

**FINAL ICECUBE FUEL REPORT
Season 2009/10**

Terry Benson
2/19/10

09/10 Season Fuel Summary

Number of deep holes: 20
Number of IFD holes: 25

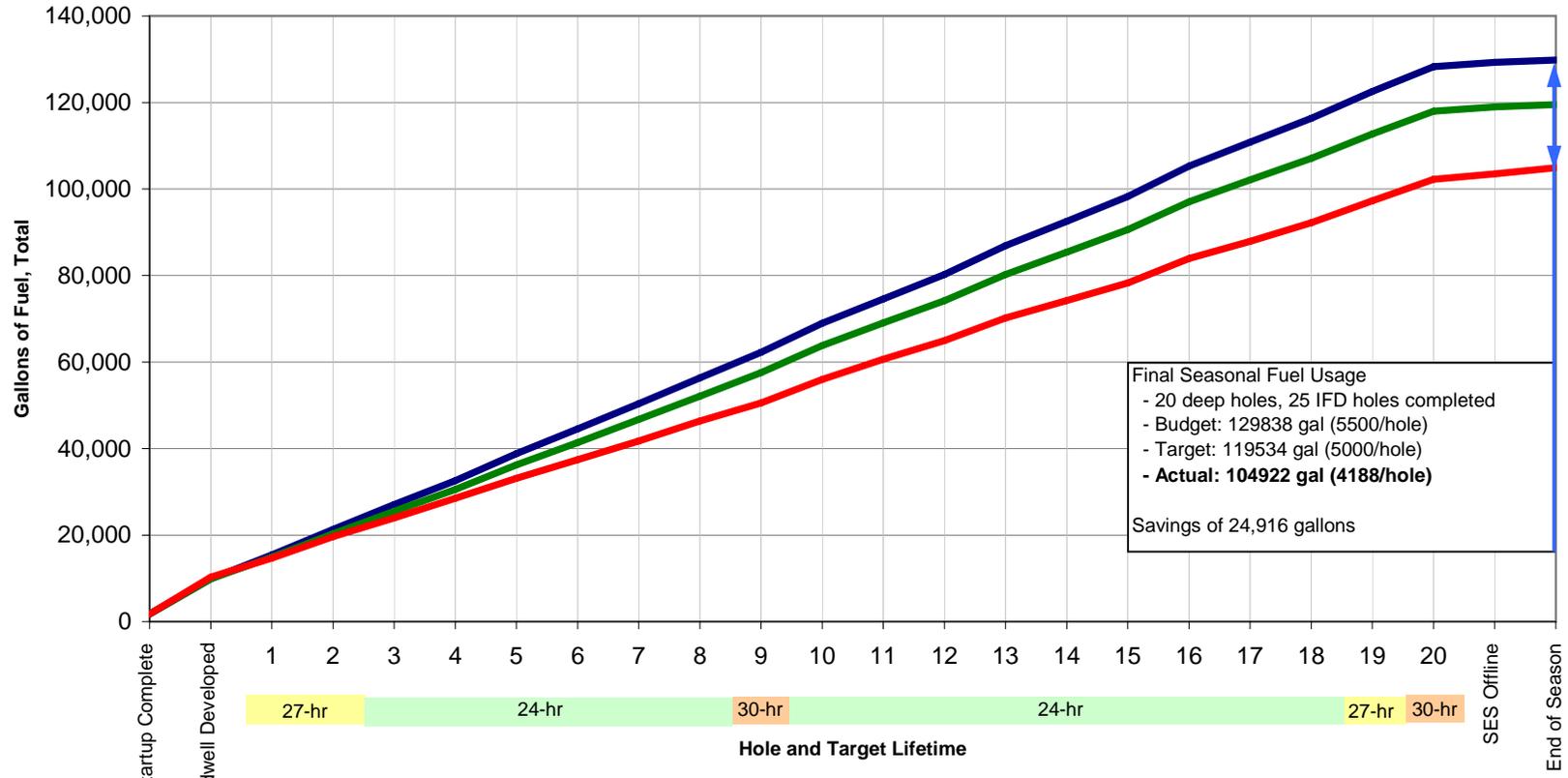
	BUDGET*	TARGET**	ACTUAL	<i>For reference</i> 08/09 (19 holes)
Total Fuel [gal]	129,838	119,534	104,922	112,220
Deep Drilling [gal]	105,000	95,000	79,672	86,769
<i>Per-Hole [gal/hole]</i>	5,250	4,750	3,984	4,567
<i>Ave Rate [gal/hr]</i>	NA	NA	130	128
IFD Drilling [gal]	6,250	6,250	5,106	4,821
<i>Per-Hole [gal/hole]</i>	250	250	204	243
Per-Hole, Deep + IFD [gal/hole]	5,500	5,000	4,188	4,810
Base [gal]	18,588	18,284	20,144	20,830
<i>Startup [gal]</i>	8,636	8,636	8,841	8,182
<i>Shutdown [gal]</i>	NA	NA	1,748	1,055
<i>Other [gal]</i>	NA	NA	1,168	2,000
<i>Idle [gal]</i>	9,952	9,648	8,387	9,593
<i>Ave Idle Rate [gal/hr]</i>	18	17	16	19

