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DRILLING RIG INFORMATION SYSTEMS

Sverrir Thorhallsson
ISOR - Iceland GeoSurvey
Grensásvegur 9, 108 Reykjavík
ICELAND
sverrir.thorhallsson@isor.is

ABSTRACT

Modern drilling rigs are equipped with instrumentation and data logging systems to aid the driller in his work and to allow post processing. There has been a transition from mechanical gauges and recorders of the past where the information was handwritten down on standard forms, over to the present where digital gauges and displays show a lot more data which furthermore is recorded in high resolution (e.g. every 5 seconds). There is a wealth of reports and data created during the drilling of a geothermal well. This data needs to be analysed and stored and for that computer systems are used. Part of the information technology (IT) is the drilling rig information system. This paper outlines what parameters are being monitored and how the data is stored. Such data is now available off site, either on-line or in daily reports and from databases. Drilling involves a lot of uncertainties and in some cases goes from one crisis to the other. Trained crews and application of appropriate technology minimizes the risk, but as conditions vary quite a lot it is important that the "learning curve" be steep. Post processing of the high resolution drilling data opens new possibilities for learning what works well and also what went wrong. With appropriate software it is possible to check whether there were any precursors, e.g. of sticking, that the driller could detect in time. For many geothermal drilling projects the drilling rig system information is underutilized, not because the systems are so expensive but rather because not enough human resources are devoted to it.

1. INTRODUCTION

Drilling of geothermal wells creates a lot of documents from the time of planning, contracting and purchasing, through the drilling phase with the daily reports and digital data, and finally during well testing. To manage the drilling operation, and handle all the information, a project management system is in place. Companies have their own information systems and ways of managing and filing, and there are integrated software solutions offered by a number of equipment vendors and software developers. Some standardized Daily Report forms are from the International Association of Drilling Contractors (IADC). An important part of any drilling operation is monitoring its progress, obtaining optimum results, learning from experience, and ways of handling unforeseen incidences. There are many critical decisions to be made during drilling of geothermal wells and for that reliable data is a must. All modern rigs have digital drilling information systems and they are easy to fit to older ones. They are an improvement over earlier mechanical strip-chart recorders "Geolograph" due to higher resolution and the usefulness of the digital format. The "Mud Logging" company typically hosts the data logging system and installs sensors but also merges data from the drilling contractor and service companies. The new systems provide high resolution data of the main drilling parameters and great accuracy. The rig information is shared on site between the mud logger, driller, toolpusher, company man and other subcontractors via displays and some rigs allow on-line access over the Internet or via other data links. The main drilling parameters are graphed in low resolution on the geologist lithological plots, a carry over from the "Geolograph" days, but the high-resolution data is often not analyzed. Important lessons can be learned from evaluation of all the drilling data e.g. optimum rate of penetration (ROP), on precursors to sticking, condition of down-hole equipment, fishing operations, identifying loss/production zones, drilling in loss zones, bit cooling, equipment condition monitoring. Additional information is now being obtained by measurement while drilling (MWD) for steering of directional wells and in the future additional simultaneous geophysical logging by logging while drilling (LWD) can be expected to be applied for geothermal drilling as now in petroleum drilling. This paper will focus on the data collection system, how it is applied by the drilling crew for geothermal drilling, and ways of using the information for critical decision making. Some of this may lead to an "information overload", thus it is for example a question just how much the driller can take advantage of from the drillers console and computer displays. It is sometimes stated that a good drilled goes by what he hears and feels as much as by any instrument. In geothermal drilling where there is a danger of getting stuck, sensing the level of vibration and noise and taking appropriate action is the secret of a good driller!

2. PARAMETERS MEASURED

For petroleum drilling NORSOK of Norway has produced a table of parameters to be logged and frequency. There is a similar IADC list. It is quite comprehensive and a subset has been applied to drilling information systems for geothermal rigs in Iceland, as indicated by bold lettered lines in the table in Appendix I.

The preferred units of measure are the SI units but as much of the drilling industry still operates with FPS system and barrels (US units), thus the reported units of measure may differ from site to site.

Previous to the digital age a mechanical strip chart recorder was used, it can still be found on some rig but rarely in use. The paper "Geolograph" has 24 hr chart on a drum only 6 pens (some models had 10-12 pens) recording the time interval it took to drill 1 ft (to be converted to ROP), hook load, standpipe pressure, bit rotation (RPM), stokes per minute (SPM) on the mud pumps. Other measurements were made manually and recoded on the standardized IADC Drilling Report form.

3. INSTRUMENTS

The drillers still prefer the mechanical gauges and many rigs have both. The large mechanical hook load and weight on bit indicator is the main instrument that the driller relies on and is not happy to part with (M/D Totco). They claim it is more "alive" than the digital one, even though it mimics its looks on computer displays. Mechanical pressure gauges and ammeters are still popular on the rig.

