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Geothermal Drilling Time Analysis: A Case Study of Menengai and Hengill

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ABSTRACT

Drilling operations are run on tight schedules and drilling time delays come at a high cost. A large part of drilling workdays is spent on making the wellbore and activities that support drilling, contributing to productive time (PT) while a significant part of the time is spent on drilling problems and activities aimed at finding solutions and solving these problems. This contributes to non-productive time (NPT). Problems occurring in drilling can be avoided sometimes but in other occasions they are beyond the drilling crew control, their causes are numerous and their effects undesirable. This paper analyses drilling time for 15 wells drilled in Menengai, as well as identifying the cause of NPT and attempting to find solutions aimed at increasing PT while reducing NPT to make the drilling process effective. Data from Hengill wells in Iceland was used for comparison.

1. INTRODUCTION

The objective of drilling a geothermal well is to drill a fit-for-use well, in a safe manner, using the available technology while minimising the overall cost. To control well costs, it is important to improve drilling efficiency and cut down on drilling time. There are many factors and events that push drilling operation behind schedule such as drilling problems and some technical and non-technical non-productive time (NPT). It is almost certain that problems will occur while drilling a well, even in very carefully planned wells. For example, in areas in which similar drilling practices are used, hole problems may have been reported where no such problems existed previously because formations are nonhomogeneous. Therefore, two wells near each other may have totally different geological conditions (PetroWiki, 2013a).

The most common drilling problem in geothermal wells leading to NPT has always been formation related, leading to stuck pipe and bottom hole assembly failure. In some cases efforts to retrieve the string are unsuccessful and this leads to expensive process of side-tracking or in the worst case abandoning the well when it is considered not economically viable to continue working on that well. Such wells bring the drilling company into time overruns and eventually cost overruns. Other common causes of NPT in drilling geothermal wells include, but are not limited to, lost circulation, formation damage and rig equipment failure. Personnel experience and available technology may also influence drilling time.

This paper presents analysis of drilling time of 15 wells drilled in Menengai geothermal field and compares them to 19 wells drilled in Hengill field in Iceland. Time spent on different activities was analysed and how they in turn affect drilling performance with emphasis on NPT as the major cause of drilling time extension. The aim of this paper is to identify NPT affecting wells drilled in Menengai field using wells drilled in Hengill area to compare drilling performance, determine their cause and effect and attempt to give solutions to reduce them and positively influence drilling performance. The activities analysed included actual drilling, running casing, cementing casing and circulation losses, logging, reaming, fishing, stuck drill pipe, repairs, wait on water and 'other' activities.

2. DRILLING TIME

2.1 Factors influencing drilling time

The time taken to drill and complete a well directly influences the cost of any geothermal project. Hence completing a well in time is cost effective and essential. Measured depth is the most important factor in predicting the time it will take to drill a well (Noerager, 1987). But this is not always the case as drill rates are often constrained by factors that the driller does not control (Kaiser, 2007). These factors include:-

Geological conditions - The most obvious aspect of the downhole environment that influences drilling difficulty is physical characteristics of the rock (lithology). Drilling on hard and very hard abrasive formations results in the most difficult problems in the drilling industry despite the developments and improvements of drilling tools, equipment, machines and techniques. Soft formation are easily eroded by drilling fluid resulting in large cavities in the well bore. Cementing this type of formation is problematic resulting in several backfills hence longer cementing time. Loose formation that collapses easily adds to hole cleaning time and could end up causing stuck pipe while a fractured formation will result in lost circulation problems.

Prevailing reservoir conditions - Downhole pressure, temperatures and reservoir fluids affect the way a well is drilled. They provide information to locate the productive zones and hence influence where casings are set and how cementing is done. Formation pressure influences how much drilling fluid is pumped into the wellbore. Higher wellbore pressures may cause formation damage and lost circulation problems resulting into greater problems such as stuck pipe.

Available technology - Recent advancement in technology has benefitted the drilling industry and the choice lies with the operator to suit his preference. Top drive, power swivels, air/foam balanced drilling, PDC bits, horizontal drilling, casing while drilling, reverse circulation cementing, logging while drilling, environmentally safe fluid formulations, micro drill, and coiled tubing are all good examples of these improvements (Dumas et al., 2012). The use of current technology has revolutionised how drilling is carried out and increased drilling progress efficiency and safety. In addition, implementation of new technologies has led to reduction in drilling time and cost.

