STUCK DRILL PIPE WHILE DRILLING OPERATION

by

Mohamed Noureldin Abdelwahid

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr.Sonny Irawan

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMED NOURELDIN ABDELWAHID

ABSTRACT

Oil and companies spend about $20 billion annually on drilling. Unfortunately, not of that money is well spent. A significant portion, around 15%, is attributed to losses.

These losses include loss of material, such as drilling equipment (***Stuck pipe***) and fluids, and loss of drilling process continuity, called nonproductive time (NPT).

The objective s of this project are mainly concern and focusing about the downhoe problem during drilling operation in particularly the stuck pipe.

The significant objectives of this project are:

- To measure the parameters that cause the stuck pipe such as Bit weight, coefficient of friction, rate of penetration ,drag and force and mud density
- To identify the potential formation that makes the stuck pipe by drilling fluid.

The methodology of the project are first to have an ultimate background about the downhole problem and the causes that associated with stuck pipe, gathering necessary data for the analysis purpose and compare with the theoretical knowledge and to further conduct an experiment on the drilling fluid to configure the mud cake that mainly cause the differential stuck.

ACKNOWLEDGEMENTS

Praise always must be to Allah the Almighty in the first place for his blessing. I would like to offer my enormous gratitude for my mother, father, brother and sisters through their unremitting support and motivation that have lead me to this level of knowledge. Moreover, I convey my glory gratefulness to my supervisor Dr. Sonny Irawan for his constructive guidance along the range of this project. Last but not least, through the endearing power of friendship that I find this struggle worth conquering, so I thank all my friends for their tremendous support they have towed upon me.

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INTRODUCTION

1.1 Background

1.1.1 Introduction to stuck pipe

Wells are generally drilled to recover natural deposits of hydrocarbons and other desirable, naturally occurring, materials trapped in geological formations in the earth's crust. A slender well is drilled into the ground and directed to the targeted geological location from a drilling rig at the surface. In conventional "rotary drilling" operations, the drilling rig rotates a drill string comprised of tubular joints of steel drill pipe connected together to turn a bottom hole assembly (BHA) and a drill bit that is connected to the lower end of the drill string. During drilling operations, a drilling fluid, commonly referred to as drilling mud, is pumped and circulated down the interior of the drillpipe, through the BHA and the drill bit, and back to the surface in the annulus.

When drilling has progressed as far as the drillstring can extend without an additional joint of drillpipe, the mud circulating pumps are deactivated and the end of the drillstring is set in holding slips that support the weight of the drillstring, the BHA and the drill bit. The kelly is then disconnected from the end of the drillstring, an additional joint of drillpipe is threaded and torqued onto the exposed, surface end of the drillstring, and the kelly is then reconnected to the top end of the newly connected joint of drillpipe. Once the connection is made, the mud pumps are reactivated to power the drill motor and drilling resumes.

When the drill string is no longer free to move up, down, or rotate as the driller wants it to, the drill pipe is stuck. Sticking can occur while drilling, making a connection, logging, testing, or during any kind of operation which involves leaving the equipment in the hole.

1.2 Problem Statement

One of the critical problems of the well is when the drill pipe or BHA got stuck in the hole.

Basically there are two types of the stuck pipe :

1. ***Differential Stuck***

Originated from permeable formation exposed to wellbore fluid, pressure of wellbore fluid higher than pressure of formation fluid, Drill string, BHA component, casing or logging contacts permeable formation

Mud pressure holds object against formation and filtercake builds around stuck object, holding it firmly in place

2. ***Mechanical stuck***

Mechanical could be from unconsolidated formation and casing failure

The purpose of this research is to utilize the facility of the university available such as mud lab to elaborate and analyze the chemicals in such away that could possibly help add a solution for differential stuck, by following the analysis that has been done previously researcher in the petroleum field.

1.3 Objectives

- To measure the parameters that cause the stuck pipe such as Bit weight, coefficient of friction, rate of penetration ,drag and force and mud density
- To identify the potential formation that makes the stuck pipe by drilling fluid.

1.4 Scope of Study

The scope of this project as mentioned before is to investigate the parameters that mainly influence the stuck pipe by collecting data from the field and conducting drilling fluids experiments.

CHAPTER 2

LITERATURE REVIEW

2.1 Principle of stuck pipe

Stuck pipe is one of the most important problems you will find in the oil-industry. Let us figure out how drill pipe affected by forces down the hole and the following figure illustrate these forces.

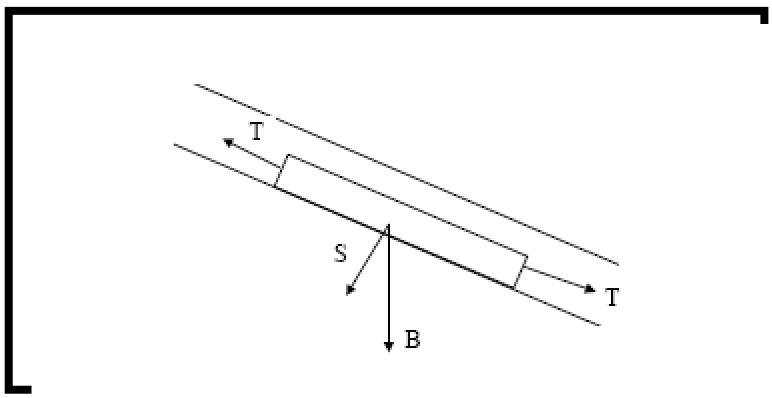

Figure 1: free body diagram of drillstring in the hole

(Sources: Sugar land learning center, stuck pipe prevention Revised in December1999)

- ***T1*** and ***T2,*** tension: the drill pipe is always in tension when drilling.
- ***S***, side force: when 2 surfaces are in contact with a perpendicular side force acting between them, any attempt to move one surface relative to the other will result in a friction force resisting the motion.
- ***B***, buoyant weight: apparent weight of the element in the mud.

Stuck drill pipe is an expensive and unproductive operation. All to often the blame is placed at the feet of the mud engineer when really we should be looking in other directions. Unfortunately the drilling industry is somewhat slow at working out cost and cost effectiveness and would sooner spend time and money attempting to free stuck pipe than on prevention. Forget all the hype about engineering, the major cause of pipe becoming stuck is human error and as long as you have untrained people running the show expect to join the ranks of companies that spend almost as much freeing the string as they do drilling the hole. It is impossible to cover the subject of stuck pipe in just a few pages. It is a subject that needs training and discussion but most of all it needs understanding. There are tool that monitor the progress of the operation day and night but can not normally be seen from the office. Computers mounted in the office are ok but take time to react. The chart in the mud loggers shack is far better for this and also shows the trend.

2.1.1 What is a "Stuck Pipe"?

Drilling a well requires a drill string (pipe & collars) to transmit the torque provided at the surface to rotate the bit, and to transmit the weight necessary to drill the formation.

The driller and the directional driller steer the well by adjusting the torque, pulling and rotating the drill string.

When the drill string is no longer free to move up, down, or rotate as the driller wants it to, the drill pipe is stuck. Sticking can occur while drilling, making a connection, logging, testing, or during any kind of operation which involves leaving the equipment in the hole.

We can define:

- *MO*, maximum over pull : the max. Force that the derrick, hoisting system, or drill pipe can stand, choosing the smallest one.
- *BF*, background friction: the amount of friction force created by the side force in the well.
- *FBHA*: The force exerted by the sticking mechanism on the *BHA* (Bottom Hole Assembly)

The drill string is stuck if ***BF + FBHA > MO***

In other words, the drill string is stuck when the static force necessary to make it move exceeds the capabilities of the rig or the tensile strength of the drill pipe. Stuck pipe can result in breaking a part of the drill string in the hole, thus losing tools in the hole. A few variables must be taken into account when dealing with stuck pipe: pore pressure of the formation, mud system, and the depth versus time (the longer in the hole without action, the more likely to get stuck).The consequences of a stuck pipe are very costly includes:

- Lost drilling time when freeing the pipe.
- Time and cost of fishing: trying to pull out of the hole the broken part of the BHA.
- Abandon the tool in the hole because it is very difficult or too expensive to remove it.

In that case the oil company pays the service company that provides the tools to replace the tool. In fact, an average cost per well of sticking pipe is about $50 000 US. Our service is to avoid the costly loss of the BHA (bottom hole assembly) to the client. The oil company responsibility is to protect the service company tools contained in the BHA

2.2 Differential Sticking

Differential sticking is one of the most common causes of pipe sticking. It is due to a higher pressure in the mud than in the formation fluid. Differential sticking happens when the drill collar rests against the borehole wall, sinking into the mud cake. The area of the drill collar that is embedded into the mud cake has a pressure equal to the formation pressure acting on it.

The area of the drill collar that is not embedded has pressure acting on it that is equal to the hydrostatic pressure in the drilling mud. This is shown in Fig. 2. When the hydrostatic pressure (P_h) in the well bore is higher than the formation pressure (P_f) there will be a net force pushing the collar towards the borehole wall. Over pull due to differential pressure sticking can be calculated from the product of the differential pressure force times the friction factor: $Overpull = F_{dp} f$ …………………… (1)

Where F_{dp} = differential pressure force [psi/in^2] and f = friction factor.
The differential pressure force is the difference in hydrostatic force and the formation force acting on the drill collar. The hydrostatic force is the hydrostatic pressure times the cross sectional area that is in the borehole and the formation force is the formation pressure times the cross sectional area that the mud cake is in contact with. This is shown in Figure. 3. Note that the cross-section area is used to calculate the force but not the surface area of the drill collar. The differential pressure force is defined:

$$F_{dp} = \left(144 \text{ in}^2 / \text{ft}^2\right) A_{mc} (P_h - P_f) \quad \ldots\ldots\ldots\ldots\ldots..(2)$$

Where F_{dp} = differential pressure force [lbf], A_{mc} = cross section embedded in mud cake [ft^2], P_h = hydrostatic pressure [psi], and P_f = formation pressure [psi].

The friction factor depends on the formation and the drill collar surface. It varies from 0.15 to 0.50.

The hydrostatic pressure is defined:

$$P_h = TVD \cdot g = \frac{TVD \cdot r \cdot 0.433 \text{ psi / ft}}{8.3\text{ppg}} \qquad \text{………………………… (3)}$$

Where P_h = hydrostatic pressure [psi], TVD = true vertical depth [ft], γ = pressure gradient of the mud [psi/ft], and ρ = mud weight [ppg]. Fresh water has a density of 8.33 ppg and a pressure gradient of 0.433 psi/ft. Formation brine in the Gulf of Mexico is 9 ppg, which is equal to 0.47 psi/ft.

However the mud density differs from place to place according to formation in that particular area.

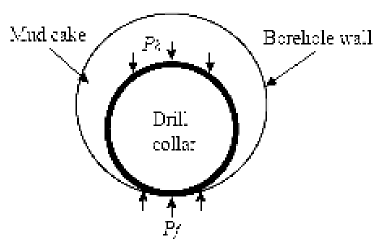

Figure 2: Differential sticking. P_h is hydrostatic pressure and P_f is formation pressure.

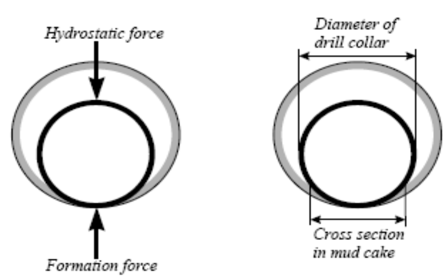

Figure 3: Hydrostatic force and formation force that are acting on the drill collar.