* budget model based on 130000 gal for 20 holes (5500/hole; 20000 base)

** target model based on 120000 gal for 20 holes (5000/hole; 20000 base)

- 24,916 gallons under budget.
- “Macro” average: 104,922 gallons / 20 holes = 5,246 gallons/hole.
- 8 additional IFD holes drilled, covering all of the 10/11 season’s holes, no more firm drilling required for project.
- Average fuel-per-hole reduced to 4,188 gallons from 4,810 gallons in the 08/09 season, a 13% reduction (note that the 08/09 season demonstrated a 13% reduction from the 07/08 season).
- Best fuel use during deep drilling was 3,647 gallons on Hole 82 (7th of the season, 24-hr lifetime).
- 15 of the 20 holes were drilled using the 24-hr lifetime strategy.
- Idle fuel usage below target.
- IFD fuel usage below target.
- Independent dips between RPSC and IceCube within 63 gallons of each other at season’s end (0.06%).

IceCube Fuel Usage, 2009-10 Season (by Hole)



— BUDGET MODEL - 129838 gal seasonal total*
— TARGET MODEL - 119534 gal seasonal total**
— ACTUAL - 104922 gal seasonal total

Actual for 2008/09 for 19 holes
 112,220 gal
 4,810 / hole
 20,830 base

* budget model based on 130000 gal for 20 holes (5500/hole; 20000 base)
 ** target model based on 120000 gal for 20 holes (5000/hole; 20000 base)

Hole-by-Hole

Hole Sequence	Hole Location	Target Lifetime	Total Deep Drill Duration [hr]	Frequency, HoleStart-to-HoleStart [hr]*	Turnover, HoleEnd-to-HoleStart [hr]*	Issues/Notes	Fuel Consumed [gal]	Fuel Factor**	Ave Fuel Rate [gph]	+ 204 IFD
1	8	27	33	na	na	Return water pump drive failure	4310	160	127.0	4514
2	9	27	32	50	16		4180	155	129.6	4384
3	16	24	30	45	13	Load cell amplifier box connector: loose wire	3956	165	128.3	4160
4	25	24	31	46	15		3983	166	128.4	4187
5	85	24	29	49	18		3872	161	131.0	4076
6	84	24	32	44	14	Gen3 back, but syncing failed	3871	161	118.6	4075
7	82	24	30	50	18	No camp comms at start of hole	3647	152	118.7	3851
8	81	24	30	46	16	Generator drop-out during ream	3948	165	128.9	4152
9	86	30	32	42	11		4004	133	122.6	4208
10	35	24	27	61	28	Load cell issues at startup	3734	156	137.0	3938
11	34	24	32	36	9	Gen3 drops out ~4 hrs in	4214	176	130.2	4418
12	24	24	30	40	7		4202	175	137.8	4406
13	15	24	29	46	15		3933	164	131.8	4137
14	23	24	29	38	8	Return water pump power cord failure	3805	159	127.6	4009
15	33	24	28	38	9		3866	161	134.8	4070
16	43	24	30	75	47	Accidental E-stop	3850	160	128.3	4054
17	32	24	27	33	3		3766	157	139.5	3970
18	42	24	29	41	14	Stop to fix MHP4 Hot hose leak	3844	160	129.8	4048
19	41	27	32	45	15	Drillhead comms lost ~380 meters	4218	156	131.1	4422
20	51	30	33	44	12	No drillhead comms	4467	149	133.3	4671
		BEST	27	33	3		3647	133	118.6	3851
		WORST	33	75	47		4467	176	139.5	4671
		AVERAGE	30	46	15		3984	160	129.7	4188

