Differentially Stuck Pipe

Background

Pipe sticking poses a significant global challenge in drilling operations. It stands as the most prominent cause of non-productive time (NPT), contributing substantially to increased well costs (Yarim et al., 2008; Reid et al., 2000; Pal et al., 2000). In severe cases, it can even necessitate abandoning the ongoing wellbore and opting for a sidetrack. Estimated that stuck pipe incidents can account for approximately 25% of the total budget in deep oil and gas wells. In certain regions, the expenses incurred due to differentially stuck pipe events alone can escalate to as much as 40% of the overall well cost (Reid et al., 2000). In 1991 research found that BP had spent more than $30 million every year for stuck pipe issues. Between 1985 and 1988, an average of $170,000 was spent per well because of stuck pipe. Lastly, in a technical paper titled “Evaluation of Differential Pressure Sticking and Stuck Pipe in Oil and Gas Drilling Technology and Its Production Operations”, March 2020, the economic losses by Nigeria Development Petroleum Company for only 2 wells that got differentially stuck was approximately US$ 50 million.

Stuck Pipe is the largest source of NPT in drilling worldwide

In the drilling industry, the term "stuck pipe" is commonly used to refer to the issue at hand. It is important to note that "stuck pipe" encompasses various elements such as drill pipe, drill collars, drill bits, stabilizers, reamers, casings, tubing, and other tools or equipment that can become lodged during drilling operations. Once a pipe is stuck, it loses its ability to be raised, lowered, or rotated. The presence of a stuck pipe leads to increased drilling costs due to operational downtime. In severe cases, if the stuck pipe cannot be released economically, it may result in the complete abandonment of the drilling operation at a particular site.

Stuck pipe is a situation when the drill string cannot be moved from the well. The pipe may be partially moved and you may be able to circulate and rotate the pipe. Personnel on the rig must be able to identify the cause of stuck pipe in order to figure out the right way to free the pipe.

Mechanical sticking (hole collapse) is probably the most common form, but some studies have indicated differential sticking as increasingly more common.

Stuck Pipe Categories

There are 3 categories of stuck pipe as follows:

1. **Mechanical sticking:** Pack off and bridging are occurred when there is something in the wellbore as formation cutting, junk, etc accumulating around drilling string/BHA and that stuff blocks the annulus between drill string and the wellbore. You should remember that either big or small debris can stick the pipe.

It normally occurs when the mud pumps are off for an extended period of time such as when pulling out of hole. It is quite a tough job to free the pipe in case of packoff or bridging and the chance of success is lower than differential or keyseating.

Indications on the rigsite:

1. A sudden rise in circulating pressure.
2. Extreme torque and drag.
3. A decrease in set-down weight while running in the hole.
4. A reduction in cutting dimensions, or an abundance of anomalous and large cuttings over the shakers.

2. Differential sticking: Differential sticking happens when drill string is pushed against permeable formations by differential pressure between hydrostatic and formation pressure. The frictional force between drillstring and formation is so high that you will not be able to move the pipe. The differential sticking tends to easily happen when drilling through depleted reservoir is conducted. Moreover, this stuck mechanism almost always happens when the drill string has been stopped moving for a long time.

Indications on the rigsite:

1. Overpulls on connections or after surveys
2. No string movement
3. Full circulation
4. Subsurface losses
5. High overbalance
6. A permeable formation is exposed in the open hole

3. Keyseating: We can define Key seating term in drilling as a groove in the hole side made by the Drill Pipe rotating against the borehole wall at the same point and wearing a groove or key seat in the wall. During tripping out of the hole, the bottom hole assembly BHA. drill collar, stabilizer, mud motor, or any big diameter component may wedge into one of these large grooves, which may be too small for it to pass through. This Key Seating sticking will likely happen in a soft formation in directional wells while dropping or building inclination. It can also occur at the casing shoe if a groove is worn in the casing pipe.

Indications on the rigsite:

1. Wiper trips haven't been done.
2. The situation occurs when pulling out of the hole only.
3. Circulation is not restricted.
4. High overpull suddenly occurs when the BHA is pulled into the key seat.
5. Tripping back is possible.

History

The evolution of determining the causes of pipe sticking outside of hole collapse is interesting. Before the 1940's, it was generally considered that the causes of stuck pipe were due to keyseating. Not from doglegs in a KOP in directional drilling, but from the drillpipe over time "wearing a groove in the wall of the hole with the drillstring and sticking larger pipe in the smaller groove when the drillstring is pulled." "Wall sticking" was also considered a prime culprit. It wasn't until the mid-1950's that differential pressure sticking was introduced. That then provoked the interest of the drilling engineers to investigate the problem more fully. Nevertheless, "wall sticking" was considered a key component, and still is. It is recognized that the area of contact may increase, even double, with a thick filter cake. Operators paid more attention to filter cake thickness than the fluid loss values, but of course, they are directly related.

Differential Sticking

Differential sticking occurs during most drilling operations. The hydrostatic pressure exerted by the drilling mud column is greater than the formation fluid pressure. In permeable formations, the mud filtrate flows from the borehole into the rock pores and builds up a filter cake. A pressure differential exists across the filter cake which is equal to the difference between the pressure of the mud column and the pressure of the formation.

When a pipe is positioned centrally within the borehole, the hydrostatic pressure, generated by the mud overbalance, exerts equal force in all directions around the pipe. However, if the pipe comes into contact with the filter cake, the mud overbalance starts exerting pressure to push the pipe further into the filter cake. This results in an increased contact area between the pipe and the filter cake. Although filtrate continues to be expelled and squeezed from the filter cake between the pipe and the formation, causing the cake to shrink, it allows the pipe to penetrate deeper into the filter cake, thereby further expanding the contact area. This phenomenon is amplified in directional wells. If the pressure difference is significant enough and acts over a sufficiently large area, the pipe may become stuck. Differential sticking commonly occurs when the pipe remains motionless for a certain period, such as during pipe connections or surveying activities.