(Sources: Sugar land learning center, stuck pipe prevention Revised in December 1999)

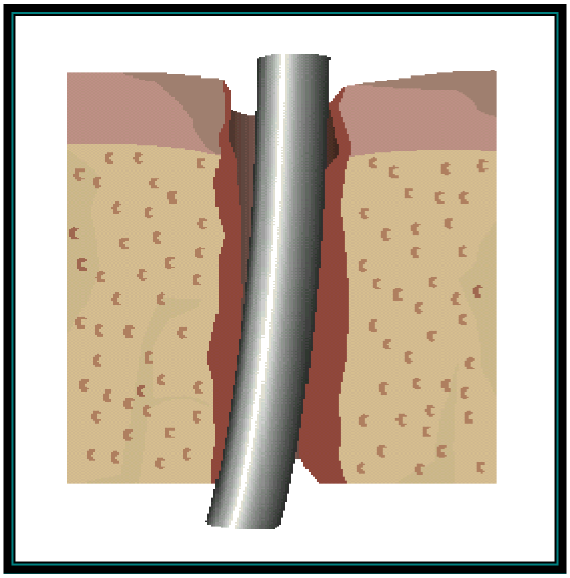

Figure 4: Differential sticking

(Sources: Stuck pipe 1997 Guidelines & Drillers Handbook Credits)

Written by

Colin Bowes & Ray Procter

2.2.1Preventative Action

Any action taken to reduce or eliminate one or more of the above causes will reduce the risk of differential sticking.

Well design

Where possible design casing setting depths to minimize overbalance across potential sticking zones, i.e. design for minimum overbalance. Limit mud weight to the minimum required for hole stability and well control.

Table 1: Hole size and recommended low gravity solid (% LGS)

Hole Size (inches)	**Recommended % LGS**
17.5	10-15
12.25	8-10
8.5	5-8
6	5-8

Mud

Use OBM where possible. Keep fluid loss to a minimum. Maintain a low concentration of LGS. Keep gels low.

Stationary string

Keep the string moving. Pre-plan to minimize the down time for operations that require the string to remain static (surveys, minor repairs, etc.). Consider rotating the string during drilling and tripping connections while BHA is opposite high risk sticking zones.

Well bore contact

Minimize BHA length when possible. Maximize BHA stand-off. Use spiral drill collars.

Rig team awareness

The rig team can be made aware of the depth of permeable formations and the estimated overbalance in those zones.

2.2.2 *Rig site indications*

- Overpulls on connections and after surveys
- No string movement
- Full unrestricted circulation
- Losses
- High overbalance
- Permeable formation exposed in open hole

2.2.3 Freeing

First Actions in the event of Differential Sticking

1. Establish that Differential Sticking is the mechanism, i.e, stuck after a connection or survey with full unrestricted circulation across a permeable formation (Sand, Dolomite and possibly Limestone).

2. Initially circulate at the maximum allowable rate. This is to attempt to erode the filter cake.
3. Slump the string while holding 50% of make-up torque of surface pipe (unless mixed string of pipe is being used). Use an action similar to what would be used with a bumper sub - see note below.
4. Pick up to just above the up weight and perform step 2 again.
5. Repeat 2. & 3. Increasing to 100% make-up torque until string is freed or until preparations have been made to:

- either - spot a releasing pill

2.3 ***Over pressured Formations***

A different type of instability occurs when the formation pressure exceeds the mud hydrostatic pressure. In this case the rock is able to support the extra stresses when the drill bit has passed.

An additional stress is applied to the rock if the hydrostatic pressure is less than the formation pore pressure. The formation in this case will tend to “pop” or “heave” into the wellbore. The shale pieces can sufficiently accumulate to pack off the BHA and cause sticking. The heaving shale condition occurs only when no permeable sand is present, since permeable sand with a higher pore pressure than mud pressure would cause a kick.

Warning Signs

1. Large, brittle, concave shaped carvings.
2. Recently crossed a fault.
3. Absence of permeable formations.
4. Large overpulls at connections.
5. Restricted circulation due to cavings loading the annulus.
6. Torque may increase.

Identification

a. Circulation restricted or impossible.
b. Stuck shortly after pumps off.

2.3.1 Preventative Action

- ***Monitor all cuttings; be on a lookout for large concave shale pieces.***

  How to monitor these cutting that is mud engineer responsibility, mud weight has to be maintained and viscosity as well

- ***Monitor Rate of Penetration (ROP - Drilling Rate).***
- ***Follow hole cleaning procedures.***

  The ten factors identified as being of most importance to good hole cleaning in deviated wells are:

  a. Annular velocity
  b. Mud density
  c. Mud rheology
  d. Mud type (oil or water)
  e. Cutting size
  f. ROP
  g. Drill pipe rotation
  h. Drill pipe eccentricity
  i. Drill pipe diameter
  j. Hole angle (45-90 deg) or 0 deg in vertical well

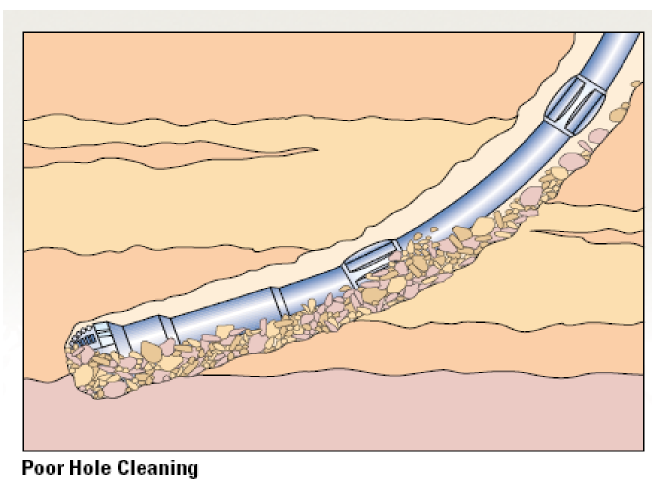

Figure 5: Poor Hole cleaning
(Source: www.slb.com/media/services/resources/oilfieldreview)

2.4 Mechanical and well geometry

2.4.1 Other Stuck Pipe Types - First Action

Guidelines for freeing stuck pipe other than Pack-offs and Differential sticking.

a) Ensure circulation is maintained.

b) If the string became stuck while moving up, (apply torque) jar down.

c) If the string became stuck while moving down, do not apply torque and Jar up.

d) Jarring operations should start with light loading (50k lbs) and then systematically increased to maximum load over a one hour period. Stop or reduce circulation when; a) cocking the jars to fire up and b) jarring down. Pump pressure will increase jar blow when jarring up, so full circulation is beneficial (beware of maximum load at the jar - see jarring section of this manual).

e) If jarring is unsuccessful consider acid pills, if conditions permit. Details can be found in the Best Practices chapter for running acid pills.

2.4.2 Key Seating

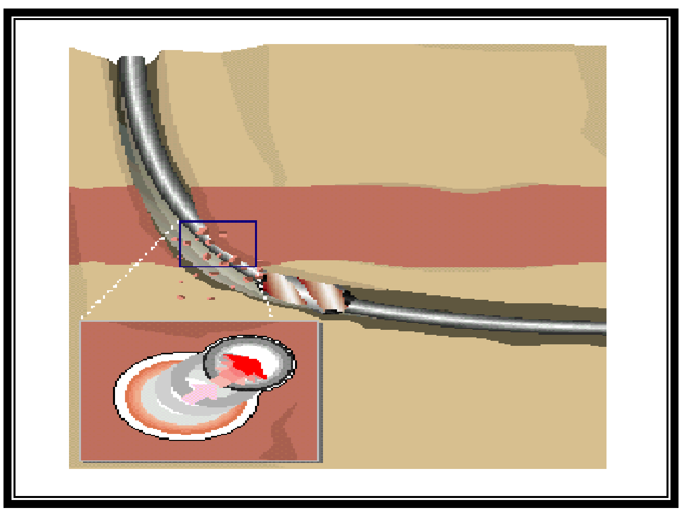

Figure 6: Key seating

(Sources: Stuck pipe 1997 Guidelines & Drillers Handbook Credits)

Written by

Colin Bowes & Ray Procter

Key seating is caused by the drill pipe rotating against the bore hole wall at the same point and wearing a groove or key seat in the wall. When the drill string is tripped, the tool joints or the BHA are pulled into the key seat and become jammed. Key seating can also occur at the casing shoe if a groove is worn in the casing.

This mechanism normally occurs:

- At abrupt changes in angle or direction in medium-soft to medium-hard formation.
- Where high side wall forces and string rotation exist.
- While pulling out of the hole.
- After long drilling hours with no wiper trips through the dogleg section.

2.4.2.1 Preventative Action

Minimize dogleg severity. Perform reaming and/or wiper trips if a dogleg is present. Consider running string reamers or a key seat wiper if a key seat is likely to be a problem.

2.4.2.2 Rig Site Indications

- Occurs only while POOH.
- Sudden overpull as BHA reaches dogleg depth.
- Unrestricted circulation.
- Free string movement below key seat depth possible if not already stuck in key seat.
- Cyclic overpull at tool joint intervals on trips.

2.4.2.3 Freeing

If possible, apply torque and jar down with maximum trip load. Back ream out of the hole. If present use key seat wiper.

1. Drilling Engineering institute of petroleum Engineering, Heriot-Watt University

2.5 Junk

Figure 7: Junk in the hole

(Sources: Stuck pipe 1997 Guidelines & Drillers Handbook Credits)

Written by

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2.5.1 Description

Junk is any garbage and some pieces fall down in the hole while practicing drilling, when connecting pipe and handling pipe sometimes and small particles from the rotary table fall in the hole and jams the drill string.

This mechanism usually occurs:

- Due to poor housekeeping on the rig floor.
- The hole cover not being installed.
- Down hole equipment failure.

2.5.2 Preventative Action

Encourage good housekeeping on the rig floor and regular inspection of handling equipment. Keep the hole covered at all times. Inspect downhole equipment before it is run in the hole and again as it is being run through the rotary table. Inspect slip and tong dies regularly. Install drill string wiper rubber as quickly as possible.

2.5.3 Rig site indications

- Repair/maintenance work recently performed on the rig floor.
- Missing hand tools / equipment.
- Circulation unrestricted.
- Metal shavings at shaker.
- Sudden erratic torque.
- Inability to make hole.

2.5.4 Freeing

Follow the first action procedure refer to the appendix

2.6 Types of formation

2.6.1 Reactive formation

Water sensitive shale is drilled with less inhibition than is required. The shale absorbs the water and swells into the well bore. The reaction is 'time dependent', as the chemical reaction takes time to occur. However, the time can range from hours to days.

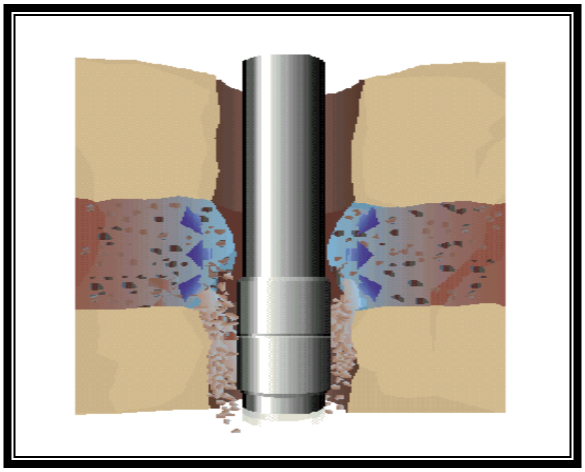

Figure 8: Reactive formation

(Sources: Stuck pipe 1997 Guidelines & Drillers Handbook Credits)
Written by Colin Bowes & Ray Procter

2.6.1.1 Preventative action

Use an inhibited mud system. Maintain the mud properties as planned. The addition of various salts (potassium, sodium, calcium, etc.) will reduce the chemical attraction of the water to the shale. Various encapsulating (coating) polymers can be added to WBM mud to reduce water contact with the shale. Monitoring mud properties is the key to detection of this problem. Open hole time in shale should be minimized. Regular wiper trips or reaming trips may help if shales begin to swell. The frequency should be based on exposure time or warning signs of reactive shales. Ensure hole cleaning is adequate to clean excess formation i.e. clay balls, low gravity solids etc.