Equipment and consumables availability - Drilling companies have invested in expensive equipment. It is important to ensure that this equipment is always available for efficient drilling. When equipment breaks down, there is need to restore it quickly through repair and replacement of parts. Spare parts for drill rigs are a complicated and important task to be handled. To avoid having to stop the drilling operations it is very important to have a functioning system to provide spare parts if and when a component breaks down or needs maintenance (Samland, 2011). It should be noted that the integrity of drilling equipment and its maintenance are major factors in minimizing drilling problems.

Drilling materials and consumables such as cement, fuel, drilling detergent, drilling mud and even water are also important without which, drilling cannot proceed. Drilling operations will be greatly compromised without proper planning for these materials.

Personnel experience. Given equal conditions during drilling operations, personnel are the key to the success or failure of those operations (PetroWiki, 2013a). Drilling is an industry of learning by doing and it takes years to build the experience necessary for the industry. Experience will make a difference on how efficient a drilling job is carried out in that operations will be safer and drilling performance improved. Other than experience it is important to keep training personnel on new technologies and new engineering practices as the drilling industry is changing fast with increased automation and better procedures intended to improve performance.

Well specifications affect how much time is spent on a particular well. There may not be much time difference in drilling directional and vertical wells, (Sveinbjörnsson, 2013) but directional wells do come with their unique challenges other than those encountered in vertical wells. More surveys have to be carried out, and it is not possible to apply desired weights or rotary speeds as it is in vertical wells. Other factors on well specification may include the number of casing strings and where they are set. Correct determination of where casing strings are set to shield against problematic zones such as lost circulation zones, will ensure reduction in drilling problems. Bit- and casing-size selection can mean the difference between a well that must be abandoned before completion and a well that is an economic and engineering success. Improper size selection can result in holes so small that the well must be abandoned because of drilling problems (PetroWiki, 2013a).

2.2 Drilling time

Drilling time is the time required to make the wellbore to maximum depth. It includes productive time (PT) spent on activities that are actually contributing towards the construction of wellbore and were planned for, and non-productive time (NPT) spent on activities that had to be done but were not planned for. This information is represented in Table 1 showing a summary of PT and NPT activities adapted from previous work done by Adams et al., (2009) to fit this study. Drilling time for a particular well or project can be identified through reports generated from drilling and logging wells in an area. This data is able to detect trends and irregularities on drilling time and delineate problematic areas. Proper analysis of drilling data will provide insight on expected characteristics and problems to be encountered in the well which is important in planning for any well.

TABLE 1: PT and NPT activities

Activity	PT	NPT
Drilling	Actual drilling Tripping in drill	Stuck pipe BHA change Reaming Fishing Circulating to clean well
Casing	Running in casing	Stuck casing\hung up casings Lay down damaged casing joints
Logging	Running in logging tool Actual logging	Stuck tool string
Cementing	Cementing casing	Cementing loss\plug jobs Cement backfills\top ups
Equipment	Equipment service Nippling up BOP and Blowie line	Equipment breakdown
Others		Wiper tripe Tripping in for other reasons other than drilling Wait on materials, spares, fuel and personnel, water and instructions

2.2.1 Non Productive Time (NPT)

NPT is any occurrence which causes a time delay in the progression of planned operations. It includes the workdays required to resolve that problem and the time to bring the operation back to the point or depth at which the event occurred. NPT is thus anything that you do not intend to do but are required to do anyway. Therefore anything that occurs outside of the well's original plan should be counted as NPT (Kadaster et al, 1992). Hsieh, (2010) defines NPT as time periods during which drilling operation is ceased or penetration rate is very low, and it is not a performance metric of what has gone wrong but a way to identify things that can be better.

2.2.2 The Causes of NPT

Causes of NPT in drilling are varied and they can be due to unforeseeable events beyond what the drilling crew can control or due to inadequate planning for a job.

2.2.3 Effects of NPT

Time overrun affects the progress of drilling, leading to fewer wells drilled by the end of the stipulated drilling project period. Time overrun means the drilling crew could not carry out their work within the scheduled period. It is important that the drilling time is reviewed at the completion of the well, knowledge built on the causes of the delays and transferred to the next wells to be drilled to improve efficiency.

Cost overrun arises when the cost of the well surpasses the budget allocation. This could be due to overhead costs that are required to solve the problems that caused NPT and keep the crew on the rig the extra days. Drilling problems such as sticking and fishing may require the involvement of a fishing specialist which will increase the drilling cost. Cost overrun is related to time overrun, once a project cannot be completed on time, it will most certainly incur extra cost.

