Improving The Accuracy Of Mechanical Backoff In Stuck Pipe Situation During Drilling: Case Study, MW24, Menengai Geothermal Project

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ABSTRACT

A stuck drill string occurs when the static force required in moving the string exceeds the drilling rig capabilities or the tensile strength of the drill pipe. This may be due to several causes such as inadequate removal of drilled cuttings from the annulus, wellbore instabilities, squeezing (creeping) and key seating. A drill string can either be mechanically or differentially stuck. Freeing a mechanically stuck drill string depends upon the cause. In the case of cuttings fill in the annulus, rotating and reciprocating the drill string and increasing flow rate of the drilling fluid without exceeding the maximum allowed equivalent circulating density (ECD) is a possible remedy for freeing the pipe. For hole narrowing as a result of plastic shales and salts, increasing the mud weight and circulating fresh water may free the drill string. However if the drill string is stuck because of key-seating the most successful solution is backing off below the key seat. Other operations such as tripping in with a fishing bottom hole assembly (BHA) or plugging back and side tracking to continue drilling the well to the target depth may be carried out. Mechanical backing off is the last resort to recover the drill string as the exact backing off point cannot be precisely determined. This paper looks at how the accuracy of the mechanical backoff can be improved by taking into account parameters such as the neutral point weight, maximum overpull, make up torque, pick up weight, weight of string and slack off weight. Data from MW24; a vertical exploration well in the Menengai Geothermal Project is used in the computations and determining the best approach in conducting a mechanical backoff procedure.

1.0 INTRODUCTION

There are two types of drill string sticking scenarios: differential or mechanical. Differential sticking occurs when the hydrostatic pressure of the drilling fluid is greater than the pore pressure of a permeable formation as shown in Figure 1. This overbalance presses the drill string against the well bore and is often initiated when the drill string is stationary or moving slowly and comes in contact with a permeable formation or a thick mud cake, Costo *et al.* (2012). Mechanical sticking on the other hand occurs when the drill string is being moved and is caused by physical obstruction or restriction, Costo *et al.* (2012). This is caused by inadequate well cleaning, formation instability (pack off) or key seating as shown in Figure 2, Figure 3 and Figure 4. The drill string cannot be rotated or moved up and down. This usually occurs while drilling, making a connection, tripping in/out or during an operation where the drill string is in the well bore, Nyakiti (2016).

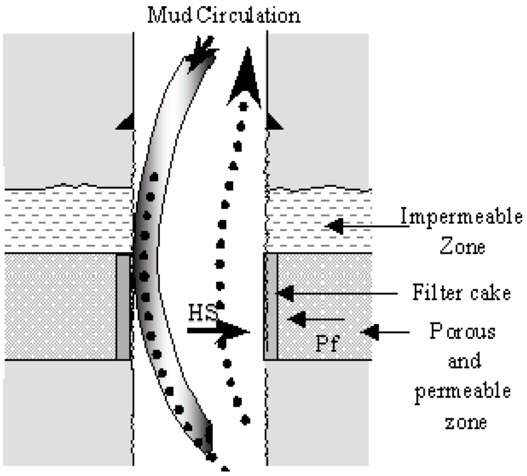


Fig 1: Differential sticking

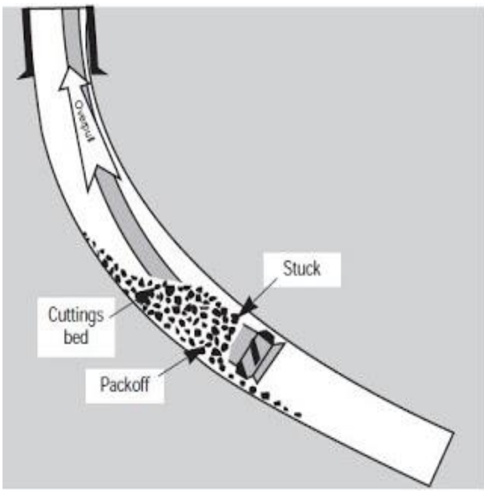


Fig 2: Packoff (Mechanical sticking)