2.6.1.2 Rig site indications

- Hydrated or mushy cavings.
- Shakers screens blind off, clay balls form.
- Increase in LGS, filter cake thickness, PV, YP, MBT.
- An increase or fluctuations in pump pressure.
- Generally occurs while POOH.
- Circulation is impossible or highly restricted.

2.6.1.3 Freeing

POH slowly to prevent swabbing

This mechanism normally occurs:

- When using WBM in shales and clays in young formations.
- When drilling with an incorrect mud specification. Particularly, an insufficient concentration of inhibition additives in OBM and WBM such as salts (KCl, CaCL), glycol and polymer.

2.6.2 Mobile Formations

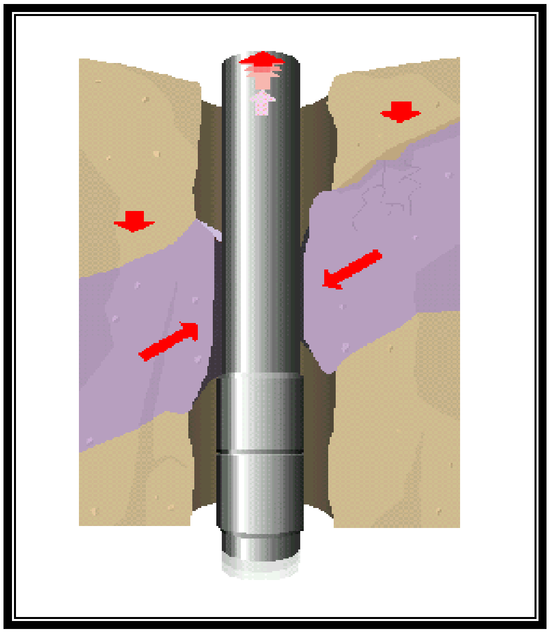

Figure 9: Mobile formation

(Sources: Stuck pipe 1997 Guidelines & Drillers Handbook Credits Written by)
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The mobile formation squeezes into the well bore because it is being compressed by the overburden forces. Mobile formations behave in a plastic manner, deforming under pressure. The deformation results in a decrease in the well bore size, causing problems running BHA's, logging tools and casing.

A deformation occurs because the mud weight is not sufficient to prevent the formation squeezing into the well bore.

This mechanism normally occurs while drilling salt.

2.6.2.1 Preventative Action

Maintain sufficient mud weight. Select an appropriate mud system that will not aggravate the mobile formation. Plan frequent reaming, wiper trips particularly for this section of the hole. Consider bi-centre PDC bits. Slow trip speed before BHA enters the suspected area. Minimize the open hole exposure time of these formations. With mobile salts consider using a slightly under-saturated mud system to allow a controlled washout.

2.6.2.2 Rig site indications

- Over pull when moving up, takes weight when running in.
- Sticking occurs with BHA at mobile formation depth.
- Restricted circulation with BHA at mobile formation depth.

2.6.2.3 Freeing

Spot a fresh water pill if in a salt formation. (Consider the effect on well control and on other open hole formations). If moving up, apply torque and jar down with maximum trip load. If moving down, jar up with maximum trip load. Torque should not be applied while jarring up.

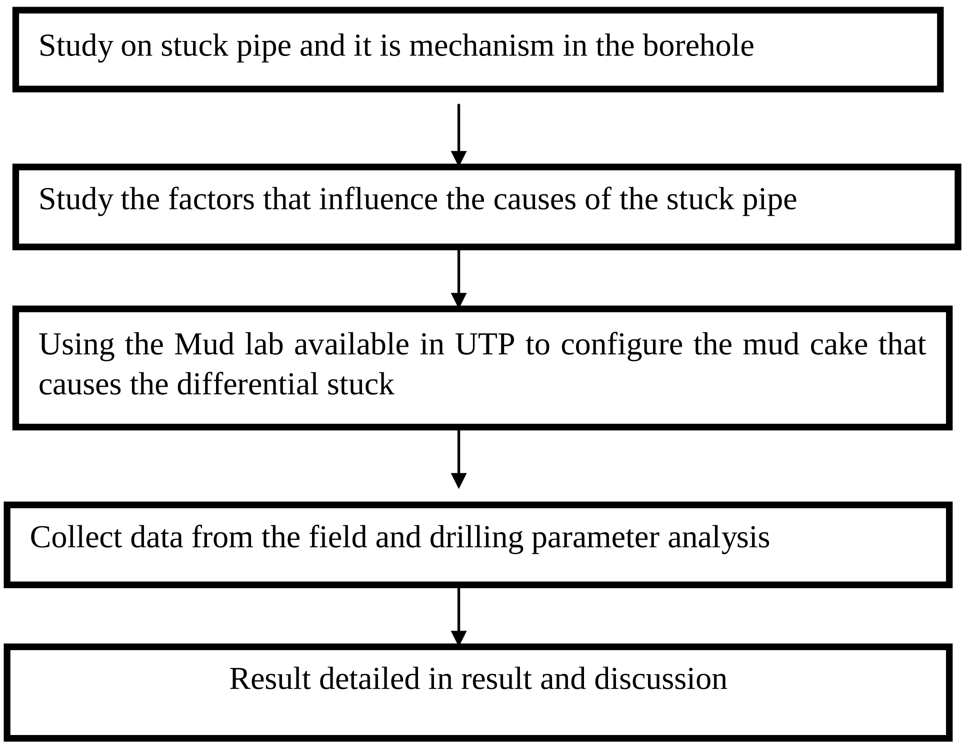
CHAPTER 3

METHODOLOGY

3.1 Project procedure

This procedure summarizes the methodology carried for the second half of the project which is the progress part one of the whole project.

3.1.1 Project identification part 1



3.2 Drilling Fluid experiment

- Primary configuration of filter cake that has a tremendous effect in causing the differential stuck.

3.2.1 Material and Test Equipment

3.2.1.1 Multi-mixer

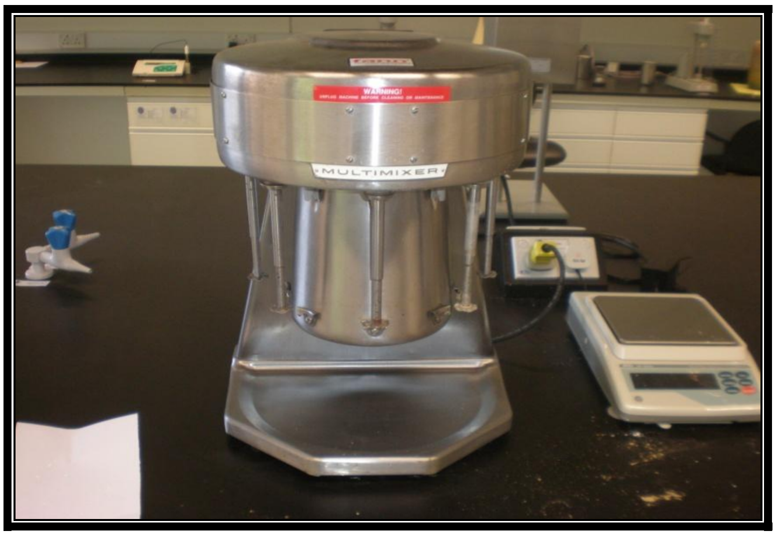


Figure 10: Multi-mixer

(Source: UTP drilling Fluid lab)

A mixer is used to mix the additives as shown in above. All components are consecutively added into the mixture and blended for 5 minutes before adding the next component. Once all the components have been added, the mixture is further mixed for another 30 minutes to ensure it is standardized. The mixture is removed from the mixing cup and poured into the conventional mud balance to measure the mud weight.

Basically in the field they use mud tank for mixing and there is agitator that helps mix the fluids.

3.2.1.2 Electronic measuring sensor

Figure 11: Electronic measuring sensor

Source: UTP drilling Fluid lab

1- Electronic measuring sensor is a device which measures the weight of additive required by gram. First it s needed to be set to zero first then measure the weight of the paper or container for the error consideration.

Fig 12: Mud balance

(Source: UTP drilling Fluid lab)

3.2.1.3 Mud balance

2- Mud Balance is one of the most important equipment used to measure the density of the mud in pound per gallon (*ppg*).

Procedure for measuring the density of mud

a. Make sure the mud balance equipment is clean and dry.
   For calibration, fill the mud cup till full with water and close it with the lid. Make sure a bit of excess water flows out from the hole in the center and wipe it, **(Note: Water density is 8.33 lb/gal)**
b. Place the mud balance on the base support and adjust the rider along the gratuated scale untill the air bubble is in between the two lines.

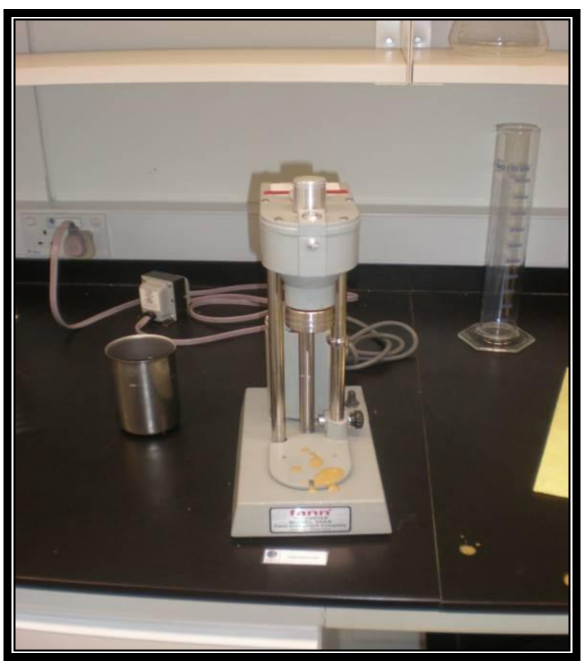


Fig 13: viscometer

(Source: UTP drilling Fluid lab)

3.2.1.4 Plastic Viscosity and Yield Point Determination

The viscosity of a mud is made up of two variables, plastic viscosity (PV) and yield point (YP). These values, as well as timed gel strength, are measured with a direct-indicating viscometer, such as the viscometer as shown in Figure 13.

