

GEOHERMAL DRILLING PERFORMANCE IMPROVEMENT THROUGH A COMPREHENSIVE NON-PRODUCTIVE TIME ANALYSIS

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ABSTRACT

In the development of geothermal projects, one of main thing that has the greatest level of challenge and high costs are drilling operations. Drilling operations planning must be carried out properly and precisely so that the well can be completed effectively and efficiently in term of depth, time and cost.

However, in carrying out drilling operations problems cannot be eliminated. Operational problems can be categorized into surface and subsurface problems. All these problems lead to unplanned operational time in geothermal well construction, commonly defined as Non-Productive Time (NPT). NPT has a direct relationship to the cost overrun of wells.

Processing standardized daily drilling reports is the main information in identifying existing NPT, which explicitly stated as NPT or sometime disguised in Productive Time (PT). All these NPTs are then classified and analyzed to get the root cause and define ways to improve the performance during drilling campaign.

This paper aims to describe a comprehensive NPT analysis of all operating times to improve geothermal well performance. The proper NPT analysis can minimize problems in drilling, improve the drilling performance and in the end increase the economic value of geothermal development projects.

1. INTRODUCTION

The objective of geothermal well drilling is to drill wells according to plan, in a safe manner, using available technology while looking at the overall cost. To control costs, it is important to increase drilling rate and reduce drilling time. Drilling time analysis is important because it will affect the analysis of the drilling project.

There are many factors and events that affect the time and cost of drilling a well. It can be classified as observable or non-observable factors (Kaiser, 2007). Factors include physical characteristics, geology, and wellbore parameters, while indirect characteristics, such as operator experience and wellbore quality. Not only that, other factors such as good planning and execution, team communication, leadership, and project management skills will also affect drilling performance, but capturing and recognizing the NPT root cause is still lacking.

Therefore, we invite you to share a comprehensive method to analyze all NPT in drilling activity to improve the performance of geothermal well. It is hoped that with proper analysis, NPT problems can be identified, analyzed and minimized. Thus, drilling performance can be continuously improved efficiently, and increase the economic value of geothermal development projects.

2. BASIC THEORY

2.1 Drilling Introduction

Drilling is the process of making a hole either vertically or directionally into the earth to tap the resource stored in reservoirs such as oil, gas, water, heat, steam and others. The drilling operation is carried out by a rig which has several operating systems. According to Azar, 2007, drilling for these resources require two major constituents: skilled manpower and hardware systems. In addition to these, hardware and consumable materials such as casings, cement, mud, water and others are needed in the making of the holes.

The drilling action involves breaking the ground and lifting the rock cuttings from the resulting hole by suspending them in a circulating drilling fluid. The actual breaking of the ground is achieved by use of a rock bit which is rotated under controlled weight to crush and shear the surface. Drill pipes are connected to the rock bit in order to drill deeper and deeper. To prevent collapsing of the well bore walls and formation fluids invading the hole, the well is cased and cemented. Drilling is one of the most critical, complex and costly operations in geothermal resource development projects.

2.2 Non-Productive Time

During the drilling process, there are numerous occurrences or eventualities that cause stoppage of drilling operations or marginal reduction in advancement of the drilling progress. Such occurrences are classified as nonproductive time (NPT). Non-Productive Time (NPT) is defined as time which drilling operation is ceased or did not related to the construction of the well; for example, time spent on fishing, stuck pipe, waiting on equipment repairs, tool transportation, lost circulation and tripping in/out. Non-Productive Time (NPT) is the main cause of drilling project delays and huge costs overruns in drilling projects due to standby charges and penalties on equipment and personnel.

Moreover NPT is also defined as the time in which the drilling operation ceases in an unplanned way or when the drilling penetration rate becomes excessively low (Dew and Childers 1989). Given the colossal investments in the drilling ventures, the drilling time has become intimately reflective of its operational costs. Therefore, reducing the NPT should improve drilling performance and reduce

well cost to save money. The NPT concept started in the 1960s, and since then many studies and approaches emerged in an attempt to control lost time to acceptable values.

Productivity can be defined as the ratio between efficiency of a process and the effectiveness of the process. The efficiency of a process is a measure of the resource consumed to run the process. Meanwhile, the effectiveness of a process is the ratio between the expected throughput and the actual throughput.