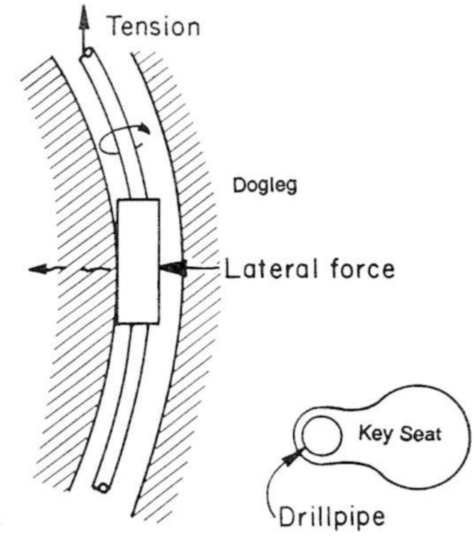


Fig 3: Key seating (Mechanical sticking)

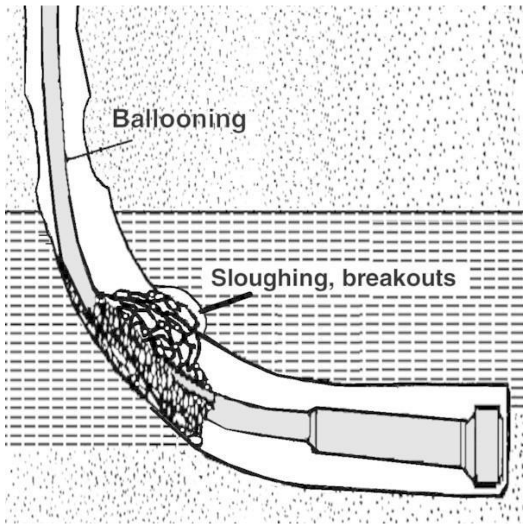


Fig 4: Sloughing, breakout and ballooning

A mechanically stuck drill string is a major non-productive cost that drilling companies incur which affects the final cost of drilling a well especially for extended reach and highly deviated wells, Sugar Land Learning Center (1999). These types of wells present many technical challenges, most of which require unconventional solutions as compared to vertical or low-angle wells.

1.1 Previous studies

Research has been done to determine the best reactive approaches to free a mechanically stuck drill string. Awili (2014) sugggests recovering a stuck drill string using a combination of left hand torque and explosive charges.The limitation of this procedure is the difficulty in availing the explosives on site due to legal restrictions. In 2013, Rachain.J *et al* developed a procedure for performing blind backing off for situations where a perforating gun cannot be used. The research however could not precisely determine the backing off point.

2.0 STUCK DRILL STRING DECISION MODEL

The decision to backoff, fish, plug, sidetrack or abandon a wellbore after the drill string is stuck depends on the outcome of a number of processes as shown in Figure 5, Bowes (1997). A differentially stuck drill string may be freed by:

1. Reducing the mud hydrostatic pressure in the annulus by reducing the mud weight.
2. Spotting oil around the stuck portion of the drill string.
3. Washing over the stuck pipe.

Freeing a mechanically stuck drill string will depend on the cause of sticking. For hole narrowing as a result of plastic shales and salts, increasing the mud weight and circulating fresh water may free the drill string. However, if the drill string is stuck because of key-seating the most successful solution is backing off above the key seat, Santos (2000).