The viscometer is a portable rotational viscometer, powered by a manually turned crank that drives the spindle through a precision gear train. Speeds of 300 and 600 rpm are selected by a shift lever. The procedure for conducting the test for PV, YP, and gel strengths is described below:

a. Obtain a sample of the mud to be tested. Measurements should be made with minimum delay.
b. Fill thermal cup approximately 2/3 full with mud sample. Place thermal cup on viscometer stand. Raise cup and stand until rotary sleeve is immersed to scribe lie on sleeve. Lock into place by turning locking mechanism.
c. Flip VG meter toggle switch, located on right rear side of VG meter, to high position by pulling forward.
d. Position red knob on top of VG meter to the 600 rpm speed. When the red knob is in the bottom position and the toggle switch is in the forward (high).
e. With the sleeve rotating at 600 rpm, wait for dial reading in the top window of VG meter to stabilize (minimum 10 seconds). Record 600-rpm dial reading.
f. With red knob in bottom position, flip the VG meter toggle switch to low position by pushing the toggle switch away from you. Wait for dial reading to stabilize (minimum 10 seconds). Records 300 rpm dial reading.
g. The Plastic Viscosity and Yield Point are calculated from the 600 rpm and 300 rpm dial readings as follows:

Plastic Viscosity (cP) = (600 rpm dial reading) - (300 rpm dial reading)……. (4)

Yield Point (Ib/100 ft^2) = (300 rpm dial reading) – (Plastic Viscosity)………. (5)

Material used:

Barite and bentonite at standard API, the following reading shows the parameters for the mud.

CC's of FILTRATE collected X 2 (static)

- 30 minutes
- 250 - 300°F (or higher)
- 3.75 sq. in. 50 Watman paper
- 500 psi - Differential Pressure (600 psi – TOP, 100 psi - BOTTOM (back pressure)).

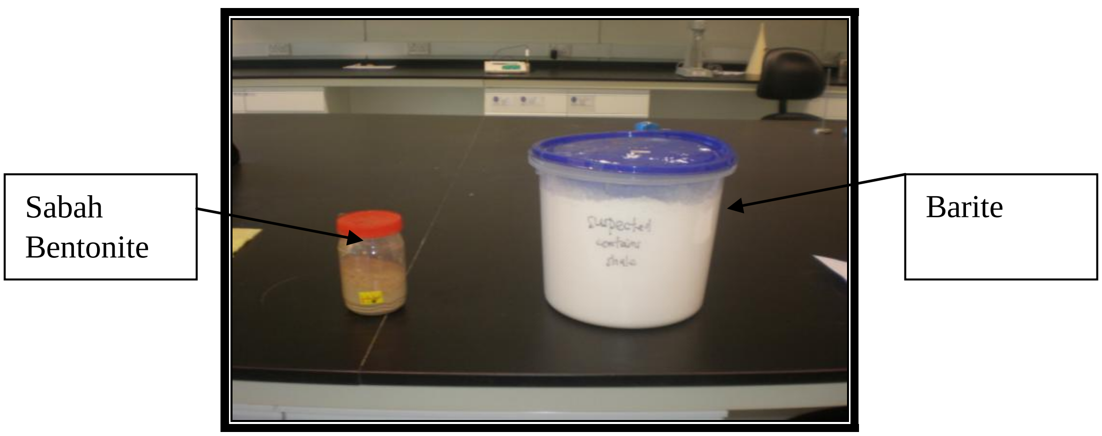


Figure 14: Barite and Bentonite

(Source: UTP drilling Fluid lab)

CHAPTER 4

4. RESULT AND DISCUSSION

4.1 Data gathering and analysis

4.1.1Sample 1

Table 2: experimental data from sample 1

Barite weight (g)	Bentonite weight (g)	Mud density (ppg)	Gel strength	YP
50.1	22.5	9.3	23	20

4.1.2 Sample ***2***

Table 3: experimental data from sample 1

Barite weight (g)	Bentonite weight (g)	Mud density (ppg)	Gel strength	YP
68.67	22.5	9.9	23	20

Table 4: Volume of fluid loss per minute of time

Sample1		Sample2	
Time (min)	volume (ml)	Time (min)	Volume (ml)
1	0.1	1	0.5
2	0.2	2	0.9
3	0.3	3	1.6
4	0.4	4	2.2
5	0.45	5	2.8
6	0.56	6	3.6
7	0.6	7	4.4
8	0.8	8	4.8
9	1	9	5.2
10	1.2	10	5.8
11	1.3	11	6.2
12	1.4	12	6.8
13	1.6	13	7.2
14	1.78	14	7.8
15	1.9	15	8.2
16	2	16	8.8
17	2.2	17	9
18	2.3	18	9.4
19	2.4	19	9.8
20	2.6	20	10.4
21	2.8	21	11
22	2.95	22	11.4
23	3.1	23	11.6
24	3.2	24	12
25	3.4	25	12.4
26	3.6	26	12.8
27	3.8	27	13.2
28	3.9	28	13.6
29	4	29	14
30	4.2	30	14.2

The result shown in table above demonstrates the volume of fluid loss within the 30 minute time.

It has been observed that sample 1 volume loss by average of 0.15ml per minute however for sample 2 the fluid loss is greater compared to sample 1 by average of 0.4 ml per minute which is quite a lot.

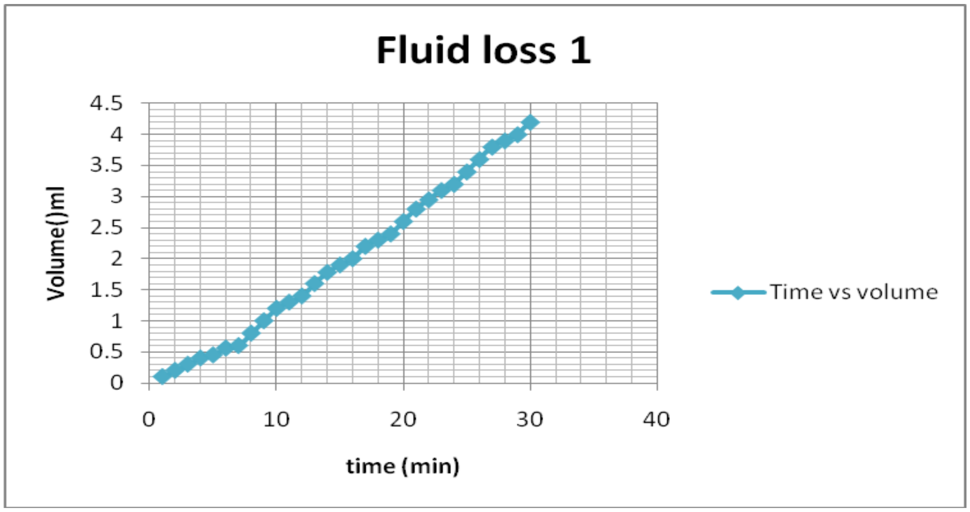


Figure 15: Fluid loss chart for sample 1

The chart above shows clear result about the losses of fluid with respect to time for sample 1

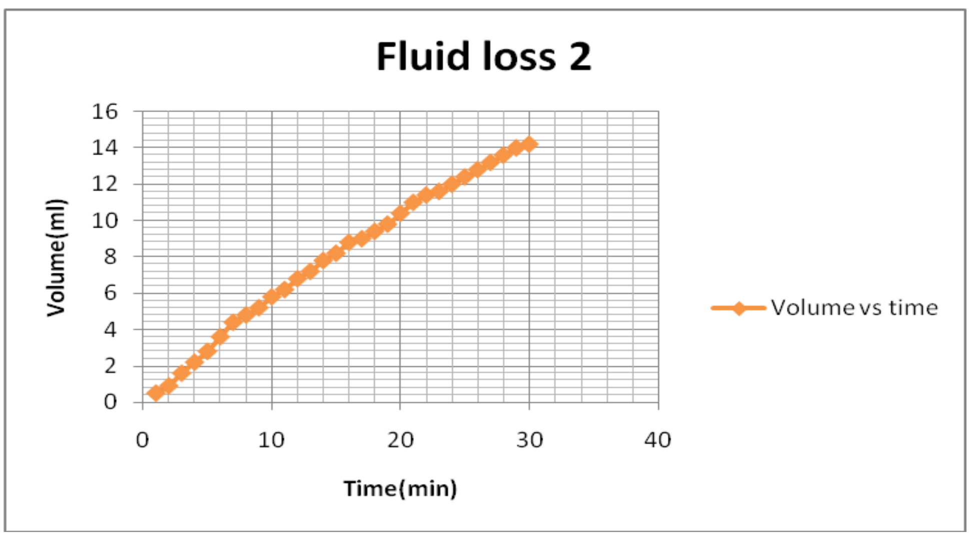


Figure 16: Fluid loss chart for sample 2

For sample 2 the chart above shows the large fluid loss with respect to time compare with sample1.

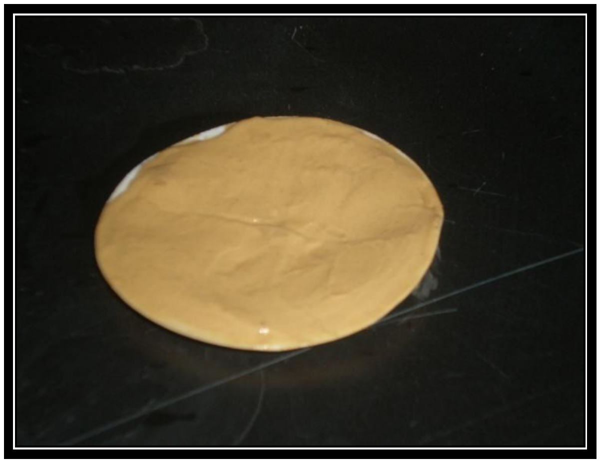


Figure 17: Filter cake for sample 1

Source: UTP drilling Fluid lab)

The picture above shows the result of the filter cake thickness for sample 1 when measured with electronic caliper the thickness found to be 5.1mm.

Figure 18: filter cake for sample2

(Source: UTP drilling Fluid lab)

After conducting the same experiment, for sample 2 by increasing the weight of barite from 50.1gram to 68.67gram the result has been shown in the picture above as the filter cake thickness has increased to become 14.87mm in other word double size the first sample.

4.1.3 IDFREE spotting fluid

The IDFREE spotting fluid consists of IDFREE, a blend of surfactants and emulsifiers mixed with diesel oil and water to form a stable emulsion. Once formulated the fluid is displaced to the open hole to cover the interval of stuck pipe. The IDFREE spotting fluids acts to reduce the surface tension between the well bore and the drill string.

The IDFREE also penetrates the wall cake promoting its removal from the well bore. The density of the spotting fluid is of primary importance. A fluid density lower than the existing mud weight will have a tendency to percolate or migrate up the mud column rendering the spotting fluid ineffective.

Table 5: The chart following gives recommended formulation at various densities.

IDFREE Formulation (100 bbls)						
Density lbs/gal	7.3	10	12	14	16	18
IDFREE (bbl)	8.0	8	8	8	8	8
Diesel (bbl)	65	58	54	49	51	44
Water (bbl)	28	26	22	21	11	10
Barite (50 kg sxs)	nil	127	228	318	423	518

The success of spotting fluids depends to a large degree on the volume displaced and on proper placement; obviously a greater volume will ensure that maximum coverage is obtained, and the possibility of inefficient placement is reduced. Generally a 50 % excess is used to allow for possible hole enlargement, inaccuracies in fluid placement and to allow some fluid to remain in the pipe to be displaced in small quantities at regular intervals.

4.2 Data field

This table shows some data collected from daily drilling report for a well owned by GNPOC, joined venture company from (Chinese Malaysian and Sudanese company).the purpose from this information data is to analyze the drilling parameter and establish the relation between the depth and rate of penetration, weight on bit torque and flowrate.