Change of well plan/side-tracking: A drilling plan may change from vertical to inclined drilling through side tracking in order to respond to disruption caused by drilling problems. Reason for sidetracking is to get past a problematic zone such as a circulation loss zone that cannot be healed, an incompetent formation that keeps collapsing or a fishing challenge. This may be justified by the high investment already in that particular well in terms of time and money or the belief that the well will be a good producer. This is a consequence of NPT as the change of plan always comes after time has been spent on trying to solve the problem.

The drilling plan may also be changed when drilling problems do not allow drilling to proceed. This may be due to harsh wellbore conditions such as extreme temperatures and pressures causing drillstring failure leading to a reduction in target depth to depths that the drillstring can perform.

Total abandonment: When skill and force fail in retrieving the drillstring lost in the well sometimes the only solution is to abandon the stuck portion and drill a sidetrack around it, changing the drilling program completely and potentially adding millions of dollars to the well cost (Aldred et. al, 1999). A well is abandoned when it is deemed not economically viable in terms of time and cost to continue putting resources into it, even when the well is at an advanced stage. Other reasons for abandoning a well are the same as those for change of well plan or side tracking. Problematic wells that are advanced in depth may still be used for production even if drilling is terminated before the target depth is reached.

3. DATA ANALYSIS

Of the total time it takes to drill a geothermal well, only 30-40% is actually spent to make hole by rotating the drill bit on bottom. The rest of the time is spent on: rig-up and down, to install and cement casings, installing valves, logging, operations to solve drilling problems related to loss zones, unstable formation or for "fishing" when the drill string becomes stuck or breaks. A good way to assess what the problem may be is to look at a curve potting depth vs. days that the job has taken for each well. Any "flat spots" where there is no advance in depth for several days shows clearly up and will indicate that there may be a problem (Thórhallson, 2006). Figure 1 shows drilled depth vs. workdays for the Menengai wells.

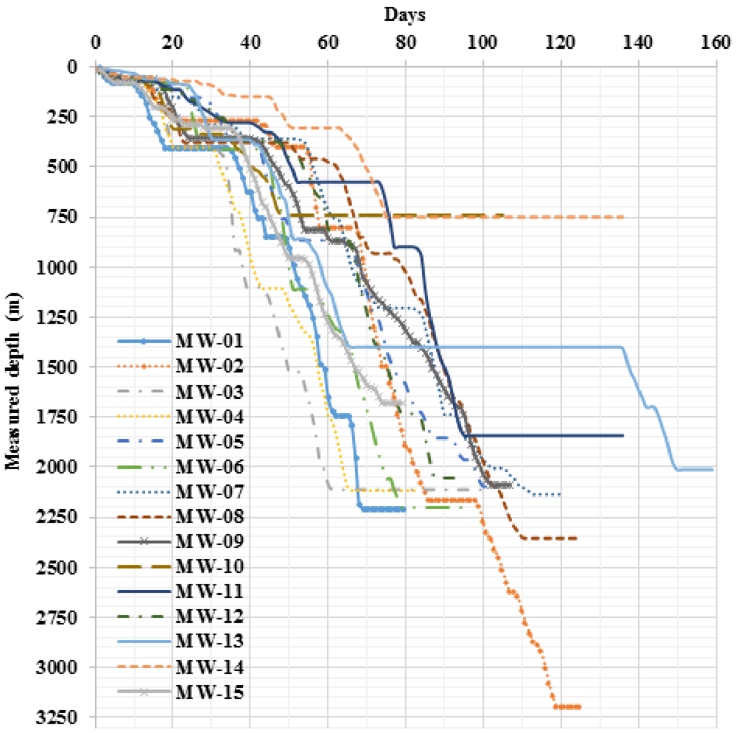


FIGURE 1: Depth vs. days graphs for Menengai wells MW01 to MW15

Well construction activities and drilling problems affecting overall drilling time were considered for 15 wells drilled in Menengai and 19 wells drilled in Hengill to compare total time for the wells. These wells are represented in Table 2. In the analysis of activities sections more wells in Hengill were used to strengthen the data set.

TABLE 2: Summary of wells studied. Note that section 0 is excluded in workdays.