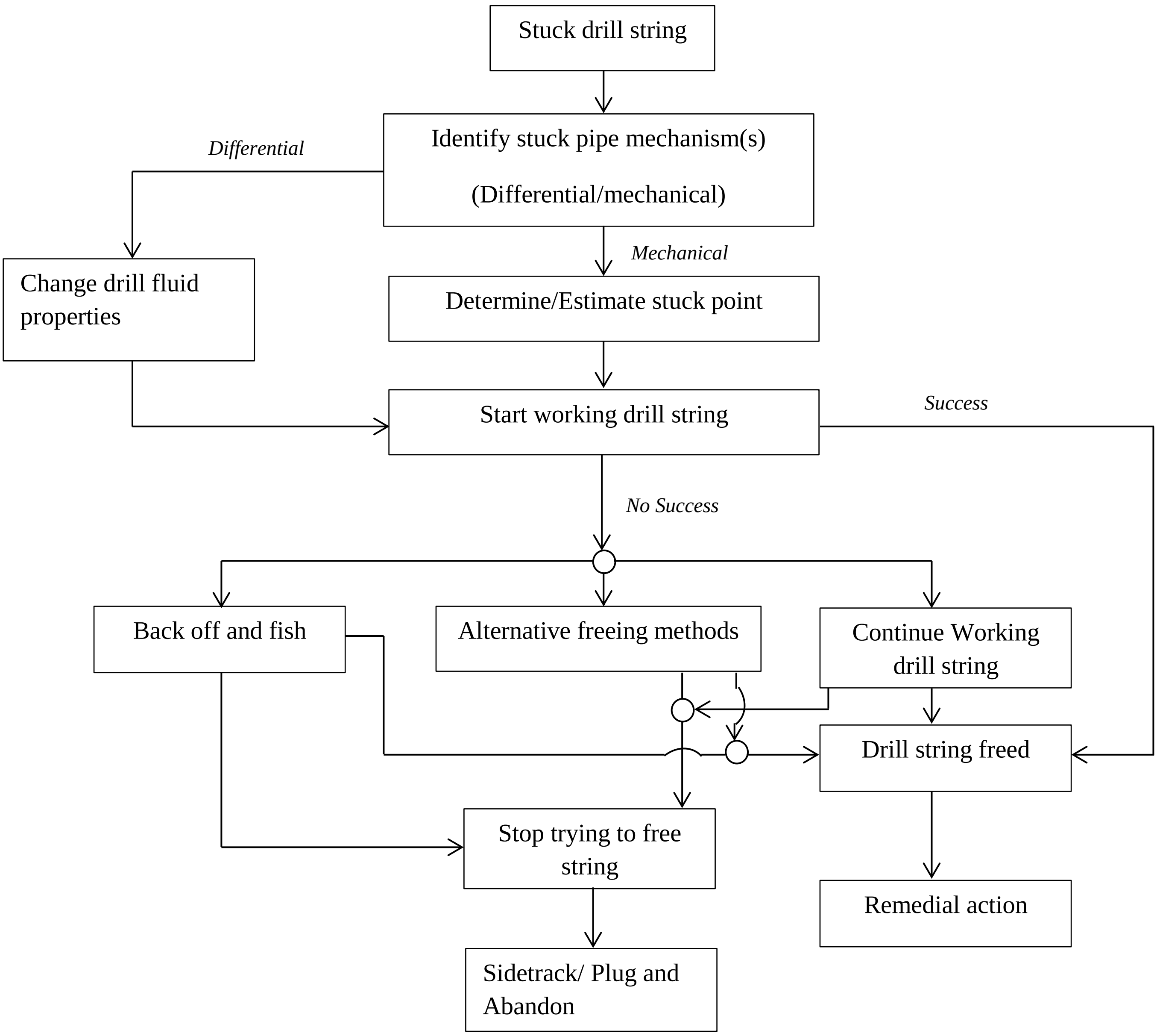


Fig 5: Stuck drill string decision model

3.0 MECHANICAL BACKOFF

Mechanical backing off is the intentional break out of a stuck drill string by applying left hand torque and transmitting it down hole, Rachain.J *et al* (2013). This is the last method used to recover a drill string as the exact backing off point cannot be precisely determined. The primary advantage of this time-proven technique is that it allows the drill string to be separated from the stuck section and reconnected with full mechanical integrity. However, in order for a backoff to be a viable option in a vertical well, the drill string must be rotationally stuck at some point in the well.

The success rate of a mechanical backoff is usually low due to the unpredictability of the operation. However, the accuracy can be improved if parameters such as the stuck point, neutral weight, maximum overpull weight, backoff torque and make up torque are correctly determined as in the case of well no 24 (MW24) in Menengai geothermal field.