Table 6: Data from field

Formation			Depth		ROP	ROP	Avg WOB	Avg.RPM	TRQ	SPP	FLOW RATE	
			Depth (m)From	To	w/o conn	w/conn	klbs	rpm	klbs-ft	PSI	m3/mn	gpm
Meterage		Baraka SH/SS	2142	2200	4.10	3.91	11	157	2-5	2811	3.00	805.00
(last 24hrs)		Baraka SH/SS	2200	2260	6.32	5.88	15	157	2-5	2910	3.00	802.00
Bit Time		Baraka SH/SS	2260	2356	8.81	8.06	13	161	1-4	2958	3.00	800.00
(last 24hrs)		Baraka SH/SS	2356	2415	7.66	7.10	14	164	1-3	2962	3.00	800.00
Total Bit		Baraka SH/SS	2415	2459	3.83	3.57	16	107	0.5-2	2783	3.00	800.00
Time(hrs)		Baraka SH/SS	2459	2497	2.94	2.79	29	119	3-5	2821	3.00	797.00
Av. ROP		Gazal SH	2497	2506	1.73	1.66	28	112	3-4	2792	3.00	799.00
Min ROP		Gazal SH	2506	2544	5.07	4.63	14	214	2-5	2928	2.90	776.00
Max ROP		Gazal SH	2544	2615	5.63	5.10	16	204	3-5	2950	2.93	774.00
		Zarqa SH	2615	2638	5.47	4.89	19	204	3-4	2850	2.92	771.00
		Zarqa SH	2638	2732	7.23	6.44	16	195	2.5-4.5	2900	2.86	755.00
		Aradeiba	2732	2779	3.60	3.43	16	191	2-4.5	2880	2.79	736.00
		Bentiu	2779	2793	3.11	2.97	20	203	2-3.5	2990	2.84	751.00
		Bentiu	2793	2859	4.40	4.15	16	183	2.5-4.5	2855	2.73	720.00
		Bentiu	2859	2953	6.39	5.94	16	183	2.4-4.5	2855	2.73	720.00
		Bentiu	2953	3011	9.83	8.17	15	181	3-4	2960	2.80	740.00
Operation @ 05:00			TR	Wait on daylight								
GNPOC Drilling Supervisor			Nor Azizi - A Galil Abu Fatma				GNPOC Drilling Supt.				Arsath Thulkarmine	

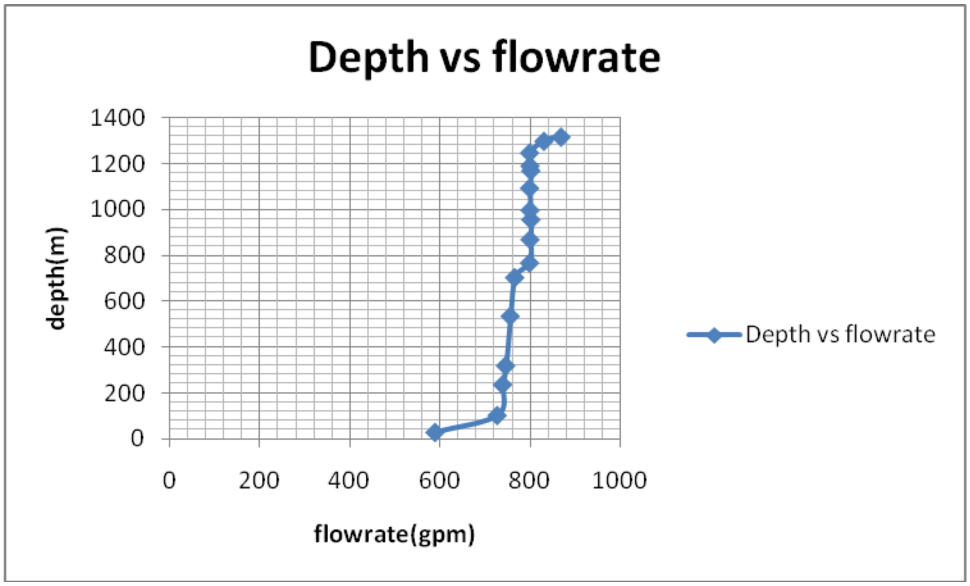


Figure19: Depth vs Flow rate

The figure above illustrates the relation between the field data as it s been realized that stand pipe pressure increases as the depth increase and flow rate has to be in the range 800gpm as specified in the table below.

Table 7 Typical flow rates to aim for in Extended Reach wells are as follows:

HOLE SIZE	TYPICAL FLOW RATES
17 1/2"	1100 gpm minimum Some rigs achieve 1250 - 1400 gpm
12 1/4"	Aim for 1100 gpm (although 800 - 1000 gpm is typically achieved) If 1000 gpm is not achievable, ensure tripping procedures are in place for poorly cleaned hole.
8 1/2"	Aim for 500 gpm

This illustrates that good flow rate and good hole cleaning and no stuck pipe was encountered in the well above.

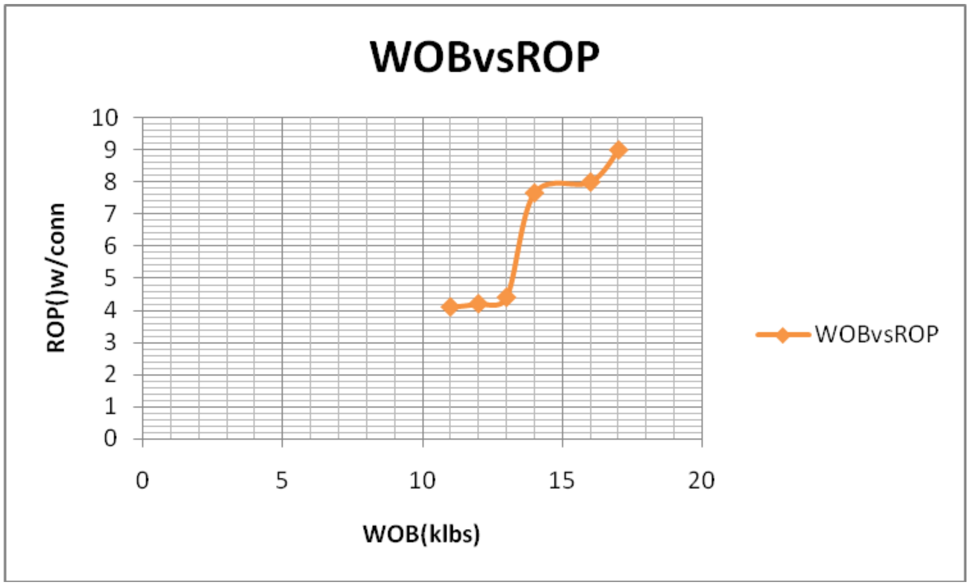


Figure 20: Depth vs weight on bit and rate of penetration

In the above chart we can observe that as the depth increase weight on bit sometimes increases depending on the formation strength and average rate of penetration indicated somehow good formation.

4.3 Drilling parameter analysis

The purpose of analyzing the drilling parameter is basically to correlate the most parameter that affect on the cause of stuck pipe.

$$ROP = \frac{13.33 * \mu * N}{D_B\left(\frac{CCS}{EFF_M * WOB} - \frac{1}{A_B}\right)}$$

T = Bit torque (ft-lbf)

DB = Bit size (inches)

µ = Bit-specific coefficient of sliding friction (dimensionless)

WOB = Weight on bit (pounds)

AB = Borehole area (sq-in)

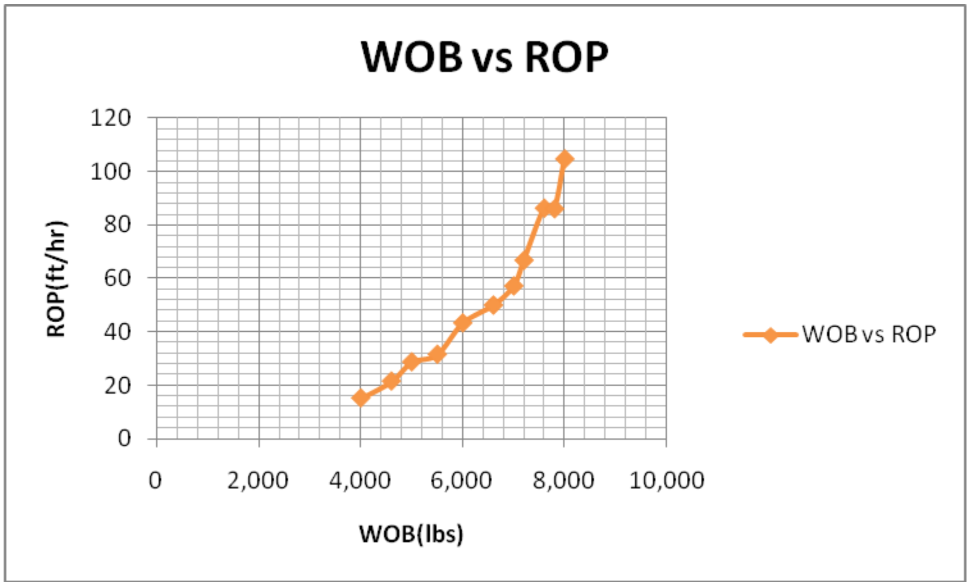
N = rpm

ROP = Rate of penetration (ft/hr)

Ccs= Compressive confined strength represent by rock strength

Table 8: Data shows the constant of in rock strength (CSS)

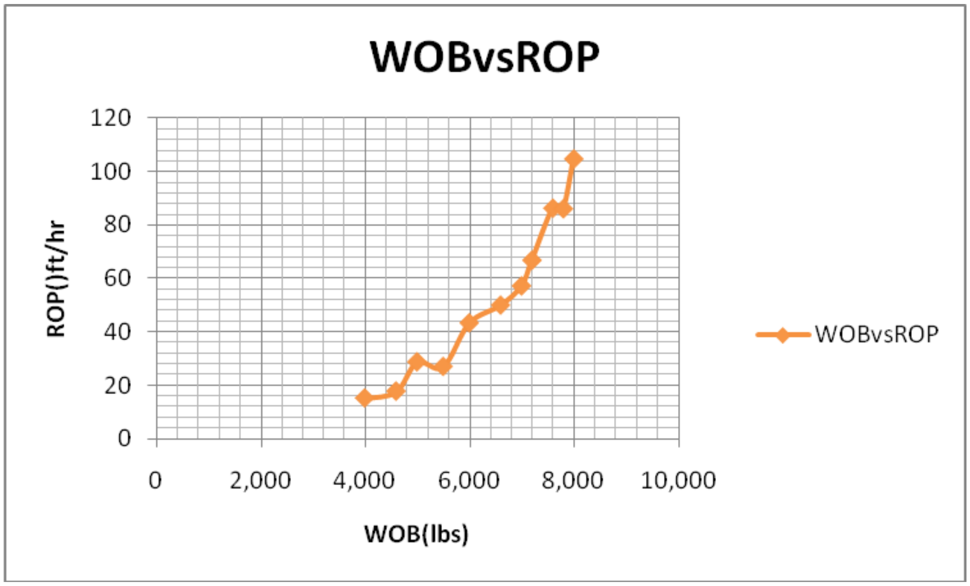
WOB(lbs)	u	N(RPM)	Db(ft)	ccs(psi)	EFFM(100%)	Ab(ft2)	ROP(ft/hr)
4,000	1	120	1.23	66,000	0.19	1.187	15.08798055
4,600	1	122	1.23	66,000	0.23	1.187	21.4364643
5,000	1.12	123	1.23	66,000	0.25	1.187	28.66956364
5,500	1	127	1.23	66,000	0.27	1.187	31.49517274
6,000	1	130	1.23	66,000	0.33	1.187	43.26418197
6,600	1	132	1.23	66,000	0.34	1.187	49.95981131
7,000	1	134	1.23	66,000	0.36	1.187	57.1619916
7,200	1	140	1.23	66,000	0.39	1.187	66.8005293
7,600	1.12	145	1.23	66,000	0.41	1.187	86.34014084
7,800	1	150	1.23	66,000	0.43	1.187	86.11123048
8,000	1.12	155	1.23	66,000	0.44	1.187	104.8239015



From the figure above relation indicates that whenever we increase the weight on bit the ROP will increase in the soft formation as given the rock strenghs to be constant throught out the process.

