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Directional Drilling in 'L' Profile

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Directional drilling is a wellbore along a predetermined trajectory to intersect a designated subsurface target. Directional drilling has a long and interesting history. However, it has only been in the past ten years that much of the new innovative technology has been introduced to meet the challenges of onshore and offshore developments.A typical directional well starts off with a vertical hole and the bottom holes location may end up hundreds or thousands of feet or meters away from its starting point. With the use of directional drilling, several wells can be drilled into a reservoir from a single platform.During the past years many innovations have taken place, including computerized well planning, more use of down hole motors and turbines, techniques to drill horizontal wells and the introduction of Measurement While Drilling (MWD).Directional drilling has now become an essential element in oilfield development, both onshore and offshore. It has made great advances over a relatively short period of time.This work deals with different applications of directional drilling and the deflection techniques used in deviation of the well. Three types of well profiles have also been studied with the designing of BHA (Bottom Hole Assembly) and the synchronization of MWD (Measurement While Drilling) with directional drilling.

Key words: Directional drilling, Onshore & Offshore development.

Directional drilling is the process of drilling a hole in a deviated way with the help of deflecting tools and by changing the BHA. In this type of drilling we use down-hole motor (mud motor). Well planning plays a important role in the directional drilling. In this technique there are three major methods are followed, they are 1.short turn radius, 2.medium turn radius and finally 3.long turn radius, this three are used for different profile according to their requirements. Drilling pipes and casing used for directional drilling should have certain yield strength and some other special properties that are not needed for conventional drilling. New technologies are been invented day to day, for the development of oil and gas industries[1-5].

Directional well profiles

Build Up And Drop Off Rates

The maximum permissible build up /one or more of the following normally determine drop off rate:

i. The total depth of the well
ii. Maximum torque and drag limitations
iii. Mechanical limitations of the drill string or casing
iv. Mechanical limitations of logging tools and production strings.

The optimum build up and drop off rates in conventional directional wells are in the range of 1.5° to 3° per 100 ft, although much higher build up rates are used for horizontal and multilateral wells.

Types of Well Profiles

If the position of the surface location is known and given the location of the target, its TVD and rectangular coordinates, it is possible to

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calculate the best well profile that fits the Coordinates of the surface and the bottom hole target that fit this data.

There are three basic well profiles, which include the design of most directional wells:

i. Build and hold trajectory. This is made up of a kick off point, one build-up section and a tangent section to target.
ii. S -Shape trajectory. This is made up of a vertical section, kick-off point, build-up section, tangent section, drop-off section and a hold section to target.
iii. Deep kick off trajectory. This is made up of a vertical section, a deep kick off and a build-up to target.

Another secondary type is horizontal wells. A horizontal well is a well which can have any one of the above profiles plus a horizontal section within the reservoir. The horizontal section is usually drilled at 90 degrees and therefore the extra maths involved is quite simple as we only need the measured length of the horizontal section to calculate the total well departure and total measured depth. The holes total TVD usually remains the same as the TVD of the well at the start of the horizontal section. However, if the horizontal section is not drilled at 90 degrees or there are dip variations within the reservoir, then the total holes TVD will be the sum of the TVD of the horizontal section and the TVD of the rest of the well.

Well Shape Types

There are three different overall shapes (Fig 1) of the well, depending on the penetration requirements. These are:Build-and-hold, S-shaped and Continuous build.

In practice, these generic shapes will be modified by local conditions. Getting the right well path through the overburden is a multidisciplinary task in which geologists advise the designer about:

i. The presence of faults
ii. The precise shape of salt formations
iii. Other subsurface hazards

Understanding the interaction between the 3D well trajectory and the formation stresses, particularly in over thrust areas, is vital to ensuring that the well can be drilled safely and efficiently.

