

**All Drilling Systems Services**

***INTEQ Drilling Engineering Stuck Pipe Solutions Guide***

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**Introduction**

INTEQ personnel can be valuable members of the drilling team in diagnosing potential stuck pipe problems. Having access to the drilling information (via the Advantage network), the geological data (from the Logging Geologist), and using the right analytical approach, INTEQ personnel can assist the client in keeping stuck pipe problems to a minimum. Effective communication between the logging unit, company-man, directional driller and mud engineer can prevent many stuck pipe situations. This guide will discuss potential causes and indicators of stuck pipe and possible solutions to free stuck pipe. The following tables illustrate the response that can be made to the many factors that can result in stuck pipe/borehole problems.

**ADVANTAGE BOREHOLE PROBLEM LOGGING PERSONNEL RESPONSEINSTRUMENTATION**

**Lithology** a. Formation Related a. Identification of Rock Types and Characteristics**Identification** b. Differential Sticking b. Identification of Permeable Sandstones**and Description** c. Cement Related c. Identification of Cement in Cuttings Samples d. Undergauge Hole d. Identification of Abrasive Formations

e. Poor Hole Cleaning e. Amount of Cuttings in Samples

**Depth and** a. Formation Related a. Identification of borehole problems from ROP**ROP** b. Wellbore Geometry b. Reduced ROP due to BHA hanging up on ledges**Recorder** c. Poor Hole Cleaning c. Reduced ROP due to poor transfer of WOB

**Monitor** All Types of Borehole Monitor trends in hole conditions, and relating trends**Calculations** Problems to lithology, hole deviation and BHA configuration

**Pump Stroke** Poor Hole Cleaning Monitoring annular velocities to adequately clean **Counters** borehole

**Pore Pressure** a. Geopressure a. Detecting abnormal or sub-normal pore pressure**Evaluation** b. Differential Sticking b. Calculation of ECD and amount of overbalance

**Lag Time** Poor Hole Cleaning Monitoring actual hole volume to determine actual versus **Determination** theoretical lag time

**Table 7-1: Response to Analysis of Borehole Conditions**

**INDICATOR** Cavings Dxc Shale Gas Flowline Shale Shale

Density Temperature Swelling Factor **CAUSES** (CEC)

**REACTIVE** Large No No No No Good High**(HYDRATING)** Quantities Indication Indication Indication Indication Indication Values**FORMATIONS**

**GEOPRESSURED** Large Decrease Decrease Increase Increase Some High**FORMATIONS** Quantities in Trend in Value in Value in Trend Indication Values

**FRACTURED &** Not No Indication No Increase No No No**FAULTED** Present Indication if Present Indication Indication Indication**FORMATIONS**

**MOBILE** Small No No No No No No**(SALT)** Quantities Indication Indication Indication Indication Indication Indication**FORMATIONS**

**UNCONSOLIDATED** Not Large No Increase No No No **FORMATIONS** Present Decrease Indication if Present Indication Indication Indication

in Trend

**Table 7-2: Indicators Available to the Field Personnel.**

**Recognizing Problem Situations**

During the course of a well, many drilling and non-drilling operations canpotentially cause stuck pipe. Careful observation of the various parametersmonitored by Advantage can pin-point many troublesome zones. Several ofthe more common are illustrated below.

**During Connections and Surveys**

The major indication of a potential problem will be increased drag, whenthe drillstring is moved.

**Questions to Answer Response**

1. Are problem formations exposed? 1. Check lag time

2. Was the borehole adequately cleaned 2. Check ROP before connection/surveybefore the connection/survey?

3. Are there indications of sticking? 3. Check lithology

4. Check annular velocities

5. Check filter cake thickness

6. Check hydrostatic overbalance

7. Check if permeable formations are exposed

**3 DS-20-20-0000-00-01 Rev. B / July 2006**

**Tripping Out**

During trips out of the hole, the common indication of stuck pipe problemswill be increased drag and overpull.

**Questions to Answer Response**

1. Are problem formations exposed above the bit? 1. Review records of previous trips. Is there a trend which can be related to a possible cause?

2. Are high swab pressures resulting in hole 2. Check if the proper lag time was completed instability? when circulating bottoms up?