The force required to pull differentially stuck pipe free depends on many factors including:

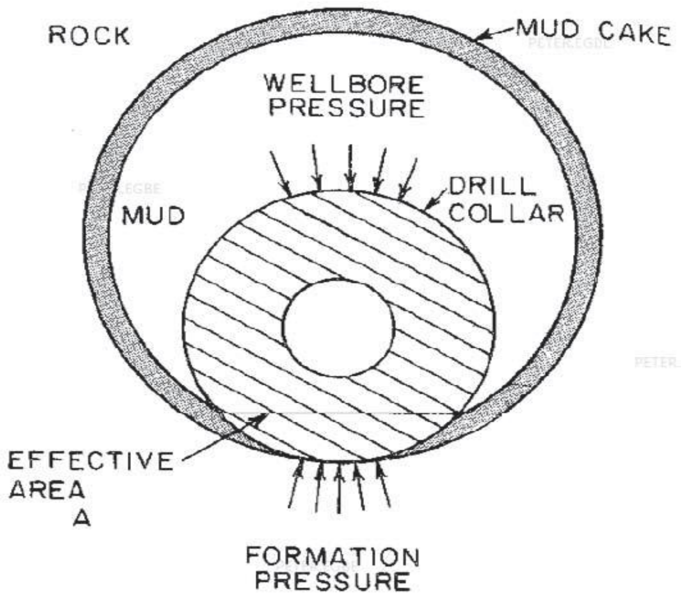
1. The difference in the pressure between the borehole and the formation. Any overbalance adds to side forces which may exist due to the deviation of the hole.
2. The surface area of the pipe embedded in the wall cake. The thicker the cake or the larger the pipe diameter, the greater this area generally is.
3. The bond developed between the pipe and the wall cake is a very significant factor, being directly proportional to the sticking force. This can include frictional, cohesive and adhesive forces. It generally tends to increase with time, making it harder to pull the pipe free.

This is critical; over time the length of stuck pipe is likely to increase, especially in deviated wells as the solids settle creating a thicker filtercake. The industry consensus is that if you do not have a chemical solution on board and haven't used it within 24 hours, the odds of freeing the pipe are less than 10%.

It has been established that the force required to **differentially stick a drillstring is influenced by a combination of the differential pressure, i.e., the overbalance pressure, in the wellbore, the contact area between the drill string and the mud filter cake, and the friction factor between the two**. This is illustrated by the equation:

$Fst = \Delta pAf$

where, Fst is the freeing force, Δp is the differential pressure between the wellbore and the permeable formation, A is the effective area of string in contact with the mud filter cake, and f is the coefficient of friction between the pipe and the mud filter cake. Based on this relationship, Fig. 3, it is clear that the overpull force required to free a differentially stuck string increases with the rate of increase of the isolated portions of the string, which is equally dependent on the pipe-to-hole diameter ratio, and the rate of mud cake thickening. The ratio of the pipe-to-hole diameter affects the initial area of the pipe isolated from the hydrostatic pressure, and is time-dependent. The rate of cake thickening (or cake build up rate) is driven by the mud characteristics and the formation permeability. The rate of cake thickening is also time-dependent. **As time passes, if the mud filter cake is permeable, fluid loss continues, and the filter cake consequently thickens**. Eventually, and with time, the filtration process through the mud filter cake continues, and the isolated portion of the string increases. **Therefore, as mentioned, the differential sticking force increases with time. Subsequently, the popular oil field understanding that the longer a string stays stuck, the harder it is to free.**



Differential sticking may be distinguished from other forms of sticking, such as mechanical sticking. Mud circulation is not interrupted as there is no obstruction in the borehole to stop the flow, as would be the case for pipe stuck due to hole bridging or caving. It is not possible to move or rotate the pipe in any direction.

In the event of pipe sticking, drillers typically attempt to liberate it through mechanical means, such as employing pulling, jarring, or reversing the direction of pipe movement if it was mobile just before sticking. However, these methods often prove unsuccessful in releasing the stuck pipe. It is important to note that there is a constraint on the amount of force that can be applied, as excessive force could potentially cause the pipe to fracture and exacerbate the situation.

If the pipe remains stuck, it is the practice to apply a pipe release agent (PRA), commonly called a "spotting fluid". These spotting fluids are chemically active mixtures, which may be oil or water based, which are placed over the stuck region in an attempt to free the pipe, if mechanically working the pipe fails to release the pipe. These spotting fluids are believed to act by attacking the mud filter cake. They are positioned in the borehole by pumping the spotting fluid down the hole to the stuck region in the form of a slug, also known as a pill. The pill generally contains sufficient material to cover the stuck zone and extend slightly beyond the area of the stuck zone. 50% excess is typically recommended and even from some sources, 100% excess. Pills frequently are left to soak the cake until the pipe is free or attempts to free the pipe are abandoned.

In a WBM, the PRA frequently consists of what may be called a mini-OBM, i.e., containing a concentration of oil-wetting agents to oil wet the solids in the filtercake thereby causing them to shrink, dehydrate, and increase lubricity. If stuck with an SBM/OBM, options have been limited to base oil pills and density reduction to reduce the hydrostatic or surfactant pills (sometimes with an acid added to dissolve any CaCO3 in the filtercake) to try and disperse the filtercake. Both are weak responses. **HDC Mk II™ was developed in the UK over 4 years with the help of both Amerada Hess and BP as a PRA for use in OBM/SBM's.** It works in WBM too.

HDC Mk II™ is the only pipe release agent (PRA) developed for SBM/OBM's.

Operations

Differentially pressured stuck pipe normally occurs:

1. When the pipe is slow moving or stationary.
2. When there is contact between the pipe and the wellbore.
3. When an overbalance is present.
4. Across a permeable formation.
5. In a thick filtercake.
6. Poor hole cleaning and excessive rates of ROP can result in an increase in annular mud weight and produce excessive overbalance.
7. Excessive fluid loss and ineffective hydraulics

Indications on the rigsite:

7. Overpulls on connections or after surveys
8. No string movement
9. Full circulation
10. Subsurface losses
11. High overbalance
12. A permeable formation is exposed in the open hole

Differential pipe sticking can be prevented by following some precautions:

1. Apply the minimum possible safe overbalance while drilling.
2. Controlling the HTHP fluid loss and consequently reducing the filter cake.
3. Minimize the drilled solids percentage in the mud system.
4. Drill with a low friction coefficient mud system (The friction coefficient can vary from 0.04 for oil-based drilling fluids to 0.35 for water-based muds)
5. Reduce the time the string is static for example when repairing or making a connection.