Hengill wells				Menengai wells			
Well no.	Total drilled depth (m)	Section 1 - 3		Well no.	Total drilled depth (m))	Section 1-3	
		Drilled depth (m)	Workdays			Drilled depth (m)	Workdays
HE-03	1,887.0	1,797.6	39	MW-01	2,207.0	2,126.3	70
HE-04	2,008.0	1,936.4	45	MW-02	3,200.0	3,120.0	112
HE-05	2,000.0	1,909.5	44	MW-03	2,112.5	2,031.5	85
HE-06	2,013.0	1,940.0	37	MW-04	2,117.0	2,035.1	72
HE-07	2,270.0	2,162.0	47	MW-05	2,095.7	2,034.7	89
HE-08	2,808.0	2,668.0	38	MW-06	2,203.0	2,122.0	73
HE-13	2,397.0	2,324.0	42	MW-07	2,135.9	2,076.9	109
HE-20	2,002.0	1,901.0	72	MW-08	2,355.6	2,290.5	113
HE-21	2,165.0	2,070.0	32	MW-09	2,089.0	2,027.5	92
HE-26	2,688.0	2,596.0	51	MW-10	740.8	679.4	94
HE-36	2,808.0	2,703.0	61	MW-11	1,842.0	1,771.5	122
HE-51	2,620.0	2,522.2	33	MW-12	1,842.0	1,783.0	82
HE-53	2,507.0	2,437.5	57	MW-13	2,012.1	1,950.8	141
HE-54	2,436.0	2,342.0	34	MW-14	750.1	687.8	117
HE-55	2,782.0	2,685.0	34	MW-15	1,679.6	1,603.6	68
HE-57	3,118.0	3,023.0	41				
NJ-23	1,751.0	1,659.0	45				
NJ-24	1,929.0	1,849.7	35				
NJ-25	2,098.0	1,993.0	31				
Average	**2,330.9**	**2,237.8**	**43.1**		**1,958.8**	**1,889.4**	**95.9**

The activities analysed included actual drilling, casing, cementing casing, cementing loss, repairs, sticking, fishing, change of BHA, wait on water and logging. Evaluation was made on time taken for each activity assuming NPT as being the main reason for the extended drilling time. Trip time was considered as part of the activity that was being tripped for. i.e., tripping time for BHA change was considered as part of BHA change time while tripping time for logging was considered as logging time. ‘Other’ activities referred to include time spent on waiting on materials, fuel and instructions, installation of BOP and wellhead and any other activities time that was are not captured in the analysis most of them being NPT activities. To compare the drilling time for different activities, the respective numbers of workdays were normalized to the same reference well both for Menengai and Hengill wells. Section 0 was excluded from the data in comparison for total time because there was a difference in width of the surface hole, 26" in Menengai and 21" in Hengill, some of the data for Hengill wells was not available as these wells were top holed. Average depth drilled per day in sections 1, 2 and 3 for Hengill wells was 52 m/day and 22 m/day for wells drilled in Menengai. The average meters per day for Menengai wells were calculated without well MW10 and MW14 as the last section for these wells was never drilled. The sections used from Hengill wells were from both vertical and directional regular diameter wells because a former time analysis of directional and vertical wells resulted in no significant difference (Sveinbjornsson, 2010). Table 3 shows the reference well used in normalisation of the data used in the analysis. The rest of the analysis carried out included more wells from Hengill including injection wells and wells whose design was changed from large to regular diameter because of problems. These addition wells included six in section 0, six in section 1, four in section 2 and three in section 3.

TABLE 3: Reference well

	Depth
section 0	80
section 1	400
section 2	850
section 3	2000

Equation 1 below was used for normalization of the drilling time data for different activities (Sveinbjörnsson, 2010).

$$\mathrm{Ti} = \frac{(\text{Drilled reference depth})}{(\text{Actual drilled depth})} \times \mathrm{ti} \tag{1}$$

Where
Ti = The normalized number of workdays for section i; and
ti = The actual number of days spent on section i.

Tables 4 and 5 show normalised data for each section and overall average working days for Menengai and Hengill respectively.