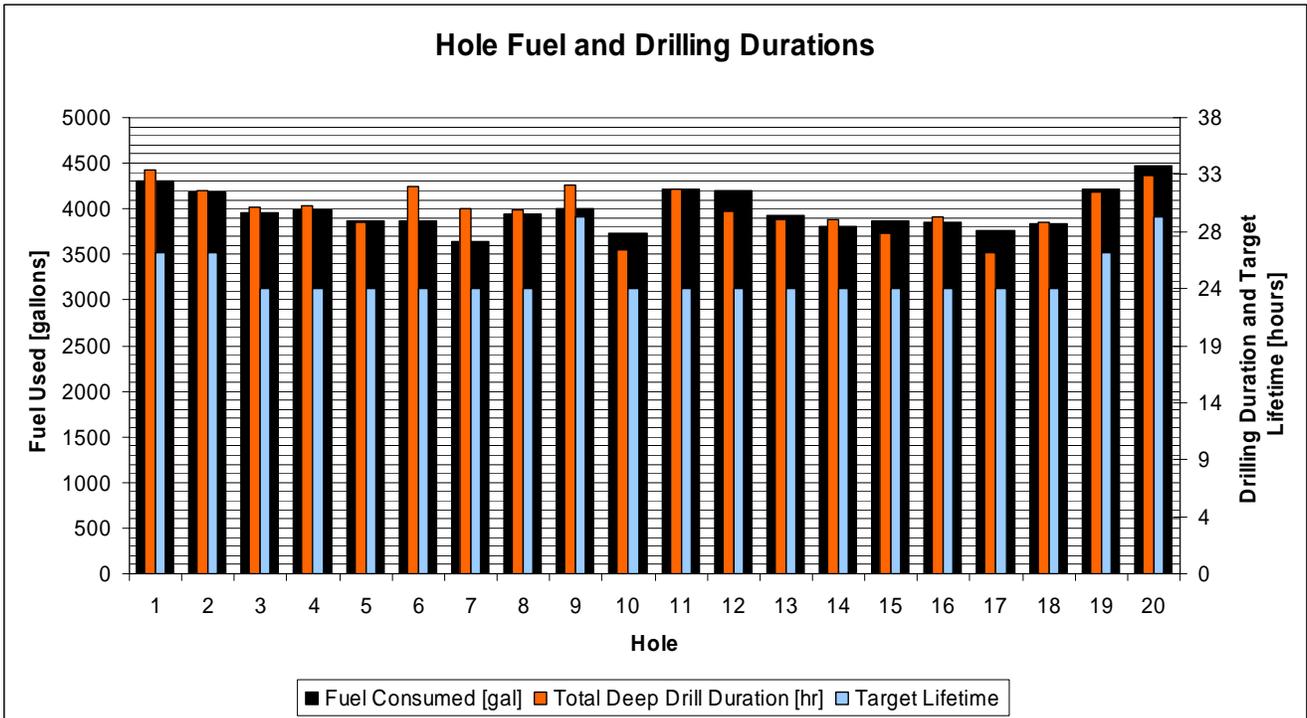
* Days off removed for Frequency and Turnover

