electrical Closet Heater #9	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	DCC:18	A (41)	9	D1712	Digital	Fired / Unfired	-	-	heater relay	No
DGH Modules:	MHP2-P1MI	Inlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:18	B (42)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
DGH I/O	MHP2-P2MI	Inlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:18	C (43)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
D1252:	MHP2-TH1	Outlet Heater #1	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	D (44)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
D1412:	MHP2-TH2	Outlet Heater #2	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	E (45)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
12:	MHP2-TH3	Outlet Heater #3	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	F (46)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
D1632:	MHP2-TH4	Outlet Heater #4	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	G (47)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
10:	MHP2-TH5	Outlet Heater #5	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	H (48)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
D1712:	MHP2-TH6	Outlet Heater #6	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	I (49)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
17:	MHP2-TH7	Outlet Heater #7	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	J (4A)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
Motor Drives	MHP2-TH8	Outlet Heater #8	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	K (4B)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP2-TH9	Outlet Heater #9	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	L (4C)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP2-FH1	Outlet Heater #1	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	M (4D)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH2	Outlet Heater #2	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	N (4E)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH3	Outlet Heater #3	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	O (4F)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH4	Outlet Heater #4	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	P (50)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH5	Outlet Heater #5	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	Q (51)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH6	Outlet Heater #6	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	R (52)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH7	Outlet Heater #7	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	S (53)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH8	Outlet Heater #8	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	T (54)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-FH9	Outlet Heater #9	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	DCC:18	U (55)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP2-T1MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	V (56)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP2-T2MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	DCC:18	W (57)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP2-P1MO	Outlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:18	X (58)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP2-P2MO	Outlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	DCC:18	Y (59)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP2-FF	MDS fuel inlet	Flow	Fuel flow	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	DCC:18	Z (5A)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH		No
	MHP2-FS	MDS main room	Pressure	Fire suppression system dump	Kidde	486536	-	-	+24V	S	DCC:18	a (61)	1	D1712	Digital	Safe / Estop Location	-	-	estop	No
	MHP2-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	DCC:18	a (61)	2	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP2-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	DCC:18	a (61)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP2-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	DCC:18	b (62)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP2-W	MDS main room	Water detector	Water leak	Dorion Products	XSS-5, SC-24	-	-	+24V	S	DCC:18	a (61)	4	D1712	digital	Leak / No Leak Location (MDS)	-	-	water	No
	MHP2-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	DCC:18	a (61)	5	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	MHP2-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	DCC:18	a (61)	6	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	MHP2-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	DCC:18	a (61)	7	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP2-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	DCC:18	a (61)	8	D1712	digital	Safe / Estop Location	-	-	estop	No

**Hot Water Drill Control System I/O**  
**Main Heating Plant 3 (MHP3)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator Type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Main Heating Plant 3 (MHP3) Ports:	MHP3-PR1	Electrical Closet Heater #1	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	1	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR2	Electrical Closet Heater #2	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	2	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR3	Electrical Closet Heater #3	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	3	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR4	Electrical Closet Heater #4	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	4	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR5	Electrical Closet Heater #5	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	5	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR6	Electrical Closet Heater #6	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	6	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR7	Electrical Closet Heater #7	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	7	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR8	Electrical Closet Heater #8	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	8	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP3-PR9	Electrical Closet Heater #9	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	10	A (41)	9	D1712	Digital	Fired / Unfired	-	-	heater relay	No
DGH Modules:	MHP3-P1MI	Inlet Manifold	Pressure	Gage Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	10	B (42)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP3-P2MI	Inlet Manifold	Pressure	Gage Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	10	C (43)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
DGH I/O	MHP3-TH1	Outlet Heater #1	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	D (44)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH2	Outlet Heater #2	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	E (45)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH3	Outlet Heater #3	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	F (46)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH4	Outlet Heater #4	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	G (47)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH5	Outlet Heater #5	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	H (48)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH6	Outlet Heater #6	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	I (49)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH7	Outlet Heater #7	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	J (4A)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH8	Outlet Heater #8	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	K (4B)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-TH9	Outlet Heater #9	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	L (4C)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-FH1	Outlet Heater #1	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	M (4D)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH2	Outlet Heater #2	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	N (4E)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH3	Outlet Heater #3	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	O (4F)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH4	Outlet Heater #4	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	P (50)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH5	Outlet Heater #5	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	Q (51)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH6	Outlet Heater #6	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	R (52)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH7	Outlet Heater #7	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	S (53)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP3-FH8	Outlet Heater #8	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	T (54)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
MHP3-FH9	Outlet Heater #9	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	10	U (55)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No	
Motor Drives	MHP3-T1MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	V (56)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-T2MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	10	W (57)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-P1MO	Outlet Manifold	Pressure	Gage Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	10	X (58)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP3-P2MO	Outlet Manifold	Pressure	Gage Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	10	Y (59)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP3-FF	MDS fuel inlet	Flow	Fuel flow	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	10	Z (5A)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH		No
	MHP3-FS	MDS main room	Pressure	Fire suppression system dump	Kidde	486536	-	-	+24V	S	10	a (61)	1	D1712	Digital	Safe / Estop Location	-	-	estop	No
	MHP3-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	10	a (61)	2	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP3-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	10	a (61)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP3-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	10	b (62)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP3-W	MDS main room	Water detector	Water leak	Dorion Products	XSS-5, SC-24	-	-	+24V	S	10	a (61)	4	D1712	digital	Leak / No Leak Location (MDS)	-	-	water	No
	MHP3-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	10	a (61)	5	D1712	digital	Condition & MDS Location	-	-	Carbon Monoxide Detect	No
	MHP3-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	10	a (61)	6	D1712	digital	Condition & MDS Location	-	-	Smoke Detect	No
	MHP3-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	10	a (61)	7	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP3-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	10	a (61)	8	D1712	digital	Safe / Estop Location	-	-	estop	No

**Hot Water Drill Control System I/O**  
**Main Heating Plant 4 (MHP4)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator Type	Controlled or Sensing Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Main Heating Plant 4 (MHP4) Ports:	MHP4-PR1	Electrical Closet Heater #1	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	1	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR2	Electrical Closet Heater #2	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	2	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR3	Electrical Closet Heater #3	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	3	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR4	Electrical Closet Heater #4	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	4	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR5	Electrical Closet Heater #5	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	5	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR6	Electrical Closet Heater #6	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	6	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR7	Electrical Closet Heater #7	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	7	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR8	Electrical Closet Heater #8	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	8	D1712	Digital	Fired / Unfired	-	-	heater relay	No
	MHP4-PR9	Electrical Closet Heater #9	Power relay	Water Heater Starter	Model 75 Modification	-	-	-	-	A	11	A (41)	9	D1712	Digital	Fired / Unfired	-	-	heater relay	No
DGH Modules:	MHP4-P1MI	Inlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	11	B (42)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP4-P2MI	Inlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	11	C (43)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
DGH I/O	MHP4-TH1	Outlet Heater #1	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	D (44)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH2	Outlet Heater #2	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	E (45)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH3	Outlet Heater #3	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	F (46)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH4	Outlet Heater #4	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	G (47)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH5	Outlet Heater #5	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	H (48)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH6	Outlet Heater #6	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	I (49)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH7	Outlet Heater #7	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	J (4A)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH8	Outlet Heater #8	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	K (4B)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-TH9	Outlet Heater #9	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	L (4C)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-FH1	Outlet Heater #1	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	M (4D)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH2	Outlet Heater #2	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	N (4E)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH3	Outlet Heater #3	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	O (4F)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH4	Outlet Heater #4	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	P (50)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH5	Outlet Heater #5	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	Q (51)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH6	Outlet Heater #6	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	R (52)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH7	Outlet Heater #7	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	S (53)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
	MHP4-FH8	Outlet Heater #8	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	T (54)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No
MHP4-FH9	Outlet Heater #9	Flow	Water heater output flow	Omega	#FTB792-ND & FLSC790-P-ND	+/- 1.5%	2% FS	9 - 35 VDC	S	11	U (55)	-	D1632	0 - 750 Hz Square Wave	GPM	2-20 GPM	0 - 10 GPM	mA to 10 GPM	No	
Motor Drives	MHP4-T1MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	V (56)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-T2MO	Outlet Manifold	RTD	Water temperature	Omega	RTD-NP1-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	11	W (57)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-P1MO	Outlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	11	X (58)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP4-P2MO	Outlet Manifold	Pressure	Gage Pressure	Seltra	C204-644	Infinite	0.11% FS	17-42 VDC	S	11	Y (59)	-	D1252	4-20 mA	psig	0-3000 psig	0-1500 psig	mA to 3,000 psig	Yes
	MHP4-FF	MDS fuel inlet	Flow	Fuel flow	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	11	Z (5A)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH		No
	MHP4-FS	MDS main room	Pressure	Fire suppression system dump	Kidde	486536	-	-	+24V	S	11	a (61)	1	D1712	Digital	Safe / Estop Location	-	-	estop	No
	MHP4-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	11	a (61)	2	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP4-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	11	a (61)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP4-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	11	b (62)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	MHP4-W	MDS main room	Water detector	Water leak	Dorion Products	XSS-5, SC-24	-	-	+24V	S	11	a (61)	4	D1712	digital	Leak / No Leak Location (MDS)	-	-	water	No
	MHP4-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	11	a (61)	5	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	MHP4-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	11	a (61)	6	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	MHP4-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	11	a (61)	7	D1712	digital	Safe / Estop Location	-	-	estop	No
	MHP4-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	11	a (61)	8	D1712	digital	Safe / Estop Location	-	-	estop	No



**Hot Water Drill Control System I/O**  
**Tower Operations Structure #1 (TOS-01)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator Type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display	
Tower Operations Structure #1 (TOS-01) Ports:	TOS01-V1	Electrical closet / Supply water hose reel	Vector Drive	Supply hose reel drum velocity	Unico	1105	-	-	-	D	TOS:17	16	-	-	-	-	-	-	-	No	
	TOS01-V2	Electrical closet / Supply water hose reel	Vector Drive	Supply hose reel level wind velocity	Unico	1105	-	-	-	D	TOS:17	15	-	-	-	-	-	-	-	No	
2	TOS1-V3	Electrical closet / Cable winch	Vector Drive	Drill head cable winch drum velocity	Unico	1105	-	-	-	D	TOS:17	11	-	-	-	-	-	-	-	No	
	TOS1-V4	Electrical closet / Cable winch	Vector Drive	Drill head cable winch level wind velocity	Unico	1105	-	-	-	D	TOS:17	12	-	-	-	-	-	-	-	No	
DGH Modules:	TOS1-V5	Electrical closet / Deployment winch	Vector Drive	Experiment cable reel velocity	Unico	1105	-	-	-	D	TOS:17	13	-	-	-	-	-	-	-	No	
7	TOS1-V6	Electrical closet / Tower hoist	Vector Drive	Tower hoist cable velocity	Unico	1105	-	-	-	D	TOS:17	17	-	-	-	-	-	-	-	No	
D1252:	TOS1-V7	Electrical closet / Return water hose winch	Vector Drive	Return water hose reel velocity	Unico	1105	-	-	-	D	TOS:17	14	-	-	-	-	-	-	-	No	
4	TOS1-V8	Electrical closet / Experiment hole	Vector Drive	Return water pump flow	Unico	1105	-	-	-	D	TOS:17	18	-	-	-	-	-	-	-	No	
D1412:	TOS1-B1	Electrical closet / Supply Hose Reel	Mechanical brake	Supply hose reel motion	Johnson Industries	38-HBHX	-	-	-	A	TOS:15	G (46)	1	D1712	digital	Engaged / Disengaged	-	-	brake	No	
1	TOS1-B2	Electrical closet / Drill Head Cable Reel	Mechanical brake	Drill head cable winch motion	Johnson Industries	38-HBHX	-	-	-	A	TOS:15	G (46)	2	D1712	digital	Engaged / Disengaged	-	-	brake	No	
	TOS1-B3	Electrical closet / Deployment Winch	Mechanical brake	Experiment cable reel motion	Johnson Industries	38-HBHX	-	-	-	A	TOS:15	G (46)	3	D1712	digital	Engaged / Disengaged	-	-	brake	No	
D1632:	SHR-C1	Supply Hose Reel	Contact	Supply hose reel drum power			-	-	-	A	TOS:15	G (46)	4	D1712	digital	Engaged / Disengaged	-	-	brake	No	
D1712:	SHR-S1	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS:15	G (46)	5	D1712	digital		-	-		No	
	27	SHR-S2	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS:15	G (46)	6	D1712	digital		-	-		No
Motor Drives	SHR-S3	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS:15	G (46)	7	D1712	digital		-	-		No	
	8	SHR-S4	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS:15	G (46)	8	D1712	digital		-	-		No
	SHR-P	HPP1 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	TOS:15	A (41)	-	D1252	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3,000 psig	No	
	DH-P1	Drill Head T Seal	Pressure	Absolute water pressure	Invensys (Sensym)	13C5000PA4K	Infinite	± 2.91% FS	10V	S	18	-	-	-	psia	psia	0 - 5000 psia	Jack Ambuel	Jack Ambuel	No	
	DH-P2	Drill Head T Seal	Pressure	Absolute water pressure	Invensys (Sensym)	13C5000PA4K	Infinite	± 2.91% FS	10V	S	18	-	-	-	psia	psia	0 - 5000 psia	Jack Ambuel	Jack Ambuel	No	
	DH-P3	Drill Head Cavity	Pressure	Absolute water pressure	Omega	PX139-030A4V	Infinite	± 1.8% FS	5V	S	18	-	-	-	psia	psia	0-30 psia	0-30 psia	Jack Ambuel	No	
	DH-P4	Drill Head Exterior	Pressure	Absolute water pressure	Paroscientific	9000-6K-101	Infinite	0.01% FS	6.4V	S	18	-	-	-	psia	psia	0 - 6000 psia	Jack Ambuel	Jack Ambuel	No	
	DH-T1	Supply Water Temperature	Thermistor	Water temperature	Omega	44018	Infinite	±0.27° F	-	S	18	-	-	-	Degrees	F	(-22°) - 212° F	32° - 200° F	Jack Ambuel	No	
	DH-T2	Drill head Exterior	Thermistor	Water temperature	Omega	44018	Infinite	±0.27° F	-	S	18	-	-	-	Degrees	F	(-22°) - 212° F	32° - 200° F	Jack Ambuel	No	
	DH-T3	Drill head Interior - Heat Sink	Thermistor	Water temperature	Omega	44018	Infinite	±0.27° F	-	S	18	-	-	-	Degrees	F	(-22°) - 212° F	32° - 200° F	Jack Ambuel	No	
	DH-LC	Drill Head Load Cell	Load Cell	Load	Transducer Techniques	TLL-3K	Infinite	1.6 % FS	10V	S	18	-	-	-	lbs	lbs	0 - 3000 lbs	Jack Ambuel	Jack Ambuel	No	
	DH-CAL1	Drill Head Calipers	MLDT	Hole Diameter	MTS Temponics	LHTRB00U00801AO	Infinite	Jack Ambuel	+24V	S	18	-	-	-	inches	inches	Jack Ambuel	Jack Ambuel	Jack Ambuel	No	
	DH-CAL2	Drill Head Calipers	MLDT	Hole Diameter	MTS Temponics	LHTRB00U00801AO	Infinite	Jack Ambuel	+24V	S	18	-	-	-	inches	inches	Jack Ambuel	Jack Ambuel	Jack Ambuel	No	
	TOS1-TH	Utility Closet / Instrument Hole	RTD	Water temperature	Global Water	WQ101	0.2 °F	0.1 °F	10-36 VDC	S	-	-	-	-	D1252	4-20 mA	F	(-58°) - 212° F	(-58°) - 122° F	temperature	No
	TOS1-TH	Utility Closet / Instrument Hole	RTD	Water temperature	Global Water	WQ101	0.2 °F	0.1 °F	10-36 VDC	S	TOS:15	B (42)	-	-	D1252	4-20 mA	F	(-58°) - 212° F	(-58°) - 122° F	temperature	No
	TOS1-WL	Utility Closet / Instrument Hole	Pressure	Water level	Setra	5261-030-A-W2-UA-S-A	Infinite	0.15% FS	24 VDC	S	TOS:15	C (43)	-	-	D1252	4-20 mA	in H2O	0-830 in H2O	0-84 in H2O	mA to 830 inH2O	No
	TOS1-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	1	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	2	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E3	Supply Hose Reel	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	3	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E4	Supply Hose Reel - Safety Cable RH	Switch	Reel stop	Square D	XY2CE1A290TK	-	-	+24V	S	TOS:15	F (45)	4	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS1-E4	Supply Hose Reel - Safety Cable LH	Switch	Reel stop	Square D	XY2CE2A290TK	-	-	+24V	S	TOS:15	F (45)	5	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS1-E5	Supply Hose Reel - Structure	Switch	Reel stop	Square D	9001TRM22	-	-	+24V	S	TOS:15	F (45)	6	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS1-E6	Drill Head Cable Winch	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	7	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E7	Drill Head Cable Winch - Safety Cable	Switch	Reel stop	Square D	XY2CH13250TK	-	-	+24V	S	TOS:15	F (45)	8	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS1-E8	Return Hose Reel	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	9	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E9	Submersible Pump Cable Reel	Switch	Reel stop	Square D	9001TRM22	-	-	+24V	S	TOS:15	F (45)	10	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS1-E10	Deployment Winch	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	11	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E11	Deployment Winch	Switch	Reel stop	Square D	9001TRM22	-	-	+24V	S	TOS:15	F (45)	12	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS1-E12	Tower - Upper Platform	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	13	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E13	Tower - Lower Wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	14	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-E14	Tower - Lower Platform	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS:15	F (45)	15	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	TOS:15	E (44)	-	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	TOS1-CO1	MDS main room	Environment	Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	TOS:15	G (46)	5	D1712	digital	Condition & MDS Location	-	-	Smoke Detect	No	
	TOS1-CO2	MDS main room	Environment	CO	Kidde	KN-COSM-IB	-	-	+24V	S	TOS:15	G (46)	6	D1712	digital	Condition & MDS Location	-	-	CO Detect	No	
	TOS1-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	TOS:15	G (46)	4	D1712	digital	Safe / E-stop Location	-	-	estop	No	
	TOS1-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	TOS:15	G (46)	3	D1712	digital	Safe / E-stop Location	-	-	estop	No	

**Hot Water Drill Control System I/O**  
**Tower Operations Structure #2 (TOS-02)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display	
Tower Operations Structure #2 (TOS-02) Ports:	TOS2-V1	Electrical closet / Supply water hose reel	Vector Drive	Supply hose reel drum velocity	Unico	1105	-	-	-	D	17	16	-	-	-	-	-	-	-	No	
	TOS2-V2	Electrical closet / Supply water hose reel	Vector Drive	Supply hose reel level wind velocity	Unico	1105	-	-	-	D	17	15	-	-	-	-	-	-	-	No	
2	TOS2-V3	Electrical closet / Cable winch	Vector Drive	Drill head cable winch drum velocity	Unico	1105	-	-	-	D	17	11	-	-	-	-	-	-	-	No	
	TOS2-V4	Electrical closet / Cable winch	Vector Drive	Drill head cable winch level wind velocity	Unico	1105	-	-	-	D	17	12	-	-	-	-	-	-	-	No	
DGH Modules:	TOS2-V5	Electrical closet / Deployment winch	Vector Drive	Experiment cable reel velocity	Unico	1105	-	-	-	D	17	13	-	-	-	-	-	-	-	No	
7	TOS2-V6	Electrical closet / Tower hoist	Vector Drive	Tower hoist cable velocity	Unico	1105	-	-	-	D	17	17	-	-	-	-	-	-	-	No	
DGH I/O	TOS2-V7	Electrical closet / Return water hose winch	Vector Drive	Return water hose reel velocity	Unico	1105	-	-	-	D	17	14	-	-	-	-	-	-	-	No	
D1252:	TOS2-V8	Electrical closet / Experiment hole	Vector Drive	Return water pump flow	Unico	1105	-	-	-	D	17	18	-	-	-	-	-	-	-	No	
2	TOS2-B1	Electrical closet / Supply Hose Reel	Mechanical brake	Supply hose reel motion	Johnson Industries	38-HBHX	-	-	-	A	TOS-15	G (46)	1	D1712	digital	Engaged / Disengaged	-	-	brake	No	
D1412:	TOS2-B2	Electrical closet / Drill Head Cable Reel	Mechanical brake	Drill head cable winch motion	Johnson Industries	38-HBHX	-	-	-	A	TOS-15	G (46)	2	D1712	digital	Engaged / Disengaged	-	-	brake	No	
3	TOS2-B3	Electrical closet / Deployment Winch	Mechanical brake	Experiment cable reel motion	Johnson Industries	38-HBHX	-	-	-	A	TOS-15	G (46)	3	D1712	digital	Engaged / Disengaged	-	-	brake	No	
D1632:	SHR-C1	Supply Hose Reel	Contact	Supply hose reel drum power			-	-	-	A	TOS-15	G (46)	4	D1712	digital	Engaged / Disengaged	-	-	brake	No	
D1712:	SHR-S1	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS-15	G (46)	5	D1712	digital		-	-		No	
27	SHR-S2	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS-15	G (46)	6	D1712	digital		-	-		No	
Motor Drives	SHR-S3	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS-15	G (46)	7	D1712	digital		-	-		No	
	8	SHR-S4	Supply Hose Reel	Limit switch assembly	Supply hose reel level wind end limits			-	-	-	S	TOS-15	G (46)	8	D1712	digital		-	-		No
	SHR-P	HPP1 Outlet	Pressure	Gage water pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	TOS-15	A (41)	-	D1252	4-20 mA	psig	0 - 3000 psig	0 - 1500 psig	mA to 3,000 psig	No	
	DH-P1	Drill Head T Seal	Pressure	Absolute water pressure	Invensys (Sensym)	13C5000PA4K	Infinite	± 2.91% FS	10V	S	18	-	-	-	psia	psia	0 - 5000 psia	Jack Ambuel	Jack Ambuel	No	
	DH-P2	Drill Head T Seal	Pressure	Absolute water pressure	Invensys (Sensym)	13C5000PA4K	Infinite	± 2.91% FS	10V	S	18	-	-	-	psia	psia	0 - 5000 psia	Jack Ambuel	Jack Ambuel	No	
	DH-P3	Drill Head Cavity	Pressure	Absolute water pressure	Omega	PX139-030A4V	Infinite	± 1.8% FS	5V	S	18	-	-	-	psia	psia	0-30 psia	0-30 psia	Jack Ambuel	No	
	DH-P4	Drill Head Exterior	Pressure	Absolute water pressure	Paroscientific	9000-6K-101	Infinite	0.01% FS	6.4V	S	18	-	-	-	psia	psia	0 - 6000 psia	Jack Ambuel	Jack Ambuel	No	
	DH-T1	Supply Water Temperature	Thermistor	Water temperature	Omega	44018	Infinite	±0.27° F	-	S	18	-	-	-	Degrees	F	(-22°) - 212° F	32° - 200° F	Jack Ambuel	No	
	DH-T2	Drill head Exterior	Thermistor	Water temperature	Omega	44018	Infinite	±0.27° F	-	S	18	-	-	-	Degrees	F	(-22°) - 212° F	32° - 200° F	Jack Ambuel	No	
	DH-T3	Drill head Interior - Heat Sink	Thermistor	Water temperature	Omega	44018	Infinite	±0.27° F	-	S	18	-	-	-	Degrees	F	(-22°) - 212° F	32° - 200° F	Jack Ambuel	No	
	DH-LC	Drill Head Load Cell	Load Cell	Load	Transducer Techniques	TLL-3K	Infinite	1.6 % FS	10V	S	18	-	-	-	lbs	lbs	0 - 3000 lbs	Jack Ambuel	Jack Ambuel	No	
	DH-CAL1	Drill Head Calipers	MLDT	Hole Diameter	MTS Tempsonics	LHTRB00U00801AO	Infinite	Jack Ambuel	+24V	S	18	-	-	-	inches	inches	Jack Ambuel	Jack Ambuel	Jack Ambuel	No	
	DH-CAL2	Drill Head Calipers	MLDT	Hole Diameter	MTS Tempsonics	LHTRB00U00801AO	Infinite	Jack Ambuel	+24V	S	18	-	-	-	inches	inches	Jack Ambuel	Jack Ambuel	Jack Ambuel	No	
	TOS1-TH	Utility Closet / Instrument Hole	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	-	-	-	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	Jack Ambuel	No
	TOS2-TH	Utility Closet / Instrument Hole	RTD	Water temperature	Omega	RTD-NPT-72-E-DUAL-MTP	0.1 °F	0.5 °F	-	S	TOS-15	B (42)	-	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	TOS2-WL	Utility Closet / Instrument Hole	Pressure	Water level	Setra	5261-030-A-W2-UA-S-A	Infinite	0.15% FS	24 VDC	S	TOS-15	C (43)	-	-	D1252	4-20 mA	in H2O	0-830 in H2O	0-84 in H2O	mA to 830 inH2O	No
	TOS2-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	1	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	2	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E3	Supply Hose Reel	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	3	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E4	Supply Hose Reel - Safety Cable RH	Switch	Reel stop	Square D	XY2CE1A290TK	-	-	+24V	S	TOS-15	F (45)	4	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS2-E4	Supply Hose Reel - Safety Cable LH	Switch	Reel stop	Square D	XY2CE2A290TK	-	-	+24V	S	TOS-15	F (45)	5	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS2-E5	Supply Hose Reel - Structure	Switch	Reel stop	Square D	9001TRM22	-	-	+24V	S	TOS-15	F (45)	6	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS2-E6	Drill Head Cable Winch	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	7	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E7	Drill Head Cable Winch - Safety Cable	Switch	Reel stop	Square D	XY2CH13250TK	-	-	+24V	S	TOS-15	F (45)	8	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS2-E8	Return Hose Reel	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	9	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E9	Submersible Pump Cable Reel	Switch	Reel stop	Square D	9001TRM22	-	-	+24V	S	TOS-15	F (45)	10	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS2-E10	Deployment Winch	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	11	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E11	Deployment Winch	Switch	Reel stop	Square D	9001TRM22	-	-	+24V	S	TOS-15	F (45)	12	D1712	digital	Operational / Stopped	-	-	reel stop	No	
	TOS2-E12	Tower - Upper Platform	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	13	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E13	Tower - Lower Wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	14	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-E14	Tower - Lower Platform	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	TOS-15	F (45)	15	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	TOS-15	E (44)	-	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	TOS2-CO1	MDS main room	Environment	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	TOS-15	G (46)	5	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No	
	TOS2-CO2	MDS main room	Environment	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	TOS-15	G (46)	6	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No	
	TOS2-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	TOS-15	G (46)	4	D1712	digital	Safe / Estop Location	-	-	estop	No	
	TOS2-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	TOS-15	G (46)	3	D1712	digital	Safe / Estop Location	-	-	estop	No	