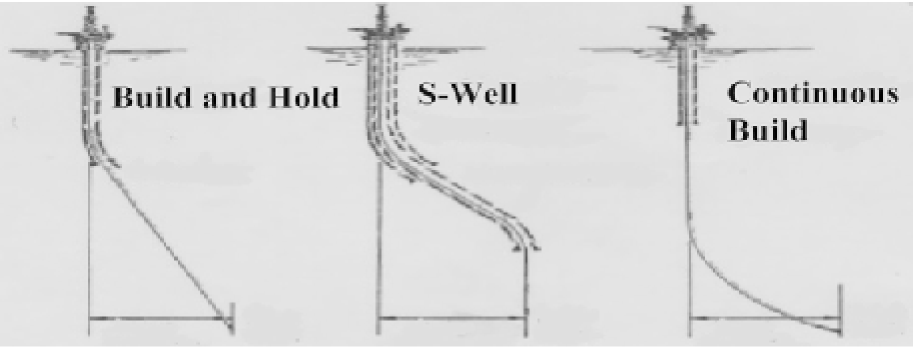

Fig. 1. Types of well shapes

Build-And-Hold Well

In general, a build-and-hold profile is planned so that the initial deflection angle is obtained at a shallow depth, and from that point on the angle is maintained as a straight line to the target zone. In general, the build-and-hold profile is the basic building block of extended-reach wells. These profiles can usually be employed in two distinct depth programs. These profiles can be used for moderate-depth drilling in areas where intermediate casing is not required and where oil-bearing strata are a single horizon. They can also be used for deeper wells requiring a large lateral displacement. In this case, an intermediate-casing string can be set to the required depth, and then the angle and direction can be maintained after drilling out below the string.

S-Shaped Well

The main reasons for drilling an S-shaped well are completion requirements for the reservoir; for example, when a massive stimulation operation is required during the completion. An S-shaped well also sets the initial deflection angle near the surface. After the angle is set, drilling continues on this line until the appropriate lateral displacement is attained. The hole is then returned to vertical or near vertical and drilled until the objective depth is reached. Surface casing is set through the upper deviated section and cemented. The wellbore is then continued at the desired angle until the lateral displacement has been reached and then returns to vertical. Intermediate casing is set through the lower vertical-return section. Drilling then continues below the intermediate casing in a vertical hole.The S-shaped well is often employed with deep wells in areas where gas troubles, saltwater flows, etc. dictate the setting of intermediate casing. It permits more-accurate bottom hole spacing in a multiple-pay area. The deflection angle may be set in surface zones in which drilling is fast and round-trip costs can be held to a minimum.

Continuous-Build Well

A continuous-build well starts its deviation well below the surface. The angle is usually achieved with a constant build to the target point. The deflection angles may be relatively high, and the lateral distances from vertical to the desired penetration point are relatively shorter than other well types. Typical applications would be in exploring a stratigraphic trap or obtaining additional geological data on a non-commercial well. Because deflection operations take place deep in the holes, trip time for such operations is high, and the deflected part of the hole is not normally protected by casing. The continuous-build profile may also commonly be found in old fields in which development of bypassed oil is carried out by means of sidetracks from existing wells that have ceased to produce economically from the original completion.

Short, Medium and Long Radius Wells:

Short radius wells, typically re-entries of old vertical wells, have curves with a 143 ft (44m) radius or smaller that cannot be drilled with conventional motors. They are used to isolate higher-/lower-pressured production zones or water sands without setting and cementing a liner. This type of drilling is desirable when kicking off below a problem formation. Medium radius wells have curves with a 200-500 ft (61-152 m) radius that can be drilled with conventional motors. Long radius wells have curves with a 750 ft (229 m) radius or larger that can also be drilled with conventional motors (Fig 2).

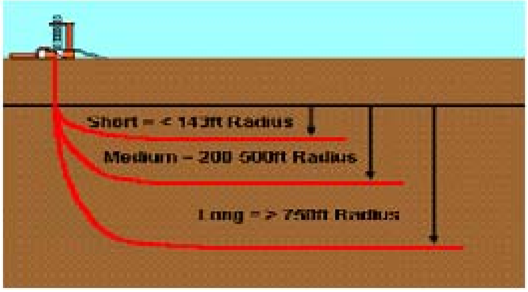

Fig. 2. Short, Medium and Long radius wells

Terminology

Kickoff Point (KOP)

The kickoff point is the location at a given depth below the surface where the wellbore is deviated in a given direction (Fig 3).