** Fuel Factor = Gallons per Hour of Lifetime

Average IFD = 204 gal/hole

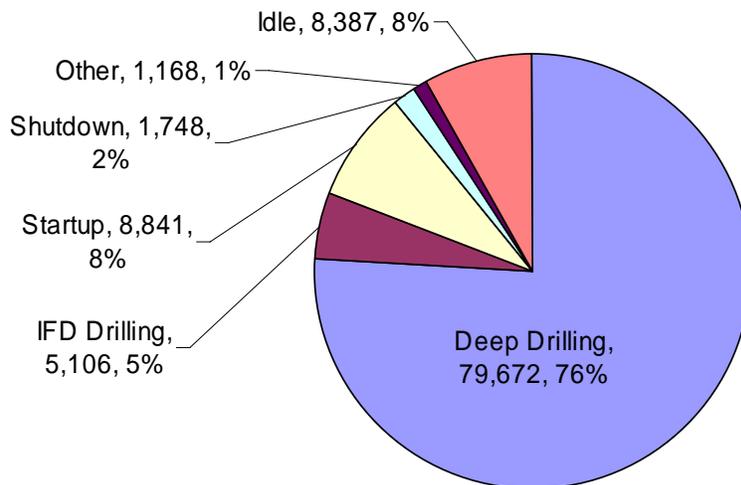
Average Deep + IFD = 3984 + 204 = **4188 gal/hole**

Details



Fuel-per-hole is shown above in black. It generally follows deep drill duration (orange), which in turn generally follows target lifetime (blue). For a given target lifetime, drill duration changes depending on downtime occurring mid-hole for resolving issues that come up, and sometimes how smoothly starting and stopping the hole goes. Some additional heat was added to the Rodwell mid-season, which is apparent by the hump of the black bars in the middle. Losing drillhead communications for the last two holes led to less risky 27- and 30-hr lifetime strategies, which are of course less fuel-efficient.

Fuel Use by Category



Rodwell

The Rodwell was developed quickly and aggressively during system startup, which shows up in larger startup fuel usage. This early development allowed for minimal heat to the Rodwell during drilling and idle between holes. During most idle periods only zero to two water heaters were run and idle rates throughout the season averaged to about 16 gal/hr, below the target minimum of 17 gal/hr.

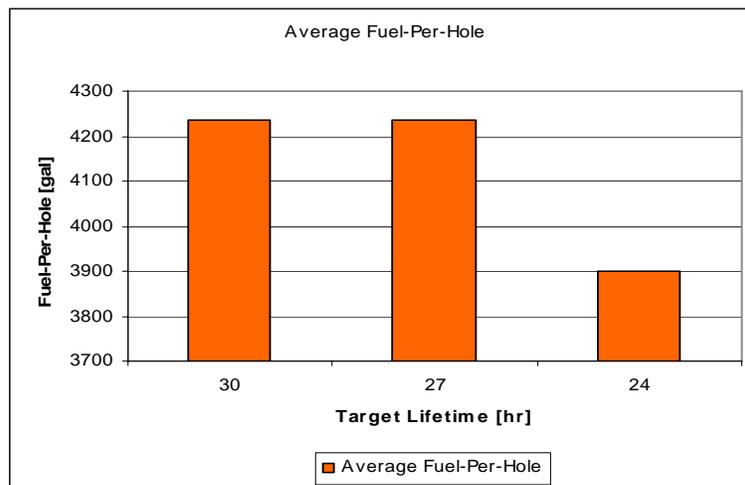
Rodwell management was again handled by a single person, who made measurements between blocks of holes and decisions about adding heat and lowering the Rodwell pump. A call for some additional heat was made about mid-season. During the last three holes the surplus water in the Rodwell was used up leaving a small amount of contingency water. Plans are to reuse the same Rodwell for the 10/11 drilling season.