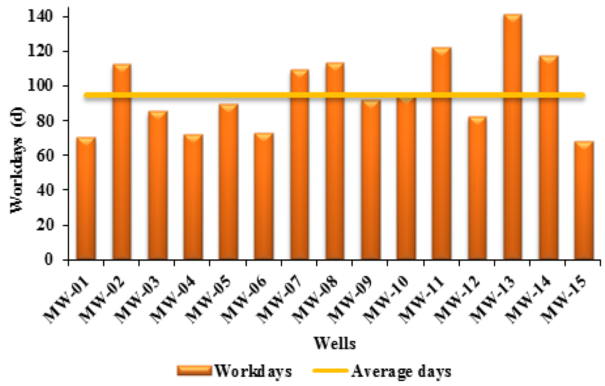
TABLE 4: Normalized days for activities in Menengai

Section	Total	Active drilling	Placing casing	Cementing casing	Cementing loss	Stuck	Reaming	Fishing	Wait on water	Changing bit	Repair	Logging	Other
0	16.7	6.5	0.5	2.6	0.9	0.2	0.5	0.1	0.6	0.1	0.6		4.1
1	31.0	10.4	1.0	3.5	2.5	0.7	1.5	0.8	3.1	0.5	0.9	0.4	5.8
2	16.1	8.1	0.6	2.4	0.5	0.1	0.3	0.9	0.2	0.7	0.4	0.2	1.7
3	45.3	20.1	1.3		0.0	5.1	1.2	2.3	0.7	2.0	5.6	1.2	6.0
Total	109.0	45.1	3.3	8.4	3.9	6.0	3.4	4.0	4.7	3.3	7.6	1.8	17.6

TABLE 5: Normalized days for activities in Hengill

Section	Total	Active drilling	Placing casing	Cementing casing	Cementing loss	Stuck	Reaming	Fishing	Wait on water	Changing bit	Repair	Logging	Other
0	5.10	2.53	0.65	0.81	0.59	0.05	0.25	0.05		0.08	0.02	0.09	
1	10.62	5.03	1.35	1.66	1.00	0.51		0.03				0.91	0.12
2	7.41	3.55	0.71	0.86	0.62	0.26	0.05		0.17	0.01	0.10	1.05	0.03
3	15.58	8.69	0.96		0.67	0.54	0.62	0.14	0.12	0.46	0.26	3.02	0.09
Total	38.7	19.8	3.7	3.3	2.9	1.4	0.9	0.2	0.3	0.6	0.4	5.1	0.2

Figures 2 and 3 shows graphs of workdays per well for actual drilled depths in each field together with the average time. The data here excludes section 0 for reasons explained above. For the 3 sections used in the graph the longest time spent on a well in Menengai was 141 days and the average time per well in Menengai was 94.5 days. The Hengill wells took an average of 43 and the well with the most workdays took 72 days. These graphs were produced from raw data before normalisation.



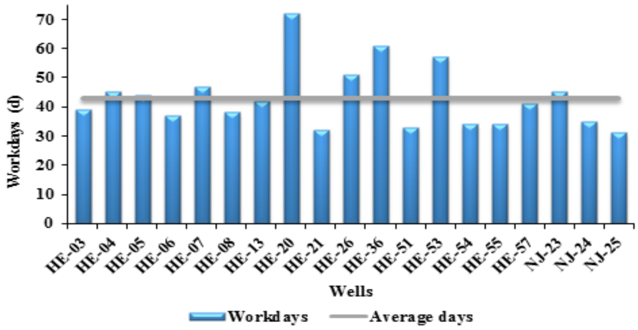
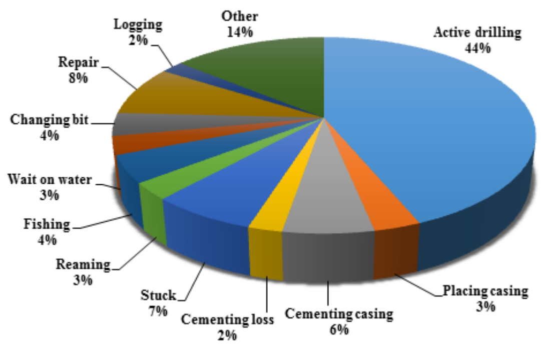


FIGURE 2: A bar graph of Menengai wells actual workdays for actual drilled depths excluding section 0 and FIGURE 3: A bar graph of Hengill wells actual workdays for actual drilled depths excluding section 0

Figure 4 and 5 are pie charts representing percentage distribution of activities in Menengai and Hengill. 44% of the time in Menengai was spent on actual drilling, accounting for 45.1 days out of 109 days while the category "other activities" took the second highest time with 14%, accounting for 17.6 days. 52% of the total time in Hengill was spent on actual drilling, accounting for 19.8 days, with logging taking up 16% of the total time, accounting for 5.1 days. The category 'Other' was lowest for Hengill with 1% accounting for 0.2 days while logging was lowest for Menengai with 2% accounting for 1.8 days. Figure 6 is a bar graph comparing the two fields, the values are weighted average of activity time per section.