**Hot Water Drill Control System I/O  
Drill Control Center (DCC)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display	
Drill Control Center (DCC)	FT-F1	Fuel Tower	Flow (instantaneous & integrated)	Fuel flow into tank	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	16	A (41)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH	flow	No	
	FT-F2	Fuel Tower	Flow (instantaneous & integrated)	Fuel Flow to Generators	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	16	B (42)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH	flow	No	
2	FT-F3	Fuel Tower	Flow (instantaneous & integrated)	Fuel Flow to HPP/SEW/DCC	Exact Flow	EFM86SR-L-W-0-B-S1	Infinite	0.1% FS	+24V	S	16	C (43)	-	D1632	0-5 V TTL Square Wave	GPH	9 - 360 GPH	0 - 50 GPH	flow	No	
DGH Modules:	FT-L1	Fuel Tower	Level Switch	High/High Level	Pneumercator	LS600-CSM w/ 3 add'l floats	-	-	N/A	S	16	D (44)	1	D1712	digital	Near Full Alarm	-	-	level N.O.	No	
7	FT-L2	Fuel Tower	Level Switch	High Level	Pneumercator	Part of above	-	-	N/A	S	16	D (44)	2	D1712	digital	Pumps off/ OK	-	-	level N.O.	No	
DGH I/O	FT-L3	Fuel Tower	Level Switch	Low Level	Pneumercator	Part of above	-	-	N/A	S	16	D (44)	3	D1712	digital	OK /Pumps on	-	-	level N.C.	No	
D1252:	FT-L4	Fuel Tower	Level Switch	Low/Low Level	Pneumercator	Part of above	-	-	N/A	S	16	D (44)	4	D1712	digital	Near empty Alarm	-	-	level N.C.	No	
1	FT-L5	Fuel Tower	Level Switch	Leak Detect in Catch Basin	Pneumercator	LS600-LD	-	-	N/A	S	16	D (44)	5	D1712	digital	Leak Detected Alarm	-	-	level N.O.	No	
DCC-FTP2	FT-P1	Fuel Tower	Pressure (instantaneous & integrated)	Input Fuel Pressure	Setra	C204-644	Infinite	0.11% FS	17-42 VDC	S	16	E (45)	-	D1252	4-20 mA	psig	0 - 100 psia	(-10) - 30 psig	pressure	Yes	
	DCC-FTP1	Fuel Tower & Netwk/ Estop Panels	Starter K3	Fuel Level	-	-	-	-	N/A	A	16	L (4C)	14	D1712	digital	Fuel Pump #2	-	-	fuel control	No	
D1412:	DCC-FTP1	Fuel Tower & Netwk/ Estop Panels	Starter K2	Fuel Level	-	-	-	-	N/A	A	16	L (4C)	15	D1712	digital	Fuel Pump #1	-	-	fuel control	No	
2	DCC-TA	Outside wall	RTD	Outside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	16	I (49)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No	
D1632:	DCC-GPS	Desktop	GPS	Time	-	-	-	-	-	S	16	-	-	-	-	HH:MM	-	-	-	No	
3	DCC-PA	Outside wall	Pressure	Barometric pressure	Paroscientific	6000-15A	Infinite	0.01% FS	25 VDC Max	S	16	J (4A)	-	-	psia	psia	0-15 psia	0-15 psia	temperature	No	
D1712:	DCC-WA	Outside wall	Anemometer	Wind speed	-	-	-	-	-	S	16	-	-	-	MPH	MPH	0-40 MPH	0-40 MPH	temperature	No	
11	DCC-WD	Outside wall	Wind Vane	Wind direction	-	-	-	-	-	S	16	-	-	-	N,E,S,W	N,E,S,W	N,E,S,W	N,E,S,W	temperature	No	
Motor Drives	DCC-E1	MDS main room	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	16	L (4C)	-	D1712	digital	Safe / Estop Location	-	-	estop	No	
	DCC-E2	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	16	L (4C)	-	D1712	digital	Safe / Estop Location	-	-	estop	No	
	DCC-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	16	K (4B)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No	
	DCC-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	16	L (4C)	-	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No	
DCC-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	16	L (4C)	-	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No		
	Fuel Tank2 Flow Valve	Solenoid	NC Fuel Solenoid	Allied	2202R8NBAKD1	N/A	N/A	120 VAC	N						N/A		N/A			1	N/A
	Fuel Tank1 Flow Valve	Solenoid	NC Fuel Solenoid	Allied	2202R8NBAKD1	N/A	N/A	120 VAC	N						N/A		N/A				N/A
	Fuel Tower Flow Valve	Solenoid	NC Fuel Solenoid	Allied	2202R8NBAKD1	N/A	N/A	120 VAC	N						N/A		N/A				N/A

Hot Water Drill Control System I/O  
**Seasonal Equipment Workshop (SEW)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Seasonal Equipment Workshop (SEW)	SEW-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	3	A (41)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
Ports:	SEW-CO1	MDS main room	Environment sensor	Carbon Monoxide	Kidde	KN-COSM-IB	-	-	+24V	S	3	B (42)	1	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
1	SEW-CO2	MDS main room	Environment sensor	Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	3	B (42)	2	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
DGH Modules:	SEW-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	3	B (42)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
2	SEW-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	3	B (42)	4	D1712	digital	Safe / Estop Location	-	-	estop	No

Hot Water Drill Control System I/O

Optical Module Lab (OML)

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Optical Module Lab (OML) Ports: 1	OML-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S		C (43)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
	OML-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S		D (44)	1	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
	OML-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S		D (44)	2	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No

**Hot Water Drill Control System I/O**  
**Tower Operations Workshop (TOW)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display	
Tower Operations Workshop (TOW) Ports:	TOW-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	TOS.15	E (50)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No	
	1	TOW-CO1	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	TOS.15	F (51)	1	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
		TOW-CO2	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	TOS.15	F (51)	2	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
DGH Modules:	2	TOW-HR1	MDS main room	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	TOS.15	F (51)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
		TOW-HR2	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	TOS.15	F (51)	4	D1712	digital	Safe / Estop Location	-	-	estop	No

Hot Water Drill Control System I/O

Generator 1

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Generator 1	GEN1-ADX	MDS Main Room									14	a (41)	10	DIN-171						
Ports:	GEN1-SM	MDS main room	Environment sensor	Smoke	Kidde				+24V	S	14	a (41)	11	DIN-171						
	GEN1-CO	MDS main room	Environment sensor	Carbon Monoxide	Kidde	KN-COSM-IB	-	-	+24V	S	14	a (41)	12	DIN-171	digital	Condition & MDS Location	-	-		No
DGH Modules:	GEN1-F	Engine Drip Pan	Fuel Detector	Fuel Leak							14	a (41)	13	DIN-171						
DGH I/O	GEN1-E	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	14	a (41)	14	DIN-171	digital	Safe / Estop Location	-	-	estop	No
D1252:	GEN1-FT	MDS Fuel Inlet	RTD	Fuel Temperature							14			DIN-141						
	GEN1-WT1	Water Outlet	RTD	Return Water Temperature							14			DIN-141						
	GEN1-WT2	Water Inlet	RTD	Hot Side Supply Water Temp							14			DIN-141						

Hot Water Drlll Control System I/O

Generator 2

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Generator 2	GEN2-ADX	MDS Main Room									14			DIN-171						
Ports:	GEN2-SM	MDS main room	Environment sensor	Smoke	Kidde				+24V	S	14	H (48)		DIN-171						
DGH Modules:	GEN2-CO	MDS main room	Environment sensor	Carbon Monoxide	Kidde	KN-COSM-IB	-	-	+24V	S	14	H (48)	1	DIN-171	digital	Condition & MDS Location	-	-		No
	GEN2-F	Engine Drip Pan	Fuel Detector	Fuel Leak							14			DIN-171						
	GEN2-E	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	14	H (48)	3	DIN-171	digital	Safe / Estop Location	-	-	estop	No



Hot Water Drlll Control System I/O

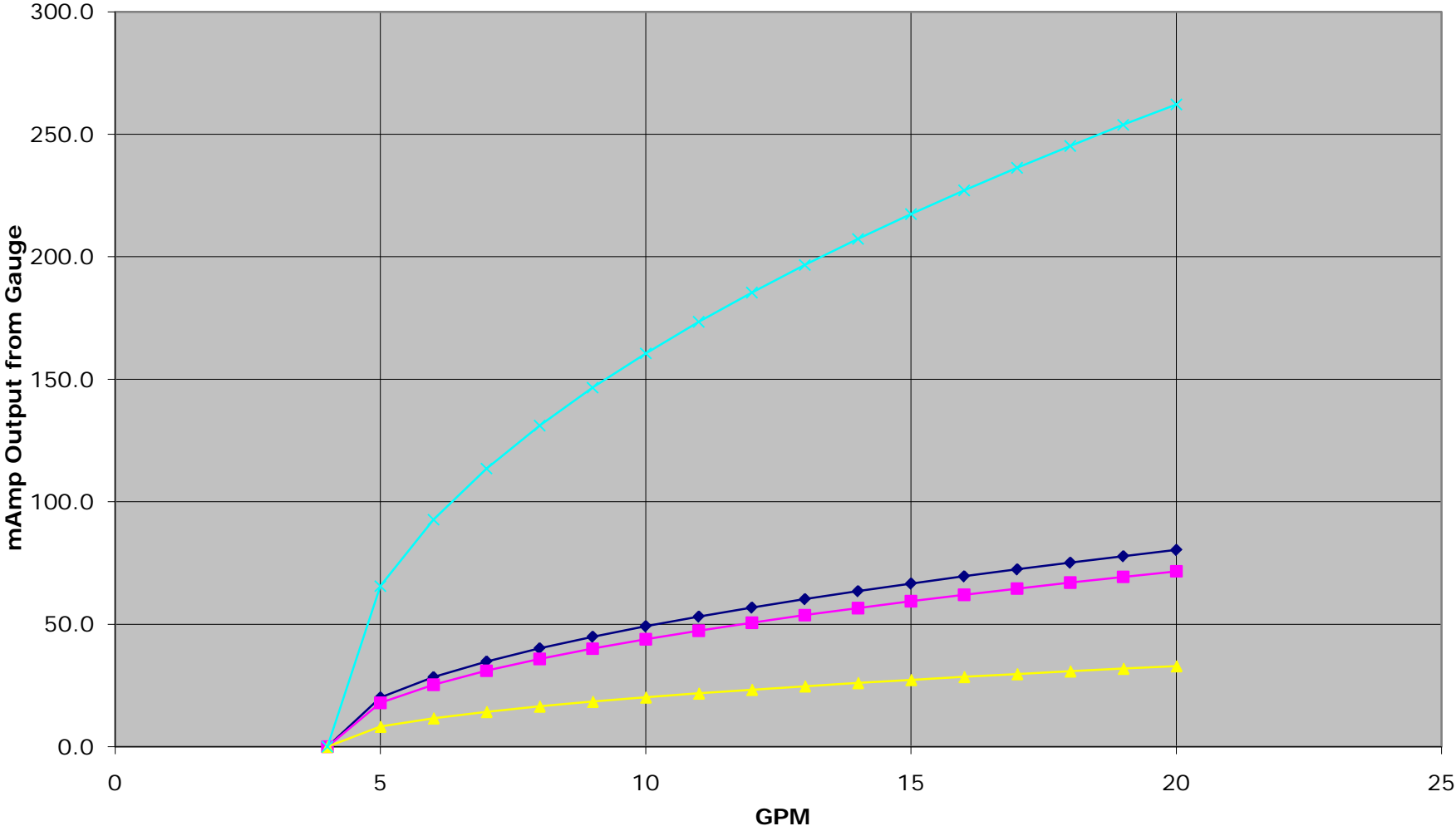
Generator 1

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Generator 1	GEN3-ADX	MDS Main Room								S	13	c (43)	10	DIN-171						
Ports:	GEN3-SM	MDS main room	Environment sensor	Smoke	Kidde				+24V	S	13	c (43)	11	DIN-171						
DGH Modules:	GEN3-CO	MDS main room	Environment sensor	Carbon Monoxide	Kidde	KN-COSM-IB	-	-	+24V	S	13	c (43)	12	DIN-171	digital	Condition & MDS Location	-	-		No
	GEN3-F	Engine Drip Pan	Fuel Detector	Fuel Leak						S	13	c (43)	13	DIN-171						
	GEN3-E	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	13	c (43)	14	DIN-171	digital	Safe / Estop Location	-	-	estop	No

**Hot Water Drill Control System I/O**  
**Power Distribution Module (PDM)**

Mobile Drilling Structure	Name	Location	Sensor/ Actuator type	Controlled or Sensed Parameter	Manufacturer/ Brand	Model Number	Resolution	Corrected Accuracy	Excitation	Actuator, Drive, Sensor	RS-485 Network	RS-485 Address	Digital Address	DGH Module Model	Output Signal	Display Units	Sensor Operating Range	Measurement Range	Function	Local Display
Power Distribution Module (PDM) Ports:	GEN1-E	MDS outside wall	Switch	E-stop	Square D	9001TRM4	-	-	+24V	S	13	N (4E)	3	D1712	digital	Safe / Estop Location	-	-	estop	No
	GEN1-T	MDS main room	RTD	Inside air temperature	Omega	RTD-870-100 OHMS	0.1 °F	0.5 °F	-	S	13	M (4D)	-	D1412	degrees	F	32 - 250 °F	32 - 200° F	temperature	No
1	GEN1-CO	MDS main room	Environment sensor	CO / Smoke	Kidde	KN-COSM-IB	-	-	+24V	S	13	N (4E)	1	D1712	digital	Condition & MDS Location	-	-	RJK needs to review the sensor documentation.	No
DGH Modules:	GEN1-HR1	MDS Utility Closet	Environment sensor	Heat rate of rise or rate compensated	Fenwal Detect-A-Fire	12-X27120-000-225	-	-	+24V	S	13	N (4E)	2	D1712	digital	Safe / Estop Location	-	-	estop	No
2																				

# Flow Meter Curves



0 - 80 GPM    0 - 60 GPM    0 - 30 GPM    0 - 260

mA to 85 psig	$y = \frac{(x - 4mA)}{(20mA - 4mA)} \times (100\text{psia} - 0\text{psia}) - [DCC - PA]\text{psia}$
mA to 250 psig	$y = \frac{(x - 4mA)}{(20mA - 4mA)} \times (250\text{psig} - 0\text{psig})$
mA to 3,000 psig	$y = \frac{(x - 4mA)}{(20mA - 4mA)} \times (3,000\text{psig} - 0\text{psig})$
mA to 830 in H <sub>2</sub> O	$y = \frac{(x - 4mA)}{(20mA - 4mA)} \times (830\text{inH}_2\text{Oobs} - 0\text{inH}_2\text{Oobs}) - [DCC - PA]\text{psia} \times 27.730 \frac{\text{inH}_2\text{O}}{\text{psi}}$
mA to 10 GPM	$y = \frac{(x - 4mA)}{(20mA - 4mA)} \times (10\text{GPM} - 0\text{GPM})$
mA to 30 GPM	$y = 4.8235 \times \sqrt{\frac{(x - 4mA)}{(20mA - 4mA)} \times 10\text{psi} \times 27.730 \frac{\text{inH}_2\text{O}}{\text{psi}}}$
mA to 60 GPM	$y = 9.6154 \times \sqrt{\frac{(x - 4mA)}{(20mA - 4mA)} \times 2\text{psi} \times 27.730 \frac{\text{inH}_2\text{O}}{\text{psi}}}$
mA to 80 GPM	$y = 1.6150 \times \sqrt{\frac{(x - 4mA)}{(20mA - 4mA)} \times 15\text{psi} \times 27.730 \frac{\text{inH}_2\text{O}}{\text{psi}}}$
mA to 260 GPM	$y = 22.2654 \times \sqrt{\frac{(x - 4mA)}{(20mA - 4mA)} \times 5\text{psi} \times 27.730 \frac{\text{inH}_2\text{O}}{\text{psi}}}$
temperature	$y = x$
estop	0 = Safe (Closed) 1 = E - stop & MDS Location(Open)
reel stop	0 = Operational (Closed) 1 = Stopped (Open)
solenoid n/o	0 = Closed (Closed, assumes N/O SSR) 1 = Open (Open, assumes N/O SSR)
solenoid n/c	0 = Open (Open, assumes N/O SSR) 1 = Closed (Closed, assumes N/O SSR)
water	0 = No Leak (Open, assume N/O SSR) 1 = Leak (Closed, assumes N/O SSR)
heater relay	0 = Fired (Open, assume N/O SSR) 1 = Unfired (Closed, assumes N/O SSR)
brake	0 = Engaged (Closed, assumes N/O SSR) 1 = Disengaged (Open, assumes N/O SSR)

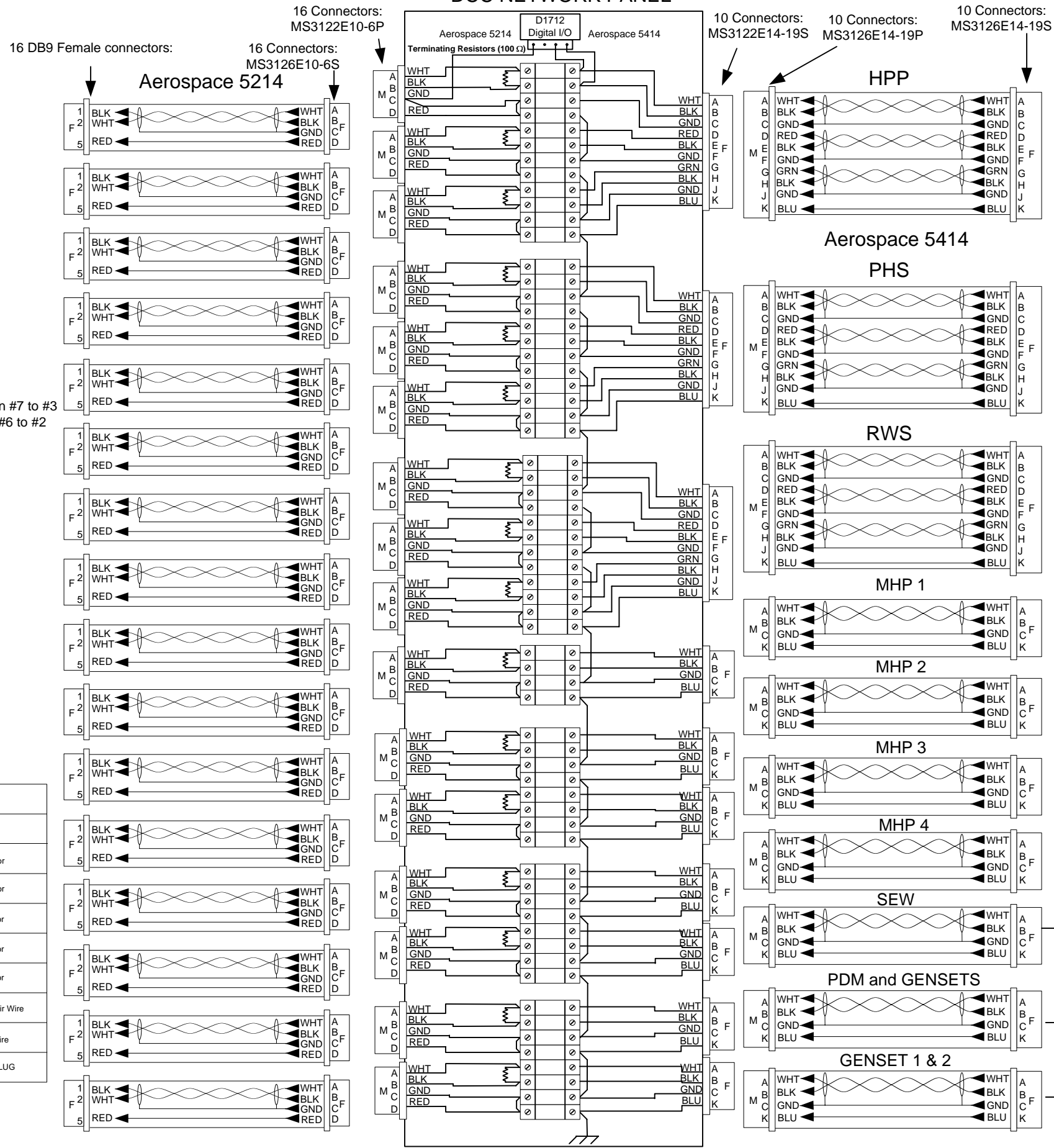
mAmps	0 - 80 GPM	0 - 60 GPM	0 - 30 GPM	0 - 260
4	0.0	0.0	0.0	0.0
5	20.1	17.9	8.2	65.5
6	28.4	25.3	11.6	92.7
7	34.8	31.0	14.3	113.5
8	40.2	35.8	16.5	131.1
9	44.9	40.0	18.4	146.6
10	49.2	43.9	20.2	160.5
11	53.1	47.4	21.8	173.4
12	56.8	50.6	23.3	185.4
13	60.2	53.7	24.7	196.6
14	63.5	56.6	26.0	207.3
15	66.6	59.4	27.3	217.4
16	69.6	62.0	28.5	227.0
17	72.4	64.5	29.7	236.3
18	75.1	67.0	30.8	245.2
19	77.8	69.3	31.9	253.8
20	80.3	71.6	32.9	262.2

<b>Ports:</b>	#VALUE!
<b>DGH Modules:</b>	#VALUE!
<b>DGH I/O</b>	
D1252:	#VALUE!
D1412:	#VALUE!
D1632:	#VALUE!
D1712:	205
<b>Motor Drives</b>	28

79 Meters

REVISIONS				
REV	CR#	DESCRIPTION	DATE	APPROVED
-	-	Original Document	05-11-05	

### DCC NETWORK PANEL

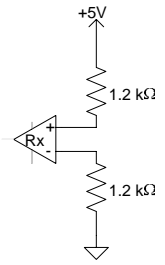


**DB9 PINOUT**  
 1: (-) DATA (BLK)  
 2: (+) DATA (WHITE)  
 5: GROUND (RED)

**To NI PCI-485I/4 Ports**  
 10: GND  
 7: RXD +  
 6: RXD -  
 3: TxD +  
 2: TxD -

Jumper pin #7 to #3 and pin #6 to #2

Resistors configured on PCI board as shown



TO HPP NETWORK PANEL

TO PHS NETWORK PANEL

TO RWS NETWORK PANEL

TO MHP1 NETWORK PANEL

TO MHP2 NETWORK PANEL

TO MHP3 NETWORK PANEL

TO MHP4 NETWORK PANEL

TO SEW N/W PANEL

TO PDM N/W PANEL

TO GEN1 N/W PANEL

**Aerospace 5414 Foamed FEP Teflon 24 AWG**

PIN#	COLOR
A	White
B	Black
C	Shld Grd
D	Red
E	Black
F	Shld Grd
G	Green
H	Black
J	Shld Grd
K	Blue