Table 9: Data shows the variation of in rock strength (CSS)

WOB(lbs)	u	N(RPM)	Db(ft)	ccs(psi)	EFFM(100%)	Ab(ft2)	ROP(Ft/hr)
4,000	1	120	1.23	66,000	0.19	1.187	15.08798055
4,600	1	122	1.23	80,000	0.23	1.187	17.64281599
5,000	1.12	123	1.23	66,000	0.25	1.187	28.66956364
5,500	1	127	1.23	77,000	0.27	1.187	26.92155272
6,000	1	130	1.23	66,000	0.33	1.187	43.26418197
6,600	1	132	1.23	66,000	0.34	1.187	49.95981131
7,000	1	134	1.23	66,000	0.36	1.187	57.1619916
7,200	1	140	1.23	66,000	0.39	1.187	66.8005293
7,600	1.12	145	1.23	66,000	0.41	1.187	86.34014084
7,800	1	150	1.23	66,000	0.43	1.187	86.11123048
8,000	1.12	155	1.23	66,000	0.44	1.187	104.8239015



From the graph above after variation in rock strength you can observe the drop in ROP eventhough the we put WOB increases, that clearly indicates that whenever there is hard formation ROP will be slow, and it could be as well from the poor hole cleaning and that may lead to stuck pipe.

- Secondly the associated bit torque for a particle bit type to drill at a given ROP in a given rock type (CCS) is computed by using the following equation

$$T = \left(\frac{CCS}{EFF_M} - \frac{4 * WOB}{\pi * D_B{}^2}\right) * \left(\frac{D_B{}^2 * ROP}{480 * N}\right)$$

T = Bit torque (ft-lbf)

DB = Bit size (inches)

μ = Bit-specific coefficient of sliding friction (dimensionless)

WOB = Weight on bit (pounds)

AB = Borehole area (sq-in)

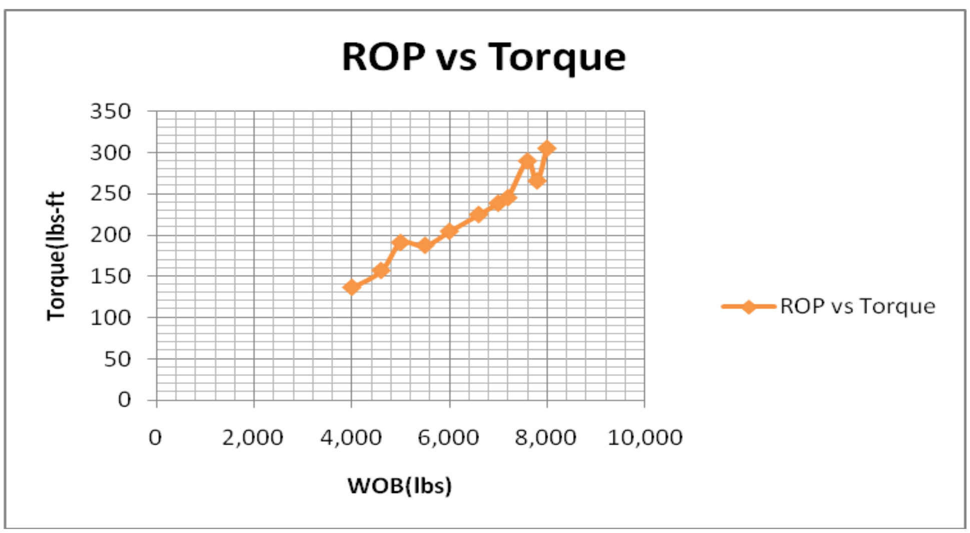
N = rpm

ROP = Rate of penetration (ft/hr)

Ccs= Compressive confined strength represent by rock strength

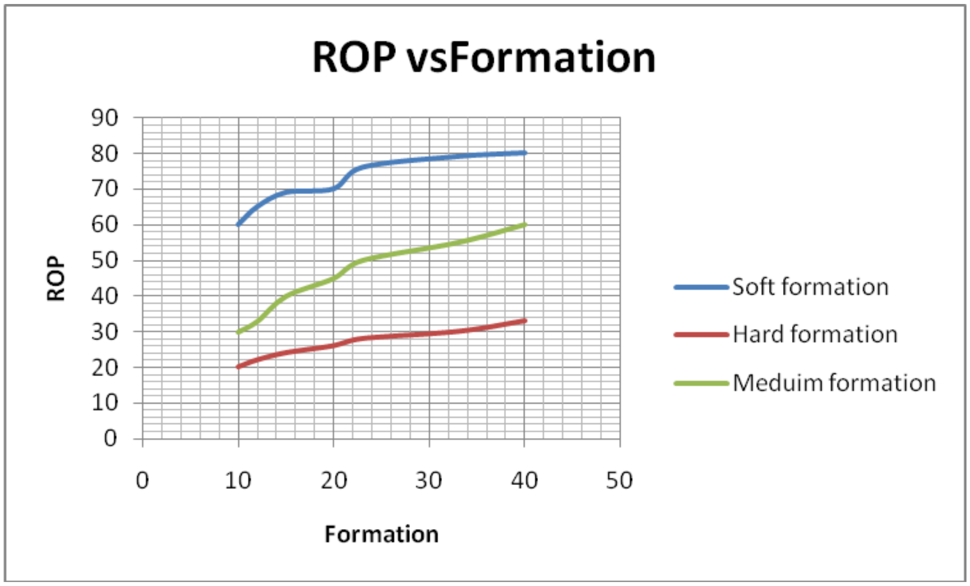
Table 10: Data shows the constant of in rock strength (CSS), but the bit coefficient changes

Torque(lbs-ft)	WOB(lbs)	u	N(RPM)	Db(ft)	ccs(psi)	EFFM(100%)	Ab(ft2)	ROP(ft/hr)
136.3257045	4,000	1	120	1.23	66,000	0.19	1.187	15.0879806
156.7748822	4,600	1	122	1.23	66,000	0.23	1.187	21.4364643
190.8566325	5,000	1.12	123	1.23	66,000	0.25	1.187	28.6695636
187.4487856	5,500	1	127	1.23	66,000	0.27	1.187	31.4951727
204.490297	6,000	1	130	1.23	66,000	0.33	1.187	43.264182
224.9397491	6,600	1	132	1.23	66,000	0.34	1.187	49.9598113
238.5729327	7,000	1	134	1.23	66,000	0.36	1.187	57.1619916
245.3898122	7,200	1	140	1.23	66,000	0.39	1.187	66.8005293
290.105939	7,600	1.12	145	1.23	66,000	0.41	1.187	86.3401408
265.8400222	7,800	1	150	1.23	66,000	0.43	1.187	86.1112305
305.3755784	8,000	1.12	155	1.23	66,000	0.44	1.187	104.823902



From the graph it’s observed that when the driller increases the WOB and there is high torque , as u can see when WOB was 7,600 lbs the torque was high because coefficent of friction 1.12 but when it drops to 1 torque has decreased a little. In this case to avoid any downhole problem such as stuck pipe might occures due to high torque and drag the driller should decrease the WOB.

A summarization of the rate of penetration with regard to the formation type, ROP will increase whenever there is soft formation zone and will decrease when drilling hard formation. The following graph illustrates the theory above.

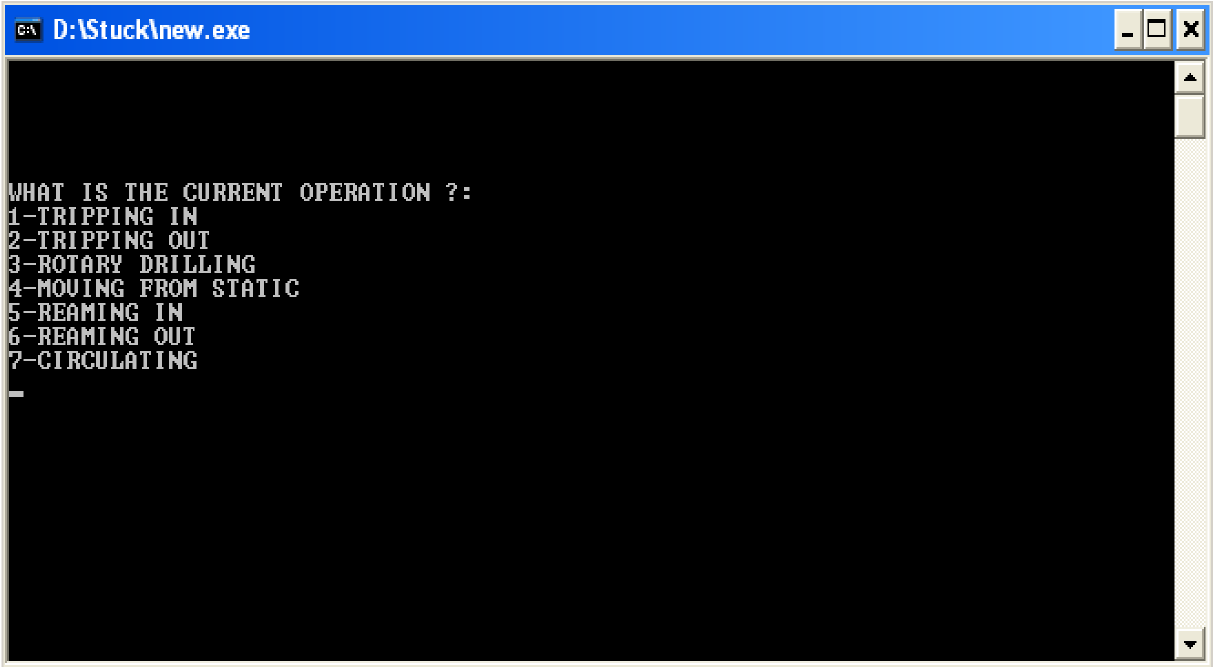


4.4 Programming part

After gathering the necessary information about the stuck pipe and it is causes, this is a program using c language to help the drilling engineers and crew members to be able to use this kind of program to indentify the current operation so they can understand what will be the prediction of the stuck pipe and help take appropriate actions.