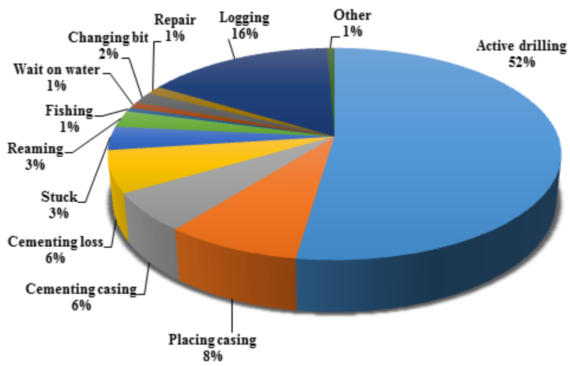


FIGURE 4: Percentage distribution of activities in Menengai and FIGURE 5: Percentage distribution of activities in Hengill

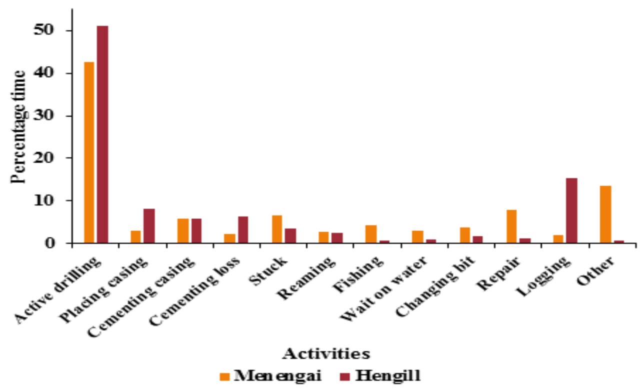
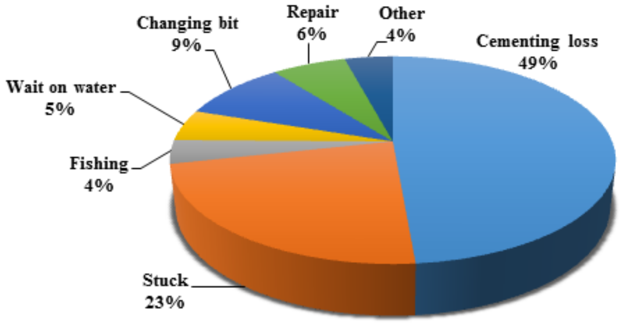


FIGURE 6: Weighted average of percentage per activity for Menengai and Hengill

Figure 7 and 8 are pie chart representations of NPT distribution in each field. 'other 'activities was the largest contributor of NPT in Menengai with 37 % while cementing loss zones was the largest contributor of NPT in Hengill wells with 49 %. The activities here were cementing loss, sticking, fishing, wait on water, changing bit, equipment repair and 'other' activities. These activities contribute to NPT as their occurrence hindered wellbore progress. The rest of the activities were considered as PT as they contributed directly to well creation. Figure 9 and 10 are pie chart representations of PT to NPT in the two fields. Menengai wells experienced a larger NPT. 40 % of the total drilling days were spent on NPT which equals 43.7 days. Hengill wells experienced lesser NPT with only 14 % of total workdays amounting to 5.4 days.



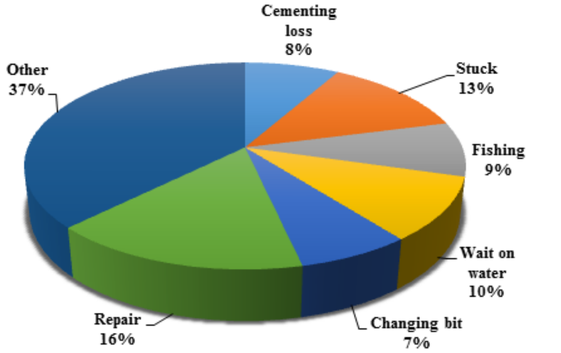
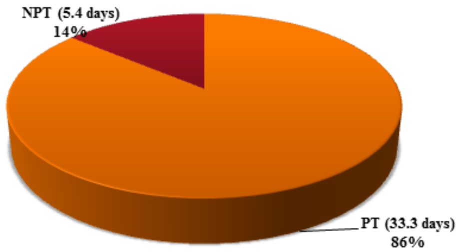


FIGURE 7: Percentage representation of NPT distribution in Hengill and FIGURE 8: Percentage representation of NPT distribution in Menengai