3. Was the hole adequately cleaned prior to the 3. Check swab pressures, should the trip speed be trip? reduced.

4. Were similar conditions experienced on 4. Check the lithology previous trips? If so, is the hole getting worse?

1. Can the problem be related to deviation or the 1. Check if overpulls are increasing on each trip BHA?

2. Is a keyseat developing? 2. Check the nature of any interbedded sequences.

3. Are there sequences of hard/soft formations 3. Relate doglegs to BHA configuration

which may result in ledges?

4. Check if conditions exists which would

encourage keyseating

**Reaming Operations (Reaming In & Reaming Out)**During reaming operations, the primary indication of hole problems will beincreased torque.

**Questions to Answer Response**

1. Are problem formations exposed? 1. Check the BHA configuration. How does it compare to the last assembly?

2. Can the problem be related to deviation and 2. Check for hard/soft interbedded sequences.BHA?

3. Can the problem be related to ledges? 3. Check for problem formations

4. It is possible that a cuttings bed has formed on 4. Correlate trends from previous trips. Is thethe low side of the borehole? problem still occurring?

5. Was the hole adequately cleaned? 5. Correlate deviation with BHA configuration.

6. Check annular velocities during circulation.

7. Check the ROP prior to reaming

8. Check lithology and location of problem formations.

**4 DS-20-20-0000-00-01 Rev. B / July 2006**

**Drilling Operations**

Though few stuck pipe problems occur while drilling, it is wise to keep in mind that theycan happen. The most commonly monitored drilling parameters which will indicateproblems are torque, pump pressure and ROP. Changes in these parameters, whenmatched with known data (i.e. cuttings lithology, ECD) can pin-point mechanisms whichcan result in stuck pipe and other borehole problems. Several problems, with their drillingparameter correlations are listed in the following table:

**INDICATOR PUMP TORQUE PRESSURE ROP**

**PROBLEM**

**Poor Hole** Increase Increase Gradual **Cleaning** Increase

**High Overbalance** Gradual No Gradual**& Permeable Sands** Increase Change Decrease

**Mobile** Gradual Increase Gradual **Formations** Increase Decrease

**Fractured and** Sudden May Be Sudden**Faulted Formations** Erratic Unaffected Increase Increase

**Geopressured** Initial Increase **Formations** Increase Increase with a Gradual Decrease

**Reactive** Gradual Increase Gradual**Formations** Increase Decrease

**Unconsolidated** Increase Increase Decrease **Formations**

**Junk** Sudden Increase No Sudden

Change Decrease

**Cement Blocks** Sudden No Sudden

Increase Change Decrease

**Table 7-3: Stuck Pipe Indicators During Drilling Operations**

**5 DS-20-20-0000-00-01 Rev. B / July 2006**

**Mechanics of Differential Sticking**

Even when all precautions are taken, stuck pipe may occur. Should this situation develop, there are still ways in which the INTEQ personnel can be of assistance. To free a differentially stuck drillstring, the driller must overcome the restraining force of the drilling fluid, which is pushing the drillstring against a permeable formation. The drillstring (drillpipe or collars) will soon become imbedded in the filter cake opposite the permeable zone if corrective action is not taken as soon as the sticking situation is noticed. The force necessary to free the drillstring will be proportional to the area of contact and pressure differential, and will increase with time because of filter cake build-up. Due to the filter cake build-up, the area of contact can double by the thickening of the filter cake. The force holding the drillstring against the borehole wall can be calculated very quickly. This force will have to be exceeded to free the drillstring. If the force is greater than thepull of the blocks or the tensile strength of the drillstring, the general practice is to addsome compound (i.e. diesel, “black magic”, etc.) to the drilling fluid to reduce the frictionbetween the drillstring and filter cake.

The equation for determining the sticking force is:

Fs (lbs)= ∆P (psi) x A (in2) x f (dimensionless)

where:

Fs = The sticking force or the total pulling force that would be required to free the pipe (lbs)

∆P = The pressure differential between the drilling fluid and the formation (psi) A = The area of contact between the drillstring and filter cake (in2)

f = The coefficient of friction between the drillstring and filter cake (dimensionless)

**Determining the Variables in the Stuck Pipe Equation**

**Pressure Differential (**∆**P)**

The pressure differential between the drilling fluid and the permeable formation isdetermined using the hydrostatic pressure of the drilling fluid (0.0519 x MD x TVD) and the estimated pore pressure of the permeable formation.