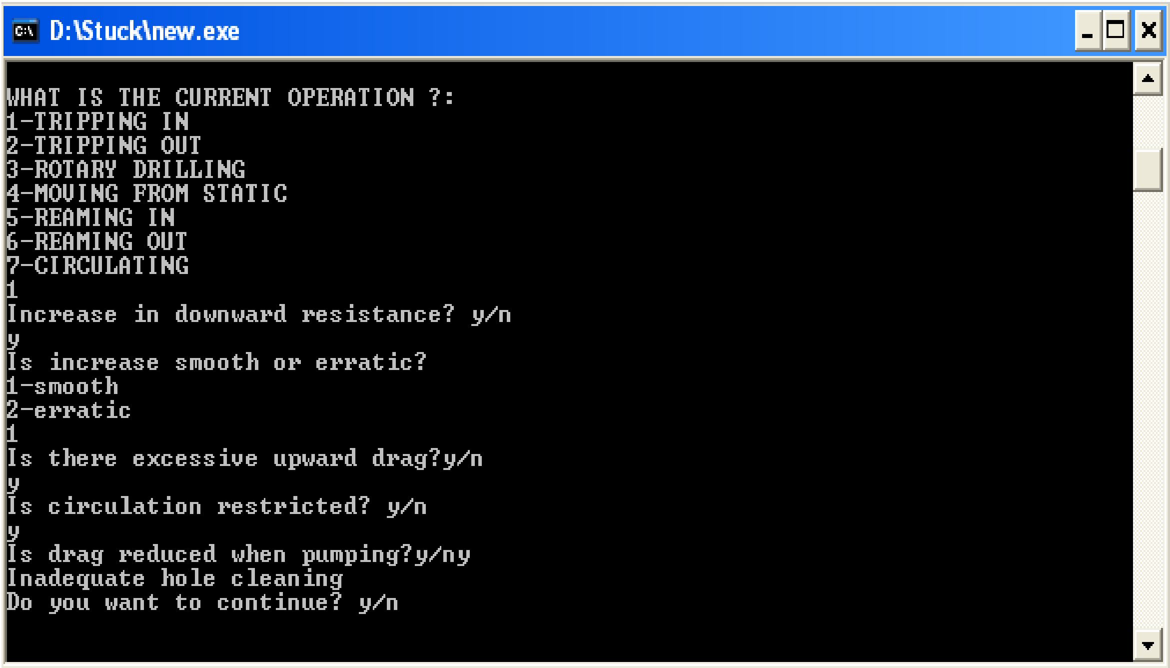
The following illustration shows the execution of the program.

- First of all after compiling the program (the code of the program will be given in appendices) the run it. The result will appear in the screen as shown below.



The program is designed in such way that it gives you and options to choose your current operations as illustrated above.

- Secondly when you choose the desired operations then the program will ask you some question giving answer of yes or no and information will be provided accordingly as shown in the following result.



The above program execution that shows how the result will be if the operation was tripping.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The loss of FILTRATE to a porous and permeable formation occurs when the hydrostatic pressure of the mud exceeds the formation pressure, and there are adequate solids in the mud to form a filter cake. The experiment above indicates that when we increase the density of the mud the thickness of filter cake increases with respect to the solid contents.

Drilling parameters such as rate of penetration and weight on bit are all depend in each other, however the formation will control on the rate of penetration as well as torque, to avoid stuck pipe these parameters have to be carefully taken into consideration and choosing the right bit for the right formation will also minimize the stuck pipe problem.

5.2 Recommendation

It is recommended for the scientist and researcher to continue carrying out studies on stuck pipe and inventing a sophisticated tools that can really help to minimize the stuck pipe which will result of reducing the cost in the future on drilling operation.

REFERENCES

1. Journal of Petroleum Science and Engineering Volume 55, Issues 1-2, January 2007, Pages 83-92 Petroleum Production Research in the Middle East .Analysis of wellbore instability in vertical, directional, and horizontal wells using field data. www.siencedirect.com/science
2. http://www.workover.co.uk/drilling_fluid/Drilling%20Fluid%20online%20training%20Stuck%20Pipe.htm
3. SUGAR LAND LEARNING CENTER Stuck Pipe Prevention SELF - LEARNING COURSE
4. Stuck pipe 1997 Guidelines & Drillers Handbook Credits Written by Colin Bowes & Ray Procter
5. Drilling Fluids Manual, KMC OIL TOOLS, Company.
6. Source: www.slb.com/media/services/resources/oilfieldreview

APPENDICES

APPENDIX A

Stuck Pipe Incident Report

The *stuck pipe incident report form* should be completed at the end of each well by the operations group whether or not any incidents have occurred. For wells where no incidents have occurred only section 1 needs completing. Wells that are in progress at the end of each quarter should also be reported. A completed copy should be sent to the stuck pipe focal point for your area through the SDE.

Reporting Guidelines

Drilling Unit**:** state name of rig

Type of Rig**:** state semi, jack-up, drill ship, land.

Drilling Contractor**:** state name

Well name**:** DOE well number after spud

Well Type**:** state EXP, APP, DEV, Re entry, Sidetrack

Directional profile**:** Vertical, Directional with max angle, S Shape, Horizontal.

Well total depth**:** state depth in metres

Hole drilled**:** Total length of hole drilled

Spud date**:** start of drilling

Dry hole days

Exp/App wells**:** Spud to start of anchor handling or start of rig down less time for testing E/A wells

Dev wells**:** Spud to last operation prior to running production casing/liner or pre-wiper trip.

Test/comp days

Exp/App wells**:** From running production casing/liner or pre casing wiper trip to final lay down of test tools.

Dev wells From running production casing/liner or pre casing wiper trip, to suspend prior to skid.

***<u>Well completion date</u>*:** Record date well operations completed i.e. rig release.

<u>Sticking incident</u>

***Date/time*:** Record details.

Depth: Depth stuck in metres or feet.

***Hole size*:** Record details.

***Hole Angle*:** Record details where stuck.

***Mud weight*:** Weight in SG or ppg of mud in hole at time of sticking.

***Overbalance*:** Record overbalance in psi.

***Mud type*:** State mud systems in use in hole.

Full Details of Incident and Action Taken

Complete detailed summary of events and actions taken throughout including recording the following points where relevant:

- Time string free after becoming stuck
- Amount of overpull to free
- If pill pumped, type volume, density, spacers, displacement rate and time after pipe stuck etc.,
- Time attempts to free were aborted i.e. sidetrack start time
- Fish left in hole
- Amount of hole lost.

Interpretation of Cause and Lessons Learnt

This should be completed following a review of what happened to identify the mechanism and cause of the incident. i.e. Mechanism: Differential sticking, Cause: BHA poor design, mud weight too high, etc. Consider any human factors relating to the time of the incident i.e. Crew change, New Rep etc,. In addition the actions taken following the incident should be reviewed to establish what other problems occurred if any and state lessons learnt to be applied to future wells.

Planned Action / Recommendation

Consider what action needs to be taken to improve awareness and avoid such an occurrence. i.e. Incorporate within stuck pipe course/workshops, review of BHA design needed, more training in specific areas.

Lost Time

State lost time in total to recommence operations from where stuck pipe incident occurred. This will include all time associated in performing a sidetrack and re-drilling relevant hole section to original depth. Record time spent to free pipe or until attempts aborted i.e. where decision taken to sidetrack.

Cost

Record

- Total cost in US dollars
- Total cost of fish in US dollars

Note: obtain respective exchange rate or QTR from you local accounts rep.

APPENDIX B

Pipe Stretch Calculation Example

Field Units

e 30 in Stretch due to differential pull P1 50000 lbs lowest pull

P2 100000 lbs highest pull

W 19.5 lb/ft Weight of drill pipe tube per foot

dP 50000 lbs differential pull

Using formula 1 $L = \frac{735294 * W * e}{dP}$ ft

Length of free pipe $L = \frac{735294 * 19.5 * 30}{50000}$ ft = 8602.9 ft

Pipe Stretch Calculation Example

SI Units

e 30 mm Stretch due to differential pull P1 50000 kN lowest pull

P2 100000 kN highest pull

W 30 kg/m Weight of drill pipe tube per foot

dP 25 kN differential pull

Using formula 1 $L = \frac{26.374 * W * e}{dP}$ m

Length of free pipe $L = \frac{26.374 * 30 * 200}{25}$ m = 6329 m

APPENDIX C

Torque and Pull Calculation Example

Allowable simultaneous torque and pull on drillpipe tube.

Field Units

D 5.000 in OD of drill pipe

d 4.365 in ID of drill pipe

Ym 135000 psi Minimum yield stress

SF 0.85 Safety factor

A 4.671 sq in Cross sectional area of drill pipe tube

J 25.719 in^4 Polar moment of inertia

$$Q(lbs) = \frac{\left(0.096167 \times [\frac{PI}{32}(D^4 - d^4)]\right)}{D} \times \sqrt{\left[(Ym \times SF)^2 - \left(\frac{P^2}{A^2}\right)\right]}$$

P 450000 lbs Tensile load

Q 30831 ft.lbs Minimum torsional yield under tension

Remember to check combined loading for the tool joint as well.

Allowable simultaneous torque and pull on drillpipe tube.

SI UNITS

D 0.140 m OD of drill pipe

d 0.120 m ID of drill pipe

Ym 100000 pa Minimum yield stress

SF 0.85 Safety factor

A 0.004 m^2 Cross sectional area of drill pipe tube

J 0.00001736 m^4 Polar moment of inertia

$$Q(N) = \frac{\left(1.154 \times [\frac{PI}{32}(D^4 - d^4)]\right)}{D} \times \sqrt{\left[(Ym \times SF)^2 - \left(\frac{P^2}{A^2}\right)\right]}$$

P 200 N Tensile load

Q 10 N.m Minimum torsional yield under tension

Remember to check combined loading for the tool joint as well.