Freeing Differentially Stuck Pipe

Initial guidelines to free the stuck drill string caused by differential sticking.

1. Apply maximum flow rate as much as you can. This will clear the annuli of any solids loading.
2. Apply maximum torque in the drillstring and work down torque to stuck depth. Torque in the string will improve chance of free the pipe.
3. Slack off weight of string to maximum sit-down weight.
4. Jar down with maximum trip load. Torque may be applied with jarring down with caution. The chance of freeing the pipe by jarring down is more than jarring up. Be patient when a hydraulic jar trips because it may take around 5 minutes each cycle.

The secondary actions to free the pipe are:

1. Reduce hydrostatic pressure by pumping low weight mud or base oil pill (if using a SBM/OBM). You must ensure that overall hydrostatic pressure is still able to control reservoir fluid to accidentally come into the wellbore.
2. Continue jarring down with maximum trip load and apply torque into drill string.

The following conditions will have an effect on the success of freeing differentially stuck pipe:

Hole Angle: Low angle holes had the best success rates for freeing stuck pipe
Hole Size: Success rate for freeing stuck pipe was slightly higher for larger than smaller holes.
Mud Weight: The chance of freeing stuck pipe is higher in wells requiring lower mud weights.
Spotting Time: The quicker the spot is applied, the higher the chance of success.
Open Hole: Open hole length does not consistently affect the success rate for freeing stuck pipe.

Reduction of Differential Pressure

The reduction of differential pressure by mud weight reduction or U-Tubing techniques has been used to free differentially stuck pipe. It can, however, cause further problems and all factors should be considered before using these techniques. Reducing hydrostatic pressure can cause certain formations, usually shale, to become unstable. Often this leads to packing off and further stuck pipe problems. Reduction of hydrostatic pressure can lead to well control problems. For these reasons many operators will use spotting fluids as their first option to free stuck pipe.

Spotting Fluid

When differential sticking occurs, **HDC Mk II™** is used to free the pipe.

Note: *It is critical to have the fluid readily available on the rig and apply it within six hours of the stuck pipe occurrence.*

Displacement procedure in Synthetic and Oil-based muds

Many pipe free pills are ineffective because they fail to contact the filter cake in which the pipe is stuck, due to the gelled mud in the narrow annulus. Thus the pipe free pill takes the easier route, up the wide annulus.

To increase the chances of placing the pipe free pill in the correct zone, the following procedures should be adopted:

- A turbulent flow or, as thin a spacer as possible, should be pumped ahead of the pipe free pill. In this instance, if base oil will not adversely affect the hydrostatic head, it should be used after prior agreement with the Operator Representative.

- As large a spacer as possible should be pumped and displaced at the maximum possible rate, with due consideration being given to the hydrostatic head.

- Thinners can be used in the spacer, but only at levels which will not cause problems if incorporated into the active mud system. This should help to remove gelled mud from the narrow side of the annulus.

- Increasing the density of the pipe free pill above that of the circulating mud weight will also act to drive out the gelled mud. The present recommendations are to increase the weight to 0.02 - 0.04 sg above circulating mud weight.

- The pipe free pill should be displaced to the stuck zone at the maximum possible rate.

- It is better to displace the entire pill at the maximum rate to the stuck zone. However, the volume of pill pumped should make allowances for contamination by the spacer ahead of the pill. Volumes should be sufficient to cover the stuck zone plus a further 50%.

HDC Mk II™

HDC Mk II™ is a non-damaging stimulation fluid, PRA, and descaling additive that dissolves **barite**, drilling fluid additives, **calcium carbonate** and **sulphate scales** (magnesium, strontium, calcium, and barium sulphate). It is unique in that it works significantly faster at a higher capacity than any competitive products (an order of magnitude faster than other products and with 4 to 6 times the capacity). It is a single phase, alkaline (pH +/-12) chemical that is **non-corrosive** and **environmentally benign**. It is inorganic, hence has high temperature limits.

Result with OBM cake: Before (right) and after (left) HDC Mk II treatment for 6 hrs @ 90 °C gave 95% dissolution.

HDC Mk II™ is a mix of chelating agents with catalysts and reaction accelerators, a result of a 4-year development project.

- **Dissolves Barite, barium sulphate scale and other sulphate compounds**
- **Dissolves CaCO3**
- **Dissolves clays at 2-4%**
- **Tends to de-emulsify**
- **Inhibitive to clays and will shrink and dehydrate clays**
- **Non-corrosive and environmentally friendly**
- **No precipitates or gaseous by-products**

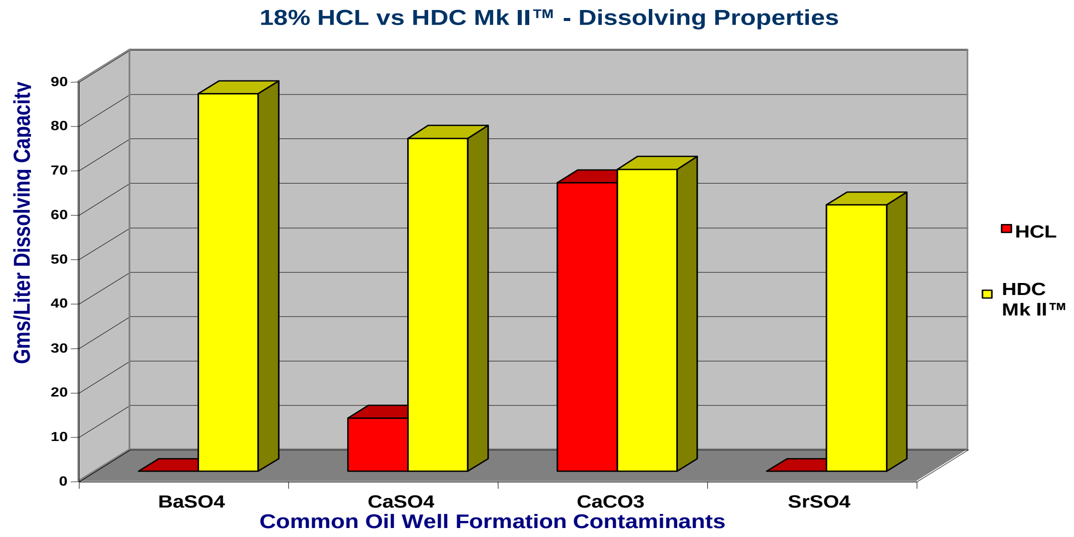
HDC Mk II™ works in both oil based and water based mud systems so that it removes oil based and water based mud filter cake in open holes as well as perforations. It removes well bore damage, scale, and barite/BaSO4 deposits. **HDC Mk II™** was developed to be a pipe release agent (PRA) for differentially stuck pipe in SBM/OBM's. It works in WBM too.