Lifetime

Significant savings were achieved by drilling primarily 24-hr lifetime holes. Fifteen of the twenty holes were targeted for 24-hr lifetimes. Holes 8 and 9 (1st and 2nd of the season) were drilled as 27-hr holes to reduce risk while crews were getting re-familiarized with the system, and Hole 41 (19th) was switched to a 27-hr hole when drillhead communications were lost. Hole 86 (9th of the season) was scheduled for dust-logging before deployment and was targeted as a 30-hr hole, and the drillhead again had no communications during Hole 51 (20th of the season) so a 30-hr hole was targeted, in other words a very conservative 27-hr hole.

Separated out by lifetime:

		<i>Drill Duration</i> [hr]	<i>Fuel Used</i> [gal]	<i>Ave Fuel + IFD</i> [gal]	<i>Standard Deviation</i> [gal]	<i>Fuel Factor</i>	
Target Lifetime	30	(2 holes)	33	4235	4439	328	141
	27	(3 holes)	32	4236	4440	67	157
	24	(15 holes)	30	3900	4104	154	162
Average:						154	



Note that not enough 27- and 30-hr holes were drilled to get very good statistics on them.

Data, Data Sources, and Data Integrity

This report is based on the following:

- Total fuel = Deep Drilling + IFD Drilling + Base
 - Deep Drilling = Total SES fuel used from start to end of each hole (some base inherently included). Primary source is SES dips.
 - IFD Drilling = Total fuel delivered to Crrel generator. Average per-hole = total fuel delivered ÷ number of IFD holes. Primary source is RPSC logs.
 - Base = Camp Startup + Idle + Camp Shutdown + Other.
 - Camp Startup = fuel drawn from 5k tanks during camp startup and Rodwell development (from SES dips).
 - Idle = fuel drawn from 5k tanks between holes (from SES dips).
 - Camp Shutdown = fuel drawn from 5k tanks after last hole (from SES dips).
 - Other = misc equipment filled at Station and TOS fuel tank fills (from RPSC logs).

Relying on 5k tank dips can introduce an error of up to ±250 gallons for fuel burned during drilling of a hole. This is the volume difference between a full vs. empty daytank, which resides between the 5k tanks and the rest of the drill system.

All drill/ream durations are based on times that the fuel dips were collected. This can introduce an error of up to one hour or more depending on when the crew decides to grab the dip and any delays that may come up between dips and actual hole startup/end. Usually startup dips are made before actual full flow (official “start”) and ending dips after reducing flow (official “end”), so durations presented here are if anything longer than actual durations. Bottom of hole dips were always made during the 15 minute dwell at the bottom of the hole. See follow-up drill/deployment summary report for official durations.

Two data sources were utilized:

- 1) SES Dips – Primary data source for SES fuel usage. Drillers dip the 5k tanks on a regular basis, notably at the start, bottom, and end of every hole, at the end of shift, and when new tanks arrive or depleted tanks are taken offline. Times are noted. This information is extracted from the DCC fuel log book and the online fuel logging website.
- 2) RPSC Logs – Secondary validating source for SES usage (in this analysis), primary source for IFD and “Other” fuel usage. Obviously this is the primary source for ultimate South Pole fuel use and budgeting.