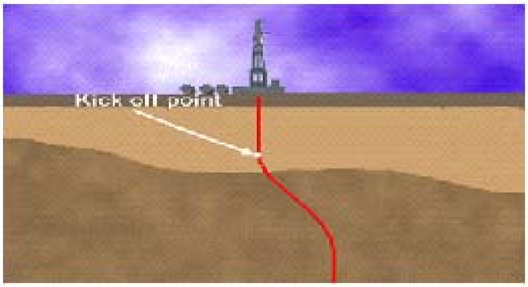

Fig. 3. Kick off Point

Well Inclination

The well inclination is the angle by which the wellbore deviates from the vertical (Fig 4).

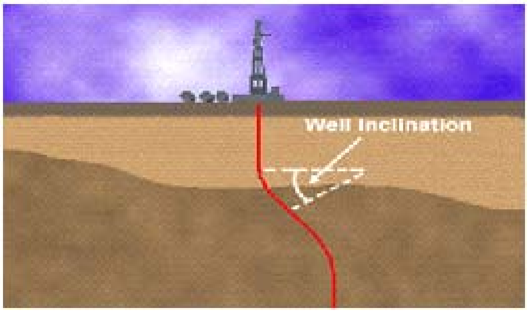

Fig. 4. Well Inclination

End of Build-up (EOB)

The end of build-up is the location where the wellbore has finished increasing (Fig 5).

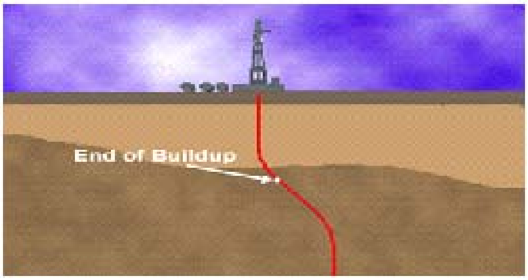

Fig. 5. End of Build up

Hold Angle

The hold angle occurs where the inclination of the borehole is held constant (Fig 6).

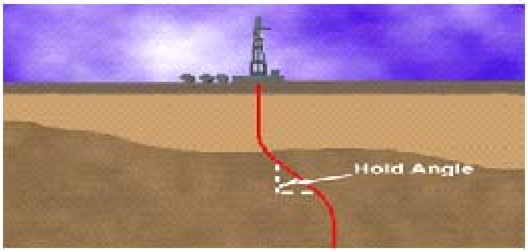

Fig. 6. Hold Angle

Tangent Section

The tangent section (hold section) occurs after a build-up where the inclination of the borehole is held constant for a certain distance. There could be an additional build or drop before reaching the target (Fig 7).

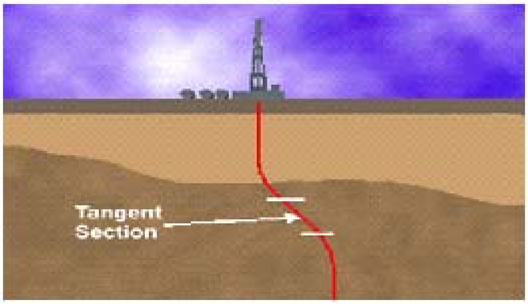

Fig. 7. Tangent Section

Start of Drop

The start of drop is the location where the wellbore starts dropping inclination (Fig 8).

End of Drop (EOD)

The end of drop is the location where the wellbore finishes dropping inclination (Fig 9).

Target Displacement

The target displacement is the lateral distance from the surface location to the target (Fig 10).