HDC Mk II™ has a specific gravity of 1.31.

HDC Mk II™ thus is primarily used for differentially pressured stuck pipe, stimulation, and barium sulphate scale. It has even been used in screened wells to dissolve the filter cake behind the screen thus increasing production.

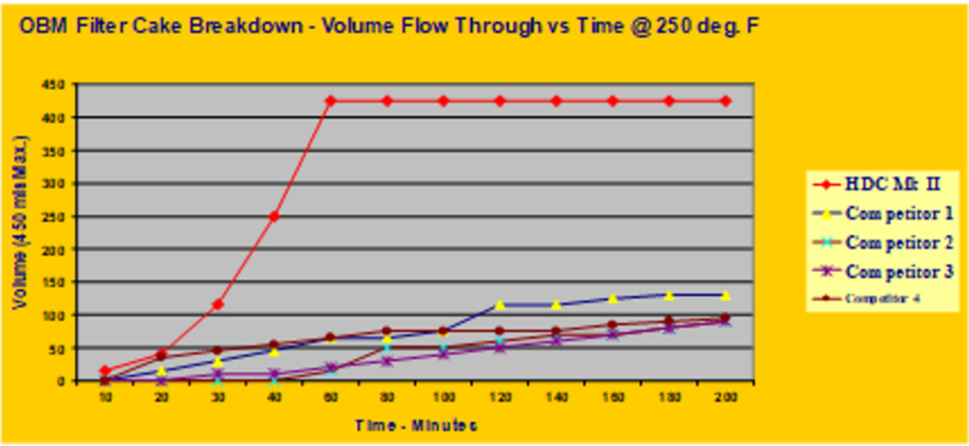
HDC Mk II™ was Gold Banded in the OCNS CEFAS system in the UK, the best environmental rating possible.

HDC Mk II™ is packaged in 200 liter drums, four to a pallet.



HDC Mk II™ dissolves a wider variety of minerals and scales than does HCL and HF without producing precipitates, re-precipitates, and/or gaseous by-products.

BP Sunbury Results with HDC Mk II

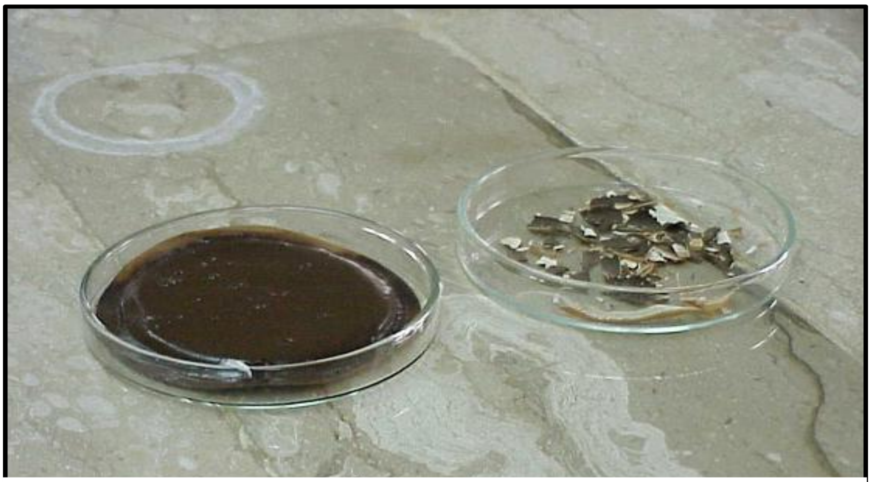


Not All Chelating Agents Are Created Equal

It is an increasing trend for companies to state they use chelates and even multichelates. Malic acid, tartaric acid, citric acid, NTA, HEIDA, HEDTA, EDTA, CyDTA, GLDA, and DTPA amongst others are chelants. They have been around for many years. What has prevented widespread adoption is these compounds exhibit a **low capacity** and dissolution rates **too slow** for the industry, but nevertheless are now being marketed for use. **HDC Mk II is the result of a 4 yr development project with the sponsorship of Amerada Hess and BP** with multiple chelating agents, catalysts and a reaction accelerator resulting in the speed more than 10x faster and the dissolve capacity 4-6x higher.

Facts and guidelines when using HDC Mk II™ :

1. The density of **HDC Mk II™** is 1.31 SG (10.9 ppg).
2. **It is used neat.**
3. As **HDC Mk II™** chelates with calcium, **a small spacer must be placed before and after, consisting of base oil or any brine NOT containing calcium** ($CaCl_2$, $CaBr_2$, etc.) such as KCL, NaCl, etc. 5 bbls will suffice, before and after.
4. If a weighted pill is required for balance to avoid U-tubing, weighted SBM/OBM can be used, but the spacer is still required.
5. The **HDC Mk II™** will typically dissolve the filtercake in just a couple of hours depending upon the temperature, the higher, the faster.
6. The temperature limit is above 260°C (500°F).
7. Assuming the BHA is stuck and near the bit, leave some excess in the drillpipe/BHA so that after 2 hours if necessary 3-5 bbls of excess **HDC Mk II™** can be pumped into the annulus. And repeat if necessary until there is no more in the drillpipe.