Productivity can be defined as a multiplier of effectiveness and efficiency if both of their value increase will also increase the sum productivity. Besides, the efficiency of a process is a measure of the resource consumed to run the process. Meanwhile, effectiveness is defined as a scenario where actual throughput is at least equal to but ideally larger, than expected throughput.

As the occurrence of NPT in a drilling operation is not in accordance with the drilling plan, there must be additional drilling time and costs in consequence. Understanding of NPT contributor in each activity and every of hole sections are thus required in developing a proper drilling plan and mitigation to optimize the drilling time and costs.

2.3 Drilling Engineering

Drilling engineering is divided into several specialties which are described in Figure. 1

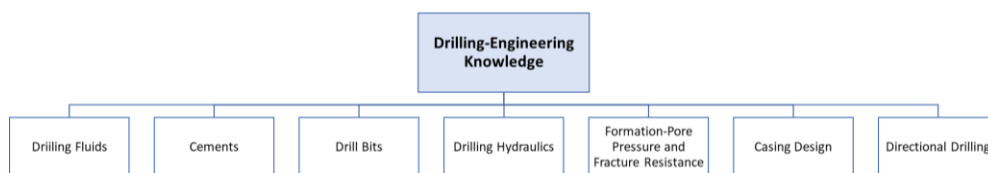


Figure 1: Basic Knowledge of Drilling Engineering (Bourgoyne, 1986)

Each part of the drilling knowledge is connected to each other in the flow path of drilling design and operation. There are many factors and events that impact the time and cost to drill a well. Factors can be classified as either observable or unobservable (Kaiser, 2007).

3. METHODOLOGY

Analyzing a drilling performance of some well starts with evaluating daily drilling report data. The data are then categorized based on their drilling productivity. Productivity of drilling activities can be categorized as productive time (PT) and non-productive time (NPT). The next step is to evaluate each category. Generally, NPT can be classified into surface NPT and subsurface NPT. In most cases, this NPT is easily distinguished on the drilling report. As for PT, for the purpose of performance improvement, it is proposed to be classified into actual PT and a hidden NPT. This hidden NPT is defined as any unplanned activity though the activity itself is a PT by definition.

All PT need to be evaluated whether it is corresponding with the planned program or not. If it is not corresponding, a proper classification will be carried out and the actual PT drilling activities need further root cause analysis investigation similar to Surface NPT, and Subsurface NPT. The analysis will be resulting recommendations for improvement to be implemented on next drilling operation.

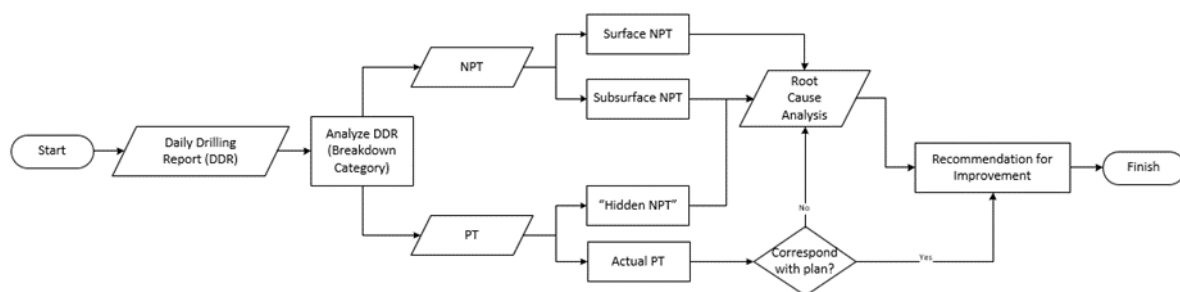


Figure 2: Methodology

4. ANALYSIS ACTIVITY IN GEOTHERMAL: A CASE STUDY

Time analysis data for well samples were obtained from daily drilling reports. The data is then grouped into activity category for each well. The average time required for each activity for each well is then calculated. The difference between this average time and the planned time for each activity is then calculated to generate the PT NPT activity. Comparison of the average time required to the

planned time allocated to each activity. This paper will take a case study in well R-27, a geothermal big hole well in Sumatera. The Day Vs Depth curve is shown from on figure 3.