Before performing the backing off process, it is necessary to determine certain parameters that will aid in ensuring the drill string is backed off at the estimated depth. These determined parameters are:

1. The stuck point.
2. Neutral point weight.

3.1 Determining the stuck point

In situations where external contractors can be sourced or the free point indicator tool (FPIT) is available, the stuck point can be determined by running in hole (RIH) the tool and determining the position to be backed off. This is however not a common practice especially in geothermal drilling because of the cost component, Muhammad *et al.* (2012). The stuck point has then to be determined by calculation using the stretch test formula.

$$SP_L = \frac{\Delta L C_{fpc}}{F_d} \quad (1)$$

Where:

SP_L = minimum length of free pipe (m)

ΔL = stretch (inches)

C_{fpc} = Free Point Constant (Drilling Engineering hand book)

F_d = pull force (klbs)

The procedure for determining the stuck point involves:

1. Tensioning the drill string with at least 50klb of load over the hanging weight of tubulars in the hole.
2. Marking a reference on the body of the drill string.
3. Increasing the pull on the pipe in increments of 100 klb over original tubulars weight.
4. Measuring amount of pipe stretch (ΔL).
5. Subtracting original weight reading from final pull weight (F_d).
6. Obtaining the Correct Free Point Constant (C_{fpc}) from drilling Engineering hand book and using equation 1 above to determine the stuck point.

3.2 Neutral Point Weight (NPW)

This is the weight in air of the drill string above the stuck point. It is useful during the working up and down of the string while transmitting torque to the desired backing off point.

Other parameters determined are:

- **Maximum Overpull weight:** determined by the overpull of the weakest component in the drill string
- **Maximum makeup (M/U) torque**: To avoid unintentional backing off, the maximum M/U that should be applied before applying the backing off torque.
- **Pick up weight (PUW):** The surface weight measurement when pulling a drilling string out of the hole. It includes both string weight and frictional drag.
- **Slack off weight (SOW):** The weight reading when the pipe is being run-in-hole (RIH).
- **Rotating weight (RW):** This is the reading on the weight indicator during normal drilling.

4.0 CONVENTIONAL BACKING OFF PROCEDURE

The standard backing off procedure for a rig using the top drive system (TDS) is as highlighted below, Bourgoyne *et al*. (1986):

1. Determine drilling parameters (PUW, SOW, RW) used prior to getting stuck.
2. Pick up the drill string at 10% over the rotating weight.
3. Apply 50% of make-up torque with left hand turn and lock the TDS.
4. Record the number of turns of the drill string.
5. Slowly work string down from the PUW to SOW for 5-10mins to transmit surface torque to the bottom.
6. Repeat steps 2-5 with 70%, 90%, 100% and 110% make-up torque.
7. The string will back off while working down.

5.0 CASE STUDY: MENENGAI MW24

MW24 is a vertical exploration well that maps out the extent of the geothermal resource in the Menengai Geothermal Development Program. The well is located at the eastern edge of the Menengai caldera geothermal field. The target depth of the well was 2400m (MW 24 geological prognosis).

The well was top holed to 503m after which GDC Ndovu 1 drilling rig completed the well. The 8½ inch hole was drilled to a depth of 2242m before getting stuck. After attempts to free the stuck string were unsuccessful, a back off operation was done, terminating the well at 2149m.

5.1 Drill string configuration

8½" DRILL STRING (PENDULUM BHA)			
Item	**Description**	**Rotation hour**	**Length (m)**
1	8½" bit	100	0.26

2	Bit sub	162	0.61
3	6½" Drill collar	108	9.18
4	8½" String stabilizer	156	1.40
5	11× 6½" Drill collar	108	100.7
6	6½" Drilling jar(w/flex)	188	10.09
7	2× 6½" Drill collar	108	18.30
8	15×5" HWDP	108	140.45
10	203 × 5"DP	156	1961.75

Table 1: Drill string configuration *(MW24 drilling program)*

5.2 Determining the stuck point

Using the stretch test method, the stuck point was determined to be at the 8½ inch string stabilizer as shown in figure 6. The backing off point was then set to be at above the stabilizer at 7316.75ft (2230m).