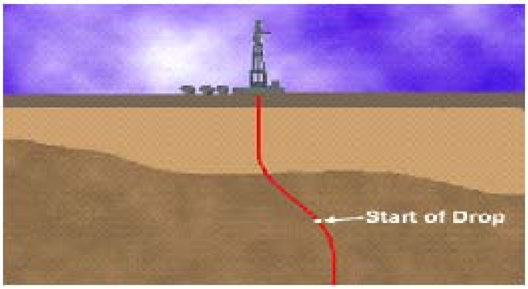

Fig. 8. Start of Dropt

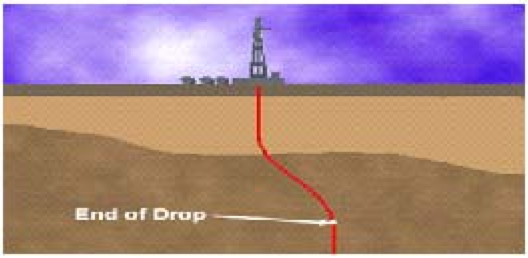

Fig. 9. End of Drop

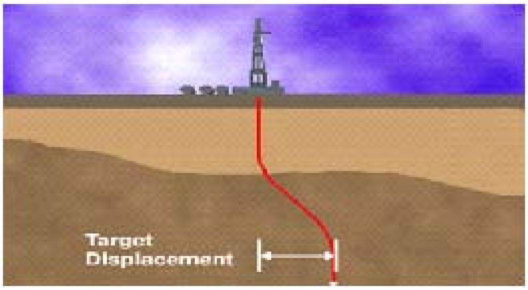

Fig. 10. Target Displacement

Target Location

The target location is a point defined in space by geographical coordinates at a given true vertical depth. A well profile could have multiple targets (Fig 11).

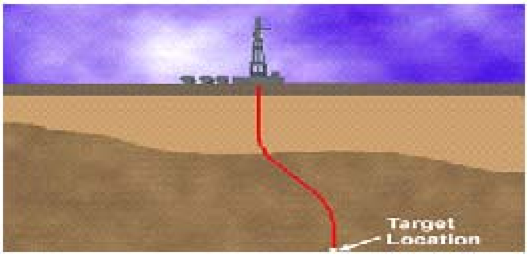

Fig. 11. Target location

Drop off Rate (DOR)

The drop off rate is the rate at which the inclination decreases. The rate is usually expressed in degrees per 100 ft or degrees per 30 m of the course length

Build-up Rate (BUR)

The build-up rate is the change of inclination of a wellbore where the angle is increased. The rate is usually expressed in degrees per 100 ft or angular increase per 30 m of the measured depth.

Turn Rate

The turn rate determines the rate a well profile turns in azimuth direction which is usually expressed in degrees per 100 ft or degrees per 30 m.

True Vertical Depth (TVD)

The true vertical depth of any point or station along a wellbore is the vertical distance from the well surface reference point to the station of interest (Fig 12).

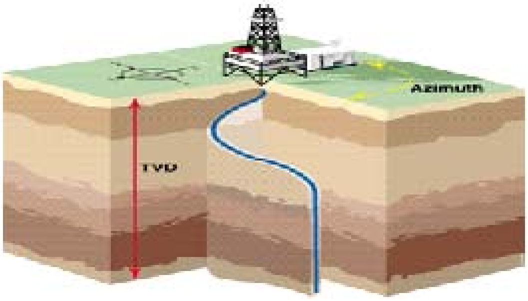

Fig. 12. True Vertical Depth

Measured Depth (MD)

The measured depth of any point or station along a wellbore is the distance from the well surface reference point to the station of interest along the actual well path (Fig 13).

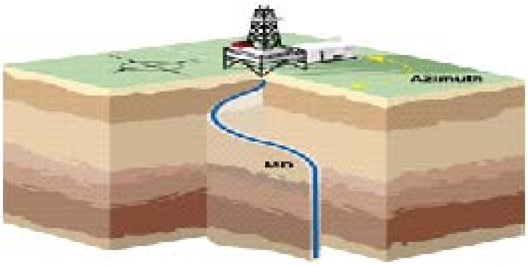

Fig. 13. Measured Depth

Horizontal Displacement (HD)

The horizontal displacement is the distance between any two points along a wellbore projected onto a horizontal plane or plan view (Fig 14).