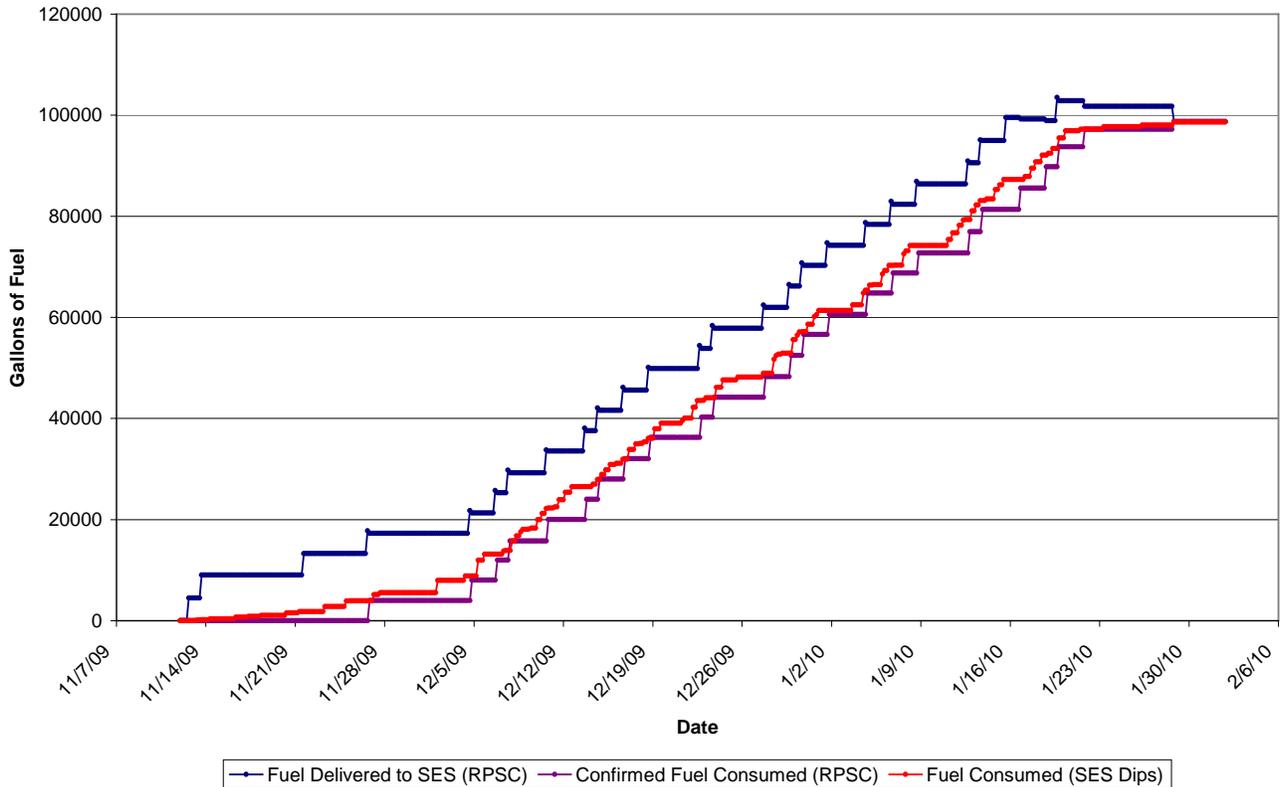
The daytank fuel meter is no longer used for analysis.

Overall fuel usage from RPSC dips and SES dips are remarkably close given the 5k dips (76% of the seasonal totals) are completely independent:

	VALUE	ERROR	
Driller Dips			
<i>Total for Season</i>	104,922	0 (0%)	
<i>SES</i>	98,648	0 (0%)	
RPSC			
<i>Total for Season</i>	104,985	63 (0.06%)	Good!!!
<i>SES</i>	98,711	63 (0.06%)	Good!!!

To ensure consistency between SES dips by the drill crew and RPSC logs the following plot is maintained:

Data Check - RPSC Logs and IceCube Dips (5k tanks)



About this plot:

- When RPSC issues a 5k fuel tank, the dark blue line steps up.
- When RPSC is returned a 5k fuel tank, the dark blue line steps down according to the fuel remaining inside. The purple line steps up by the difference (fuel that was used from the tank).
- The red line represents SES dips made by the drill crew, and has a much higher resolution (same tank is dipped many times throughout day). This line should stay within the bounds of the dark blue and purple lines (cannot use more than what is issued or less than what is confirmed used by a tank's return).
- All three (dark blue, purple, and red) should be equal (very close) at season's end.

One thing to note here is that the red line tracks very close to the purple line, and there is lots of space between it and the blue line. This represents how there was always plenty of fuel on site at drill camp and that RPSC stayed on top of fuel deliveries and returns very well.