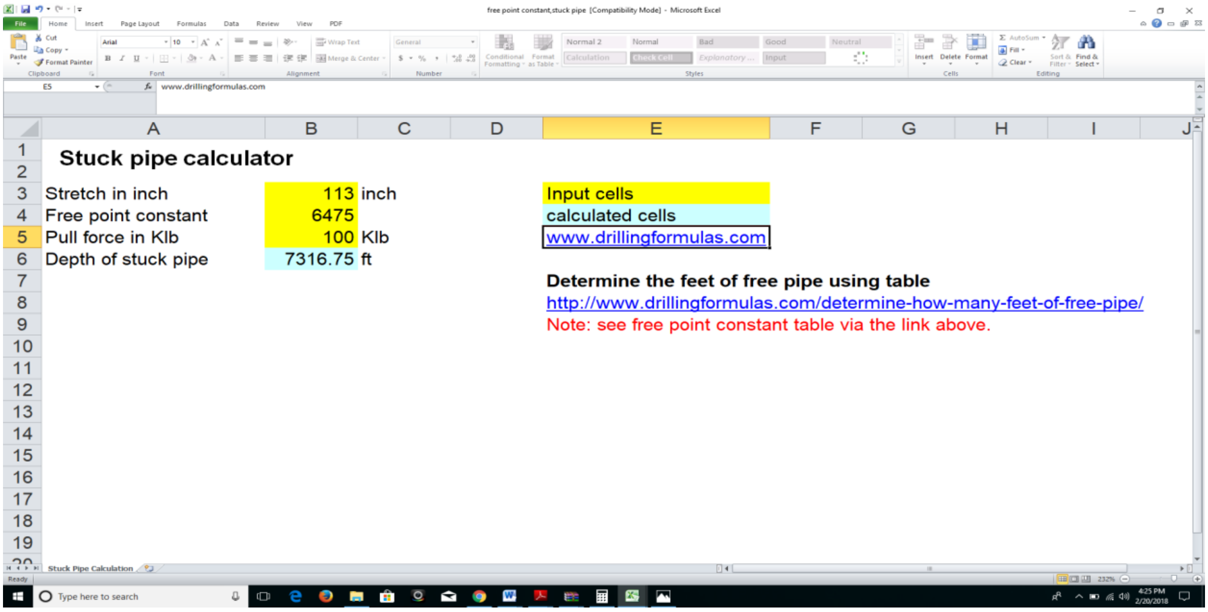


Fig 6: Stuck pipe calculator *(drilling formulas.com)*

5.3 Backing off parameters:

The drill string characteristics are highlighted in table 1 and 2 below.

No	Parameters	Weight (klbs)
1	Neutral point weight (NPW)	193
2	Maximum Overpull	436
3	Pick up weight	240
4	Slack off weight	140

Table 2: Weight characteristics of the drill string *(MW24 drilling program)*

No	Parameters	Torque (kft-lbs)
1	Make up torque 5" DP (Grade G105)	22.5
2	Maximum make up torque (10% over the makeup torque)	25

Table 3: Make up torque (*Drilling data handbook,7th Edition)*

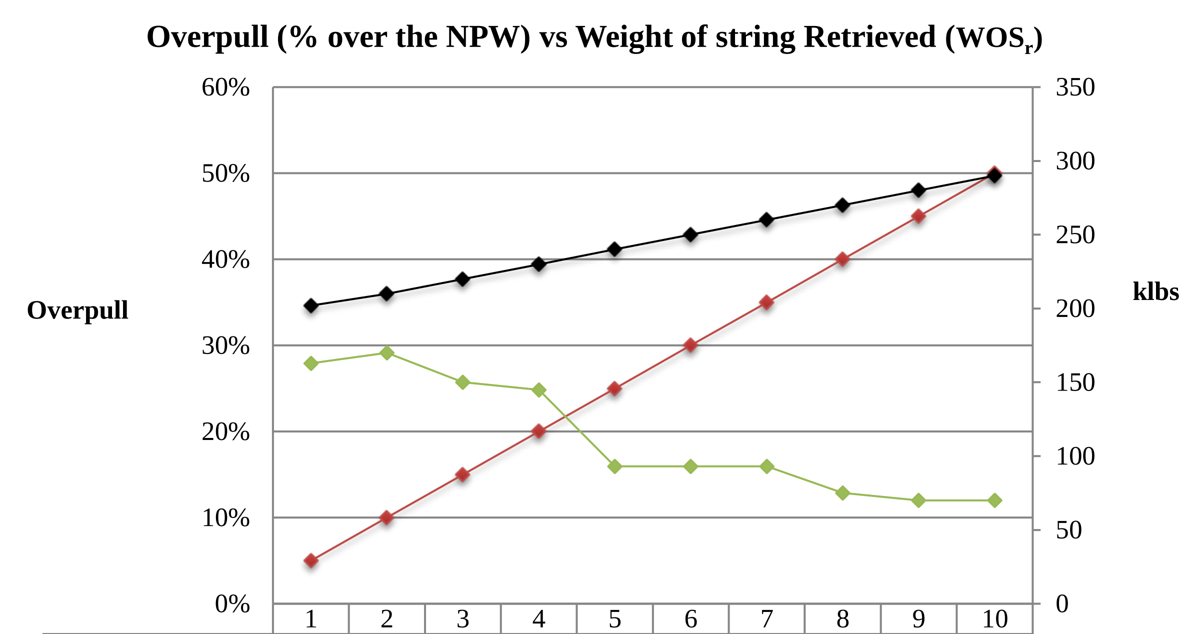
5.4 Backing off (Top drive system)