Result with OBM cake : Before and after HDC Mk II treatment for 6 hrs @ 90 °C resulted in **95% dissolution.**

What to do after the string becomes free?

Drilling Fluid Impact

HDC Mk II™ can be incorporated into the drilling fluid without loss of density or substantial quality loss. It emulsifies quite easily when strung out through the system, and exhibits no risk to human health or marine life. It is, or has been, “E” rated or Gold Banded in the UK CEFAS system, the highest environmental rating allowing for unlimited dumping offshore (although all operators are zero discharge). Fluid loss control and electrical stability will have to be restored at the interface of the pill volumes where synthetic or oil-based fluids are used, as with the case of any water intrusion into an OBM system.

In water-based muds, the pH of the spotting fluid would have the biggest impact, but this is easily treated using citric acid or allowed to deplete back to system pH as it blends in the drilling fluid.

Fluid loss and viscosity will have to be remedially treated to restore over all properties, with the weight however, unaffected.

If used as directed, the **HDC Mk II™** formulations will in effect, become spent during the spotting period, and have no effect outside the critical zone.

Note: In seawater-based fluids, the solubilised barium in the fluid will revert to barium sulphate due to the sulphate ions present in seawater.

1. Circulate at maximum allowable flow rate. Flow rate must be more than cuttings slip velocity in order to transport cuttings effectively.
2. Reciprocate and work pipe while cleaning the hole. Ensure that you can work pipe with full stand or joint while circulating.

Any balanced pill considerations must be determined based on the existing mud weight at the time the pipe became stuck.

With that in mind, the next few pages explains U-tubing.

Other Considerations

Understanding the U-Tube Concept and Importance of U-Tube

By DrillingFormulas.Com

We use the behavior of one of the fluid columns to describe the behavior regarding what is happening in the side of the fluid column, i.e., if two fluid columns are connected at bottom. Basically, this situation is simply described in the oilfield as a "U Tube".

In the oilfield, especially in drilling, a "U Tube" can be considered as a string of pipe (drill pipe and tubing) in a wellbore where fluids are able to pass inside a string of pipe (drill pipe and tubing) and the annulus (area between wellbore and string of pipe). Figure 1 below demonstrates the "U Tube" concept.

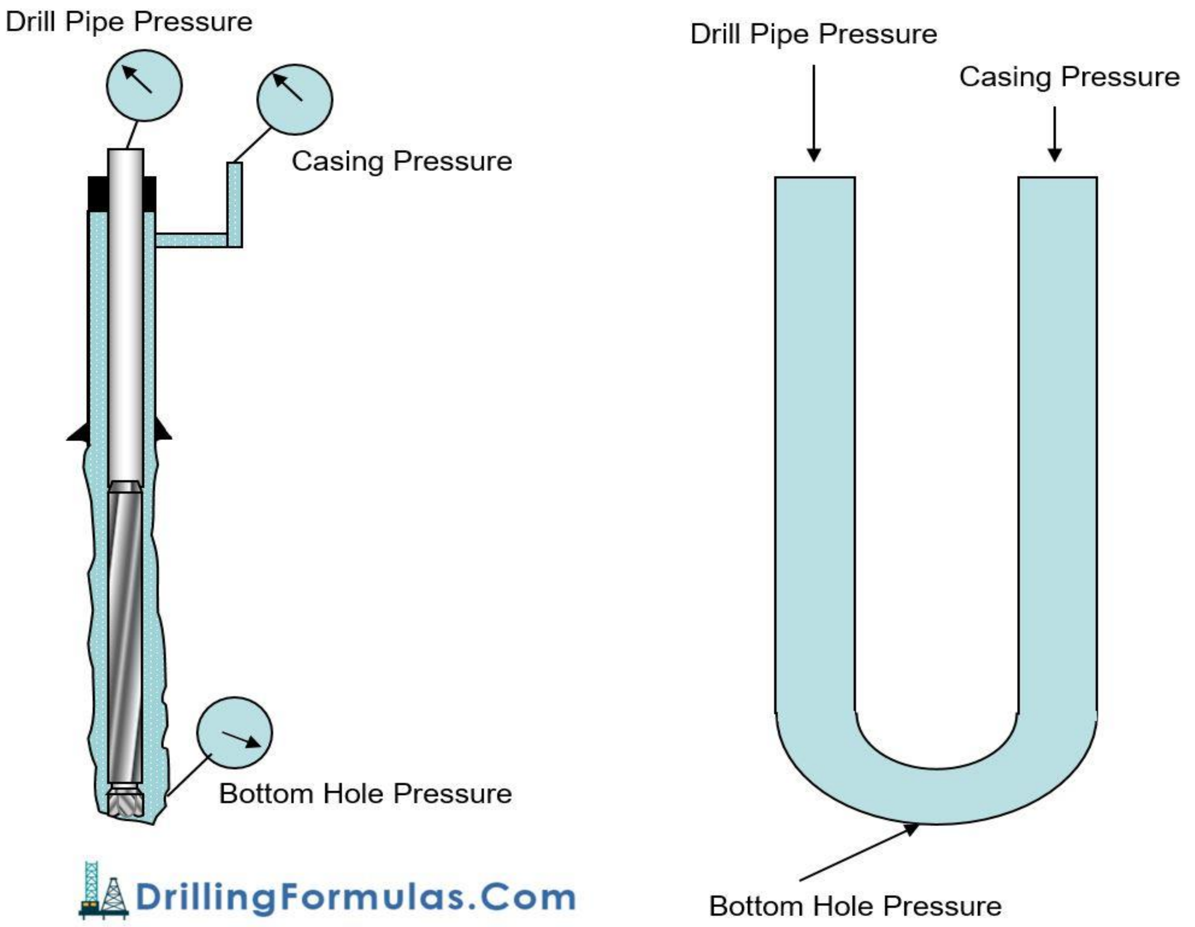


Figure 1 – U-Tube Diagram Represents Both Sides of Fluid Columns

A horizontal tube connects the right-hand side of the U-Tube and fluid levels in both columns should equalize when a fluid with a consistent density is used. The hydrostatic pressure should be equal at the bottom of both columns. The pressure found at the base of both columns is considered 'bottomhole pressure'. To replicate the opening through the nozzles in the bit, the opening at the base exists. The fluids are balanced.