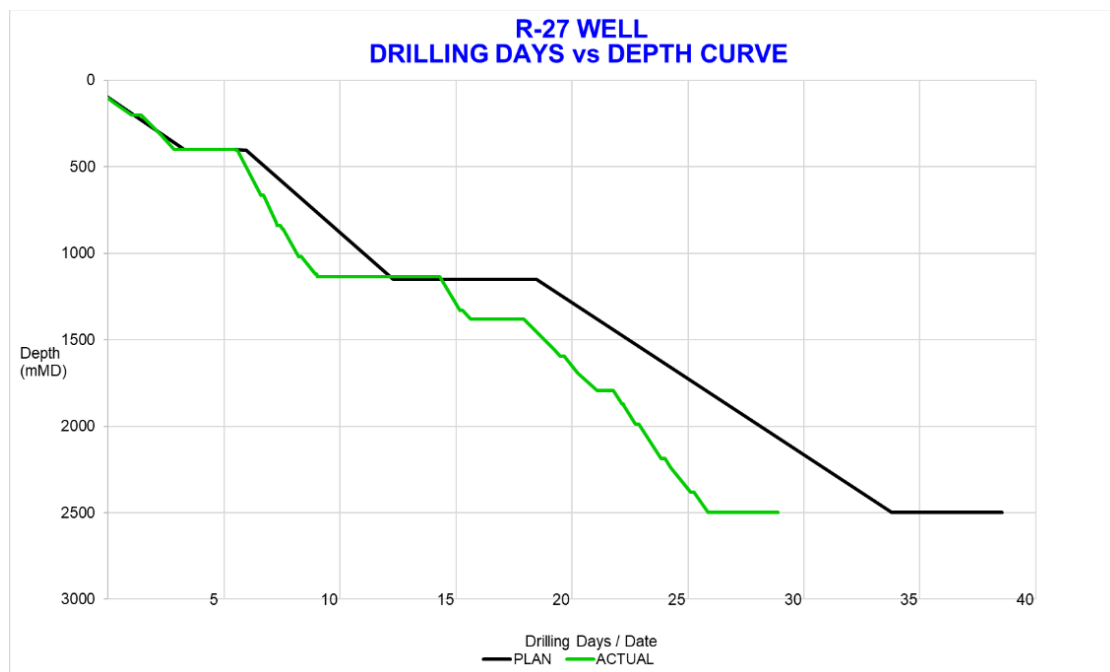


Figure 3: Drilling Days versus Depth Well R-27

The planned drilling days was 39 days from spud-in to rig released, with planned depth of 2500mMD. And the actual drilling days is 29 days with the same TD of 2500mMD. This well is an ideal example to demonstrate that despite the drilling was completed ahead of the planned time and the NPT is considered low, there is a room open for improvement as there is some hidden NPT among the PT.

4.1 Analysis PT/Drilling Time Analysis

4.1.1 Actual PT

Drilling time is the time required to drill a wellbore to the maximum depth. Drilling time is included in the productive time (PT) for activities that contribute to wellbore making and planning. Prior to drilling, a well program is created showing the planned time for each activity. In well R-27, with a well depth of 2500mMD it is planned to take 39 days from spud to completion. summary of activities and time allocated are given in Table 1.

Table 1: Breakdown of the planned time allocated to drilling activities

Code	Description	Total Hrs	% of Total
BOPOPS	BOP Nipple Down	10.50	1.5
	BOP Nipple Up	19.00	2.7
	BOP Testing	8.00	1.1
	Flowline Installation	2.00	0.3
	Master Valve Installation	1.00	0.1
	Total	40.50	5.7
CASING	Running Casing	54.50	7.7
	Running Casing on Drill Pipe	9.00	1.3
	Total	63.50	9.0
CEMENT	Drilling Cement/Shoe	2.00	0.3
	Primary Cement Operations	14.00	2.0
	Secondary Cement Operations	3.50	0.5
	Waiting On Cement	2.50	0.4
	Total	22.00	3.1
COMPLETE	Laying Down Pipe	0.50	0.1
	Rig Down	0.50	0.1
	Total	1.00	0.1
DRILL	Circulate/Condition Mud	43.50	6.2
	Drilling Ahead w/ Connections	325.00	46.2
	Drilling Cement/Shoe	15.50	2.2
	Reaming/Underreaming	5.50	0.8
	Total	389.50	55.3