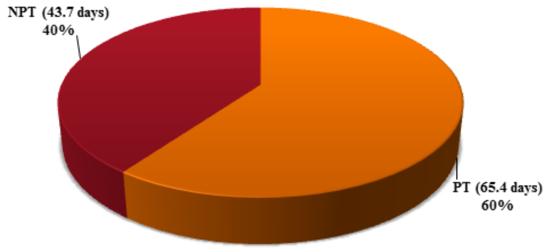


FIGURE 9: Productive time to non-productive time in Hengill and FIGURE 10: Productive time to non-productive time in Menengai

4. DISCUSSIONS.

Using the normalised data to the reference well, wells drilled in Hengill took an average of 38.7 days to complete the well to 2000 m while wells drilled in Menengai took an average of 109 days. Therefore it took almost three times longer to complete similar well in Menengai as in Hengill. From the raw data analysis it was found that the average depth per day was 52 m/day in Hengill while it was 22.9 m/day in Menengai. The actual rate of penetration with bit on bottom was 102 m/day in Hengill and 46 m/day in Menengai. There was more NPT in Menengai wells by 40% of total work time while Hengill wells incurred NPT of 14.7% of the total work time.

Actual drilling

45.1 days were spent on actual drilling in Menengai and 19 days in Hengill which was 42.7 and 51.0% of workdays respectively. It could be possible that the length of time spent in drilling Menengai wells could be due to hard formation as the rate of penetration was relatively low. Section 0 in Menengai took 6.5 days while In Hengill it took 2.5 days. This can be explained by the fact that in Menengai this section is drilled using a tricone bit that depends on rotary action to drill and due to the shallow nature of the hole in this section weight on bit is far too low and large vibrations are experienced. In Hengill this section is generally drilled with airhammer therefore the drilling is faster, furthermore the diameter of the hole in Menengai is usually large while a regular diameter is used in Hengill

Casing

Casing time for both fields was relatively low, with 3.3 days in Menengai and 3.7 days in Hengill. The size of the casings and depths did not influence the casing time much considering section 0 in Menengai is large diameter. On considering the percentages, Menengai wells spent 3% of total time in placing casing while Hengill wells spent 8% of total time in placing casings. This could be attributed to the fact that the 18⅝" casing in Hengill was welded and the other casings screwed together.

Cementing casing

Cementing in Menengai was longer with an average of 8.4 days while Hengill spent on average 3.3 days on cementing. This indicates that most of the cementing jobs for Hengill wells was done in the first step therefore reducing backfills. The use of caliper logs ensured shorter cementing time for Hengill well. The formation in Menengai is much fractured and most of the cement went into sealing the fractures. Figure 11 is a pie chart representation of total casing cementing job carried out in Menengai. Backfills took four times longer than primary cementing as there was no information on cement volume needed.

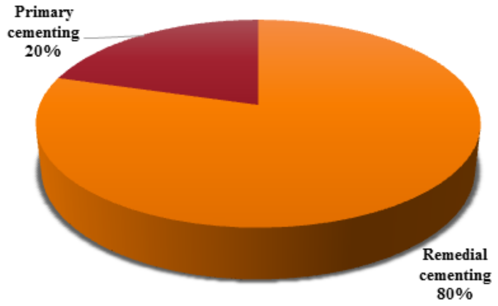


FIGURE 14: Ratio of primary cementing to remedial cementing time in Menengai

Cementing loss

Cementing loss time in Menengai was 3.9 days while in Hengill it was 2.9 days. This translates to 2% of total workdays in Menengai and 6 % of total workdays in Hengill. Lost circulation problem is pronounced in Menengai and this is due to the fractured nature of the Menengai formation. Drilling practices may also leads to induced fractures aggravating loss circulation problems. If not managed loss circulation can cause other problems in the well bore.

Logging

Hengill wells were logged more often than the Menengai wells. 16% equivalent of 5.1 days of total workdays in Hengill were spent on logging. While 2 % equivalent of 1.8 days was spent on logging in Menengai. Several logs were carried out throughout the course of drilling the wells in Hengill while in Menengai most of the well logs were carried out towards during well completion. These logs usually included temperature, pressure, caliper, cement bond log (CBL) and other well completion logs. The caliper and CBL logs were not carried out in Menengai. The frequency of logging was also low in Menengai compared to Hengill.