**Aerospace 5214 Foamed FEP Teflon 24 AWG**

PIN#	COLOR
A	White
B	Black
C	Shld Grd
D	Red
E	Black
F	Shld Grd

Note: All connectors manufactured by ITT Cannon (excluding DB9)

**University of Wisconsin Antarctic Astronomy and Astrophysics Research Institute (A3RI) Project IceCube**  
 222 W. Washington Ave. Madison, WI 53703

**TITLE:**  
 ICECUBE ENHANCED HOT WATER DRILL – DRILL CONTROL CENTER CONTROL SYSTEM SCHEMATIC

Originator TIM MURRAY	Date	Engineer TIM MURRAY	Date	NA
Quality Assurance MICHAEL ZERNICK	Date	Project Approval ROBERT PAULOS	Date	NA

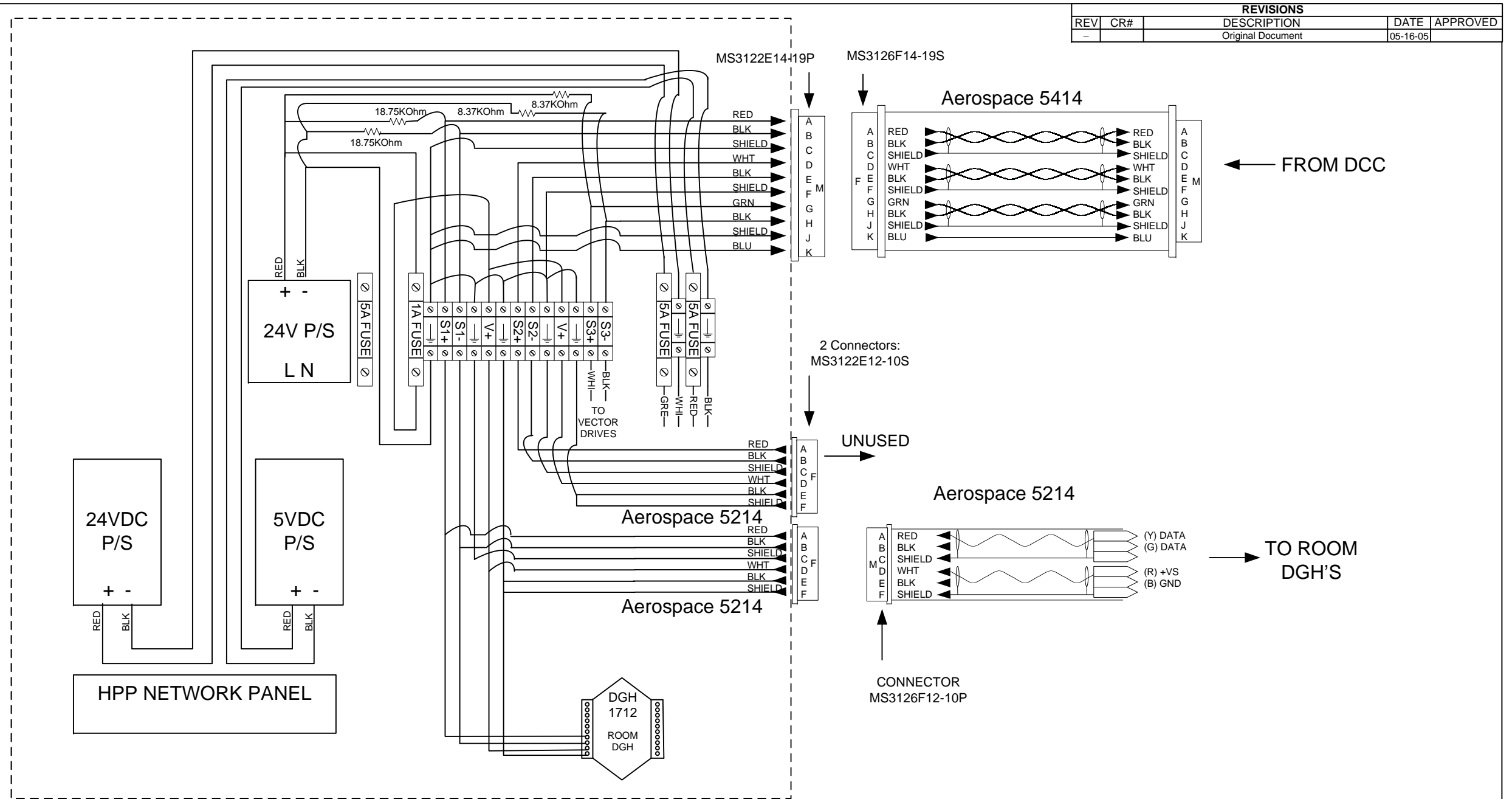
FILE NAME 8510-0083 050525.VSD	SIZE B	SHEET 1	OF 1	DRAWING # 8510-0083	REV -
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### PARTS LIST

Item Number	Quantity	Part Number	Description
-	16	MS3126E10-6S	6 Pin Amphenol Connector
-	16	MS3122E10-6P	6 Pin Amphenol Connector
-	10	MS3122E14-19S	6 Pin Amphenol Connector
-	10	MS3126E14-19P	6 Pin Amphenol Connector
-	10	MS3126E14-19S	6 Pin Amphenol Connector
-	10	Aerospace 5214	Shielded Dual Twisted Pair Wire
-	10	Aerospace 5414	Shielded 4 twisted Pair Wire
-	16	DB9	9 SOCKET STRAIGHT PLUG

Note: twist all pairs

REVISIONS				
REV	CR#	DESCRIPTION	DATE	APPROVED
-		Original Document	05-16-05	



**Room Sensors DGH Pinout**  
D00 MDS Main Room E-Stop  
D01 MDS Outside E-Stop  
D02 Water Leak Detect  
D03 Smoke Detect  
D04 CO Detect  
D05 Heat Rate of Rise Main Room  
D06 Heat Rate of Rise Electrical Closet

PARTS LIST			
Item Number	Quantity	Part Number	Description
-	1	MS3126F14-19P	6 Pin Amphenol Connector
	1	MS3126F14-19S	6 Pin Amphenol Connector
	1	MS3122E14-19P	6 Pin Amphenol Connector
	2	MS3122E12-10S	6 Pin Amphenol Connector
	1	MS3126F12-10P	6 Pin Amphenol Connector
	4	Aerospace 5214	Shielded Dual Twisted Pair Wire
	2	Aerospace 5414	Shielded 4 twisted Pair Wire

Aerospace 5414 Foamed FEP Teflon 24 AWG	
PIN	COLOR
A	Red
B	Black
C	Shld Grd
D	White
E	Black
F	Shld Grd
G	Green
H	Black
J	Shld Grd
K	Blue

Aerospace 5214 Foamed FEP Teflon 24 AWG	
PIN	COLOR
A	Red
B	Black
C	Shld Grd
D	White
E	Black
F	Shld Grd

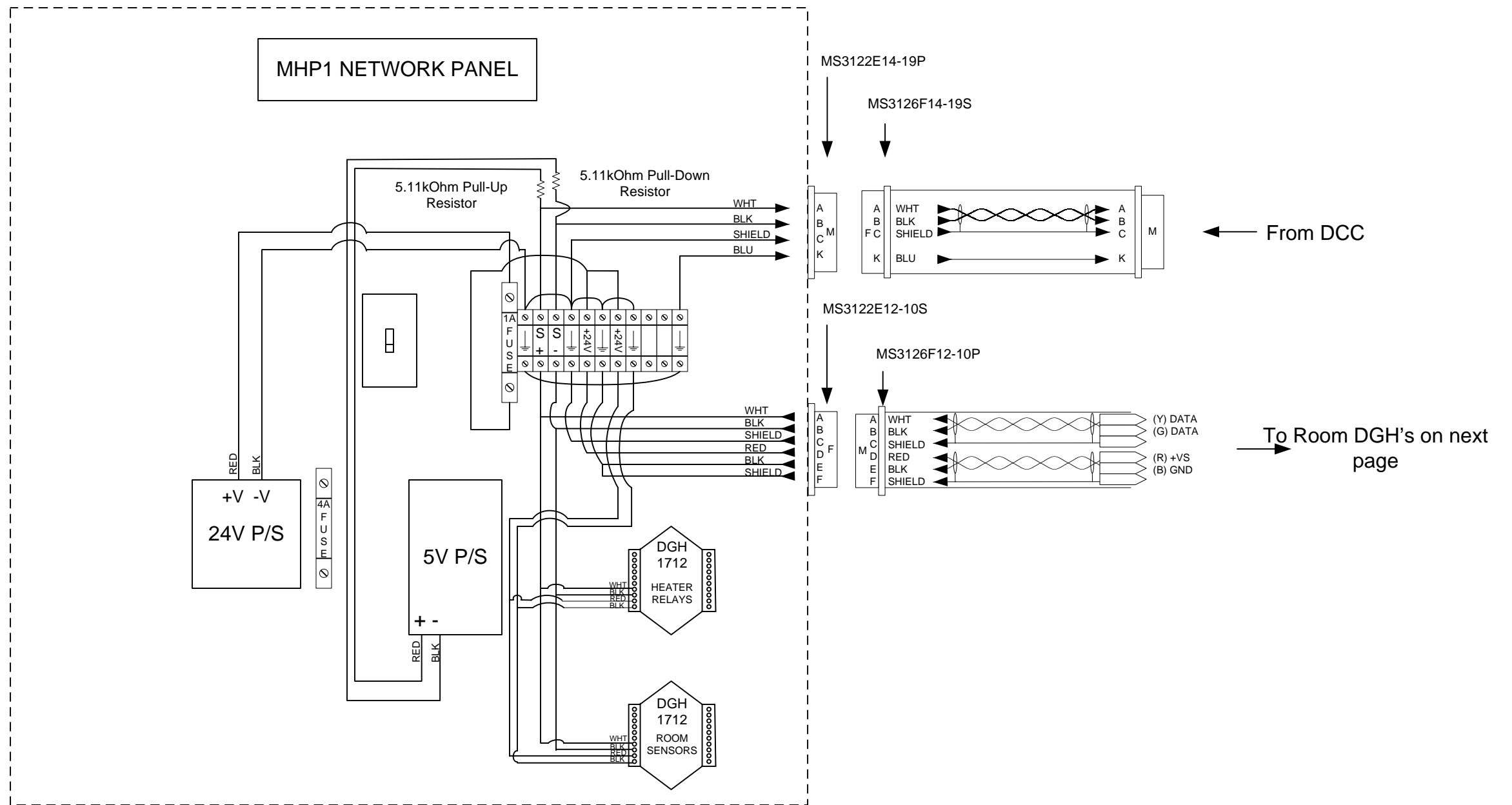
All connectors are manufactured by ITT Cannon

**University of Wisconsin**  
**Antarctic Astronomy and Astrophysics Research**  
**Institute (A3RI) Project IceCube**  
222 W. Washington Ave. Madison, WI 53703

**TITLE:**  
ICECUBE  
ENHANCED HOT WATER DRILL – HIGH PRESSURE PUMP CONTROL SYSTEM  
SCHEMATIC

Originator TIM MURRAY	Date	Engineer TIM MURRAY	Date	NA
Quality Assurance TOM DEMKE	Date	Project Approval ROBERT PAULOS	Date	NA
FILE NAME 8510-0085 050525.VSD	SIZE B	SHEET 1	OF 2	DRAWING # 8510-0085
				REV -

REVISIONS				
REV	CR#	DESCRIPTION	DATE	APPROVED
-		Original Document	05-11-05	



### PARTS LIST


Item Number	Quantity	Part Number	Description
	1	MS3122E14-19P	6 Pin Amphenol Connector
	1	MS3122E12-10S	6 Pin Amphenol Connector
	1	MS3126F14-19S	6 Pin Amphenol Connector
	1	MS3126F12-10P	6 Pin Amphenol Connector
	1	DGH 1712	Heater Relay
	1	Aerospace 5214	Shielded Dual Twisted Pair Wire
	1	Aerospace 5414	Shielded 4 twisted Pair Wire
	2	DGH 1712	DIGITAL I/O
	11	DGH 1412	RTD READOUT
	4	DGH 1252	4-20 mA READOUT
	10	DGH 1632	FREQ. COUNTER READOUT

Aerospace 5414 Foamed FEP Teflon 24 AWG	
PIN	COLOR
A	White
B	Black
C	Shld Grd
D	Red
E	Black
F	Shld Grd
G	Green
H	Black
J	Shld Grd
K	Blue
L	Black
M	Shld Grd

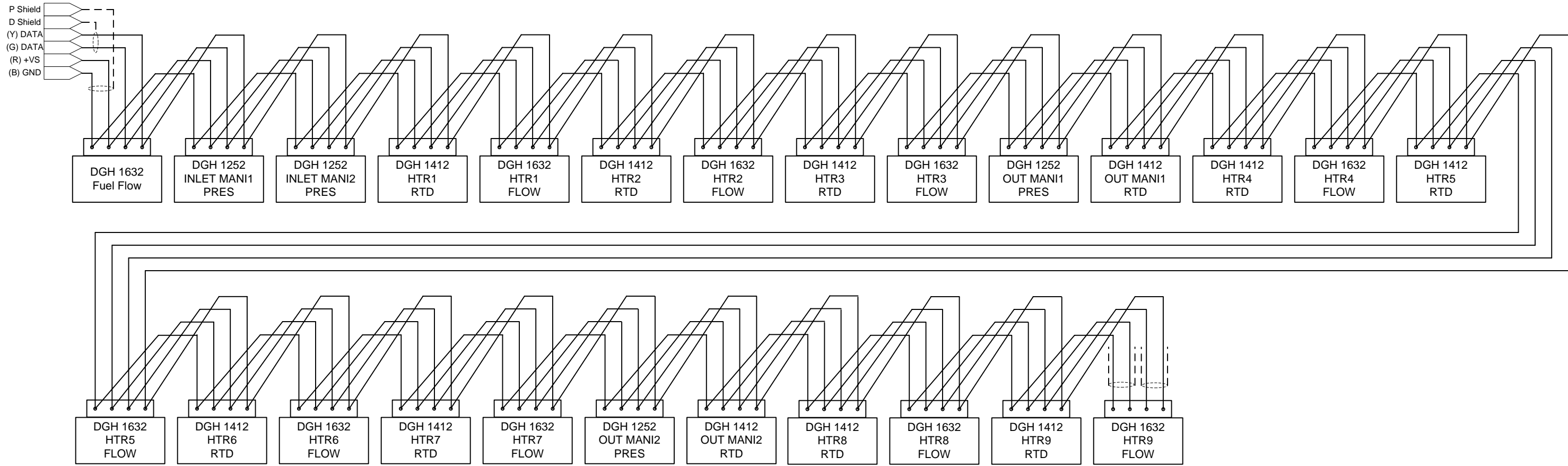
Aerospace 5214 Foamed FEP Teflon 24 AWG	
PIN	COLOR
A	White
B	Black
C	Shld Grd
D	Red
E	Black
F	Shld Grd

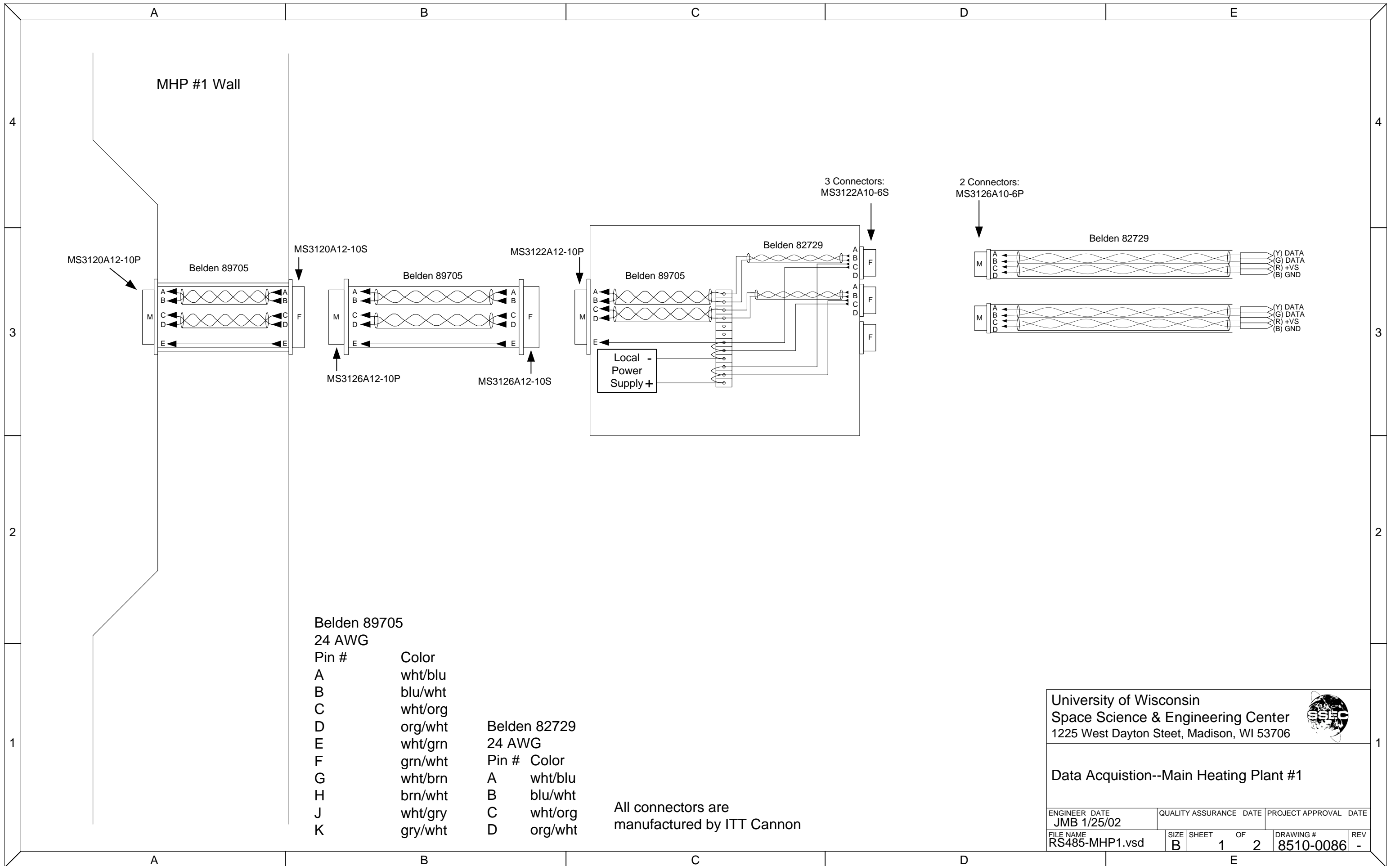
Heater Relay DGH Pinout:	
D00	Heater 1 Relay
D01	Heater 2 Relay
D02	Heater 3 Relay
D03	Heater 4 Relay
D04	Heater 5 Relay
D05	Heater 6 Relay
D06	Heater 7 Relay
D07	Heater 8 Relay
D08	Heater 9 Relay

Room Sensors DGH Pinout	
D00	Fire Suppression System
D01	MDS Main Room E-Stop
D02	MDS Outside E-Stop
D03	Water Leak Detect
D04	Smoke Detect
D05	CO Detect
D06	Heat Rate of Rise Main Room
D07	Heat Rate of Rise Electrical Closet

<b>University of Wisconsin</b> <b>Antarctic Astronomy and Astrophysics Research</b> <b>Institute (A3RI) Project IceCube</b> 222 W. Washington Ave. Madison, WI 53703				
<b>TITLE:</b> ICECUBE ENHANCED HOT WATER DRILL - MAIN HEATING PLANT #1 CONTROL SYSTEM SCHEMATIC				
Originator TIM MURRAY	Date	Engineer TIM MURRAY	Date	NA
Quality Assurance MICHAEL ZERNICK	Date	Project Approval ROBERT PAULOS	Date	NA
FILE NAME 8510-0086 050511.VSD	SIZE B	SHEET 1	OF 2	DRAWING # 8510-0086
				REV -







Belden 89705  
24 AWG


Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht
G	wht/brn
H	brn/wht
J	wht/gry
K	gry/wht

Belden 82729  
24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht

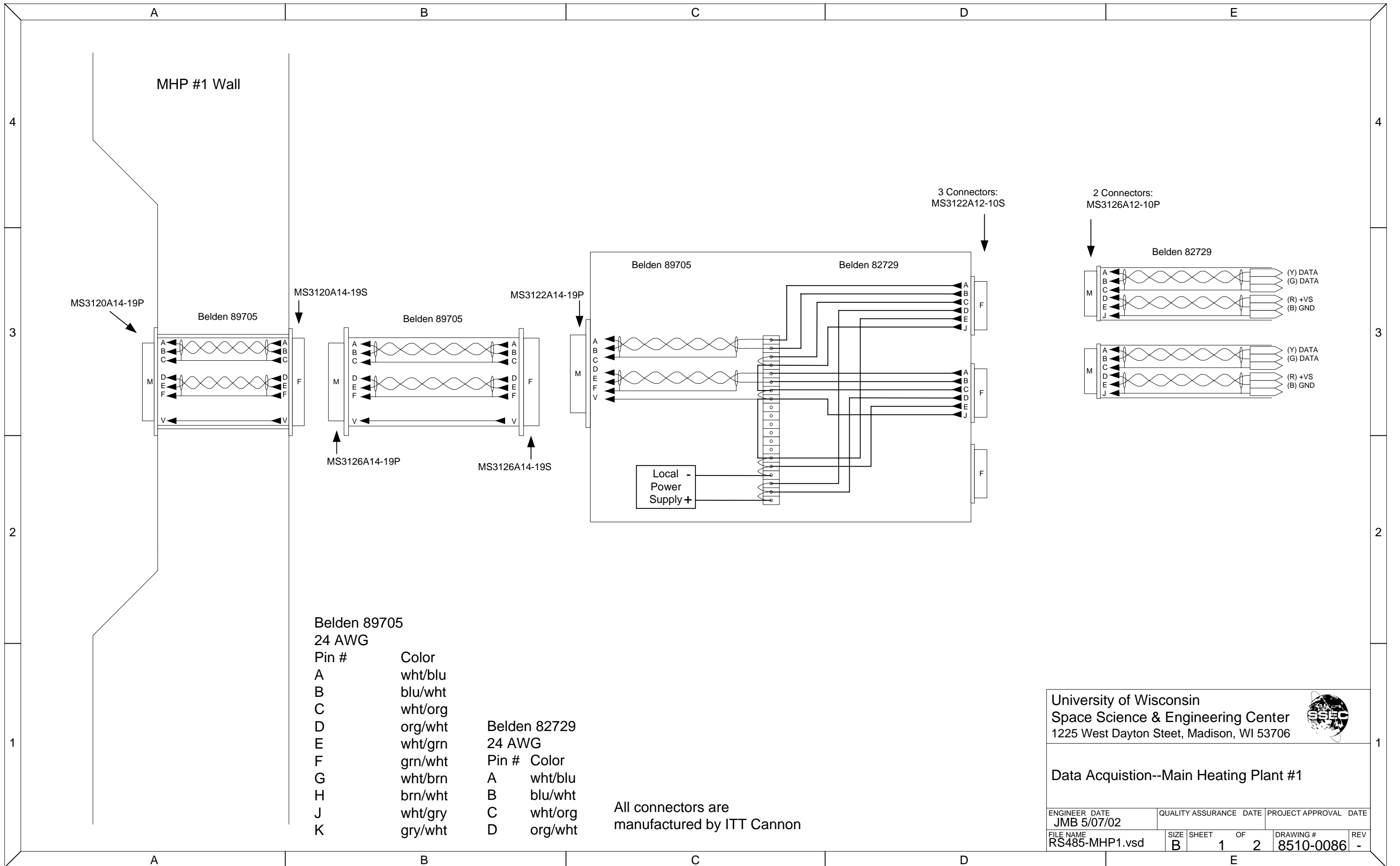
All connectors are  
manufactured by ITT Cannon

University of Wisconsin  
Space Science & Engineering Center  
1225 West Dayton Street, Madison, WI 53706



Data Acquisition--Main Heating Plant #1

ENGINEER DATE JMB 1/25/02	QUALITY ASSURANCE DATE	PROJECT APPROVAL DATE
FILE NAME RS485-MHP1.vsd	SIZE B	SHEET OF 1 2
DRAWING # 8510-0086		REV -