**Area of Contact (A)**

The effective area of contact is the chord length of the imbedded portion of the drillstring multiplied by the thickness of the permeable formation. The most acceptable equation is:

A = PC x (TF x 12)

where PC is the chord length or circumference of the pipe stuck against the formation(inches), TF is the thickness of the formation causing the stuck pipe (feet) and 12 is the conversion from feet to inches.

**6 DS-20-20-0000-00-01 Rev. B / July 2006**

**Coefficient of Friction (f)**



Though very seldom quantitatively defined in field operations, “f” will normally varybetween 0.07 (for invert emulsion muds) and 0.40 (for low solids native muds). As themud density increases, the amount of solids (barite, sand, bentonite, etc.) also increases,which increases the coefficient of friction.

The coefficient can be determined using a specialized mud test apparatus called a “stickometer”. This test uses a torque plate which is pushed against a filter cake at 500 psi. After a set time limit, the plate is rotated using a torque wrench and the amount oftorque required to rotate the plate is measured.

The coefficient of friction is the ratio of the force necessary to initiate sliding of the plate to the normal force on the plate. The core face of the stickometer is 3.14 inches, theradius of the plate is 1 inch, and the differential pressure used is 500 psi. Because of thegeometry of the core face the torque is multiplied by 1.5. The formula then becomes:

|  |  |  |  |
| --- | --- | --- | --- |
|  | *f* |  | *Torque*(*in* − *lbs*)×1.5  = K  500*psi* ×3.14*in*2 ×1*inch* |

**Preventing Stuck Pipe**

If the driller is unable to free the stuck pipe or the force necessary to free the pipe isgreater than the force that can be applied by the blocks, then other remedial measures must be used. Normally a lubricating fluid is “spotted” in the troublesome area and isused to dissolve the filter cake. Spotting procedures and calculations have beenmentioned in the “*Advanced Logging Procedures*” manual, under “Additional Volume Calculations”.

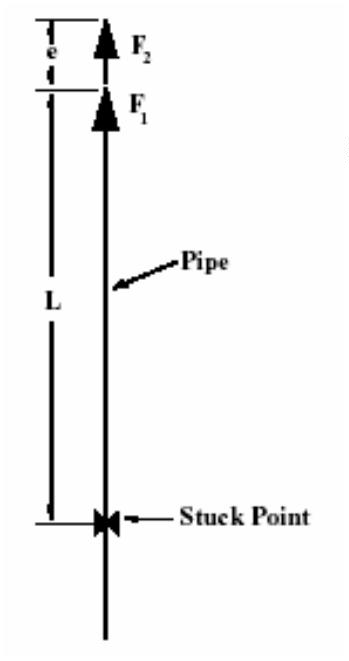
These spotting procedures are facilitated by pin-pointing the depth at which the pipe isstuck. The depth (or free point - stuck point location) can be calculated from relatively simple measurements taken on the rig floor. With reference to Figure 7-1, the procedureto determine the variables is as follows:

1. An upward force “F1” is applied to the pipe. This must be greater than the total weightto insure that the entire string is in tension.

2. A reference point is marked on the drillpipe at the surface, normally at the top of therotary table.

3. A greater upward force “F2” is applied, causing the free portion of the drillstring tostretch by an amount “e”. The stretch is measured above the reference point.

**Figure 7-1 Determination of Stuck Pipe Variables**



Once the measurements have been taken, they are used in the following equation:

|  |  |  |  |
| --- | --- | --- | --- |
|  | *SPL* |  | [ ] [ ] [ ]  *ft* (735 10 )  = × ×  (*w*) *lbs* / *ft* (*e*) *inch*  ×  3  (*F F* )  −  [*lbf* ]  2 1 |

where:

SPL = Stuck Pipe Location [ft]

735 x 103 = Unit correction factor including the Youngs Modulus and the density for steelw = Drillpipe weight [lbs/ft] e = Length of stretch [inches)

F1 = Force applied when pipe is in tension [lbf]F2 = Force applied to stretch pipe to “e” [lbf]

The stuck pipe location produced from this equation will be a best guess value for acouple of reasons: (1) Since all boreholes are crooked to some extent, there can be a considerable amount of friction between the borehole and drillpipe, and (2) If the borehole is highly deviated, it will be very difficult to place the drillstring in tension without it coming into contact with the borehole. However, this calculation is simple to perform and is much better than the industry's nomograms for stuck pipe stretch. The value from the SPL equation will also provide a “near-enough” depth for a starting point when a free-point indicator is lowered into the drillstring.