Nowadays standard industrial instrumentation equipment is used for the rig. A few systems have applied bus technology to simplify the wiring, but most still use the industry standard 2-wire current transmitters (4-20 mA). The temperature and pressure transmitters have integrated circuits that accept 10-30 VDC and produce a linear 4-20 mA signal. To measure pump stokes of the mud pumps or bit rotation encoders or proximity detectors can be used used together with pulse to current transmitters that deliver 4-20 mA. For block position encoders or proximity detectors on the wire rope or crown block are used. For small rigs a manometer arrangement has been applied where the height of the block is measured by a pressure transmitter connected to a water reservoir canister ending at the top drive. The level in tanks is measured either by pressure transmitters or ultrasonic sensors. Magnetic flow meters are used to measure the returns from the well, thus allowing monitoring of the loss of circulation. The accuracy is sometimes inadequate and thus changes in total mud tank volume over a time period is used to monitor the rate of loss. During that period no fluid makeup can take place or large losses over the mud shakers.

There have been development programs to improve the flow meter by designing a rolling float meter (Sandia 1998). Measurements are additionally made by the mud loggers at regular intervals as part of the mud volume accounting and also at set intervals by measuring the drop of the level in the tanks, e.g. for 15 minutes. The drillers also monitor the loss by adjusting the strokes of the mud pump to keep the well full to the brim but no overflow, as that flow corresponds to the loss. Another recent development in Iceland has been applying a vibration sensor to the top drive. Drilling large diameter holes in volcanic rock may require adjusting the weight on bit and rotation to reduce the vibration level and also when drilling through fractured rock. Vibration also indicates stick/slip and its early identification can reduce the chances of getting stuck.

4. DATA LOGGING

There are a number of off-the-shelf data multichannel loggers that can be applied to the drilling rig. The signals are generally of the current type (4-20 mA) and are converted A/D with anywhere from 12 to 16 bit resolution by a PLC or data logger. There are several high-level software programs available for those that want to build their own systems or total packages for hardware and software can be purchased. For most geothermal drilling the data acquisition system is provided as a service from the mud logging company, using their own proprietary solutions. The output is on multiple screens where the numbers as well as the trend data is plotted. The drillers console also commonly has digital displays. The data is stored on servers where it can be accessed, either as standard reports and graphs or the raw data downloaded in various versions in ASCII format. By having access to the raw data other programs can be applied for the analysis. Each data line has its corresponding time and depth. Timeline data versus depth is possible for all the parameters measured and calculated values.

5. INTERPRETATION

It is beyond the scope of this paper to describe how all these drilling parameters are used. The lecture and group work assignments will deal with case histories. The primary use is for the driller to carry out his work and to make it easier for him to spot early signs of problems. For geothermal drilling the question of well stability, hole cleaning and fluid losses are important, to avoid getting stuck. Location of loss zones is important as they may have to be cemented off in the cased portion of the well and in the open-hole interval the losses indicate the future production zones.

The data is very valuable in determining the causes of drilling problems. The emphasis should be lessons learned, rather than to gain evidence for any claims. Some drillers resent this level of recording their work and that goes for the drilling contractor as well. It is therefore important that the analysis be transparent and conducted in good faith.

APPENDIX I: Parameters to be logged and frequency

Item	Data Type	Parameter	Abbr.	Display Req. Prefrd. Units	Meas. Syst. Resolution	Display Update Accuracy	Data Value Rate, secs	Displayed
1	**Reference**	**Well Name**	**WELL**					**Actual**
2	**Reference**	**Date**	**DATE**	**yyyy:mm:dd**	**-**	**-**	**1/day**	**Actual**
3	**Reference**	**Time**	**TIME**	**hh:mm:ss**	**00:00:01**	**1 sec/day**	**1**	**Actual**
4	**Reference**	**Total Measured Depth**	**TD**	**m**	**0,05**	**-**	**5**	**Max**
5	**Reference**	**Bit Depth**	**BMD**	**m**	**0,05**	**-**	**5**	**Actual**
6	**Drilling**	**Rate of Penetration**	**ROP**	**m/hr**	**0,1**	**-**	**5**	**Ave/Max**
7	**Drilling**	**Block Position**	**BPOS**	**m**	**0,05**	**0,02**	**5**	**Ave**
8	**Drilling**	**Standpipe Pressure**	**SPP**	**bar**	**1**	**0,25%**	**5**	**Ave/Max**
9	**Drilling**	**Hookload**	**HKLD**	**kN**	**5**	**1,0%**	**1**	**Min/Ave/Max**
10	**Drilling**	**Weight on Bit**	**WOB**	**kN**	**0,5**	**-**	**5**	**Min/Ave/Max**
11	**Drilling**	**Rotary/Topdrive Speed**	**SRPM**	**rpm**	**1**	**0,5%**	**1**	**Ave/Max**
12	**Drilling**	**Rotary/Topdrive Torque**	**STOR**	**kN-m**	**0,5**	**1,0%**	**1**	**Ave/Max**
13	**Mud**	**Pump Speed, per pump**	**PSPM**	**spm**	**1**	**0,5%**	**10**	**Ave/Max**
14	Mud	Total Pump Speed	SPM	spm	1	-	10	Ave/Max
15	Mud	Total Pump Strokes	TSTK	stk	1	-	20	Actual
16	Mud	Mud Density In	MDI	sg	0,01	2,0%	30	Ave
17	Mud	Mud Density Out	MDO	sg	0,01	2,0%	30	Ave