**Belden 89705**  
24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht
G	wht/brn
H	brn/wht
J	wht/gry
K	gry/wht

**Belden 82729**  
24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht

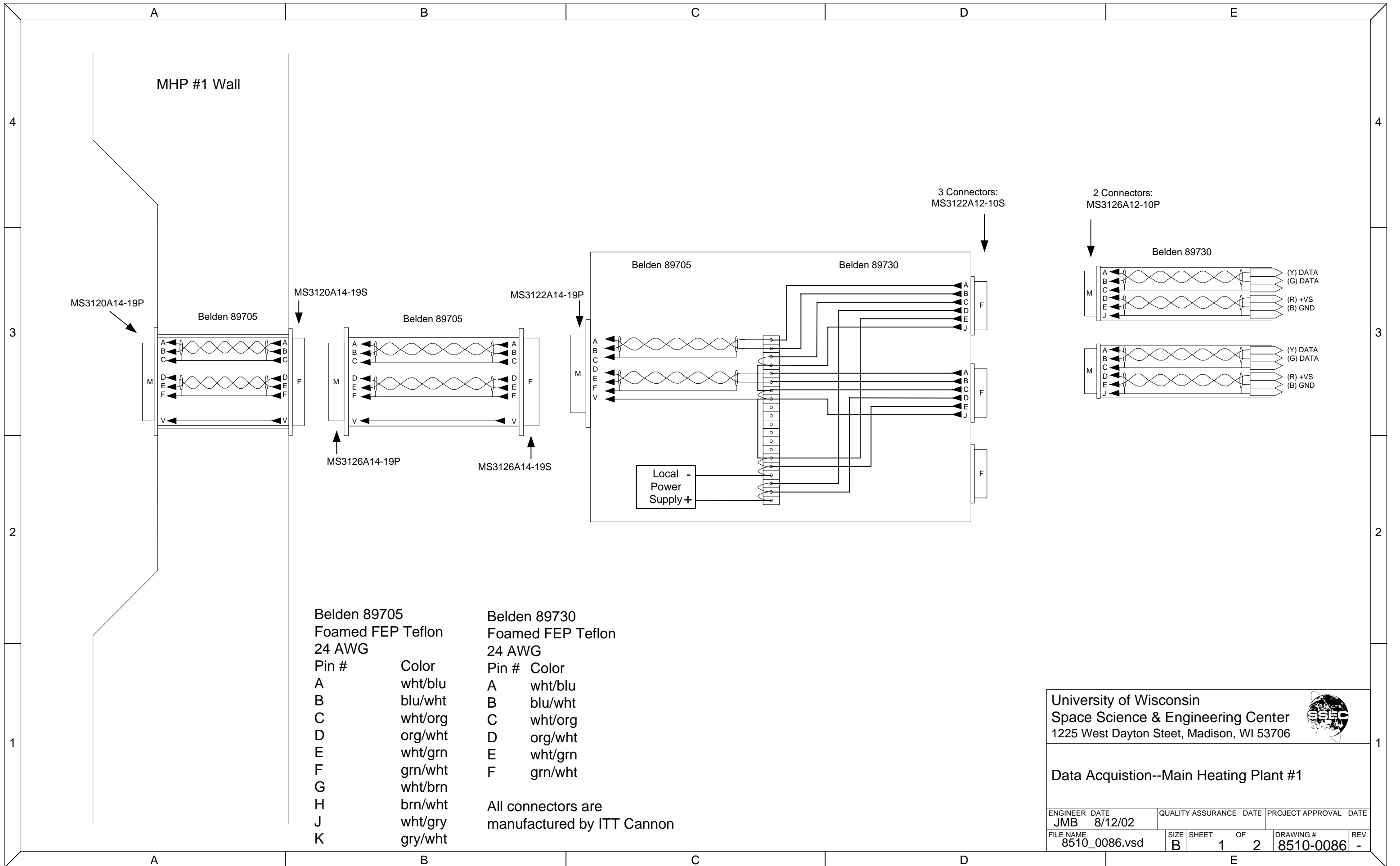
All connectors are manufactured by ITT Cannon

University of Wisconsin  
Space Science & Engineering Center  
1225 West Dayton Street, Madison, WI 53706



**Data Acquisition--Main Heating Plant #1**

ENGINEER DATE JMB 5/07/02	QUALITY ASSURANCE DATE	PROJECT APPROVAL DATE
FILE NAME RS485-MHP1.vsd	SIZE B	SHEET OF 1 2
DRAWING # 8510-0086		REV -



Belden 89705  
 Foamed FEP Teflon  
 24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht
G	wht/brn
H	brn/wht
J	wht/gry
K	gry/wht

Belden 89730  
 Foamed FEP Teflon  
 24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht

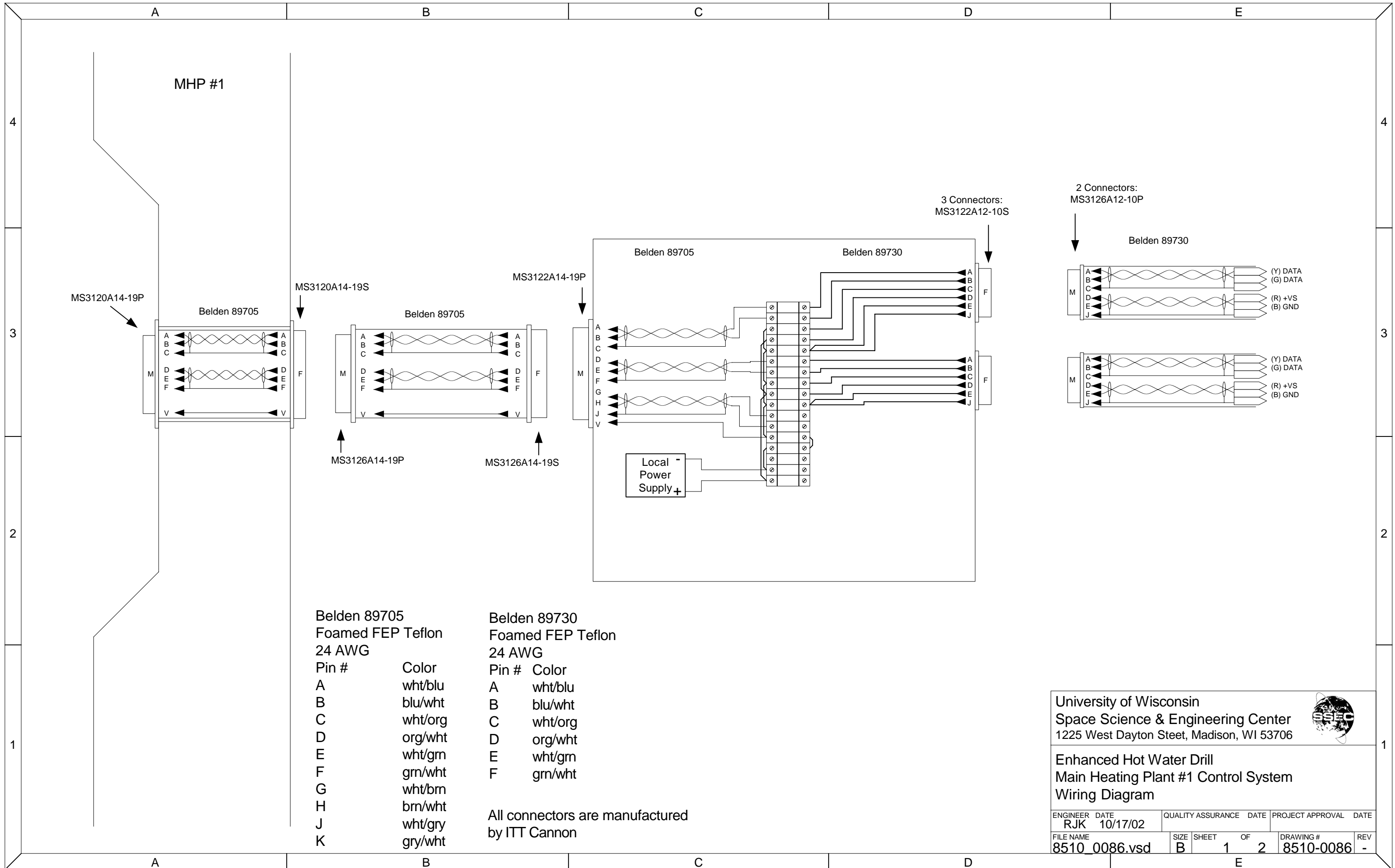
All connectors are  
 manufactured by ITT Cannon

University of Wisconsin  
 Space Science & Engineering Center  
 1225 West Dayton Street, Madison, WI 53706



Data Acquisition--Main Heating Plant #1

ENGINEER JMB	DATE 8/12/02	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
FILE NAME 8510_0086.vsd	SIZE B	SHEET 1	OF 2	DRAWING # 8510-0086	REV -



Belden 89705  
Foamed FEP Teflon  
24 AWG


Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht
G	wht/brn
H	brn/wht
J	wht/gry
K	gry/wht

Belden 89730  
Foamed FEP Teflon  
24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht

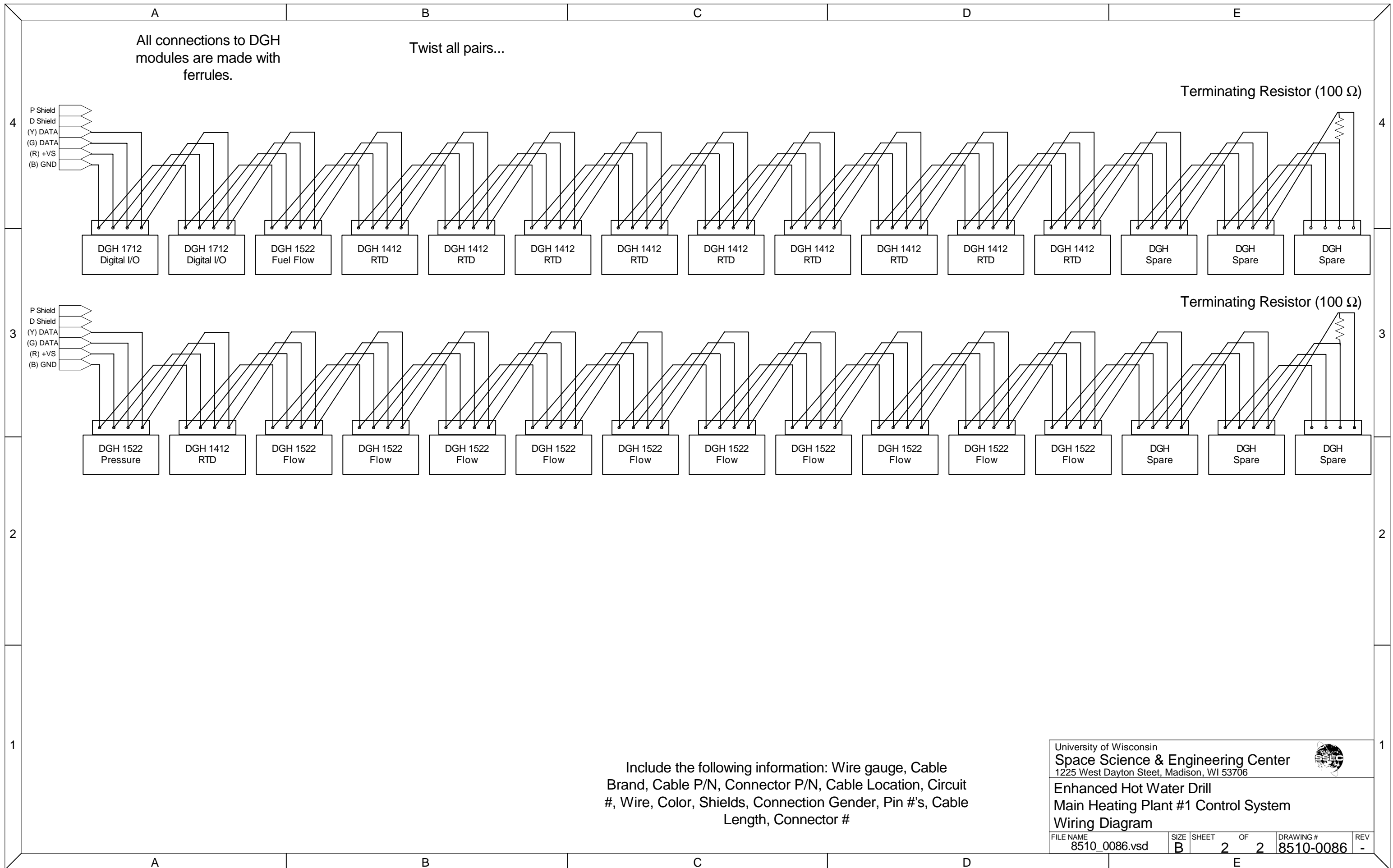
All connectors are manufactured by ITT Cannon

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Space Science & Engineering Center  
1225 West Dayton Steet, Madison, WI 53706



Enhanced Hot Water Drill  
Main Heating Plant #1 Control System  
Wiring Diagram

ENGINEER RJK	DATE 10/17/02	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
FILE NAME 8510_0086.vsd	SIZE B	SHEET 1	OF 2	DRAWING # 8510-0086	REV -



All connections to DGH modules are made with ferrules.

Twist all pairs...

Terminating Resistor (100 Ω)

Terminating Resistor (100 Ω)

Include the following information: Wire gauge, Cable Brand, Cable P/N, Connector P/N, Cable Location, Circuit #, Wire, Color, Shields, Connection Gender, Pin #'s, Cable Length, Connector #

University of Wisconsin  
**Space Science & Engineering Center**  
 1225 West Dayton Street, Madison, WI 53706



**Enhanced Hot Water Drill**  
**Main Heating Plant #1 Control System**  
**Wiring Diagram**

FILE NAME	SIZE	SHEET	OF	DRAWING #	REV
8510_0086.vsd	B	2	2	8510-0086	-

REVISIONS				
REV	CR#	DESCRIPTION	DATE	APPROVED
-	-	Original Document	01-24-05	

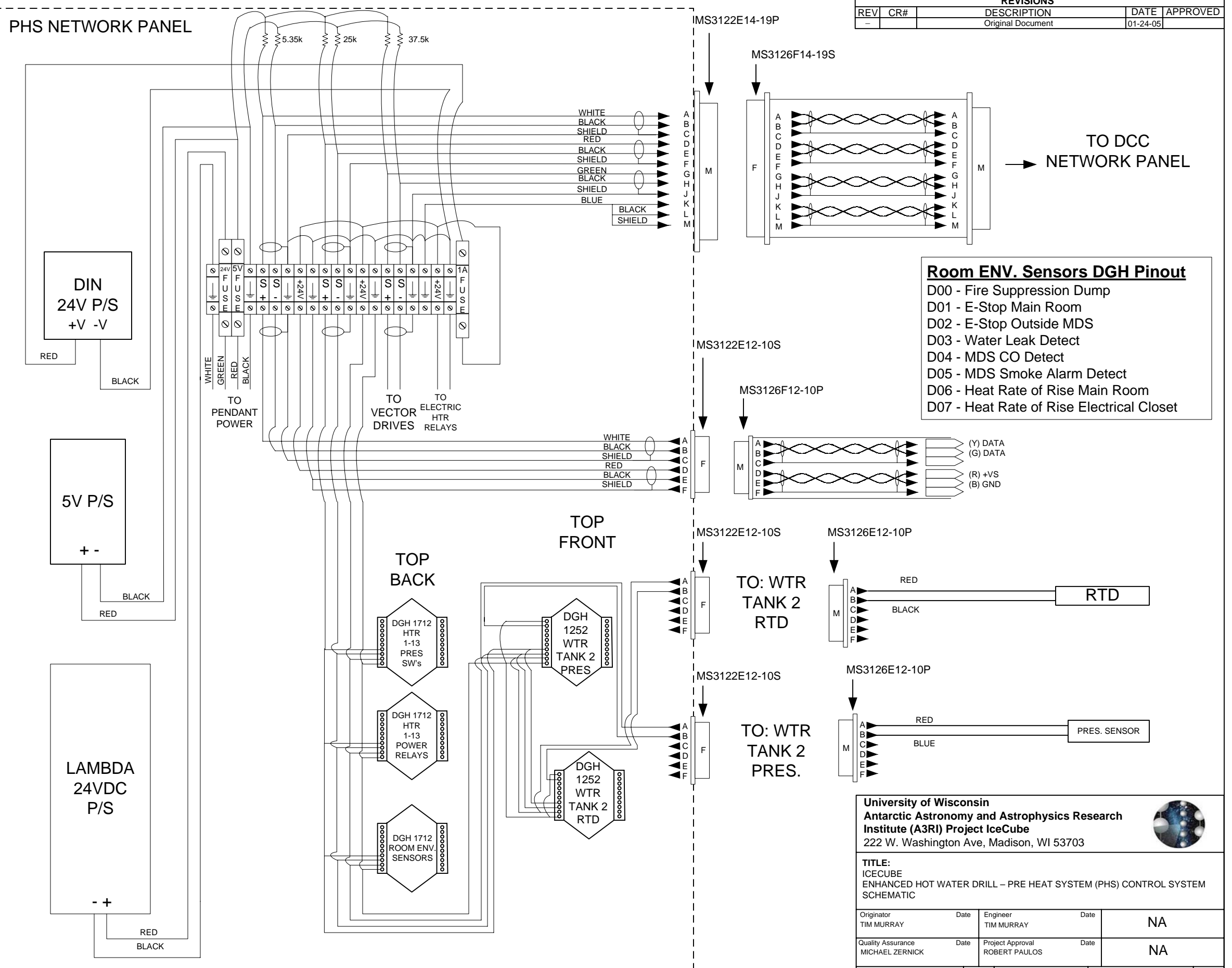
**HTR 1-13 Pressure Switch  
DGH Pinout**

- D00 - HTR 1 (STINGER)
- D01 - HTR 2 (STINGER)
- D02 - HTR 3 (STINGER)
- D03 - HTR 4 (STINGER)
- D04 - HTR 5 (STINGER)
- D05 - HTR 6 (STINGER)
- D06 - HTR 7 (STINGER)
- D07 - HTR 8 (WITCO)
- D08 - HTR 9 (WITCO)
- D09 - HTR 10 (WITCO)
- D10 - HTR 11 (WITCO)
- D11 - HTR 12 (ELECTRIC)
- D12 - HTR 13 (ELECTRIC)

**HTR 1-13 POWER RELAYS DGH  
Pinout**

- D00 - HTR 1 (STINGER)
- D01 - HTR 2 (STINGER)
- D02 - HTR 3 (STINGER)
- D03 - HTR 4 (STINGER)
- D04 - HTR 5 (STINGER)
- D05 - HTR 6 (STINGER)
- D06 - HTR 7 (STINGER)
- D07 - HTR 8 (WITCO)
- D08 - HTR 9 (WITCO)
- D09 - HTR 10 (WITCO)
- D10 - HTR 11 (WITCO)
- D11 - HTR 12 (ELECTRIC)
- D12 - HTR 13 (ELECTRIC)

**PHS NETWORK PANEL**



**Room ENV. Sensors DGH Pinout**

- D00 - Fire Suppression Dump
- D01 - E-Stop Main Room
- D02 - E-Stop Outside MDS
- D03 - Water Leak Detect
- D04 - MDS CO Detect
- D05 - MDS Smoke Alarm Detect
- D06 - Heat Rate of Rise Main Room
- D07 - Heat Rate of Rise Electrical Closet

**PARTS LIST**

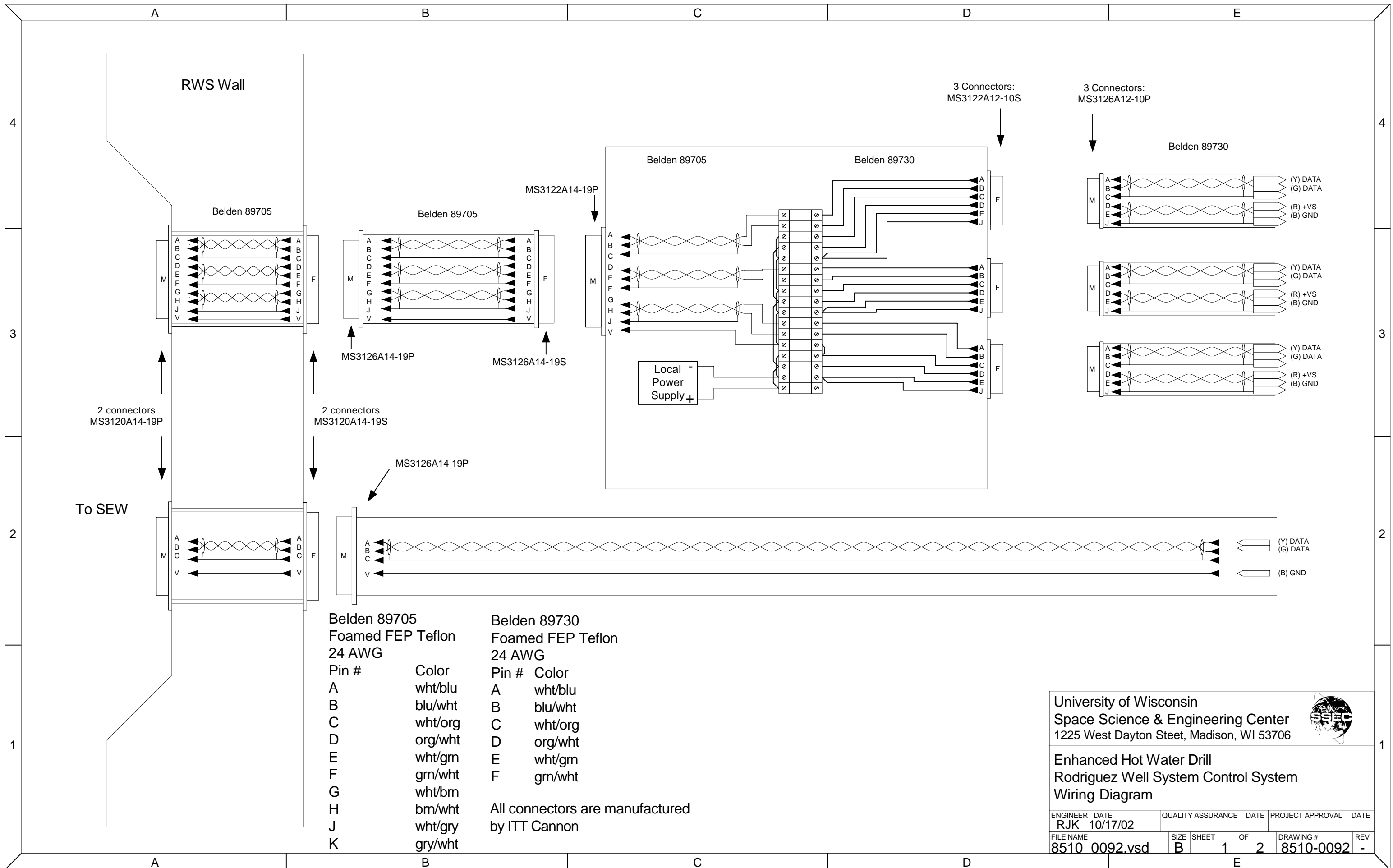
Item Number	Quantity	Part Number	Description
-	1	MS3122E14-19P	6 Pin Amphenol Connector
-	1	MS3126F14-19S	6 Pin Amphenol Connector
-	3	MS3122E12-10S	6 Pin Amphenol Connector
-	1	MS3126F12-10P	6 Pin Amphenol Connector
-	1	DGH 1712	HTR 1-13 PRESSURE SWITCH
-	1	DGH 1712	HTR 1-13 POWER RELAY
-	1	DGH 1712	ROOM ENV. SENSOR
-	2	DGH 1252	PRESSURE, RTD

University of Wisconsin  
 Antarctic Astronomy and Astrophysics Research  
 Institute (A3RI) Project IceCube  
 222 W. Washington Ave, Madison, WI 53703

**TITLE:**  
 ICECUBE  
 ENHANCED HOT WATER DRILL – PRE HEAT SYSTEM (PHS) CONTROL SYSTEM  
 SCHEMATIC

Originator TIM MURRAY	Date	Engineer TIM MURRAY	Date	NA
Quality Assurance MICHAEL ZERNICK	Date	Project Approval ROBERT PAULOS	Date	NA

FILE NAME 8510-0090 051805.VSD	SIZE B	SHEET 1	OF 1	DRAWING # 8510-0090	REV -
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**Belden 89705**  
Foamed FEP Teflon  
24 AWG


Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht
G	wht/brn
H	brn/wht
J	wht/gry
K	gry/wht