**Preventing Stuck Pipe**

During the course of a well, there are many operations or items within those operationswhich can prevent stuck pipe from occurring. Even when problems are evident, there are

generally ways to prevent the drillstring from sticking. This section will list the mostcommon causes of stuck pipe, the most commonly used operations to prevent thedrillstring from sticking, and the operations required if preventive measures fail.

**Differential Sticking**

Much has been said in this section on differential sticking. It should be remembered that this type of sticking will develop if six factors are present; (1) a permeable formation, (2) thick filter cake (due to a high water loss), (3) the drillstring is in contact with that filter cake, (4) an overbalance situation exists, (5) insufficient drillstring movement and, (6) a lack of circulation between the drillstring and the filter cake. Preventive measures include:

1. Moving the drillstring as much as possible

2. Rotate the drillstring on connections

3. Always begin pipe motion in a downward direction

4. Ensure a pit is available for pumping pills

5. Use grooved or spiral drill collars

6. Minimize the length of unstabilized drill collars

7. Minimize the length of the BHA

8. Use undergauge stabilizers when possible

9. Consider placing the jar(s) in the heavy-weight pipe section

10. Use survey methods that are of short duration

There are basically three methods which can be followed if the drillstring becomes differentially stuck. The first operation is to immediately work/jar the drillstring (downwards if possible) and apply right-hand torque. Secondly, reducing the hydrostatic pressure may be an option (well control considerations must be taken into account). Thethird operation involves spotting a friction reducing fluid within the stuck zone. If thesemethods fail, then back-off operations, using a free-point indicator, must be considered. The fish can then be recovered using washover pipe, or a DST tool can be used to reduce the hydrostatic pressure followed by the washover pipe.

**Geopressured Formations**

These formations have a pore pressure which exceed the hydrostatic pressure of thedrilling fluid. If these formations are not permeable (for example, shales), once drilled,these formations will “cave” into the borehole. Preventive measures include:

1. Clean the hole of cuttings when not drilling

2. Observe the cuttings for cavings, some being large and convex/concave in appearance

3. Increase the mud density if possible

4. Ream on each connection 5. Perform regular wiper trips

6. Monitor pump pressure for annular loading

7. Control the ROP

8. Minimize the time in the open hole when tripping

**9 DS-20-20-0000-00-01 Rev. B / July 2006**

9. Recognize overpull, then circulate to clean the hole

10. Monitor the drilling fluid's parameters

If geopressured formations are causing stuck pipe problems, great care must be taken to ensure well control problems do not develop. The first step in correcting the situation isto establish circulation. If possible, pipe movement should be downwards, gradually increasing these applied forces. Once full circulation is established and pipe movement is unrestricted, an increase in the mud density is advisable.

**Reactive Formations**

These are naturally occurring bentonitic shales, generally known as “gumbo shales”. The clays within the shales react with the mud filtrate and hydrate. The hydrated shales willthen fall or swell into the borehole. When drilling, the bit tends to “ball-up” with theseclays. When tripping, the BHA can become stuck in the smaller diameter (swelled)portions of the borehole. Preventive measures include:

1. Avoid long time periods without circulation

2. Be prepared to stop drilling and circulate

3. Plan to initiate wiper trips whenever necessary

4. Carefully monitor swab/surge pressures

5. Be prepared to ream when tripping

6. Carefully monitor drilling fluid properties

If the drillstring is stuck in reactive formations, circulation must be established.Concentrate on working the drillstring downwards. Rotation may help dislodge thepacking-off borehole material. Increasing the mud density, if possible, may also bebeneficial.

**Unconsolidated Formations**

These naturally occurring sand and gravel formations will collapse into the boreholewhen drilled. When this occurs, they can easily bury the bit or form a bridge around thecollars. Preventive measures include:

1. Control the ROP

2. Use all solids removal equipment

3. Be prepared for shale shaker screen binding

4. Use viscous sweeps before drilling

5. Ream after each connection

6. Avoid excessive swab/surge pressures

7. Avoid excessive circulation opposite those zones

If sticking does occur, establish circulation first. Then concentrate on working thedrillstring downwards to disturb the bridge/mound. Once the drillstring is free, ensure thematerial is circulated out before drilling. Increase the mud density if possible.