After all the parameters highlighted had been determined and a pre-job safety meeting conducted, the following back off procedure was followed:

1. The drill string was tensioned to the initial pick up weight of 240klbs.
2. The drill string was over torqued to 25kft-lbs (10% over make-up torque).
3. The number of turns (right hand) of the drill string is recorded while applying the maximum torque till stationary.
4. The drill string was tensioned to initial pick up weight (240klbs) and worked down to the neutral point weight (193klbs) for 10 minutes.
5. The TDS was unlocked, and the number of left hand turns recorded.
6. Steps 3-5 were repeated until the number of right turns were equal to the left turns.
7. The drill string was tensioned to 5% over the neutral point weight.
8. Break out torque (22.5 kft-lbs) was applied.
9. The string was worked down to the neutral point weight for 5-10mins.
10. If the drill string hasn't backed off, repeat step 7-9 with 5% and 10% over breakout torque.
11. The string should back off while working down at 10% over breakout torque.
12. Record the weight of string.
13. Pull out of hole (POOH) to determine the exact backing off point.
14. If the string hasn't backed off at the set point, stab in and repeat the procedure with 10%, 15%, 20%, 25%, 30%, 40% and 50% over the neutral point weight (overpull).

6.0 RESULTS

The figure 6 and table 4 below summarize the results of the backoff procedure at MW24.



	1	2	3	4	5	6	7	8	9	10
% above NPW	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Overpull(klbs)	202	210	220	230	240	250	260	270	280	290
WOSr	163	170	150	145	93	93	93	75	70	70

Fig 7: Graph of Overpull vs Weight of string retrieved

Overpull (O_p) (% over the NPW)	**Relationship**	**Maximum WOS_r**
5-10	$WOS_r \; \alpha \; O_p$	170klbs
15-20	$WOS_r \; \alpha \; \frac{1}{O_p}$	150klbs
25-35	$WOS_r \; \alpha \; \frac{1}{O_p}$	93klbs
40-50	$WOS_r \; \alpha \; \frac{1}{O_p}$	75klbs

Table 4: Backoff results

7.0 DISCUSSION AND RECOMMENDATIONS

It can be seen from the results that with an overpull of between 5% and 20% over the neutral point weight, the weight of string retrieved is closer to the target backoff point. Above 20% the backoff point is higher than the target and the retrieved weight of string reduces with increased overpull.

To therefore improve the accuracy of mechanical backoff, the following is recommended:

- The stuck point, weight of string, neutral point weight, maximum overpull and make up torques should be correctly determined.
- A pre- job safety meeting should be conducted and a job safety analysis (JSA) done to highlights the hazards associated with mechanical backing off.
- Ensure that over torqueing the drill string with 110% of makeup torque is done up to the bottom of the drill string or at least close to the backoff point to avoid accidental backing off. This is checked by confirming the number of right hand turns are equal to the number of left hand turns.
- Use an overpull of between 5-20% over the neutral point weight to ensure the backoff point is closest to the target. The optimal being at 10%.
- Work the string down to the neutral point weight and not the slack off weight.
- In case of a Kelly drive system, the rotary table and slips will be used to apply both the makeup torque and the reverse torque. The same procedure highlighted above will be followed.
- Procedure 5.4 above should be followed during mechanical blind backing off.

8.0 CONCLUSION

Even though mechanical backoff is unpredictable, the accuracy can be improved by taking into account the properties of the drill string as highlighted above. For the case of MW24, the back off point had been set at 7316.75ft (2230m) based on the stuck point calculation. From the above results, the best backed off point was at 7050ft (2149m), with an overpull of 210 klbs (10% above the NPW).

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