**Belden 89730**  
Foamed FEP Teflon  
24 AWG

Pin #	Color
A	wht/blu
B	blu/wht
C	wht/org
D	org/wht
E	wht/grn
F	grn/wht

All connectors are manufactured by ITT Cannon

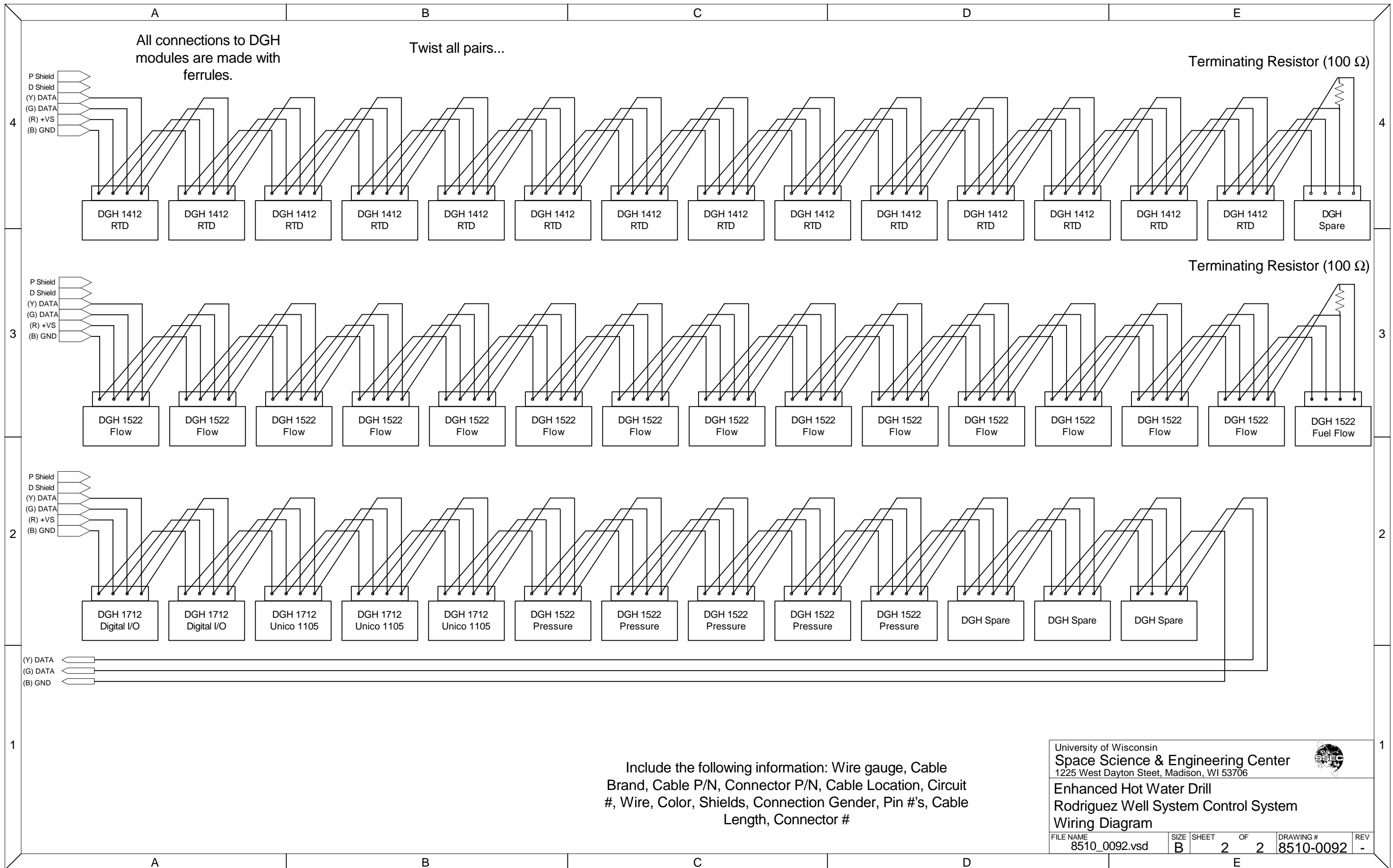
University of Wisconsin  
Space Science & Engineering Center  
1225 West Dayton Steet, Madison, WI 53706



**Enhanced Hot Water Drill  
Rodriguez Well System Control System  
Wiring Diagram**

ENGINEER RJK	DATE 10/17/02	QUALITY ASSURANCE	DATE	PROJECT APPROVAL	DATE
FILE NAME 8510_0092.vsd	SIZE B	SHEET 1	OF 2	DRAWING # 8510-0092	REV -





All connections to DGH modules are made with ferrules.

Twist all pairs...

Terminating Resistor (100 Ω)

Terminating Resistor (100 Ω)

Include the following information: Wire gauge, Cable Brand, Cable P/N, Connector P/N, Cable Location, Circuit #, Wire, Color, Shields, Connection Gender, Pin #'s, Cable Length, Connector #

University of Wisconsin  
**Space Science & Engineering Center**  
 1225 West Dayton Street, Madison, WI 53706



**Enhanced Hot Water Drill  
 Rodriguez Well System Control System  
 Wiring Diagram**

FILE NAME	SIZE	SHEET	OF	DRAWING #	REV
8510_0092.vsd	B	2	2	8510-0092	-



**Transformer Specifications for the Enhanced Hot Water Drill**

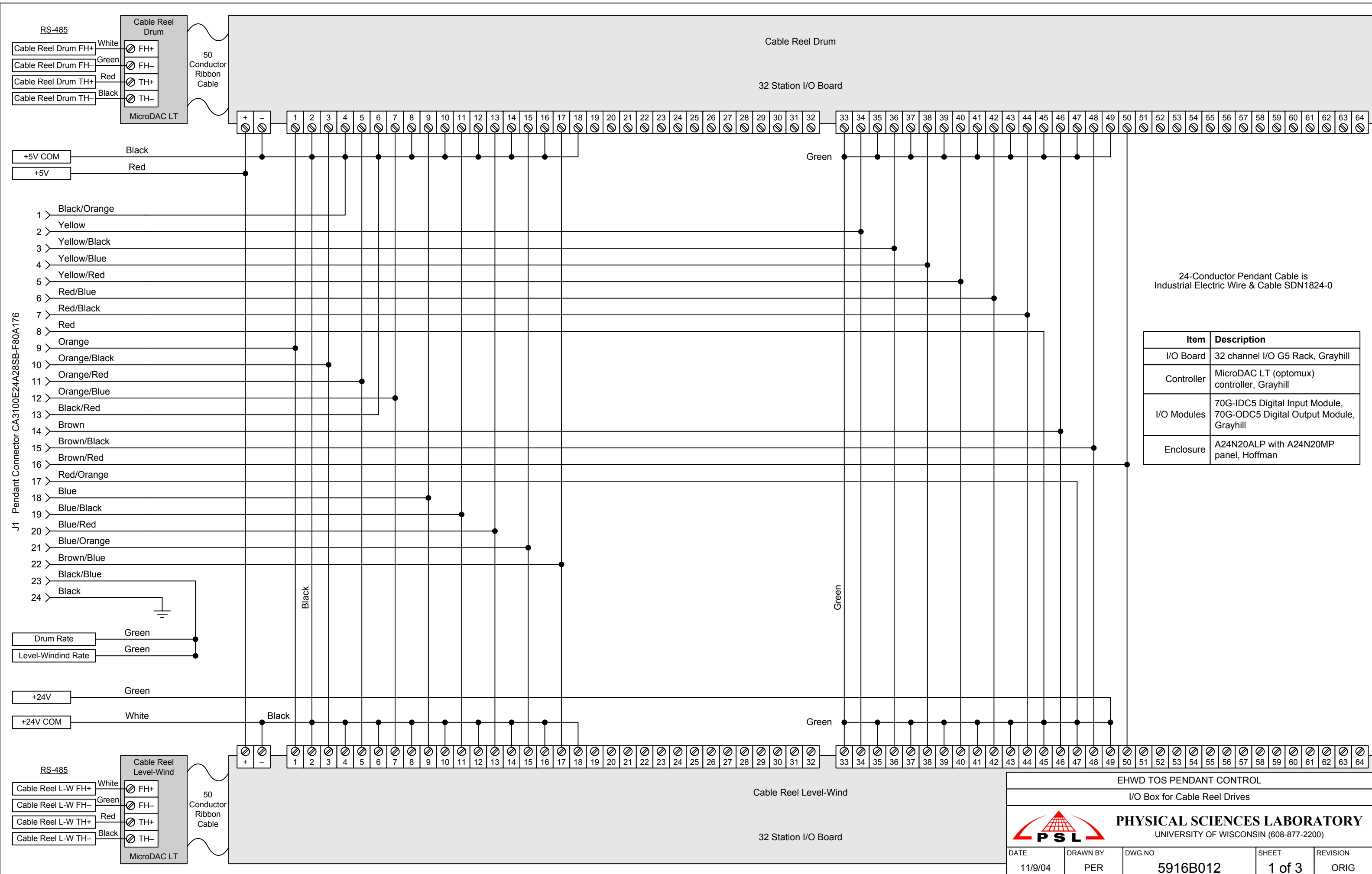
Revision Date:	10/28/02
Last revised by:	Koch/Dirix/Berry

MDS or Application	Item	Description	Rating	Efficiency	Application - Loads	MFG.	Model	Height	Width	Depth	Weight	Mounting	Quantity	Price (US\$ ea)	Total (US\$)
								in.	in.	in.	lbs.				
<b>High Pressure Pump (HPP)</b>															
	Transformer	3 480 to 480Y	75 KVA	96.36%	2 MainPumps	SQUARE-D	75T145HDIT	37	30	20	550	Floor	2	5,951.00	11,902.00
	Transformer	1 480 to 120/240	25 KVA	96.36%	ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	1	2,646.00	2,646.00
<b>Main Heating Plant (MHP)</b>															
<b>MDSs 1 through 4</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	Main Heaters Furnace Outlets (120/240) Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	4	2,646.00	10,584.00
<b>Pre-Heater System (PHS)</b>															
	Transformer	1 480 to 120/240	37.5 KVA	96.36%	WaterHeaters(Model 75) WaterHeaters(Stingers) ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	37S3H	30	20	20	325	Floor	1	3,003.00	3,003.00
<b>Rodriguez Well System (RWS)</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	WaterHeaters(Stingers) WaterHeaterPump(2x2HP) Winch/Motor ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	1	2,646.00	2,646.00
<b>Drill Control Center (DCC)</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	1	2,646.00	2,646.00
<b>Tower Operations Structure #1 (TOS-1)</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	2	2,646.00	5,292.00
<b>Tower Operations Structure #2 (TOS-2)</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	2	2,646.00	5,292.00
<b>Seasonal Equipment Workshop (SEW)</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	1	2,646.00	2,646.00
<b>Optical Module Lab (OML)</b>															
	Transformer	1 480 to 120/240	50 KVA	96.36%	Vacuum Pump DAQ ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	50S3H	30	20	20	350	Floor	1	3,652.00	3,652.00
<b>Tower Operations Workshop (TOW)</b>															
	Transformer	1 480 to 120/240	25 KVA	96.36%	ElectricHeaters Outlets (120/240) Furnace Lights	SQUARE-D	25S40F	20	15	13.5	402	Wall	1	2,646.00	2,646.00
<b>Spares</b>															
	Transformer	3 480 to 480Y	75 KVA	96.36%		SQUARE-D	75T145HDIT	37	30	20	550	Floor	1	5,951.00	5,951.00
	Transformer	1 480 to 120/240	50 KVA	96.36%		SQUARE-D	50S3H	30	20	20	350	Floor	1	3,652.00	3,652.00
	Transformer	1 480 to 120/240	37.5 KVA	96.36%		SQUARE-D	37S3H	30	20	20	325	Floor	1	3,003.00	3,003.00
	Transformer	1 480 to 120/240	25 KVA	96.36%		SQUARE-D	25S40F	20	15	13.5	402	Wall	1	2,646.00	2,646.00
<b>Total</b>											<b>6068</b>	<b>Total</b>		<b>\$64,555.00</b>	

**Motor Drive Specifications for the Enhanced Hot Water Drill**

Revision Date: 10/28/02  
 Last revised by: Keith DeWaters

MDS	Item	Application - Loads	Integrated or Separate motor	Submersible	Motor Location	Ambient Temp C	Ambient Temp F	Motor Output Hp	Input Voltage Volts	# of phases	Line Length m	Line Length ft	Lead Length m	Lead Length ft	LC Filter	Reactor	RFI Filter	Dynamic Brake W	Pendant Control	Feedback	MFG.	Model	Rating Hp	Efficiency %	Height in.	Width in.	Depth in.	Weight lbs.	Quantity	Price (\$\$\$)	Total (\$\$\$)	Notes																														
High Pressure Pump (HPP)	Flux Vector Drive	High Pressure Pumps	Separate	No	Indoors	21.1	70	50	480	3	20	66	10	33	No	Line Reactor	Line	No	One - 24VDC	Yes	Unico	1100	50	92.0	21.2	10.84	13	66	4	8,500.00	34,000.00																															
	Flux Vector Drive	Primer Pumps	Integrated	Yes	Outdoors	23.9	75	2	480	3	20	66	15	49	Lead	No	No	No	No	No	Unico	1105	3	92.0	12.31	9.5	7.75	17	4	3,000.00	12,000.00																															
Main Heating Plant (MHP)																																																											0.00			
Pre-Heater System (PHS)																																																											0.00			
Rodriguez Well System (RWS)	Flux Vector Drive	Water Heater Pump (heaters)	Separate	No	Indoors	21.1	70	7.5	480	3	20	66	10	33	No	No	No	No	24 VDC	No	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	4,000.00	4,000.00																															
	Flux Vector Drive	Water Heater Pump (heaters)	Separate	No	Indoors	21.1	70	5.0	480	3	20	66	10	33	No	No	No	No	No	No	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	4,000.00	4,000.00																															
	Flux Vector Drive	Water Heater Pump (heaters)	Separate	No	Indoors	21.1	70	3.0	480	3	20	66	10	33	No	No	No	No	No	No	Unico	1105	3	92.0	12.31	9.5	7.75	17	2	3,000.00	6,000.00																															
	Flux Vector Drive	Water Heater Pump (heaters)	Separate	No	Indoors	21.1	70	3.0	480	3	20	66	10	33	No	No	No	No	No	No	Unico	1105	3	92.0	12.31	9.5	7.75	17	2	3,000.00	6,000.00																															
Rodriguez Well System (RWS)	Flux Vector Drive	Rodriguez Well Pump	Integrated	Yes	Outdoors	0.0	32	7.5	480	3	10	33	100	328	Lead	No	Yes	No	No	No	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	4,000.00	4,000.00																															
	Flux Vector Drive	Hose reel	Separate	No	Outdoors	-45.6	-50	2	480	3	10	33	15	49	No	No	No	100 120 VAC	No	Unico	1105	3	92.0	12.31	9.5	7.75	17	1	3,000.00	3,000.00																																
	Flux Vector Drive	Water Heater Pump (heaters)	Separate	No	Indoors	21.1	70	7.5	480	3	10	33	10	33	No	No	No	No	No	No	Unico	1105	10	92.0	15.16	9.5	8.75	24	2	4,000.00	8,000.00																															
	Flux Vector Drive	Tank transfer pumps	Integrated	Yes	Outdoors	10.0	50	2	480	3	10	33	10	33	No	No	No	No	No	No	Unico	1105	3	92.0	12.31	9.5	7.75	17	2	3,000.00	6,000.00																															
Drill Control Center (DCC)																																																											0.00			
Tower Operations Structure #1 (TOS-1)																																																												0.00		
Tower Operations Structure #1 (TOS-1)	Flux Vector Drive	Return water pump	Integrated	Yes	Outdoors	0.0	32	50	480	3	335	1099	90	295	Lead	Line	Yes	No	No	No	Unico	1100	50	92.0	21.2	10.84	13	66	1	7,000.00	7,000.00																															
	Flux Vector Drive	Hose reel drum	Separate	No	Outdoors	-45.6	-50	25	480	3	335	1099	25	82	Lead	Line	Yes	300 signals	Resolver	Unico	1105	25	92.0	15.16	9.5	8.75	24	1	7,000.00	7,000.00																																
	Flux Vector Drive	Hose reel level wind	Separate	No	Outdoors	-45.6	-50	10.0	480	3	335	1099	25	82	Lead	No	Yes	No	120V signals	Resolver	Unico	1105	3	92.0	12.31	9.5	7.75	17	1	4,000.00	4,000.00																															
	Flux Vector Drive	Return water hose winch	Separate	No	Outdoors	-45.6	-50	10.0	480	3	335	1099	20	66	Lead	No	Yes	300 signals	Resolver	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	5,000.00	5,000.00																																
	Flux Vector Drive	Drill head cable winch	Separate	No	Outdoors	-45.6	-50	15.0	480	3	335	1099	20	66	Lead	Line	Yes	2000 signals	Resolver	Unico	1105	25	92.0	15.16	9.5	8.75	24	1	7,000.00	7,000.00																																
	Flux Vector Drive	Drill head cable winch level wind	Separate	No	Outdoors	-45.6	-50	5.0	480	3	335	1099	20	66	Lead	No	Yes	No	120V signals	Resolver	Unico	1105	3	92.0	12.31	9.5	7.75	17	1	4,000.00	4,000.00																															
	Flux Vector Drive	Deployment winch	Separate	No	Outdoors	-45.6	-50	25.0	480	3	335	1099	20	66	Lead	Line	Yes	6000 signals	No	Unico	1100	50	92.0	21.2	10.84	13	66	1	8,500.00	8,500.00																																
	Flux Vector Drive	Tower hoist	Separate	No	Outdoors	-45.6	-50	7.5	480	3	335	1099	10	33	No	No	Yes	300 signals	No	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	5,000.00	5,000.00																																
	Tower Operations Structure #2 (TOS-2)																																																													0.00
	Tower Operations Structure #2 (TOS-2)	Flux Vector Drive	Return water pump	Integrated	Yes	Outdoors	0.0	32	50	480	3	335	1099	90	295	Lead	Line	Yes	No	No	No	Unico	1100	50	92.0	21.2	10.84	13	66	1	7,000.00	7,000.00																														
Flux Vector Drive		Hose reel drum	Separate	No	Outdoors	-45.6	-50	25	480	3	335	1099	25	82	Lead	Line	Yes	300 signals	Resolver	Unico	1105	25	92.0	15.16	9.5	8.75	24	1	7,000.00	7,000.00																																
Flux Vector Drive		Hose reel level wind	Separate	No	Outdoors	-45.6	-50	10.0	480	3	335	1099	25	82	Lead	No	Yes	No	120V signals	Resolver	Unico	1105	3	92.0	12.31	9.5	7.75	17	1	4,000.00	4,000.00																															
Flux Vector Drive		Return water hose winch	Separate	No	Outdoors	-45.6	-50	10.0	480	3	335	1099	20	66	Lead	No	Yes	300 signals	Resolver	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	5,000.00	5,000.00																																
Flux Vector Drive		Drill head cable winch	Separate	No	Outdoors	-45.6	-50	15.0	480	3	335	1099	20	66	Lead	Line	Yes	2000 signals	Resolver	Unico	1105	25	92.0	15.16	9.5	8.75	24	1	7,000.00	7,000.00																																
Flux Vector Drive		Drill head cable winch level wind	Separate	No	Outdoors	-45.6	-50	5.0	480	3	335	1099	20	66	Lead	No	Yes	No	120V signals	Resolver	Unico	1105	3	92.0	12.31	9.5	7.75	17	1	4,000.00	4,000.00																															
Flux Vector Drive		Deployment winch	Separate	No	Outdoors	-45.6	-50	25.0	480	3	335	1099	20	66	Lead	Line	Yes	6000 signals	No	Unico	1100	50	92.0	21.2	10.84	13	66	1	8,500.00	8,500.00																																
Flux Vector Drive		Tower hoist	Separate	No	Outdoors	-45.6	-50	7.5	480	3	335	1099	10	33	No	No	Yes	300 signals	No	Unico	1105	10	92.0	15.16	9.5	8.75	24	1	5,000.00	5,000.00																																
Seasonal Equipment Workshop (SEW)																																																													0.00	
Optical Module Lab (OML)																																																													0.00	
Tower Operations Workshop (TOW)																																																														0.00
Spare Drives	Flux Vector Drive																																																													
	Flux Vector Drive																																																													
	Flux Vector Drive																																																													
	Flux Vector Drive																																																													
	Flux Vector Drive																																																													
																										<b>Total</b>	<b>1154</b>			<b>Total</b>	<b>290,500.00</b>																															



J1 Pendant Connector CA3100E24A28SB-F80A176

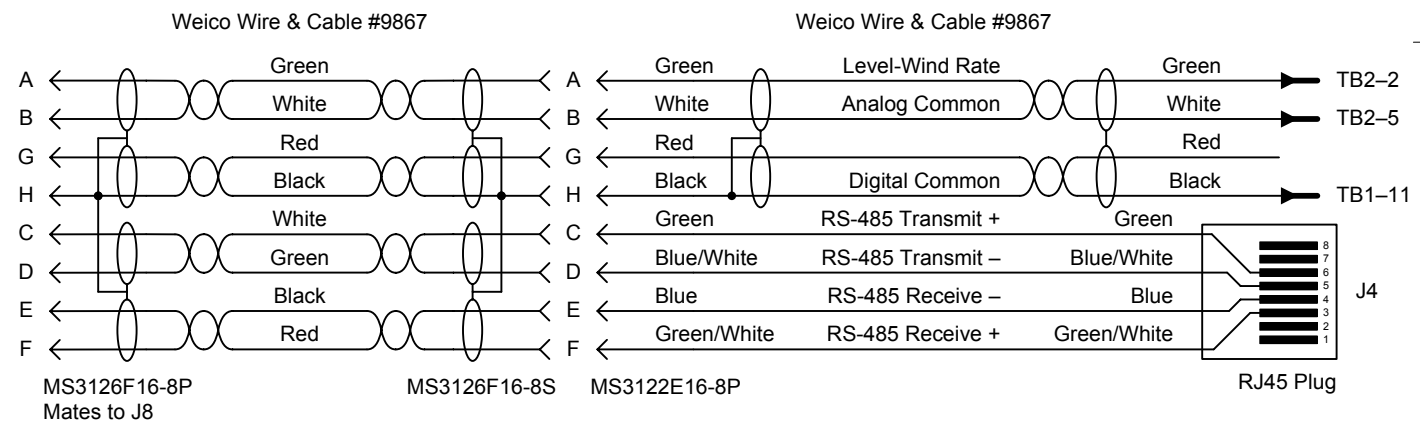
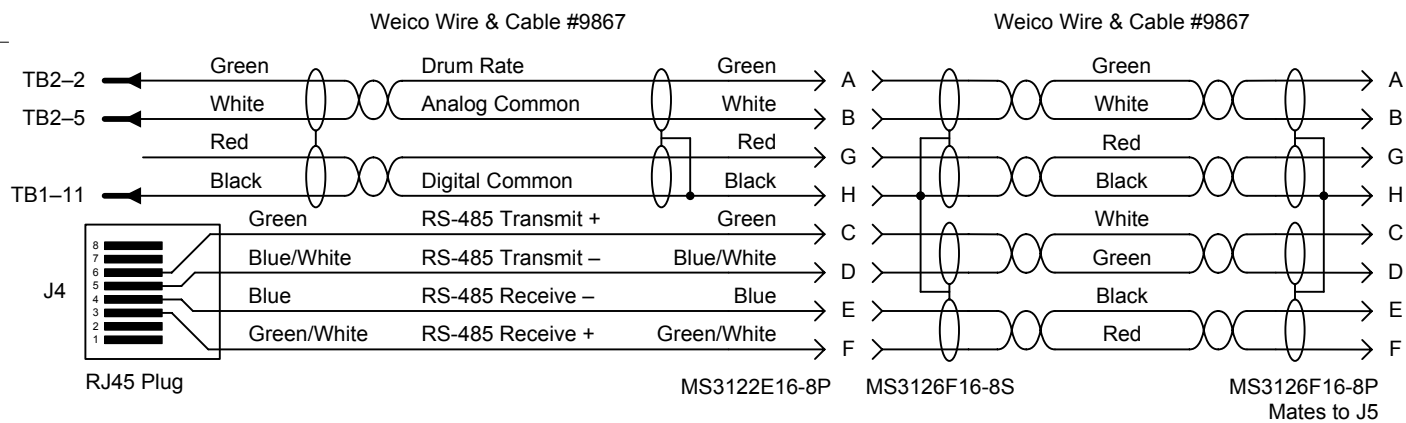
24-Conductor Pendant Cable is Industrial Electric Wire & Cable SDN1824-0