**10 DS-20-20-0000-00-01 Rev. B / July 2006**

**Mobile Formations**

These are naturally occurring plastic formations, most commonly shales and salt. Whendrilled, they will tend to “flow” into the borehole. Preventive measures include:

1. Recognize there is a reaction time associated with these formations 2. Regular wiper trips are normally required

3. Condition the mud prior to drilling those formations

4. Use “eccentric” PDC bits to drill these formations

5. Increase the mud density if possible

6. Minimize open hole time

If the drillstring becomes stuck in a mobile formation, the annulus may become packed-off, so concentration must be placed on establishing circulation. The drillstring should beworked up and down, if possible. If circulation is possible, in a squeezing salt formation a fresh water pill should be pumped immediately. When oil-based muds are used, a water/ detergent spacer should be used ahead of the pill. Repeat the pill procedure every 2 hours until the drillstring is free. Once the drillstring is freed, an increase in the mud density should be considered.

**Fractured/Faulted Formations**

These are naturally occurring formations. When the fractured or faulted formation is drilled, there will be a tendency for pieces of the formation to fall into the borehole. The size of the pieces will vary from pebbles to boulders. They will more commonly occur in limestones and shales. Preventive measures include:

1. Clean out excess fill before drilling 2. Minimize surge pressures

3. Place the jar in the heavy-weight pipe section 4. Be prepared to wash/ream when tripping in

5. Design a BHA to minimize the risk of hitting a ledge

6. Use low circulation rates/pressures to clean the hole

If it is determined that faulted/fractured formations are the cause of the sticking, thedrillstring should be worked up and down to try and break up the pieces of formation. If limestone is causing the problem, an inhibited acid (HCl) pill can be used to dissolve the limestone. The pill should be spotted with a large water spacer.

**Key Seating**

Key seats are the result of the drillstring wearing an additional hole into the side of the borehole. This “extra” hole will generally have the I.D. of the drillpipe's tool joints and the drill collars will not pass through this extra hole when tripping out. Preventivemeasures include:

1. Minimize pipe rotation

2. Use wiper trips often

3. Minimize dogleg severity

**11 DS-20-20-0000-00-01 Rev. B / July 2006**

4. Carefully design the BHA

5. Minimize the length of rathole below casing

6. Have a surface jar on location

7. If the problem is recognized, cure it before drilling ahead

If the drillstring becomes key seated, the drillstring should be worked upwards gradually, this will depend on how long the key seat is, and if the BHA is not jammed into the keyseat. The drillstring should try to be rotated up and out of the key seat with minimumtension.

**Borehole Geometry (Profile and Ledges)**

The borehole is seldom drilled in a smooth manner. Ledges and washouts are common, especially when alternating hard/soft formations are drilled. Problems with boreholegeometry normally occur during tripping operations. Remember, when tripping in, the drillstring is in compression making it more flexible. When tripping out, the drillstring is in tension making it more rigid. Preventive measures include:

1. Minimize doglegs

2. Reduce the number of BHA changes

3. Ream if the BHA configuration is changed

4. Do not run stabilizers above a jar

5. Be prepared to run a hole opener if necessary

If borehole geometry problems are suspected when tripping in, a gradual upwards working force should be applied. If this occurs when tripping out, upwards forces shouldbe applied gradually to prevent the drillstring from further jamming. If a ledge issuspected, then a combination of upward/downward forces should be used to try and remove the ledge.

**Undergauge Borehole**

When drilling long sections of abrasive formations, the gauge protection on the bit andstabilizers can become so worn it becomes ineffective. Any additional hole that is drilled will be undergauge. Preventive measures include:

1. Properly gauge the bit and stabilizers after each run

2. Ream back to bottom if an undergauge hole is suspected

3. Never force a new bit to bottom

4. Select bits with good gauge protection (5&7 feature in roller cone bits) 5. Carefully run fixed cutter bits after roller cone bits

If the assembly is ‘bit stuck’ with a drilling motor, the drive sub’s freedom of movementwill prevent any torsional force from being transmitted to the bit. When this is the case,several options should be weighed to free the bit from the formation.

Firstly, conventional mechanical means should be used to break the bit free from theformation as soon as sticking has been determined. The pipe should be pulled up to, but

**12 DS-20-20-0000-00-01 Rev. B / July 2006**

not exceeding the ultimate loading force listed in the motor specification. Activation ofjars to free the assembly should be used.