Code	Description	Total Hrs	% of Total
EVALUATE	Completion Test	26.50	3.8
	Test Casing	4.00	0.6
	FIT / LOT / XLOT / SRT	1.00	0.1
	Wireline Logging	11.00	1.6
	Total	42.50	6.0
MOB	Rigging Up	24.50	3.5
	Total	24.50	3.5
OTHER	Cut and Slip Drill Line	3.00	0.4
	Other Activity	0.50	0.1
	Hold Safety Meeting	0.50	0.1
	Total	4.00	0.6
PROBLM	Operational Problem	1.00	0.1
	Rig Repairs	1.00	0.1
	Stuck Pipe Operations	1.00	0.1
	Total	3.00	0.4
TRIP	BHA Operations	32.50	4.6
	Tripping in	20.50	2.9
	Tripping Out	45.00	6.4
	Wiper Trip	15.50	2.2
	Total	113.50	16.1
Total Elapsed Time for Well		704.00	
Total Non-Productive Time for Well		4.50	0.6
Total Productive Time for Well		699.50	99.4

As shown in table 1, drilling involves numbers of activities. Ideally actual drilling occupies 50-60% of the time it takes to complete a well. Other time is spent on value-adding activities, such as casing and cementing, or on necessary but non-value activities such as tripping and Circulating. Occasionally, non-value-added activities outside the well plan such as fishing and stuck pipe operations, wait on repairs, etc., also occur. In planning the time required to drill a well, drilling and other necessary activities are adjusted to the expected time.

4.1.2 “Hidden” PT

During drilling a well, any activity that takes longer than plan is considered as hidden NPT even though it is not contributed to traditional non-productive time (NPT). Any activities that occur that are not in the plan are NPT activities. NPT is calculated as the time required for an activity outside the planned time.

It should also be noted that there were some activities that took less time than planned, suggesting that if NPT activities are reduced it may be possible to see more efficient drilling under the currently planned time. In this case, it can be taken from several cases in the summary plan and actual operations. In well R-27 the data will be displayed in the 26" hole section. (Table 2. & Table 3.) The following is the table operation summary plan and the actual in 26" hole section.

Table 2: Operation Summary Plan in 26" Hole Section

Plan Time Summary			
Plan date & time Start	Main Operation Summary	Plan Time (hrs)	Depth (mMD)
07-Mar-19 07:00	SPUD IN WELL R-27 ON 7 Mar@ 07:00 HRS.	R27	57
11-Mar-19 01:00	Drill 26" hole.	89.8	400
11-Mar-19 11:00	After TD 26", Circulate, wiper trip, POOH	10.0	400
11-Mar-19 14:30	Cut 30" conductor. Rig up to run 20". Make up shoe track	3.6	400
11-Mar-19 22:00	Run casing to bottom	7.6	400
12-Mar-19 02:30	M/U and run stinger. Change link bails. M/U cement head.	4.5	400
12-Mar-19 05:00	Circ. & cond. Mud	2.6	400
12-Mar-19 12:00	Pump cement. POOH & L/D stinger	7.1	400
12-Mar-19 21:30	Install Base Plate. Back off Landing Joint. N/D Flowline. Cut and L/D 30". (Top Job offline)	9.1	400
12-Mar-19 23:30	Install drilling head	2.0	400
13-Mar-19 06:30	N/U BOP & Flowline. Test BOP	7.0	400
13-Mar-19 14:30	M/U and run 17-1/2" BHA. Drill shoe track and rathole.	8.1	403
13-Mar-19 16:30	Perform LOT / FIT	2.0	403
Total Plan Time		153.4	