The mathematical relationship for this is shown below;

BHP = HP + SP

Where;

BHP = bottomhole pressure

HP = hydrostatic pressure

SP = surface pressure

With the U-tube concept applied, both sides of the fluid columns can be described with the equation below;

BHP = SIDPP + HP string = SICP + HP annulus

Where;

BHP = bottomhole pressure

SIDPP = shut in drillpipe pressure

HP string = hydrostatic pressure in drill string

SICP = shut in casing pressure

HP annulus = hydrostatic pressure in annulus

When the fluid density in both columns is equal, U-Tubes can be relatively simple. Surface pressures on the drillpipe and casing side will be the same when the drillpipe and casing are full of the same fluid density. However, U-Tubes become more difficult when fluids with varying densities are found in the columns. Despite the same BHP, both HP and SP will differ.

With hydrostatic and surface pressure equal in both columns, U-Tubes aren't too interesting because both columns are filled with fluids of the same density. For example, when the annulus and drillpipe contain the same weight drilling mud while a bit is run to the hole's bottom. The hydrostatic pressure is equal at both the casing and drillpipe side, fluid levels are static at the top, and the surface pressure on the drillpipe and casing sides are zero.

On the other hand, when columns are occupied by fluids of different densities, there's likely to be a difference in both surface pressure and hydrostatic pressure in both columns (drillstring and casing side). For example, this is commonly seen in a kick with the bit on bottom as you can see from the Figure 2 diagram. As the formation pressure increases above the hydrostatic pressure (generated by mud in the well), it kicks. The well will stop flowing if it's shut-in; a surface pressure on the drillpipe gauge is then a reflection of the pressure underbalance. As opposed to the drilling mud in the annulus, the fluid now contains a lighter weight formation fluid and this leads to a reduction in total hydrostatic pressure (within the annulus). The shut-in casing pressure increases above shut-in drillpipe pressure to compensate to the underbalanced in the annulus side compared to the drillpipe side.

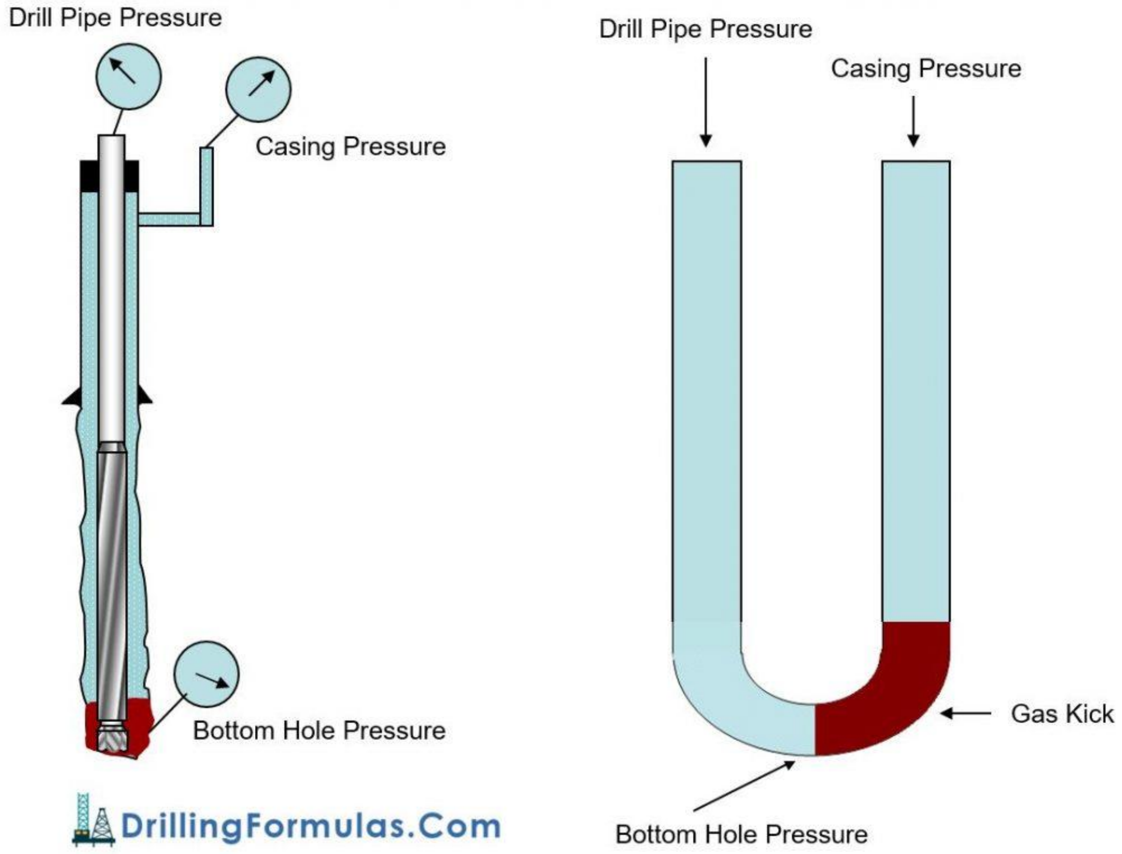


Figure 2 – U-Tube Diagram Represents Both Sides of Fluid Columns with Gas Kick

Why is U-Tube very important?

It is very vital to keep a basic concept of U-Tube in mind.

If there are two different fluids between inside of the string and the annulus, fluids always flow from a higher pressure area to a lower pressure. If the system is NOT closed, the lighter fluid will flow out and it will be stopped when the system pressure is stabilized (see the Figure 3 below).