APPENDIX D

The C language programming code for stuck pipe prevention.

```
#include <stdio.h>
#include <conio.h>
int main()
{
char c1;
int op,q1;
do{
printf("\n\n\n\n\n")
printf("WHAT IS THE CURRENT OPERATION ?:\n");
printf("1-TRIPPING IN\n");
printf("2-TRIPPING OUT\n");
printf("3-ROTARY DRILLING\n");
printf("4-MOVING FROM STATIC\n");
printf("5-REAMING IN\n");
printf("6-REAMING OUT\n");
printf("7-CIRCULATING\n");

scanf("%d",&op);
switch(op)
{
case 1:
{
  printf("Increase in downward resistance? y/n \n");
  scanf("%s",&c1);
  if(c1=='y')
        {
```

```
printf("Is increase smooth or erratic?\n");
printf("1-smooth\n");
printf("2-erratic\n");
scanf("%d",&q1);
if(q1==1)
  {//smooth
        printf("Is there excessive upward drag?y/n\n");
        scanf("%s",&c1);
        if(c1=='y')
        {
                printf("Is circulation restricted? y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                {
                        printf("Is drag reduced when pumping?y/n");
                        scanf("%s",&c1);
                        if(c1=='y')
                        {
                                printf("Inadequate hole cleaning\n");
                        }
                        else
                        {
                                printf("Reactive formation\n");
                                printf("Mobile formation\n");
                        }
                }
                else{

                        printf("Was previous bit undergauge?y/n\n");
                        scanf("%s",&c1);
```

```
                    if(c1=='y')
                            printf("Undergauge hole No\n");
                    else{
                            printf("Wellbore geometry\n");
                            printf("Formation ledges\n");
                    }
            }
    }

  else
printf("Inadequate hole cleaning (cutting beds)");


}
    else
    {
     //Erratic
printf("Is there excessive upward drag?y/n");
 scanf("%s",&c1);
 if(c1=='y')
 {
        //Yes
        printf("Was previous bit undergauge?y/n");
        scanf("%s",&c1);
        if(c1=='y')
         //Yes
                printf("Undergauge hole No\n");
        else
        {
                printf("Are dog-legs excessive?y/n\n");
                scanf("%s",&c1);
```

```
if(c1=='y')
{// Yes
printf("Has there been a BHA change on this trip?y/n\n");
scanf("%s",&c1);
if(c1=='y')
//    Yes
        printf("Wellbore geometry\n");
else
// No
        printf("Formation ledges\n");
}
else
{
// No
        printf("Can resistance and drag be related to formations?y/n\n");
         scanf("%s",&c1);
         if(c1=='y')

         //Yes
              printf("Fractured/faulted formations\n");
              //No
         else
             printf(" Cement blocks\n Junk\n String component failure\n");

  }
        }
    }
     else
     {
```

```
                    printf("Hole bridged. Can this be related to problem formations?y/n\n");
                    scanf("%s",&c1);
                    if(c1=='y')
                    {
                    //yes
                           printf("Reactive formations\n Mobile formations\n Fractured/faulted formations\n Unconsolidated formations\n");
                     }
                    else
                    {
                    //No
                           printf("Formation ledges\n Wellbore geometry\n Cement blocks\n Junk\n");
                    }
                }
              }
            }
                    else
            printf("??? Increase in downward resistance will be observed! ");


   break;
   }
case 2:


  {
  printf("Increased drag or overpull? y/n \n");
  scanf("%s",&c1);
  if(c1=='y')
       {
```

```
printf("Is overpull smooth or erratic?\n");
printf("1-smooth\n");
printf("2-erratic\n");
scanf("%d",&q1);
if(q1==1)
  {//smooth
        printf("Is  overpull in new hole section?y/n\n");
        scanf("%s",&c1);
        if(c1=='y')
        {
                printf("Are known problem formations exposed in new hole section? y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                {
                        printf("Is circulation restricted?y/n");
                        scanf("%s",&c1);
                        if(c1=='y')
                        {
                                printf("Reactive formations (bit/stabiliser balling)\n Mobile formations \nUnconsolidated formations\n");
                        }
                        else
                        {
                                printf("Wellbore geometry \nFractured/faulted formation\n");
                                                }
                }
                else{


                        printf("Is circulation restricted?y/n\n");
```

```
                scanf("%s",&c1);
                if(c1=='y')
                        printf("Inadequate hole cleaning\n");
                else{
                        printf("Wellbore geometry \nFormation ledges\n");
                                                }
            }
        }


    else{
    printf("Are known problem formations in hole section drilled by previous bits? y/n");
    scanf("%s",&c1);
     if(c1=='y'){
            printf("Is circulation restricted?y/n\n");
            scanf("%s",&c1);
             if(c1=='y'){
                    printf("Reactive formations (bit/stabiliser balling)\n Mobile formations \nUnconsolidated formations\n");
    }else
    printf("Wellbore geometry \nFormation ledges\n");
     }else {
    printf("Is circulation restricted?y/n ");
    scanf("%s",&c1);
     if(c1=='y')
     printf("Inadequate hole cleaning\n");
     else
     printf("Wellbore geometry \nFormation ledges\n");
     }
    }}
```

```
else
{
 //Erratic
printf("Is there excessive upward drag?y/n");
 scanf("%s",&c1);
 if(c1=='y')
 {
        //Yes
        printf("Was previous bit undergauge?y/n");
        scanf("%s",&c1);
        if(c1=='y')
         //Yes
                printf("Undergauge hole No\n");
       else
       {
                printf("Are dog-legs excessive?y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                {// Yes
                printf("Has there been a BHA change on this trip?y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                //    Yes
                      printf("Wellbore geometry\n");
                else
                // No
                      printf("Formation ledges\n");
                }
                else
                {
```

```
// No
        printf("Can resistance and drag be related to formations?y/n\n");
        scanf("%s",&c1);
        if(c1=='y')

        //Yes
            printf("Fractured/faulted formations\n");
            //No
        else
            printf(" Cement blocks\n Junk\n String component failure\n");

    }
  }
}
  else
  {
    printf("Hole bridged. Can this be related to problem formations?y/n\n");
    scanf("%s",&c1);
    if(c1=='y')
    {
    //yes
        printf("Reactive formations\n Mobile formations\n Fractured/faulted formations\n Unconsolidated formations\n");
    }
    else
    {
    //No
        printf("Formation ledges\n Wellbore geometry\n Cement blocks\n Junk\n");
```

```
                }
            }
        }
    }
                else
      printf("??? Increase in downward resistance will be observed! ");



break;

}

case 3:

  {
  printf("Increased torque? y/n \n");
  scanf("%s",&c1);
  if(c1=='y')
       {
          printf("Is there a formation change?y/n\n");
          scanf("%s",&c1);
          if(c1=='y')
                printf("Increase in torque related to formation change\n");
          else
             {

                printf("Are bit hours excessive?y/n\n");
                 scanf("%s",&c1);
                 if(c1=='y')
```

```
{
printf("Tri-cone bit? y/n\n");
scanf("%s",&c1);
if(c1=='y')
        printf("Bearings worn?\n");

else printf("??? Unknown\n");
 }
else {
        printf("Are hole drags excessive?y/n\n");
        scanf("%s",&c1);
        if(c1=='y')
        {
                printf("Can drags be related to dog-legs?y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                        printf("Wellbore geometry\n");
                else{
                        printf("Is circulation restricted?y/n\n");
                        scanf("%s",&c1);
                        if(c1=='y')
                                {
                          printf("Are drags reduced when
pumping? y/n\n");
                          scanf("%s",&c1);
                          if(c1=='y')
                                {printf("Inadequate hole
cleaning\n");}
                          else{
```

```
printf("Have problem formations already been exposed?y/n\n");
 scanf("%s",&c1);
 if(c1=='y')
   {
   printf("Mobile formations, slow moving \nReactive formations\n");
   }
 else
   {printf(" Geopressured formations\nUnconsolidated formations \nFractured/faulted formations\nMobile formations, fast moving\n");
   }

   }
}

else
{
 printf("Is it possible that a fault has been drilled?y/n\n");
  scanf("%s",&c1);
  if(c1=='y'){
     printf("Fractured/faulted formations\n");}
  else
     {
     printf("Cement blocks\nJunk\nCasing\nKeyseat\n");
     }

 }

}}
```

```
                else
            {

          printf("Have abrasive formations been drilled?y/n");
           scanf("%s",&c1);
           if(c1=='y')

                  printf("Undergauge hole, causing stabilizers to hang up");
           else
           {
                        printf("Have    formations    of    varying    hardness    been
drilled?y/n\n");
                        scanf("%s",&c1);
                        if(c1=='y')
                        //    Yes
                              printf("Formation ledges, stabilizers hanging up\n");
                        else
                        // No
                              printf("Bit failure\nString component failure\n");
           }

         }
            }}}
            else
          printf("??? Increased torque will be observed!\n ");

   break;
   }
```

```
case 4:

    {
  printf("Drag trend increasing when moving string from static?y/n\n");
   scanf("%s",&c1);
   if(c1=='y')
          {
          printf("Is circulation restricted?y/n\n");
          scanf("%s",&c1);
          if(c1=='y')
          {
                 printf("Are known problem formations exposed?y/n\n");
                 scanf("%s",&c1);
                 if(c1=='y')
                        printf("Reactive formations\nFractured/faulted formations
\nMobile formations\nUnconsolidated formations\nGeopressured formations\n");

                 else
                 {
                    printf("Is drag reduced when pumping?y/n\n");
                    scanf("%s",&c1);
                    if(c1=='y')
                    printf("Inadequate hole cleaning\n");
                    else
                    printf("Reactive formations \nFractured/faulted formations \nMobile
formations \nUnconsolidated formations \nGeopressured formations\n");
                 }
          }
          else
          {
```

```
                printf("Are permeable formations exposed?y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                {
                        printf("Can drillstring be moved?y/n\n");
                        scanf("%s",&c1);
                        if(c1=='y')
                        printf("Junk \nCement blocks \nFormation ledges, stabilizers hanging up\n");
                        else
                        printf("Differential sticking\n");
                }
                else
                printf("Junk\nCement blocks \nString component failure \nFormation ledges, stabilizers hanging up\n");
        }
        }
  else
  printf("??? Increase in downward resistance will be observed! ");


   break;
   }



 case 5:
   {
   //REAMING IN


   printf("Increased torque, increased reaming weight required?y/n\n");
   scanf("%s",&c1);
   if(c1=='y')
```

```
{
    printf("Is increase smooth or erratic?y/n\n");
    scanf("%s",&c1);
    if(c1=='y')
    {
        printf("Is circulation restricted? y/n\n");
         scanf("%s",&c1);
          if(c1=='y')
          {
                printf("Are hole drags excessive?  y/n\n");
                scanf("%s",&c1);
                if(c1=='y')

                {
                        printf("Do drags increase when not pumping? y/n\n");
                        scanf("%s",&c1);
                        if(c1=='y')
                                printf("Inadequate hole cleaning\n ");
                        else
                                 printf("Mobile      formations      \nReactive      formations
\nUnconsolidated formations\n");
                }
                else
                   printf("Inadequate hole cleaning\n");
                      }
    else
        {
                   printf("Was previous bit undergauge? y/n\n");
                   scanf("%s",&c1);
                   if(c1=='y')
                            printf("Undergauge hole\n");
```

```
                else
                        printf("Wellbore geometry (sidetracking hole?)\n");
     }


     }

else
//erratic
{
   printf("Is circulation restricted?y/n\n");
   scanf("%s",&c1);
   if(c1=='y')
   {
          printf("Are up drags excessive? y/n\n");
          scanf("%s",&c1);
          if(c1=='y')
          {

             printf("Are drags increased when not pumping?? y/n\n");
             scanf("%s",&c1);
             if(c1=='y')
             printf("Inadequate hole cleaning\n");
             else
             printf("Fractured/faulted formations \n Unconsolidated formations\n");
          }
         else
           printf("Inadequate hole cleaning (cuttings beds)\n");

   }
   else
```

```
            {

                printf("Was previous bit undergauge?y/n\n");
                scanf("%s",&c1);
                if(c1=='y')
                        printf("Undergauge hole\n");
                else
                printf(" Wellbore geometry\n Formation ledges\nJunk \nCement blocks\nBit
failure\n");



            }

          }

        }
    else
    printf("??? Increased torque, reaming weight will be observed?");

     break;
     }



   case 6:
       {

         //REAMING OUT
printf("Increased torque and drag? \n");
scanf("%s",&c1);
 if(c1=='y')
```

```
 {

printf("Is increase in torque smooth or erratic? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
 {
//Smooth
printf("Is circulation restricted? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
 {
printf("Are drags reduced when pumping?  y/n\n");
scanf("%s",&c1);
 if(c1=='y')
printf("Inadequate hole cleaning\n");
else
printf("Mobile formations \nReactive formations\n");
}
else

{
printf("Is downward motion restricted? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
        printf("Wellbore geometry \nFormation ledges \nString component failure\n");
else
printf("Key seating\n");
                    }}
            else
{
```

```
//Erratic
printf("Is circulation restricted?y/n\n ");
scanf("%s",&c1);
 if(c1=='y')
printf("Unconsolidated formations \nFractured/faulted formations\n");

else
printf("Junk \nCement blocks \nString component failure\n");
                    }
}
else
printf("??? Increased torque and drag will be observed!\n")

    break;
    }

  case 7:


 {


 //CIRCULATING


printf("Increased drag and resistance? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
 {
```

```
printf("Is Is increase smooth or erratic? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
 {
//Smooth
printf("Is circulation restricted?? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
 {



printf("Is Do drags increase when not pumping? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
                                        printf("Inadequate hole cleaning\n");
else
printf("Mobile formations \nReactive formations \nGeopressured formations\n");
                         }
                    else
                    printf("Mobile formations\n");
          }
else
{
//Erratic

printf("Is circulation restricted? y/n\n");
scanf("%s",&c1);
 if(c1=='y')
               printf("Unconsolidated formations \n Fractured/faulted formations\n");
```

```
else
printf("Cement blocks \n Junk\n");

}}
else
printf(" Increased drag and resistance will be observed!\n");
  break;

}
}
printf("Do you want to continue? y/n \n");
   scanf("%s",&c1);
}
while(c1=='y');
getch();

}
```