Table 3: Operation Summary Actual in 26" Hole Section

Actual Time Summary			
Actual date & time Start	Main Operation Summary	Actual Time (hrs)	Depth (mMD)
07-Mar-19 07:00	SPUD IN WELL R-27 ON 7 Mar@ 07:00 HRS.		57
07-Mar-19 07:00	Drill 26" hole from 57 to 131 mMD	17.0	131
08-Mar-19 00:00	Drill 26" hole from 131 to 200 mMD	18.5	200
08-Mar-19 18:30	Pump 2x 50 bbls HiVis. CHC. Spot 50 bbls HiVis on bottom.	1.0	200
08-Mar-19 19:30	POOH 26" Rotary BHA to surface.	3.0	200
08-Mar-19 22:30	P/U, M/U 26" Directional BHA to 17 mMD.	1.5	200
09-Mar-19 00:00	P/U, M/U, RIH 26" Directional BHA, take weight at 186.6 m. Ream down to 200 mMD.	4.0	200
09-Mar-19 04:00	Drill 26" hole to 315 mMD	20.0	315
10-Mar-19 00:00	Drill 26" hole to section TD at 401 mMD	14.5	401
10-Mar-19 14:30	Drop Carbide + rice check. Sweep out 3 x 50 bbls HiVis. CHC.	2.0	401
10-Mar-19 16:30	POOH 26" Directional BHA to 54 m - above shoe (experience tight spot at several depths).	6.5	401
10-Mar-19 23:00	RIH back to 153 mMD.	1.0	401
11-Mar-19 00:00	RIH back to bottom at 401 mMD (no obstruction, no hole fill).	1.0	401
11-Mar-19 01:00	Sweep out 2 x 50 bbls HiVis. CHC. Spot 100 bbls HiVis.	1.5	401
11-Mar-19 02:30	POOH 26" Directional BHA to surface.	5.0	401
11-Mar-19 07:30	Prepare to run 20" Casing	2.5	401
11-Mar-19 10:00	PJSM. P/U and function test 20" Shoe.	0.5	401
11-Mar-19 10:30	Run 20" Casing STC connection + X/Over to 53 m.	5.5	401
11-Mar-19 16:00	Cont run 20" Casing to bottom.	5.5	401
11-Mar-19 21:30	Centering casing to RT by welding 4 ea lugs. Install Base Plate and set slip onto 20" Casing.	2.5	401
12-Mar-19 00:00	Release and L/D 20" Landing Joint.	1.0	401
12-Mar-19 01:00	R/D csg handling eqp, change out links + elevator, R/U Hawk Jaw. M/U Cmt Head + 5" PJ, L/D same.	1.0	401
12-Mar-19 02:00	M/U and run 5" Cmt Stinger. M/U cement head to the string. RIH and stab-in stinger into the shoe.	2.5	401
12-Mar-19 04:30	Circulate & condition Mud.	1.0	401
12-Mar-19 05:30	Perform 20" Casing Cementing Job.	3.0	401
12-Mar-19 08:30	POOH & L/D stinger.	1.0	401
12-Mar-19 09:30	N/U BOP & Flowline. Test BOP connection.	13.0	401
12-Mar-19 22:30	M/U and run 17-1/2" BHA to 367 m. Wash down and tag TOC at 396.5 mMD.	6.5	401
13-Mar-19 05:00	Drill out cement, shoe track and rathole. Drill 3 m new formation to 404 mMD. CHC.	2.0	404
13-Mar-19 07:00	Perform FIT	1.0	404
Total Actual Time		145.0	

It can be seen from the summary operation of the R-27 well in the 26" hole section taken from the summarized Daily Drilling Report data. At the size of the 26" hole the actual and planned time difference has a considerable time difference. In the actual plan size 26" hole section, which will be drilled to a depth of 400 m using two stages, namely to be drilled to a depth of 200m and followed by drilling to 400m. it can be seen that there is a difference of about 10 hours from the plan. This may need to be considered for the construction plan and the condition of the well so that it can match the actual. As for the plan time, direct drilling is carried out to a depth of 400 m. That's a small part of the activities that can be analyzed deeper to get an effective time with the possibility of minimal NPT.

Furthermore, it should also be noted that there is a detailed data analysis that needs to be analyzed more thoroughly in order to identify a hidden NPT. The following are the findings and excerpts of several daily drilling reports on the R-27 well in the 26" hole section as can be seen on the DDR well R-27.