EHWD TOS PENDANT CONTROL  
I/O Box for Cable Reel Drives

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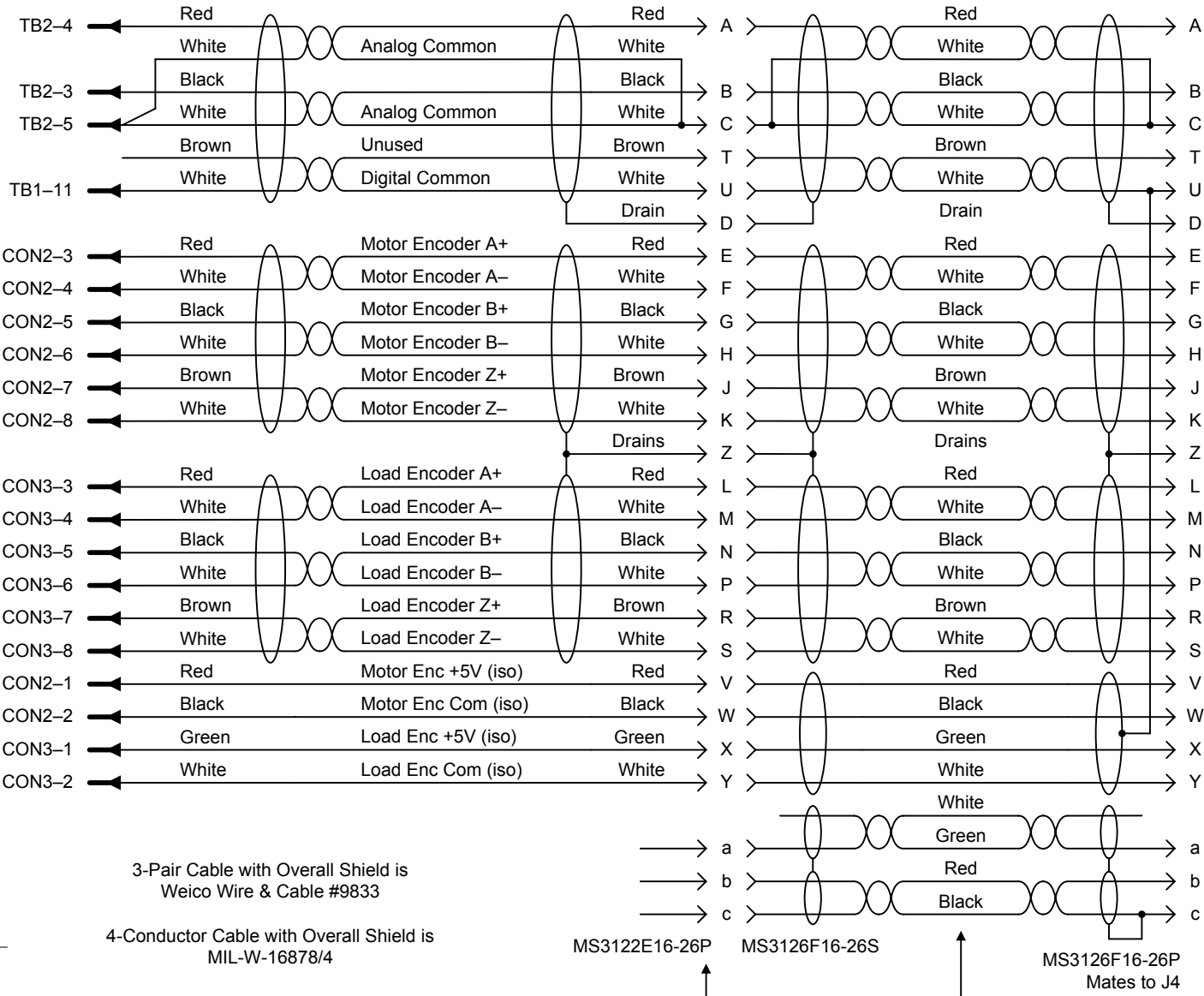
DATE 11/9/04	DRAWN BY PER	DWG NO 5916B012	SHEET 1 of 3
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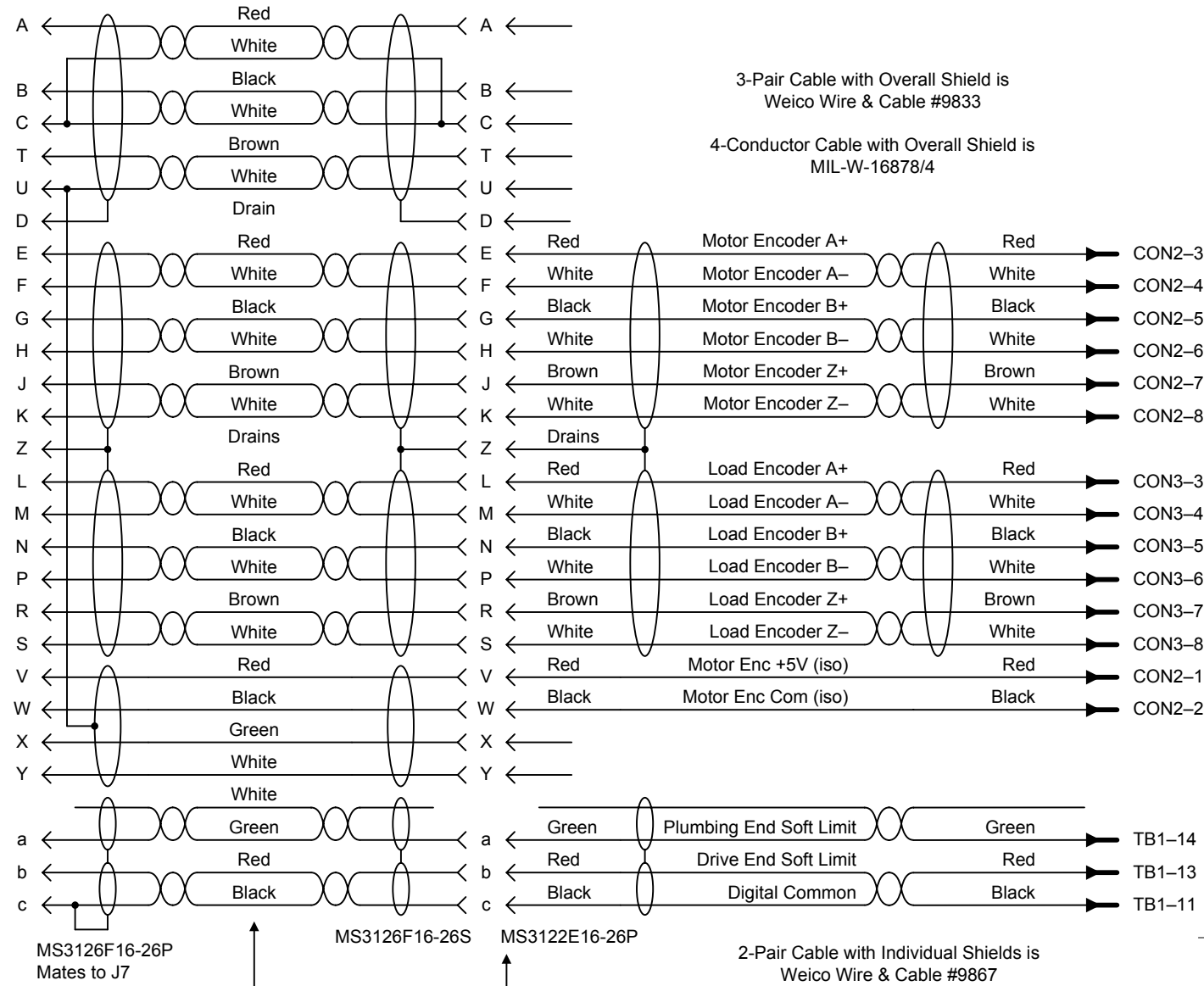
Note: Unico "Guide to Installation, Troubleshooting, and Maintenance", 1000.40-03 10/00, page 72 of 98, erroneously lists RJ45 pin 5 as Transmit + and RJ45 pin 6 as Transmit -

Cable Reel Drum Motor Drive (V1)



Panel Connectors on Cable Reel Drum Motor Drive (V1)      Cables From I/O Box to Cable Reel Drum Motor Drive

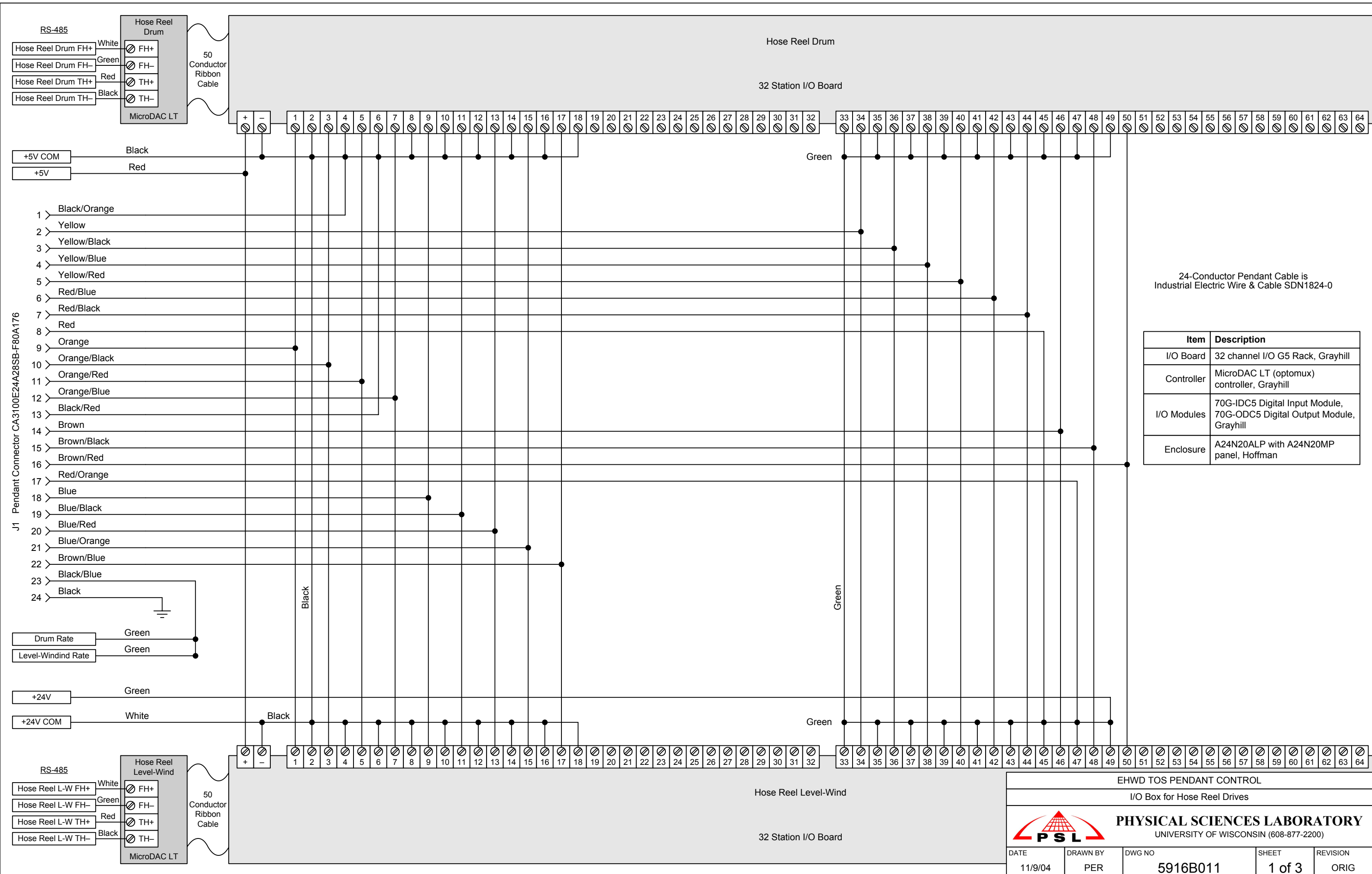
Cable Reel Level-Wind Motor Drive (V2)



Cables From I/O Box to Cable Reel Level-Wind Motor Drive      Panel Connectors on Cable Reel Level-Wind Motor Drive (V2)

Connector	Dust Cap
MS3126F16 Straight Plug	MS3180-16CA

EHWD TOS PENDANT CONTROL				
I/O Box for Cable Reel Drives				
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J1 Pendant Connector CA3100E24A28SB-F80A176

24-Conductor Pendant Cable is Industrial Electric Wire & Cable SDN1824-0

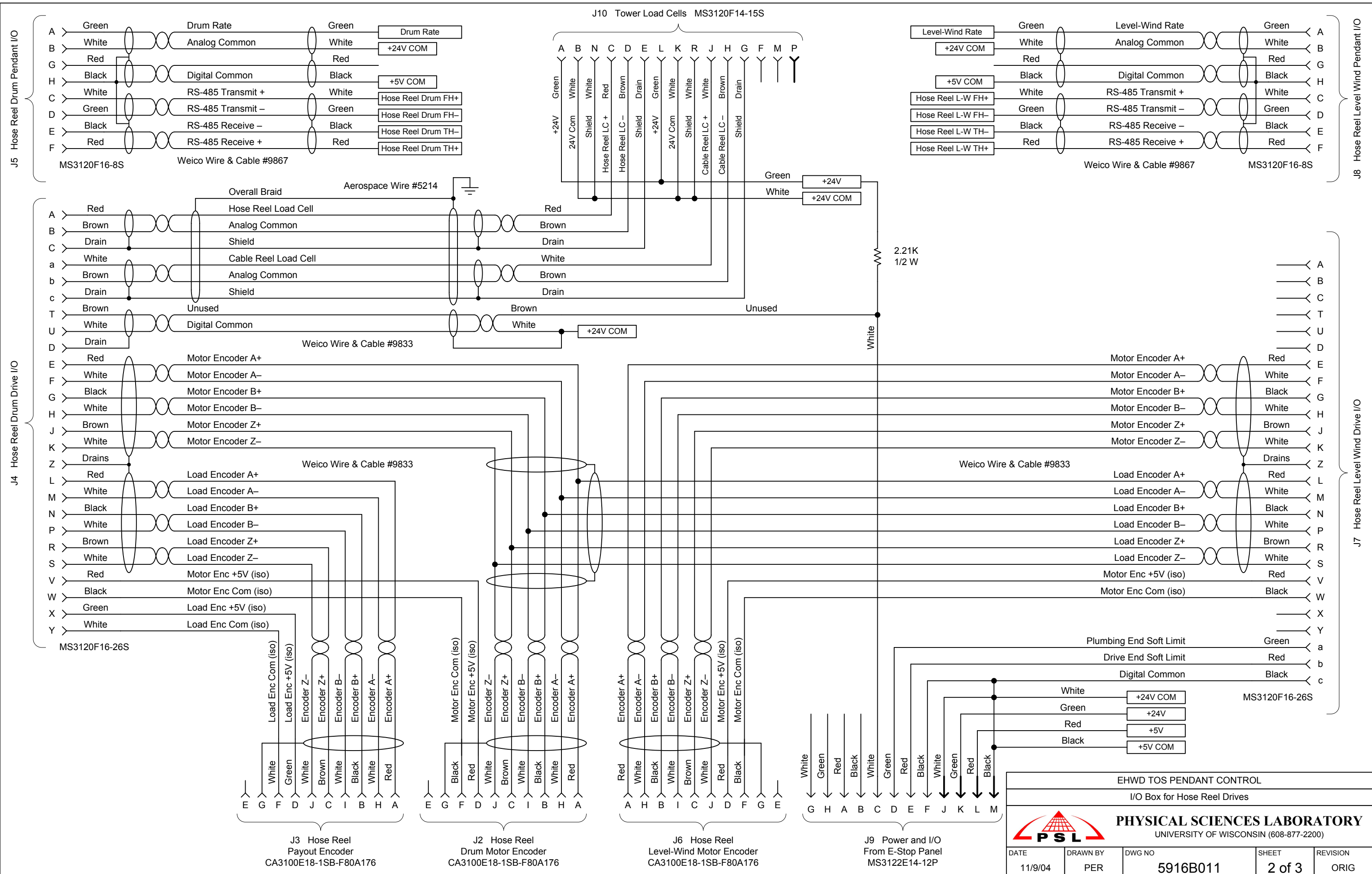
Item	Description
I/O Board	32 channel I/O G5 Rack, Grayhill
Controller	MicroDAC LT (optomux) controller, Grayhill
I/O Modules	70G-IDC5 Digital Input Module, 70G-ODC5 Digital Output Module, Grayhill
Enclosure	A24N20ALP with A24N20MP panel, Hoffman

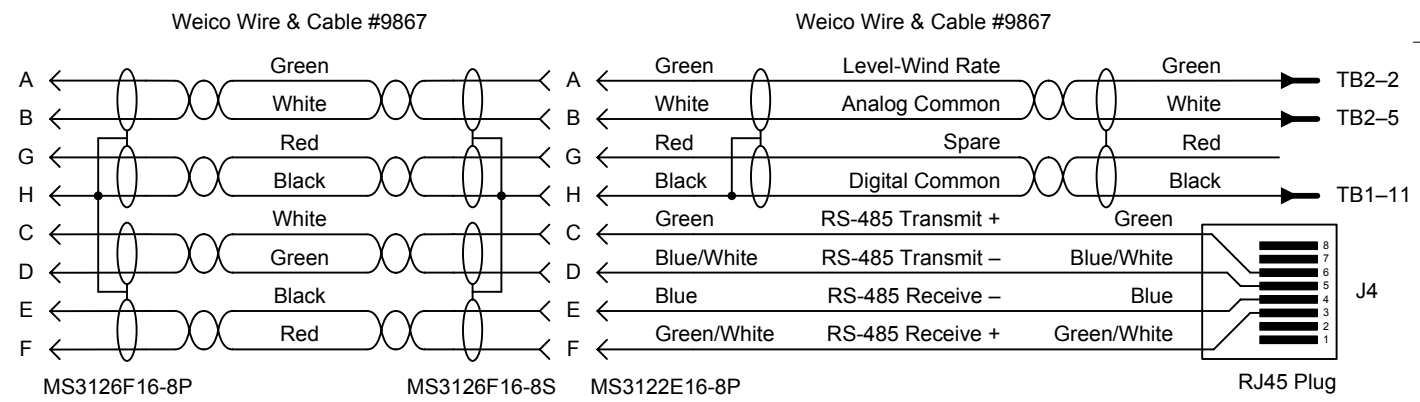
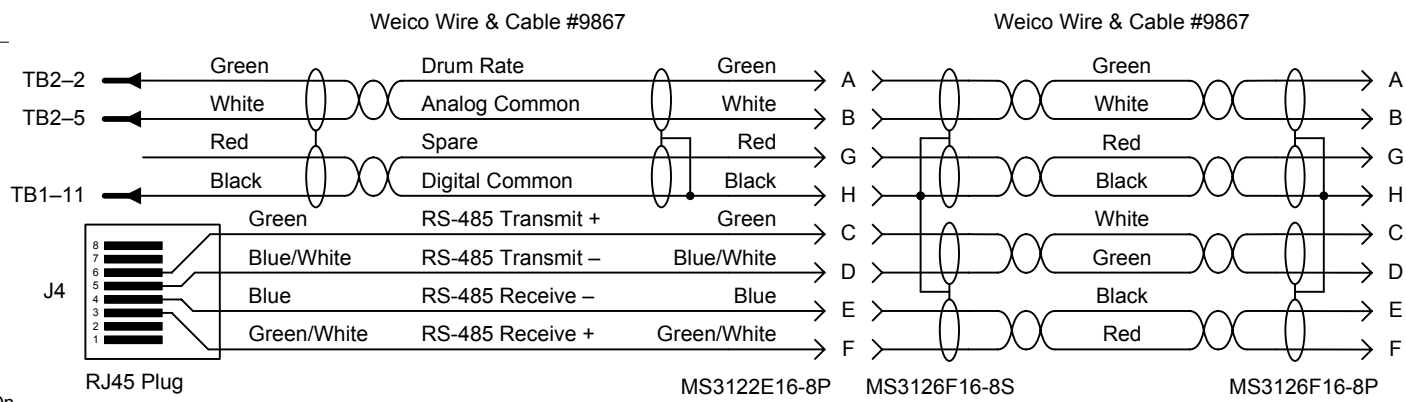
EHWD TOS PENDANT CONTROL  
I/O Box for Hose Reel Drives

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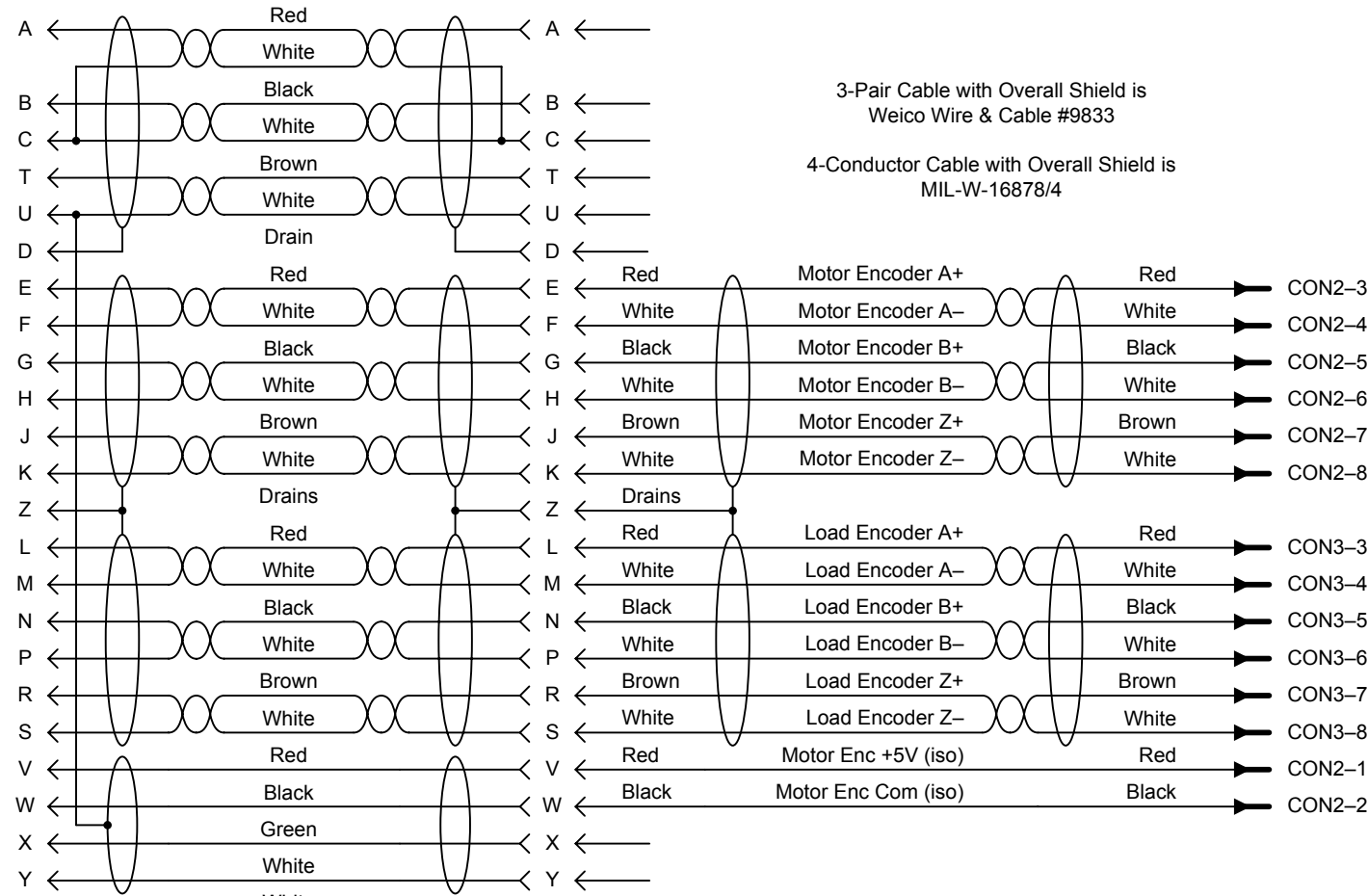
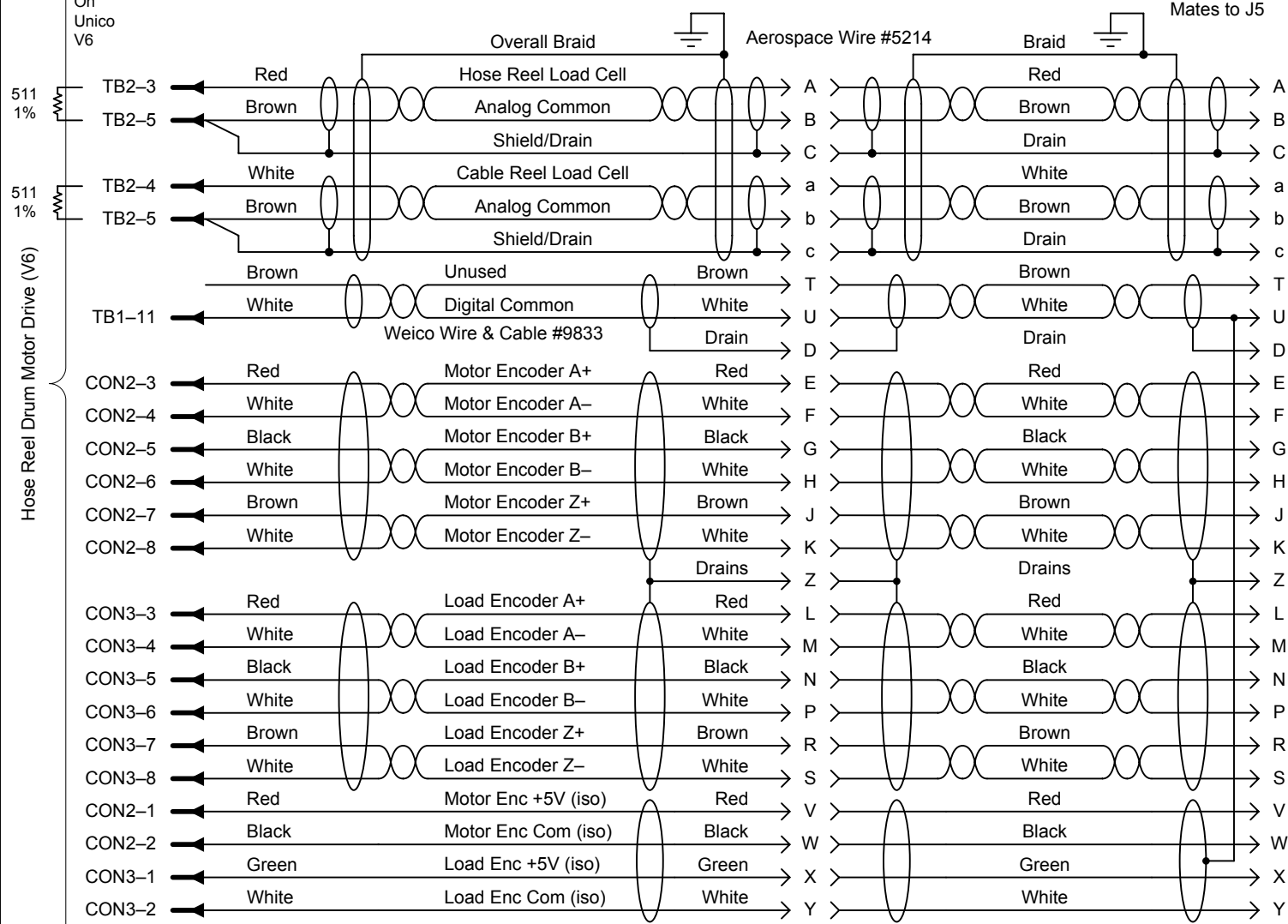
DATE 11/9/04	DRAWN BY PER	DWG NO 5916B011	SHEET 1 of 3	REVISION ORIG
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Note: Unico "Guide to Installation, Troubleshooting, and Maintenance", 1000.40-03 10/00, page 72 of 98, erroneously lists RJ45 pin 5 as Transmit + and RJ45 pin 6 as Transmit -