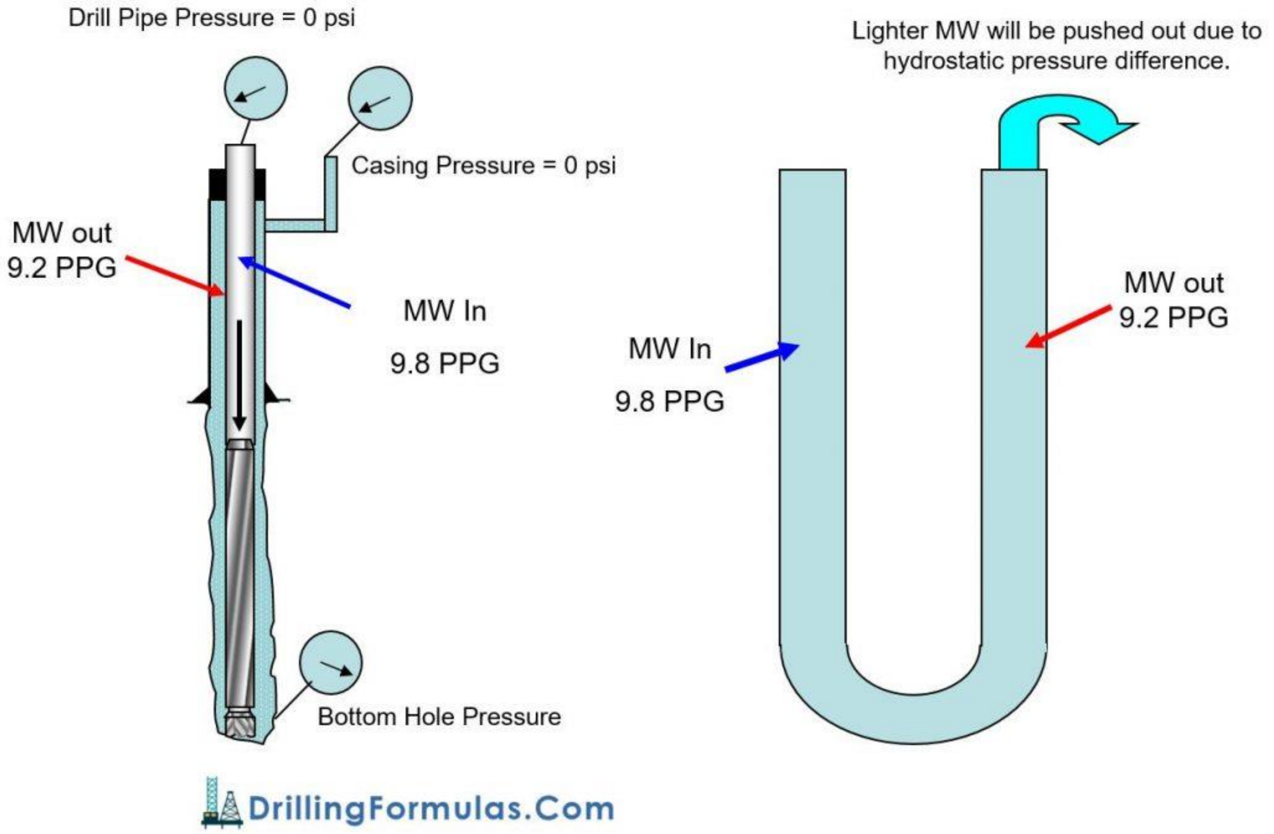


Figure 3 – U-Tube Diagram Represents Both Sides of Fluid Columns Without a Closed System

If the system is closed, for example with the well shut in, pressure must be the same at the bottom point where both sides of the U-tube are connected . Therefore, the drill pipe pressure and casing pressure (annulus pressure) respond based on the fluid in each side and the formation pressure at bottom hole (see the Figure 4).

Figure 4 demonstrates difference in hydrostatic pressure between the drill pipe and the casing when the mud weight 9.8 ppg is pumped to the bit and the well is shut in. The calculation is shown below.

BHP = SIDPP + HP string = SICP + HP annulus

BHP = 0 + (0.052 × 10,000 × 9.8) = 5,096 psi

5,096 psi = SICP + (0.052 × 10,000 × 9.2)