If pure conventional mechanical means fail to free the bit, continue to pull the pipe intension and spot acid or other appropriate drilling fluid additives around motor until it is freed. If conventional mechanical methods are unsuccessful, chemical cutters or explosive severing devices can be employed to free the pipe from the stuck assembly.

If this solution fails, and the internal BHA components allow for passage of drop balls,consider applying multiple balls to motor assembly via the drillpipe. Enough balls shouldbe dropped to lock the internal motor components preventing drive sub movement. Thesize and quantity of the balls will vary with motor size and type. Note that drop balls andthe subsequent motor locking may severely limit circulation through the drillstring.

Spotting cementing in the motor may be another option. Note that this option wouldrequire high quality pumps and monitoring equipment to ensure correct placement of thecement. Additionally, cementing runs the risk of premature setup within the pipe orassembly and the associated problems of this method.

Note that many of the above options will result in motor/BHA damage and immediatewithdrawal from the borehole is required.

**Inadequate Hole Cleaning**

Inadequate hole cleaning causes overloading of the annulus. In highly deviated orhorizontal wells, this results in the formation of a cuttings bed on the low side of theborehole. Preventive measures include:

1. Control the ROP to ensure the hole is cleaned 2. Circulate bottoms-up until shakers are clean 3. Always check the volume of cuttings coming over the shaker 4. Maintain the correct drilling fluid properties

5. Control the annular velocities 6. Recognize increased overpull

7. Always reciprocate and rotate pipe while circulating 8. Use viscous sweeps

9. Recognize low-side sections of deviated holes

10. Plan to use regular wiper trips

11. On floaters, use the riser booster pumps

If the annulus becomes overloaded, attempts to establish circulation must be attempted. In addition, a downward force should be applied gradually until circulation begins. Once circulation is established, the drillstring should be rotated to further disturb the cuttings. In low angle holes, a weighted high viscous pill should be used to “float out” the cuttings. In high angle holes, a low viscous pill should be used to disturb the cuttings bed, followed by weighted pills to carry the cuttings out of the hole.

**13 DS-20-20-0000-00-01 Rev. B / July 2006**

**Junk in the Borehole**

Junk is a foreign object in the borehole, which is not meant to be there. Since theclearance between casing and collars/stabilizers is not great, even a small piece of junk can stick the drillstring. Preventive measures include:

1. Ensure downhole tools are in good condition

2. Inspect downhole tools regularly

3. Be careful when working around the rotary table

4. Leave the hole covered when the drillstring is out of the borehole

5. Install drillpipe wipers whenever possible

If junk sticking is suspected, upward and downward working and jarring should commence to try and dislodge the obstruction. These forces should be gradually increased until the drillstring is freed.

**Cement Blocks**

After a leak-off test has been performed and drilling has resumed, the large sized collarsor stabilizers can cause blocks of cement to break loose and fall into the borehole. These large blocks can easily jam against the drillstring. Preventive measures include:

1. Minimize the length of rathole below the casing shoe

2. Always ream ratholes or cement plugs before drilling ahead

3. Be careful when tripping back through the casing shoe

If jamming occurs, attempt to dislodge or break up the obstructions by using alternating upward and downward working and jarring. These freeing forces should be gradually increased until the drillstring is freed and, if available, an acid solution can be pumped around to dissolved the cement.

**Green Cement**

A rare occurrence of stuck pipe is one due to soft or “green” cement. This occurs whenthe cement is not allowed to set properly, or because of incorrect additives andbottomhole temperature gradients, the cement does not set properly. After the normal time for WOC (Waiting On Cement) and the drillstring is tripped in to drill out the plugs and float equipment, the cement can “flash set” when pressure is applied. Preventive measures include:

1. Pre-treat the drilling fluid if green cement is suspected

2. Know the depth to the top of cement

3. Begin circulation above the top of the cement

4. Monitor cement returns at the shale shaker

5. Realize the weight-on-bit will be inaccurate

6. Restrict the ROP when drilling out cement

**14 DS-20-20-0000-00-01 Rev. B / July 2006**

If problems develop, immediate action is required to prevent the cement from setting. Upward working and jarring operations should commence as soon as possible. Ifcirculation is possible, an acid solution can be pumped to try and dissolve the cement.

**Additional Review/Reading Material**

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**15 DS-20-20-0000-00-01 Rev. B / July 2006**