Panel Connectors on Hose Reel Drum Motor Drive (V6)

Cables From I/O Box to Hose Reel Drum Motor Drive

Cables From I/O Box to Hose Reel Level-Wind Motor Drive


Panel Connectors on Hose Reel Level-Wind Motor Drive (V5)

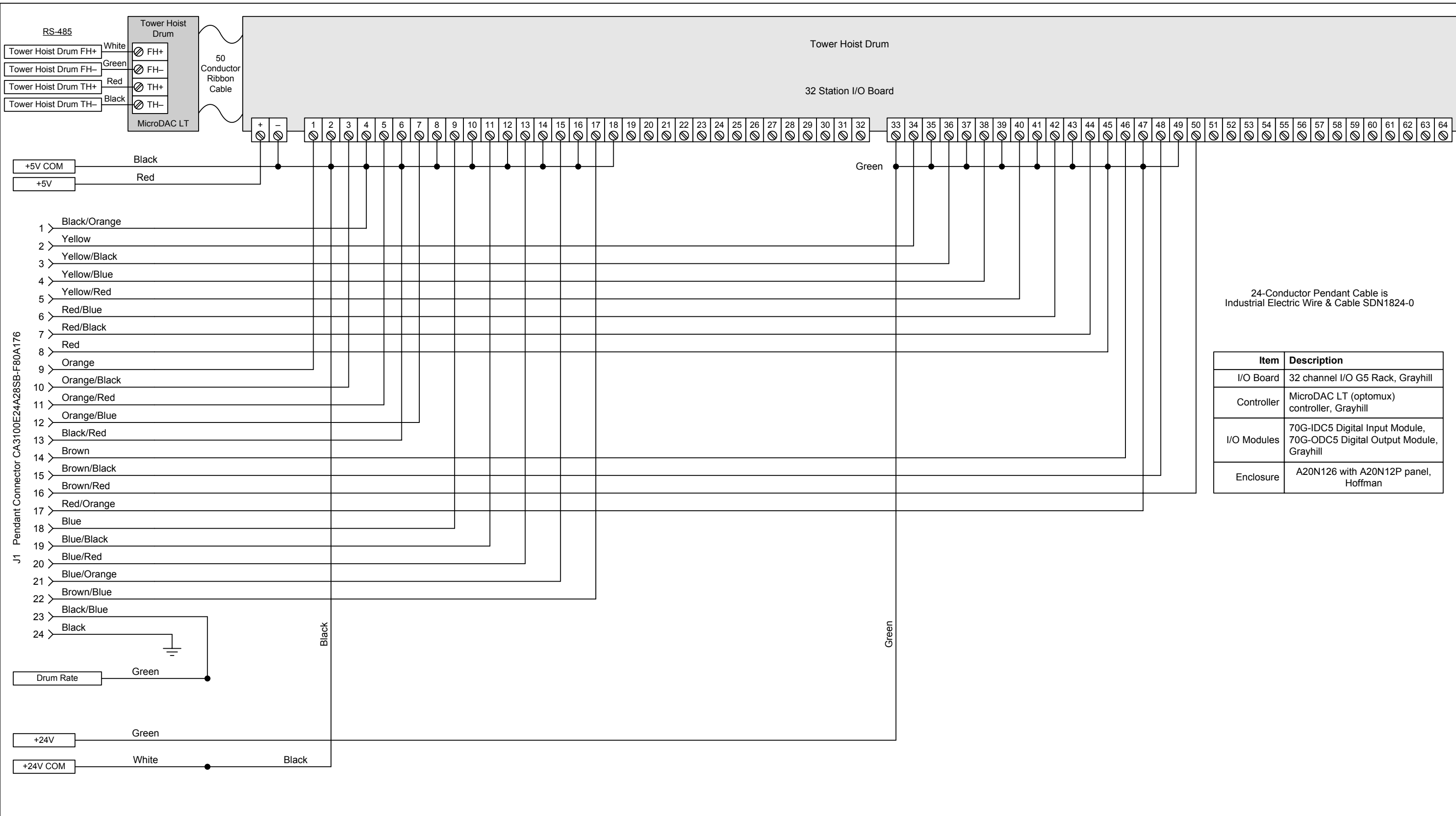
3-Pair Cable with Overall Shield is Weico Wire & Cable #9833

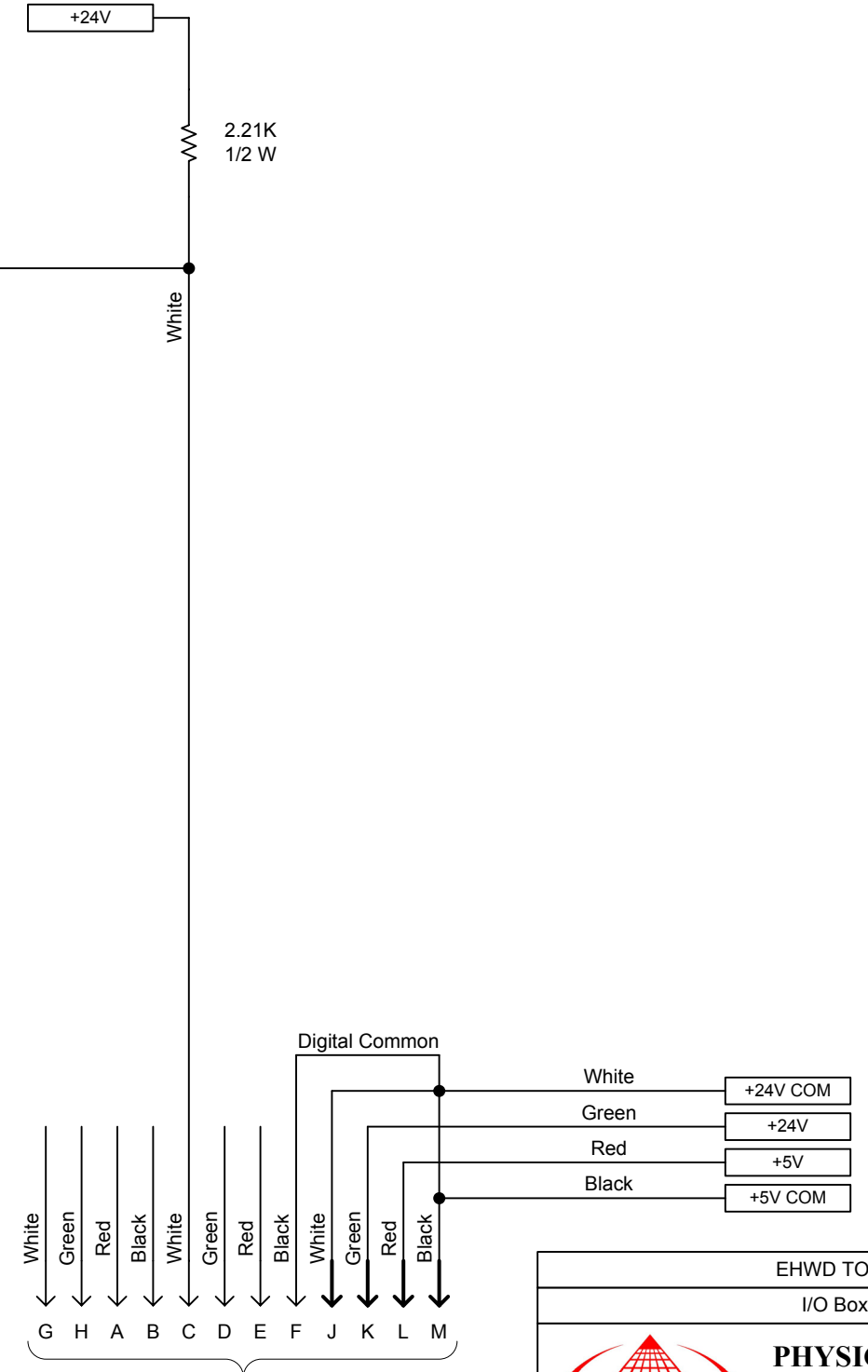
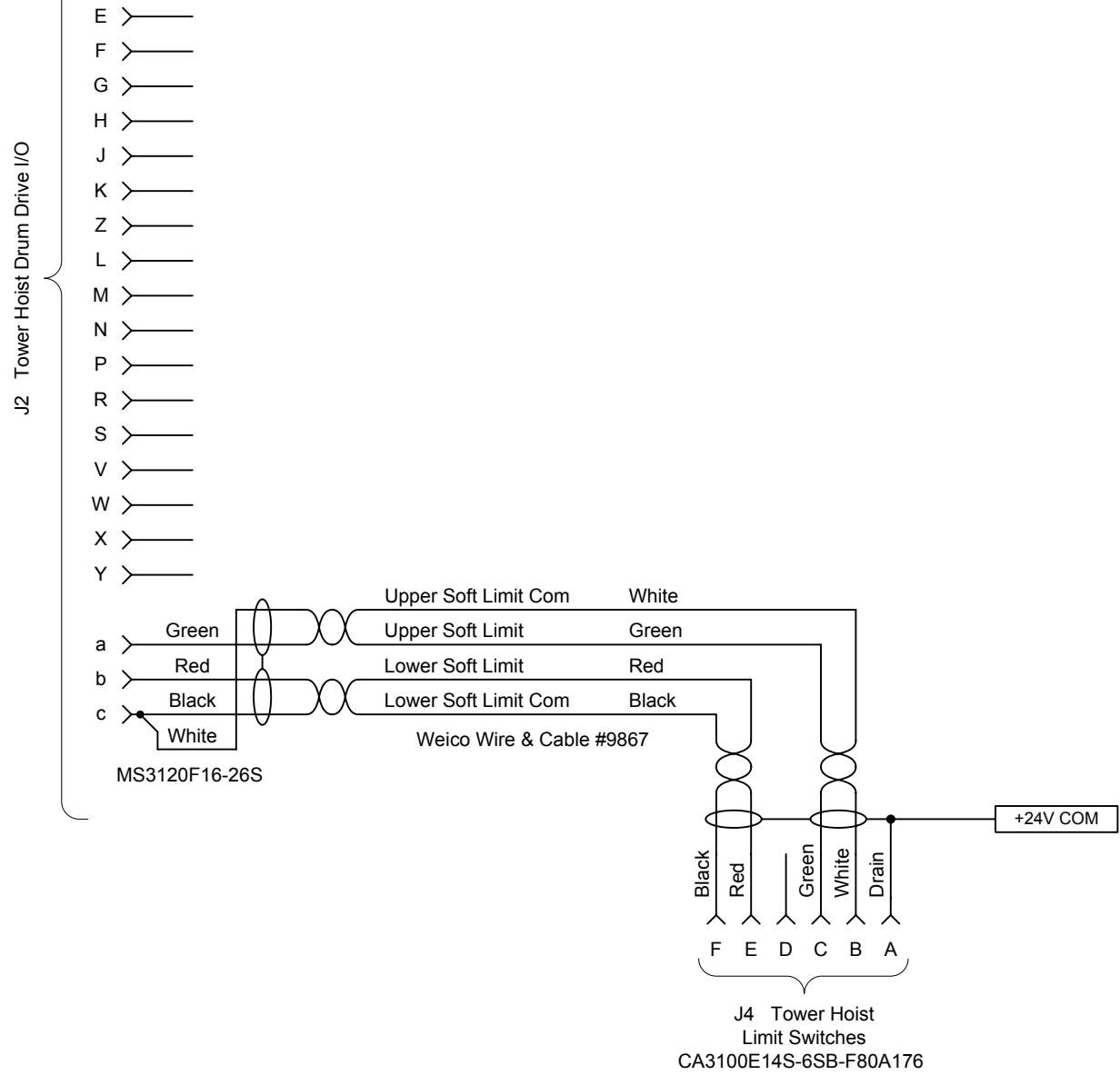
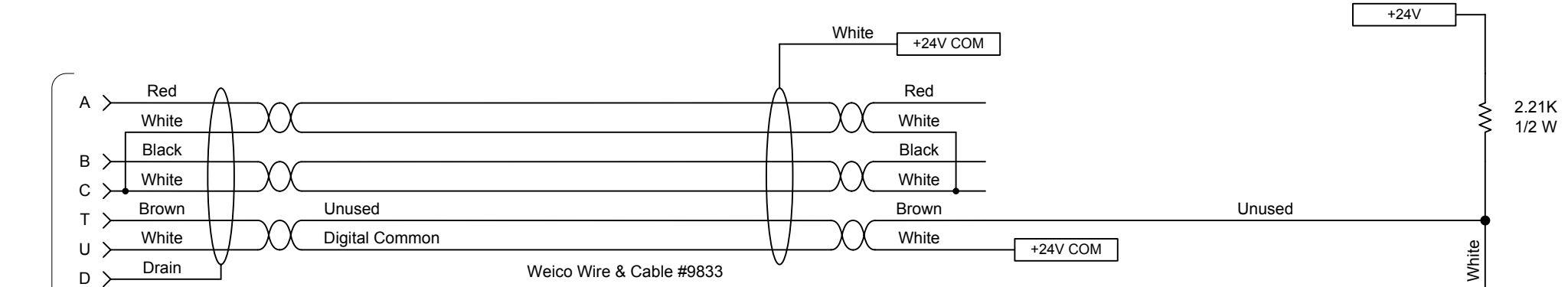
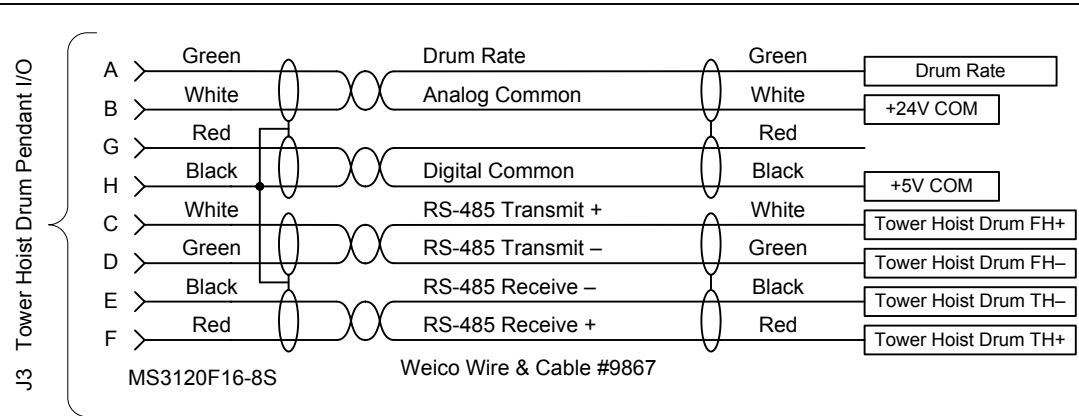
4-Conductor Cable with Overall Shield is MIL-W-16878/4

2-Pair Cable with Individual Shields is Weico Wire & Cable #9867

Connector	Dust Cap
MS3126F16 Straight Plug	MS3180-16CA


EHWD TOS PENDANT CONTROL				
I/O Box for Hose Reel Drives				
				
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EHWD TOS PENDANT CONTROL

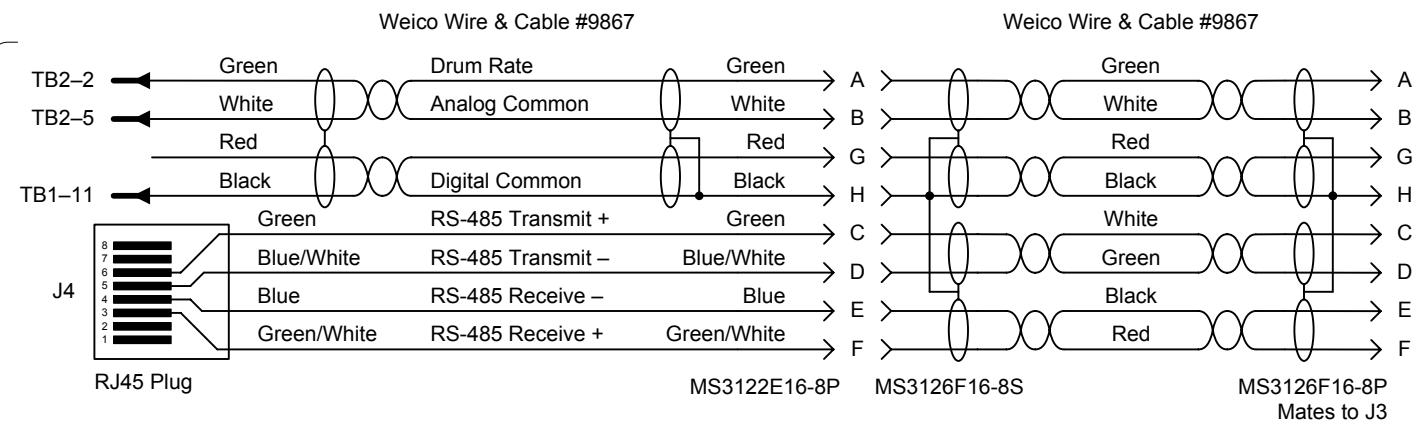
I/O Box for Tower Hoist Drive



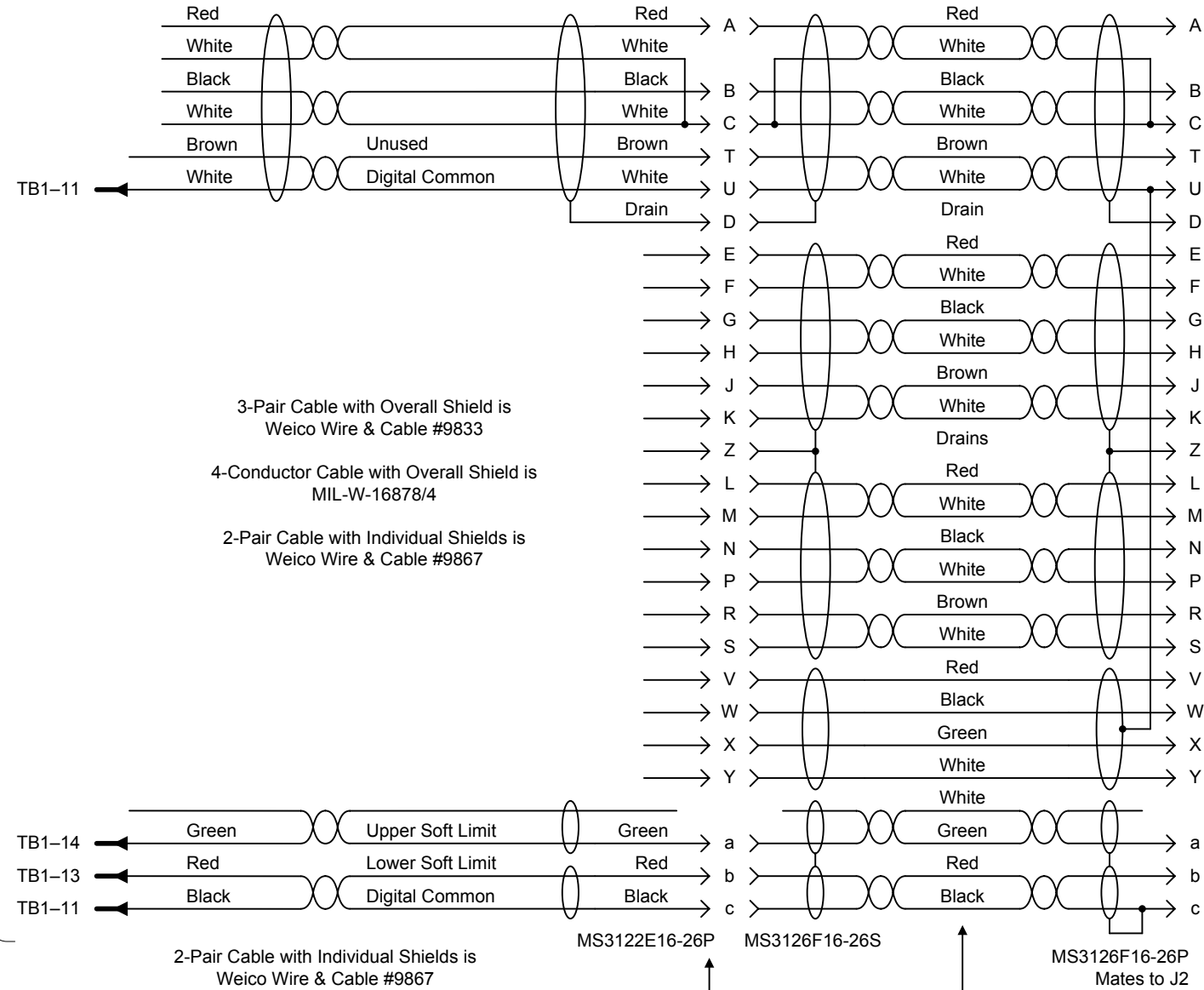
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Tower Hoist Drum Motor Drive (V7)



Note: Unico "Guide to Installation, Troubleshooting, and Maintenance", 1000.40-03 10/00, page 72 of 98, erroneously lists RJ45 pin 5 as Transmit + and RJ45 pin 6 as Transmit -




3-Pair Cable with Overall Shield is Weico Wire & Cable #9833  
 4-Conductor Cable with Overall Shield is MIL-W-16878/4  
 2-Pair Cable with Individual Shields is Weico Wire & Cable #9867