Item	Data Type	Parameter	Abbr.	Display Req. Prefrd. Units	Meas. Syst. Resolution	Display Update Accuracy	Data Value Rate, secs	Displayed
18	**Mud**	**Mud Flow In**	**MFLI**	**lpm**	**5**	**-**	**10**	**Ave**
19	**Mud**	**Mud Flow Out**	**MFLO**	**lpm**	**10**	**5,0%**	**5**	**Ave**
20	**Mud**	**Volume for each Pit**	**PVOL**	**m3**	**0,1**	**1,0%**	**5**	**Ave**
21	Mud	Total Active Pit Volume	TACT	m3	0,1	-	5	Ave
22	**Mud**	**Total Pit Volume**	**TVOL**	**m3**	**0,1**	**-**	**10**	**Ave**
23	**Mud**	**Gain/Loss Flow**	**FLGL**	**%**	**1**	**-**	**5**	**Ave**
24	Mud	Gain/Loss Trip Tank Volume	TTGL	m3	0,02	-	5	Ave
25	Mud	Gain/Loss Active Volume	AVGL	m3	0,1	-	5	Ave
26	Mud	Trip Tank Volume	TTVO	m3	0,02	0,5%	5	Actual
27	Formation	Total Gas from gas trap	TGAS	%	0,1	0,1%	5	Ave/Max
28	**MWD**	**Hole Inclination**	**INC**	**deg**	**0,02**	**0,02**	**each new meas**	**Actual**
29	**MWD**	**Hole Azimuth**	**AZI**	**deg**	**0,02**	**(7)**	**each new meas**	**Actual**
30	**MWD**	**Toolface**	**TF**	**deg**	**0,02**	**(7)**	**each new meas**	**Actual**
31	MWD	True Vertical Depth	TVD	m	0,05	-	10	Actual
32	**Cement**	**Cement Pump Pressure**	**CPPR**	**bar**	**1**	**0,25%**	**5**	**Min/Ave/Max**
33	**Cement**	**Cement Flow In**	**CFLI**	**lpm**	**1**	**-**	**5**	**Min/Ave/Max**
34	**Cement**	**Cement Density**	**CDEN**	**sg**	**0,01**	**1,0%**	**20**	**Ave/Max**

Item	Data Type	Parameter	Abbr.	Display Req. Prefrd. Units	Meas. Syst. Resolution	Display Update Accuracy	Data Value Rate, secs	Displayed
35	**Cement**	**Cement Pump Strokes, Total**	**CSTK**	**stk**	**1**	**1,0%**	**1**	**Actual**
36	**Cement**	**Cement Volume Pumped**	**CVOL**	**m3**	**0,02**	**-**	**10**	**Actual**
37	Rig	Cathead Tong Torque	CATT	kN-m	1	2,0%	each new meas	Max.
38	**Rig**	**Casing Tong Torque**	**CSGT**	**kN-m**	**0,2**	**1,0%**	**0,1 (11)**	**Cross plot**
39	Rig	Casing Make-up Speed	CSGS	rpm	1	1,0%	0,1 (11)	Cross plot
40	Rig	Rig Heave	HEAV	m	0,05	5,0%	5	Ave.
41	Rig	Compensator Movement	COMP	m	0,05	2,0%	5	Ave.
42	Rig	Ton-Km Drawworks	DTON	ton-km	1	-	60	Actual
43	Rig	Ton-Km Riser Tensioner	RTON	ton-km	1	-	60	Actual

Extra for geothermal:

	MUD	**Temp. mud standpipe**
	MUD	**Temp. mud flowline**
	MUD/AIR	**Air compr. Pressure**
	MUD/AIR	**Air compr. Flowrate**
	RIG	**Wellhead pressure**