Rpt. No.	Time	To	Hrs	End MD	Ops Code	Activity Description	Non-Prod.
1	07:00	12:00	5	75.9	DRIL	== SPUD-IN @ 07:00 hrs == Vertically drilling 26" hole from 57 m to 75.9 mMD. - FR 700-920 gpm, SPP 190-300 psi, WOB 1-15 Klbs, RPM 60-80, TRQ 0.8-10 Klbs.ft. - ROP 1.68-15.8 m/hr. - Full return, No mud Losses. - Meterage drilled 18 m, Avg ROP 4.1 m/hr. - Rotate 100%. - MTI / MTO: 21°C / 22°C. - Pump 50 bbls Hivis sweep every half stand drilled and every stand down or as per hole condition dictated. - Ream minimum twice full stand prior connection. - Drilling hard formation at 66.5- 71 mMD w/ ROP 1.6- 6 m/hr. Note: - 26" Used TCB (Varel, Type ES14V, S/N 1582040, IADC 435, nozzles 3 x 32 + 1 x 20, TFA 2.663 in^2).	
	12:00	12:30	0.5	75.9	CIRC	Attempt to break out connection between HWDP and TDS Saver Sub prior to make connection, observe connection 6-5/8" Reg above Saver Sub break out loose with 45 Klbs.ft. Re make up connection.	
	12:30	13:30	1	75.9	PROBLM	Continue circulate and spot 50 bbls Hivis on bottom. Break out 1 single HWDP off bottom with Saver Sub still connected to HWDP. Put on Mouse Hole. Break out Saver Sub off from HWDP using Hawk Jaws with 80 Klbs.ft. Re install Saver Sub on TDS, re make up to 45 Klb.ft and install Tool Joint Lock Ring.	X
	13:30	18:00	4.5	103	DRIL	Vertically drilling 26" hole from 75.9 m to 103 mMD. - FR 940-1020 gpm, SPP 350-420 psi, WOB 3-13 Klbs, RPM 75-85, TRQ 0.4-10 Klbs.ft. - ROP 2.9-16.7 m/hr. - Full return, No mud Losses. - Meterage drilled 27.1 m, Avg ROP 8.31 m/hr. - Rotate 100%. - MTI / MTO: 24°C / 25°C. - PUW / RTW / SOW at depth 103 mMD: 83 / 83 / 80 Klbs. - Pump 50 bbls Hivis sweep every half stand drilled and every stand down or as per hole condition dictated. - Ream minimum twice full stand prior connection. - Drilling hard formation at 76-77 mMD w/ ROP 3-6.4 m/hr, at 81 mMD w/ ROP 2 m/hr at 82-82.5 mMD w/ ROP 4.4-5.3 mMD, 90-91 mMD w/ ROP 4.4-5.5 m/hr, at 96.5 mMD w/ ROP 4.8 m/hr.	
	18:00	19:30	1.5	103	BHAOP	POOH 2 stands 5" HWDP from 103 m to 46 mMD. M/U 1 stand 8" DC + 1 stand 5" HWDP and RIH same, observe string take weight at 97 mMD - hole fill 6 m. Wash down to bottom at 103 mMD with FR 960-1000 gpm, SPP 400-430 psi.	

Figure 4: DDR section of Well R-27 in drilling 26" hole section.

Here, it was found that there was a problem at the beginning of the drilling, but it did not show in the operation summary of R-27. The problem that arises is caused by HWDP in the string circuit. For this problem it takes 1 hour to fix HWDP. What must be emphasized is that there must be accuracy in assessing an existing actual plan. Because an NPT analysis must be as detailed as possible so that in the future it can be the key in making drilling plan.

4.2 Analysis NPT

Activities where the actual time value taken from the graph exceeds the planned time has resulted in NPT. The causes of NPT in drilling vary, which can be caused by unexpected events that cannot be controlled by the drilling crew, or due to events outside the drilling planning plan for a job. Things that like to happen and are considered as NPT are during activities in the well or the drilling tools used. In well R-27 on 26" hole section, it can be seen that several NPTs were identified and divided into surface NPT and subsurface NPT. (Table.4) NPT Summary in R-27 on 26" hole section.

Table 4: NPT Summary of Well R-27 in 26" Hole Section

Code	Description	Total Hrs	% of Total
PROBLM	Operational Problem	1.00	0.1
	Rig Repairs	1.00	0.1
	BOP Repairs	0.50	0.1
	Stuck Pipe Operations	2.00	0.3
	Total	4.50	0.6

4.2.1 Surface NPT

At the time of drilling the R-27 well, NPT was identified in the Surface NPT section, namely problems in Operation Problems, Rig repairs and BOP Repairs. Time out for Return to PT is 1 hour for Operational Problem and Rig Repair. As for the BOP Repair 0.5 hours. This problem requires reliable personnel to assist or reduce the NPT time resulting from these problems the same conditions during drilling operations, personnel are the key to the success or failure of the operation (PetroWiki, 2013a).