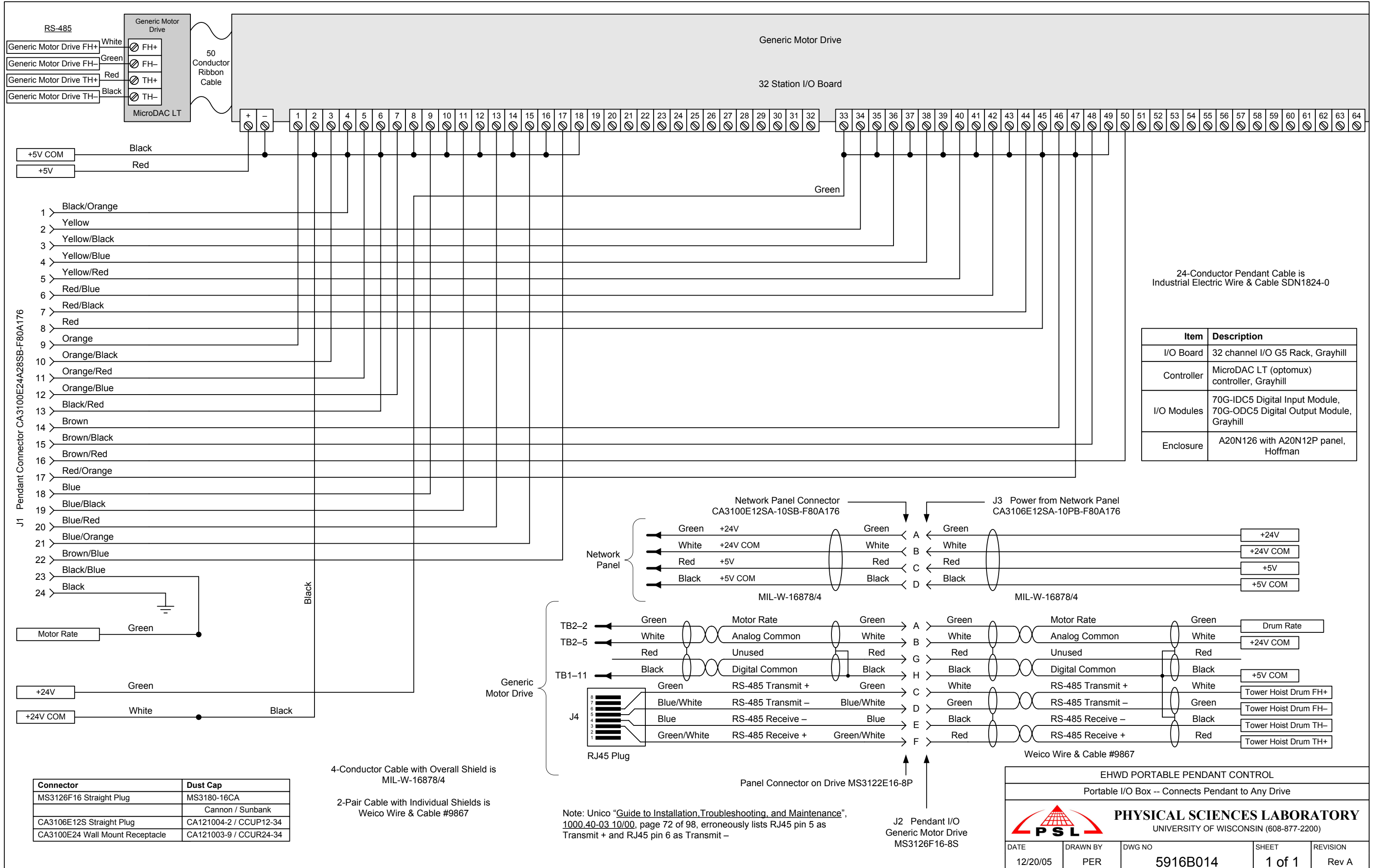
2-Pair Cable with Individual Shields is Weico Wire & Cable #9867

Panel Connectors on Tower Hoist Drum Motor Drive (V7)

Cables From I/O Box to Tower Hoist Drum Motor Drive

Connector	Dust Cap
MS3126F16 Straight Plug	MS3180-16CA

EHWD TOS PENDANT CONTROL				
I/O Box for Tower Hoist Drive				
 <b>PHYSICAL SCIENCES LABORATORY</b> UNIVERSITY OF WISCONSIN (608-877-2200)				
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J1 Pendant Connector CA3100E24A28SB-F80A176

24-Conductor Pendant Cable is Industrial Electric Wire & Cable SDN1824-0

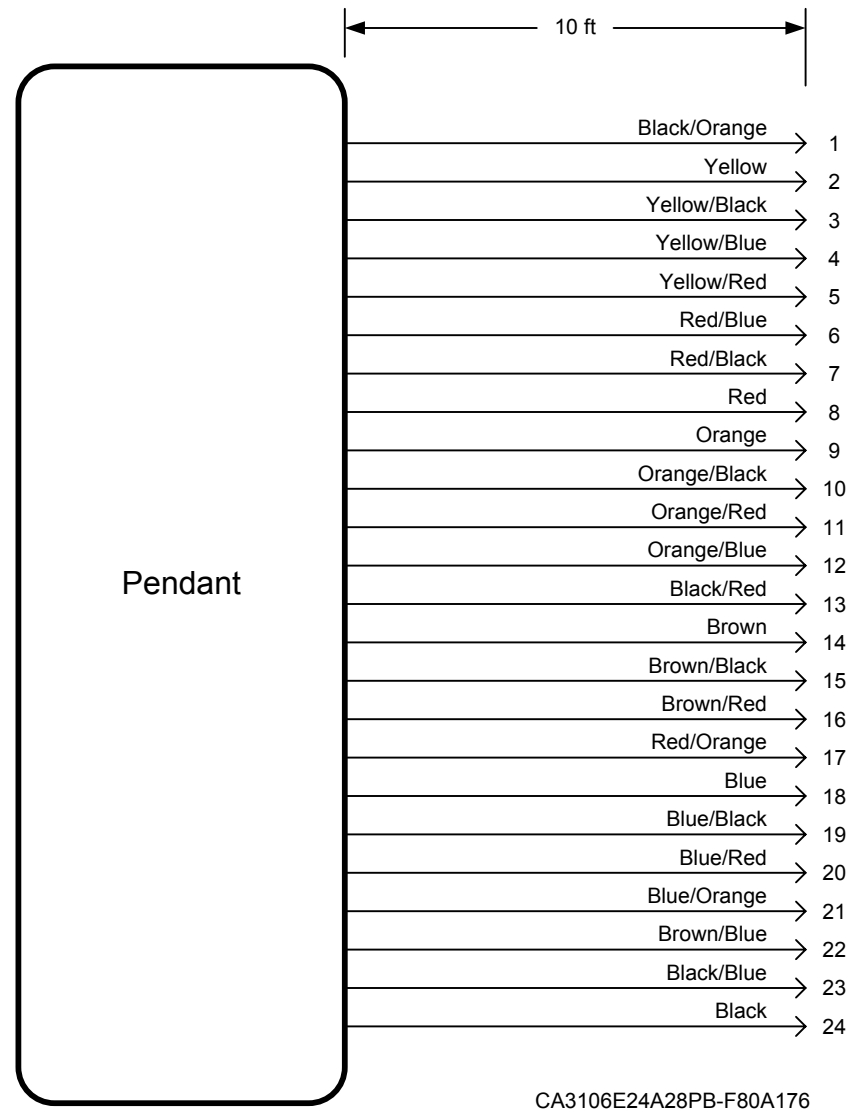
Item	Description
I/O Board	32 channel I/O G5 Rack, Grayhill
Controller	MicroDAC LT (optomux) controller, Grayhill
I/O Modules	70G-IDC5 Digital Input Module, 70G-ODC5 Digital Output Module, Grayhill
Enclosure	A20N126 with A20N12P panel, Hoffman

Connector	Dust Cap
MS3126F16 Straight Plug	MS3180-16CA
	Cannon / Sunbank
CA3106E12S Straight Plug	CA121004-2 / CCUP12-34
CA3100E24 Wall Mount Receptacle	CA121003-9 / CCUR24-34

4-Conductor Cable with Overall Shield is MIL-W-16878/4  
 2-Pair Cable with Individual Shields is Weico Wire & Cable #9867

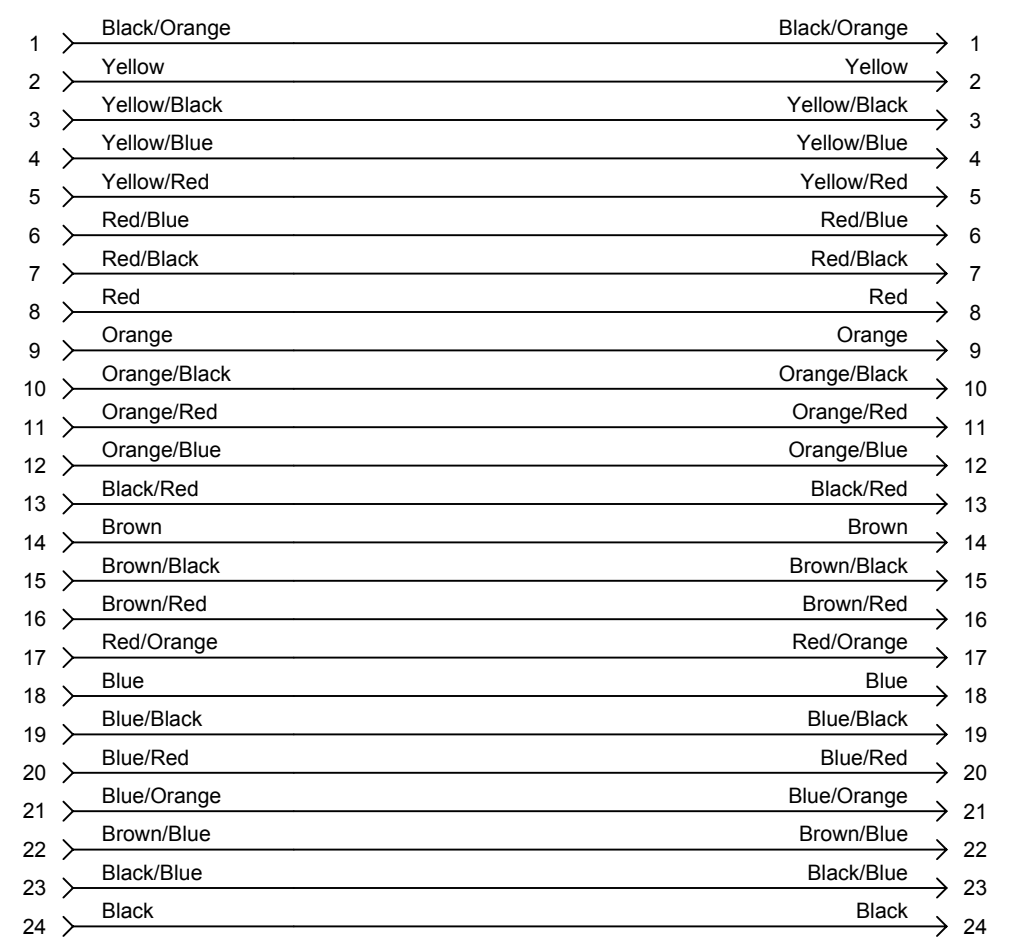
Note: Unico "Guide to Installation, Troubleshooting, and Maintenance", 1000.40-03 10/00, page 72 of 98, erroneously lists RJ45 pin 5 as Transmit + and RJ45 pin 6 as Transmit -

EHWD PORTABLE PENDANT CONTROL			
Portable I/O Box -- Connects Pendant to Any Drive			
		<b>PHYSICAL SCIENCES LABORATORY</b> UNIVERSITY OF WISCONSIN (608-877-2200)	
DATE	DRAWN BY	DWG NO	SHEET
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			Rev A



CA3106E24A28PB-F80A176

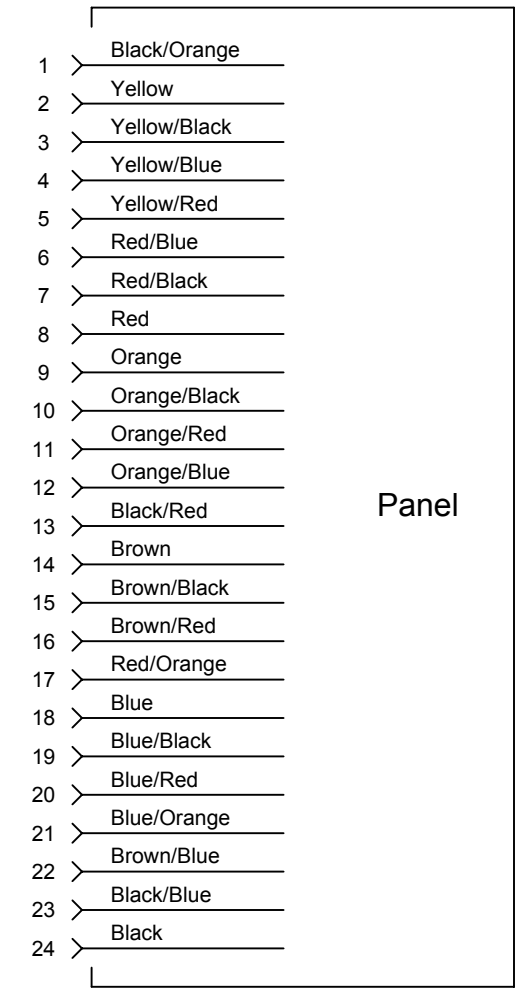
Pendant with integral 10ft cable



CA3100E24A28SB-F80A176

CA3106E24A28PB-F80A176

Pendant Extension Cable — Various Lengths




CA3100E24A28SB-F80A176

Pendant I/O Box Connection

24-Conductor Pendant Cable is  
Industrial Electric Wire & Cable SDN1824-0

Connector	Dust Cap
CA3106E24 Straight Plug	Cannon / Sunbank
CA3100E24 Wall Mount Receptacle	CA121004-9 / CCUP24-34
	CA121003-9 / CCUR24-34

EHWD PENDANT CONTROL				
Pendant Cabling				
		<b>PHYSICAL SCIENCES LABORATORY</b> UNIVERSITY OF WISCONSIN (608-877-2200)		
DATE 12/20/05	DRAWN BY PER	DWG NO 5916B015	SHEET 1 of 1	REVISION Rev A

# CALIBRATING TOWER LOAD CELLS USING INDEPENDENT LOAD CELL

TLB  
9.23.09

## System capacities

With 3 legs, side-pull chains and center-chain: 10,000 lb total load (indicated)

With 2 legs, side-pull chains only: 7,000 lb total load (indicated)

The following steps assume:

- 1) The independent load cell anchor blocks have been installed in the tower
- 2) The cable and hose are in the tower, ready to be tensioned
- 3) The system is in idle mode and the hose is full of water

## CALIBRATING BASICS

- 1) Gather people and supplies
  - a. 3 or 4 people
  - b. Independent Load Cell
  - c. Shackle box for Independent Load Cell
  - d. Chains and Rigging box for Independent Load Cell
  - e. Calibration spreadsheet running on laptop
- 2) Raw voltages, loads, and calibration constants are all read/entered at the Hose Reel Unico for both Hose and Cable load cell calibrations. The Cable Reel is slave to the hose reel. Look for ADC 1 and 2, in the 190-199 range of the Dictionary (Quit, quit, quit.... To "start" display, then 7. Help -> 10. Dictionary -> 190).
- 3) To calibrate the tower load cells, the Hose Reel Unico requires two pairs of numbers for each load cell:
  - a. Raw voltage @ min load
  - b. Raw voltage @ max load

At zero load the raw voltage should be 2 V (not 0 V – at or near 0 V the Unico will enter a "Load Cell Fault", for instance if the cable were cut or disconnected). At max load the raw voltage should be 10 V. For each load cell, the nominal and acceptable values are:

	Hose Load Cell	Cable Load Cell
<b>Min Load</b>	0 lb (+100, -0)	0 lb (+100, -0)
<b>Voltage at Min Load</b>	2 V (+0.3, -0.3)	2 V (+0.3, -0.3)
<b>Max Load</b>	5,000 lb (+300, -300)	10,000 lb (+500, -500)
<b>Voltage at Max Load</b>	10 V (+0, -0.5)	10 V (+0, -0.5)

Note that these numbers are suggestions. If the voltage is outside these ranges, offset and span may need to be adjusted at the load cell amplifier.

If max load cannot be physically attained during calibration, a data set of voltage vs. load up to the max attainable load is collected, and from there a straight-line calibration curve is fit to extrapolate voltage vs. load to the max load.



Max load is not attainable during *hose* load cell calibration due to limitations of the hose (max safe tension for hose over crescent with 200-400 psi internal pressure is 2000 lb, and 1500 lb with zero internal pressure), so a curve is needed.

Max load is attainable during *cable* load cell calibration, but getting a data set in between min/max loads is recommended to verify linearity.

- 4) The calibration procedure is to set indicated loads and record load cell amplifier raw voltage (displayed on Hose Reel Unico) in the increasing direction, and then repeat in the decreasing direction. Calibration spreadsheet will give nominal indicated loads at which to collect data for calibration points, and has space to enter the recorded values.

## SETUP AND CALIBRATION PROCEDURE

- 5) Ensure Tower is properly secured to TOS and drill cable reel is anchored
  - a. Lower straps in place and tight (Tower base to TOS base)
  - b. Upper chain/straps in place and tight (Upper, rear Tower to TOS ISO corners)
  - c. Preferred to have larger 3" straps in place for this procedure (inside Tower I-beam uprights to TOS anchor pins, both sides of opening)
  - d. Drill Cable Reel anchors and chains in place and tight

**Caution:** For this procedure, there will be no down-hole load to increase the friction force between the Tower and snow to react the pulling force from the cable reel, so proper anchoring is essential.

- 6) Install 7000 lb hoist rings onto red anchor blocks (use 5/8" hex driver). Torque to 100 ft-lb.
- 7) Assemble independent load cell, shackles, and upper rigging near the hole on floor of TOS. Hook tower hoist to pear-shaped ring with shackle and use hoist to raise assembly.



- 8) Add another small shackle to pear-shaped ring with centering washers, hook end of drill cable to it and transfer weight of assembly to drill cable, but leave the hoist hook attached. Use cable reel pendant to position assembly as high as possible but so end-wrapping of drill cable stops ~12" short of wrapping onto upper sheave.
- 9) Verify bottom of bottommost shackle (large) is of sufficient height to maintain 30° or greater sling angles. Measure and enter dimensions in calibration spreadsheet to determine correct height. Nominal minimum height of 40" from floor. Leave cable in this position for now.

Note: See Appendix to calculate height without spreadsheet.

- 10) Zero load cell.
- 11) Enable Calibration Mode on Hose and Drill Cable Reel Unicos. This mode slows down the payout/take-up speeds to give fine control and activates a torque limit to limit overshoot.
  - a. Menu number xxx
  - b. Disable -> Enable

The Calibration Mode menu also displays load cell amplifier output voltage and inputs for entering the calibration constants on the Hose Reel Unico.

Briefly run pendants through speed range to verify low reel speed is activated. Return cable to initial position.

Note: Initial max pendant speed and torque limit settings should be:

	Hose Reel	Drill Cable Reel
Max pendant speed	0.5 m/min	0.5 m/min
Torque Limited to	??	54 ft-lb (73 N-m)

- 12) Hook up side-pull slings (endless, 1" width, 2-ply, 12,400 lb basket capacity). Loop through hoist rings and loop each end to the bottommost shackle, doubling up and halving the length (12 ft slings doubled up to 6 ft lengths). The slings allow some stretching and reduce the stiffness of the system, and should be tried first instead of chain.

Alternatively, side-pull chains (blue ends) are available. While someone holds the load cell assembly centered over the hole, loop each chain through the large bottommost shackle and down through the shackle on the respective hoist ring. Close loop by hooking end of chain to itself on a BLUE LINK ONLY (this assures 30°+ sling angles). By counting links from the end, make sure both side-pull chains are hooked on links that make them equal length to each other. Chain loop length should cause chains to be semi-taught but un-tensioned when the load cell is centered over the hole.

- 13) Hook up center-pull chain (all black). This chain also loops through the bottommost shackle between the side-pull slings/chains and anchors to a shackle on the red anchor block in front of the hole. Adjust length so that load cell is centered over hole.

Note: Centering of both the hose and cable should be done for calibration since loading at angles off vertical changes the geometry and will change how the load cells experience the actual load. Damage to the cable can occur if loaded too far off vertical. **Using only the side-pull slings/chains also reduces the load capacity of this setup (to 7,000 lb instead of 10,000 lb).**

- 14) Verify proper setup and that there are no kinks or twists in any of the chains.



- 15) Again check minimum height of bottommost shackle.
- 16) Record indicated load displayed on load cell. This should only be the weight of the hanging slings/chains. Enter this weight into the calibration spreadsheet. Zero the load cell.
- Note: The spreadsheet will sum the weight of the load cell, shackles, upper rigging, and chains to get a load offset. This offset is the difference between the indicated load and the load experienced by the tower load cells. See Appendix to calculate this offset without spreadsheet.
- 17) Get true zero load and raw voltage. Lower the drill cable until the tower hoist supports the full weight of the independent load cell and there's no load on the drill cable. Record raw voltage, it should be 1.7-2.3 V. If not, a zero offset adjustment may be needed at the load cell amplifier.
- 18) Slowly raise cable to get to 10,000 lb in 1,000 lb increments, recording raw voltage at each 1,000 lb increment. Make sure tower hoist is not carrying any of the load. Move slowly: The system is stiff, so very small changes in cable position result in very large changes in load. There is no swivel-type element to eliminate twisting, so beware of any tendencies for the assembly to twist the independent load cell. Use additional shackles with load-centering washers to minimize twisting if necessary.
- 19) Go back down to true zero in 1000 lb increments.
- 20) If not going to 10,000 lb, divide desired max calibration load by 10 to get incremental load change. (For example, to test only to 7,000 lb and use extrapolation to get to full 10,000 lb range, go up in  $7,000/10 = 700$  lb increments).
- 21) Do the hose load cell in the same manner, only loading to 2,000 lb in 200 lb increments. The hose should be full of water and pressurized to 200-400 psi. In idle mode, this pressure can be achieved by not bypassing any flow in the HPP, and throttling at the return hose reel. The hose on the reel acts as a stub line and should all experience the same pressure as read at the inlet to the hose reel. **If not pressurized, only load to 1,500 lb in 150 lb increments.**

Note: The hose load cell calibration could be done using the tower hoist running through a pulley block, up over the crescent, and anchored in front of the tower somehow. The pulley block connects to the independent load cell. This would allow test points up to 5,000 lb (the independent load cell would read double that). The crescent belt blocks should be protected from the cable. However, there are reaction moments and geometry when the hose is running over the crescent that aren't accounted for when using this alternative method. It's probably best to use hose, test only to 2,000 lb, and extrapolate to 5,000 lb.

- 22) Using the calibration spreadsheet, fit lines to the data each for the hose and cable load cell calibrations. Verify linearity of the data and fit. Obtain extrapolated voltage at max load, if needed. Enter min/max values into Hose Reel Unico to finalize calibration. If zero load voltage is outside 1.7-2.3 V, or if max load voltage is greater than 10 V, offset and span may need to be adjusted for that particular load cell amplifier.
- 23) Finally, load both hose and cable and compare independent load cell indicated load with load displayed from Hose Reel Unico (taking into account the offset from Step 15) to see that they agree.

Note: Load in Newtons = 4.448 x Load in LBS.

## APPENDIX

### Hose Load Limits

1,500 lbs – pressurized to 1000 psi, and bending (damage occurs at 3,000 lbs)

5,000 lbs – pressurized to 1000 psi, no bending (failure occurs at 10,000 lbs)

10,000 lb – no pressure, no bending (failure occurs at 15,000 lbs)

The hose behaves best when pressurized some. Maintaining a pressure of 200-400 psi will protect the hose from necking and still leave margin for increased tension.

### Assuring 30°+ Sling Angles

W = distance between two red anchor blocks

h = distance from floor to center hole of red anchor blocks

H<sub>min</sub> = minimum distance from floor to bottom of bottommost shackle

$$H_{\min} = (W/2) * \text{TAN}30^\circ + h$$

### Load Offset

Known:

Weight of Independent Load Cell = 30 lb??

Weight of Shackles = 2 x 26lb/ea? = 52 lb??

Weight of Upper Rigging = 5 lb

Total Known = 87 lb??

Read from Independent Load Cell before zeroing:

Weight of hanging slings/chains = W<sub>chain</sub>

Load Offset = W<sub>chain</sub> + 87 lb

Actual Tower Load Cell Load = Indicated Load (Independent Load Cell) + Load Offset

### Leg Loads and Ratings

Approximate leg loads, and assuming 30° lifting angles on side-pull legs:

	<b>3 Legs (side and centering), 10,000 lb indicated load</b>	<b>2 Legs (side only), 7,000 lb indicated load</b>
<b>Side-Pull Legs, each</b>	5,100 lb	7,000 lb
<b>Centering Leg</b>	3,500 lb	NA

Ratings:

Small Shackles – 10,000 lb

Pear-Shaped Ring – 13,200 lb

Large Shackles – 50,000 lb

Independent Load Cell – 50,000 lb

Slings – 4,960 lb (choker); 6,200 lb (vertical); 12,400 lb (basket)

Chain – 7,100 lb

Hoist Rings – 7,000 lb

Mounting Blocks – 7,000 lb