Bottom hole assembly (BHA) change

Hengill spent 0.6 days in BHA change while Menengai spent 3.3 days. Most of the BHA change time was spent in tripping out to change worn-out bits. Reducing the number of BHA trips will eventually reduce this part of the NPT. Changing lithologies at various depths such as those in Menengai also create a set of variables that affect bit durability.

Fishing

Fishing time was longer in Menengai wells with an average of 4 days and less in Hengill wells with an average of 0.2 days. Most of the fishing time experienced in Menengai was as a result of drillstring failure from stuck pipe. In the effort to free the stuck pipe the drillstring was subjected to high torque and large weight on bit causing it to strain and eventually fail. Excessive tension from over pull and fatigue from repeated stress could have also lead to drillstring failure.

Stuck pipe

On average 6 days of Menengai wells were stuck days while Hengill wells were stuck for 1.4 days. Both drillstring and casing string experience sticking. There was more sticking in section 3 than all the other sections. In Menengai most of the sticking followed a period of problematic circulation and moment of stopped circulation such as after pipe connection. This goes to show that due to lost circulation most of the cuttings were not removed from the hole and were left suspended as a result these cuttings will fall to the bottom and on the string. Loss of circulation results in poor hole cleaning and if enough efforts are not made to regain it, sticking is inevitable.

Other activities

Other activities referred to here include, top drive, wellhead and BOP installation, and wait on fuel, material and instructions. Any other activity that had to be carried out and was not planned for was included in this category. These activities took 17.6 days in Menengai and 0.2 days in Hengill. This was the second largest time in total Menengai workdays and the largest NPT. Top drive installation is included here since in Menengai it is not used until after section 0. This is because the top section is usually characterised by hard formation depicted by the low ROP causes high string vibration leading to frequent top drive breakdown. In Hengill the top drive is rigged up on the big rig after section 0 is done. BOP installation took a relatively longer time to install in Menengai and materials took longer to be delivered on site. Significant time spent on wait on instruction during trouble time could signify planning was not efficient in the first place. A consideration should be made on planning for trouble time when planning for the well. This will ensure that when they occurred the crew will know how to proceed even if further instructions are to be given later.

Repairs

Repairs were the third largest time consumer in Menengai wells with 7.6 days while in Hengill 0.4 days. The larger part of equipment repairs was due to waiting for spare parts as the procurement process is long and some of the spares were to be sourced from abroad. Redundancy should be a consideration when sourcing for equipment and spares.

Reaming

3.4 days were spent on reaming in Menengai while 0.9 days were spent in Hengill. Reaming is usually done to straighten a crooked hole or to enlarge a tapered or tight well bore.

Wait on water.

Wait on water days were 4.7 in Menengai while 0.3 in Hengill. In Menengai this was necessitated by the severe loss of circulation encountered throughout the drilling process. Loss of circulation meant that water in the mud tanks and the pond were depleted fast and the replenishing rate was not as fast. Four rigs are drilling in the Menengai caldera and all depend on the same supply. Water in Menengai is supplied from drilled wells and sometimes brine from discharging wells. The formation is highly fractured and drilling crew experience frequent long lost circulation periods. This means that there should be a constant supply of drilling fluids in to the drilling sites.

5. CONCLUSIONS

Formation geology of Menengai played a major role in the problems experienced considering the amount of time spent on stuck pipe, reaming, cementing losses and the duration it took to drill the reference well compared to Hengill. Therefore the drilling rate depends largely on the hardness or softness of the formation being drilled on. This goes to show that bit selection is an important factor and so is the weight on bit and the RPM applied in determining drilling time. Most drilling challenges can be overcome with improved drill bit technology as the drill bit is the single equipment component most impacting the rate at which a well progresses to total depth. Improved bit life determines how often a bit must be changed and often eliminates the incremental bit trip, and resultant delays and lost time.

Drilling problems related to wellbore pressure such as lost circulation, and stuck pipe increased significantly with depth in both fields. Some of these problems can be prevented with more information. Well logs are the only link to bottom hole condition and therefore their importance cannot be over-emphasised. The more information available about the reservoir conditions the easier it is to make accurate decision on drilling and develop solutions to drilling problems such as areas to case off to avoid cold zones and make decisions how to treat loss zones.

Adequate planning from the beginning of the well will ensure that the unscheduled events or problem time are not a surprise and therefore drilling progress will not be halted. Planning for drilling materials and consumables is important and redundancy should be a consideration when sourcing for equipment and spares as this will reduce NPT and increase PT.

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