5,096 psi = SICP + 4,784 psi

SICP = 312 psi

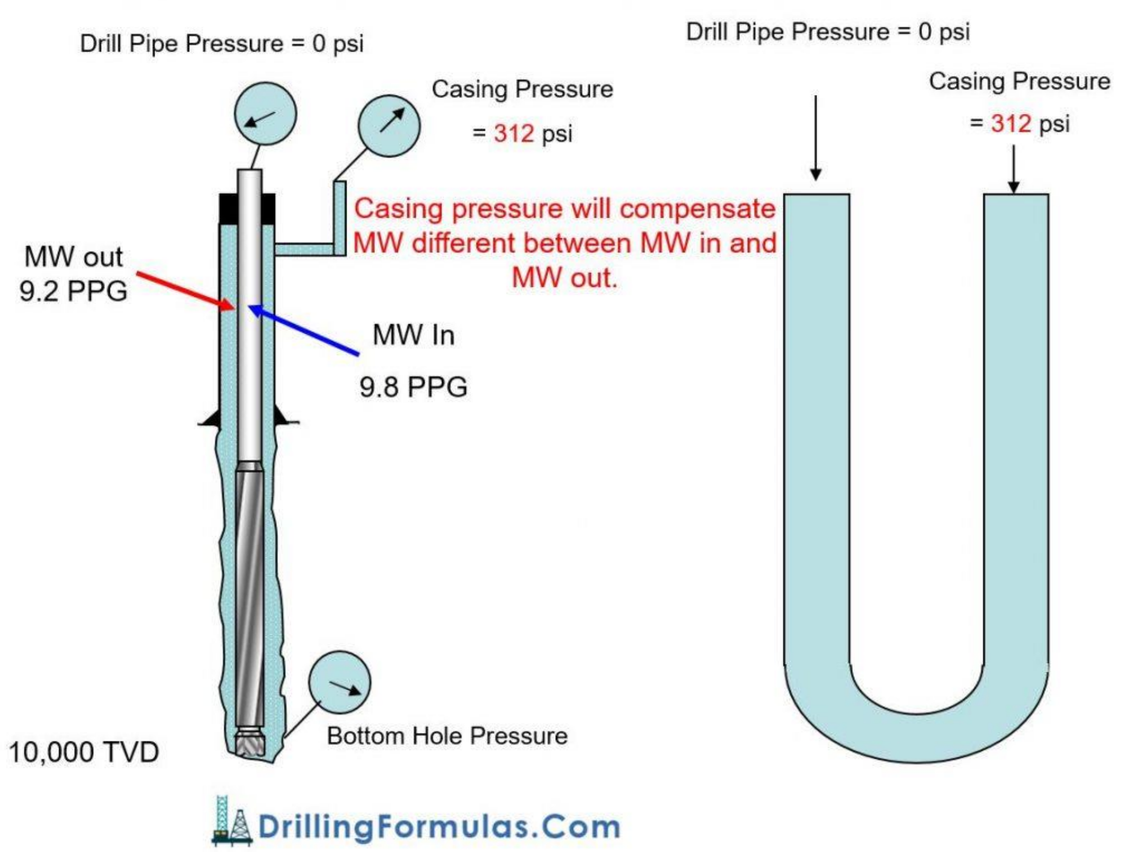


Figure 4 – U-Tube Diagram Represents Both Sides of Fluid Columns With a Closed System

The U-Tube concept can be widely applied in many drilling and workover applications such as well control, cementing, hole monitoring, pulling out of hole, pumping slugs, etc.

<u>Example:</u>

The mud weight inside the drill pipe is 9.8 ppg all the way to the bit and the mud weight in the annulus is 9.2 ppg all the way to surface. The depth is 10,000' MD/8500' TVD. The well is shut in and the drill pipe pressure is equal to 0 psi. Determine the casing pressure.

According to the U-tube concept, both sides (casing and drill pipe) have the same bottom hole pressure so we can write the equation to describe the U-tube concept as shown below;

<u>SP (casing) + HP (casing) = BHP = SP (drill pipe) + HP (drill pipe)</u>

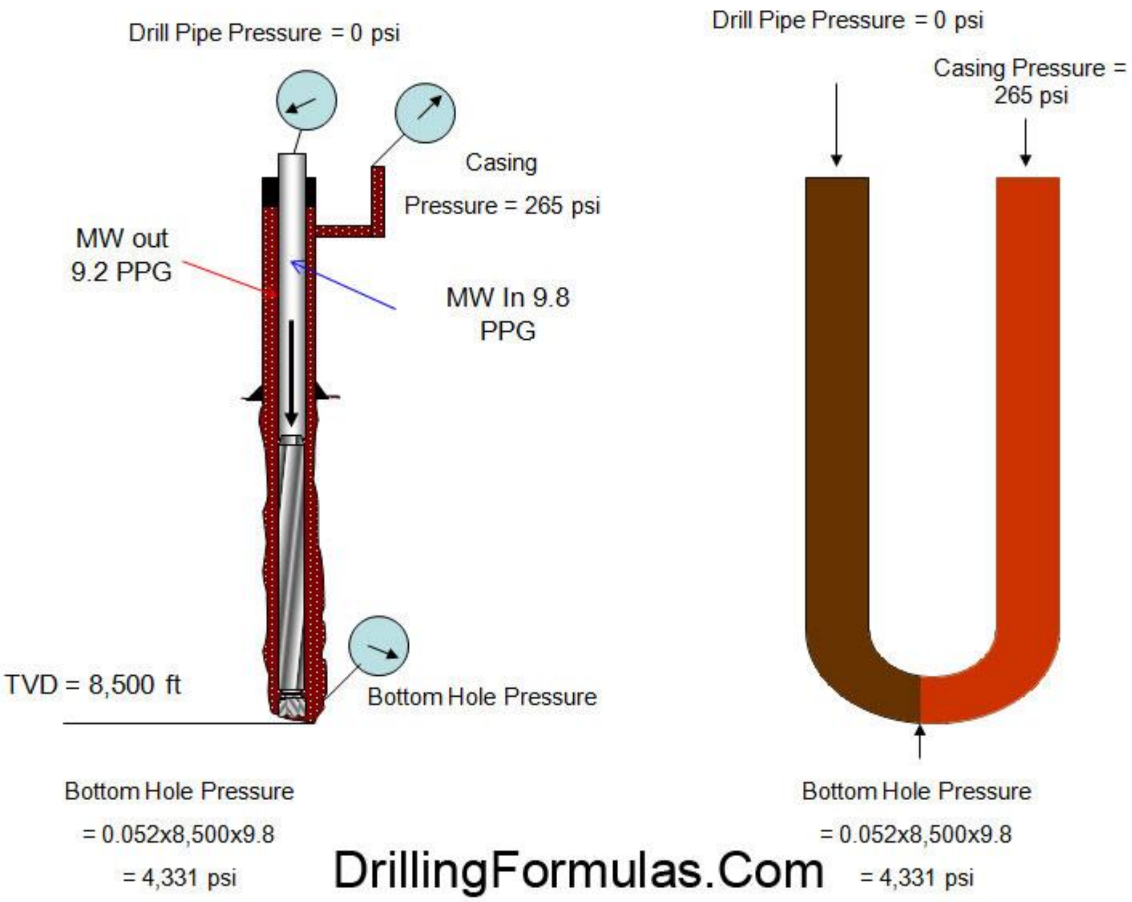
At drill pipe side: BHP = 0 psi (Drill pipe Pressure) + 0.052×9.8×8,500 (**<u>Hydrostatic Pressure</u>** at drill pipe side) = 4,331 psi

At casing side: BHP = 4,331 psi = (Casing Pressure) + 0.052×9.2×8,500 (**<u>Hydrostatic Pressure</u>** at casing)

With this relationship (**SP (casing) + HP (casing) = BHP = SP (drill pipe) + HP (drill pipe)), we** can solve casing pressure.

4331 = Casing Pressure + 4066

Casing Pressure = 4331 – 4066 = 265 psi



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Dr. Asadollah Hayatdavoudi - Professor of Petroleum Engineering and Research Professor of Engineering · University of Louisiana at Lafayette

Baroid Drilling Fluids Manual

Stuck Pipe Book

A Novel Application of Filter Cake Remover to Free Differential Stuck Pipe
Peter I. Egbe, Fawaz N. Al-Mousa and Ahmed E. Gadalla
Aramco Journal of Technology