4.2.2 Subsurface NPT

The problem identified in well R-27 is stuck pipe at a depth of 1381mMD. Indications that can be seen in the stuckpipe problem are the drill string cannot be moved, rotated or lifted, the pump pressure increases suddenly, the torque increases and so on. There are two types of pinched pipes, namely differential pipe sticking and mechanical pipe sticking. Mechanical pipe sticking can be caused by key seat, hole under gauge, wellbore instability, poor hole cleaning and related causes. Differential sticking usually occurs when high contact forces caused by low reservoir pressure, high wellbore pressure, or both, are applied to a sufficiently large area of the drill string.

The occurrence of pipe jams is widely considered to be the most expensive drilling problem facing the industry and the cost of repairing it can run into the millions of dollars. Performing well data analysis to predict possible drill chain jams is becoming more and more important.

4.3 Corresponded with plan & Root Cause Analysis

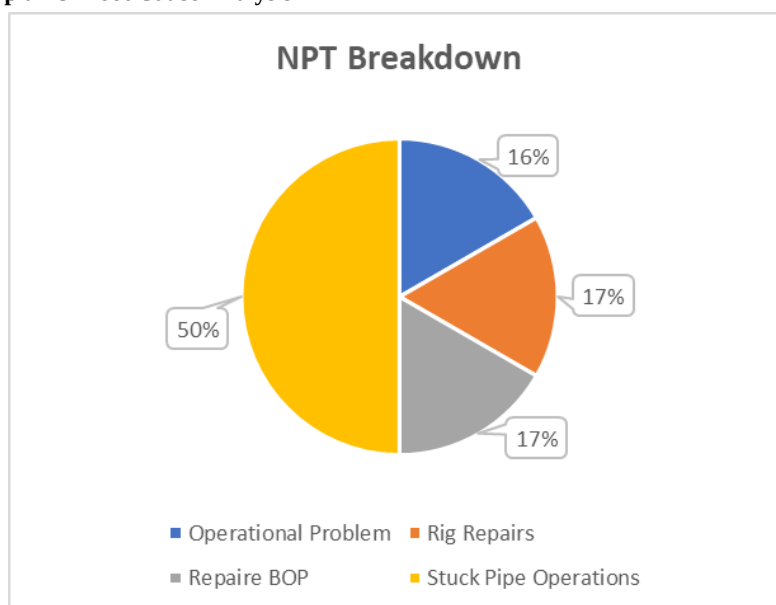


Figure 5: NPT Breakdown.

It is impossible to eliminate NPT completely, but it can be minimized as long as it doesn't impact drilling time so much. Process improvements and changes in drilling practices are fundamental to ensuring that inefficiencies in the drilling process are addressed. For the R-27 well, several problems were identified during drilling, including in terms of surface and subsurface. At well R-27 On the surface, the first problem, namely Operational Problem in the 26" hole, occurred as much as 0.14% or equivalent to half an hour of the total drilling operation duration of 704 hours (29 days). The cause of the Operational Problem was the repeated unmounting of single HWDP under Saver Sub.

Last but not least, BOP Repairs in the 26" hole section occurred as much as 0.07% or equivalent to 0.5 hours of the total drilling operation duration of 704 hours (29 days). The cause of BOP Repair is the repair of the tool from the side outlet flanges.

The second is Rig Repair in the 17-1/2" hole section, which occurred 0.14% or equivalent to 1 hour of the total drilling duration of 704 hours (29 days). The cause of the Rig Repair was the occurrence of a single HWDP installation under the Saver Sub.

6. CONCLUSION

This study shows that there are problems in the condition of PT becoming a "hidden NPT" which needs to be considered so that it can be accurate in analyzing drilling activities. The detail plan of activity is the basis, and the detail and consistent reporting (refer to drilling code) is the key to maintain the make an accurate analysis possible to be conducted. By include these "hidden" NPT, the analysis become comprehensive and the existing data can be use as reference in the future to develop drilling improvement plan.

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