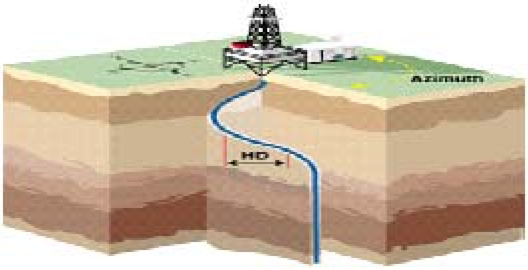

Fig. 14. Horizontal Displacement

Vertical Section (VS)

The vertical section is the distance between any two points along a wellbore projection onto a vertical section plane (Fig 15).

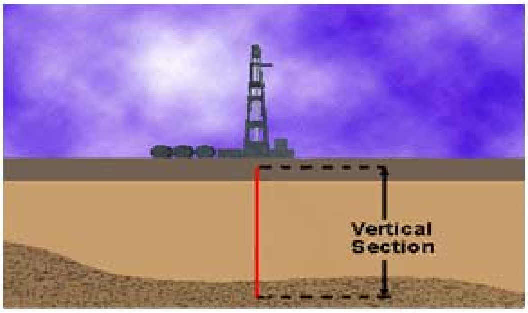

Fig. 15. Vertical Section

Deflecting tool

Positive Displacement Motors

The idea of using down-hole motors to directly turn the bit is not a new one.One of the first commercial motors was turbine driven. The first patent for a turbo-drill existed in 1873. The USSR focused efforts in developing down-hole motors as far back as the 1920's and has continued to use motorin their drilling activity. After 1945, the West focused effortsmore on rotary drilling, but field applications for downhole motor has increased spectacularly from the 1980's onwards. A turbine consists of a multistage vane-type rotor and stator section, abearing section, a drive shaft and a bit rotating sub. A "stage" consists of arotor and stator of identical profile. The stators are stationary, locked to theturbine body, and deflect the flow of drilling mud onto the rotors which arelocked to the drive shaft. As the rotors are forced to turn, the drive shaft isalso forced to turn, causing the bit sub and the bit to rotate

The PDM is made up of several sections:

1) By-pass valve or dump sub.
2) Motor section.
3) Universal joint or connecting rod section.
4) Bearing section with drive sub.

Motor Description

The positive displacement motor consists of several components. These components are described in the following paragraphs.

Dump Valve

To prevent the motor rotating while running into the hole or pulling out of the hole, a by-pass valve or dump valve is installed at the upper end of the motor. This valve has radial ports that allow communication between the drill string and the annulus. During a trip when the pumps are shut off, these ports are open to allow the drill string to drain while pulling out or fill when running in. The ports must be closed off during drilling to allow normal flow through the motor. Under the increased pressure due to the mud pumps, a piston pushes a sleeve down to cover and seal off the ports. Whenever the pumps are shut off, a spring forces the sleeve upwards, opening the ports again.

Motor Section

The motorsection consists of a rubber stator and steel rotor. The simple type is a helical rotor which is continuous and round. This is the single lobe type. The stator is molded inside the outer steel housing and is an elastometer compound. The stator will always have one more lobe than the rotor.Hence motors will be described as 1/2, 3/4, 5/6 or 9/10 motors.Both rotor and stator have certain pitch lengths and the ratio of the pitchlength is equal to the ratio of the number of lobes on the rotor to thenumber of lobes on the stator.As mud is pumped through the motor, it fills the cavities between thedissimilar shapes of the rotor and stator. The rotor is forced to give way byturning or, in other words, is displaced (hence the name). It is the rotationof the rotor shaft which is eventually transmitted to the bit (Fig 16).

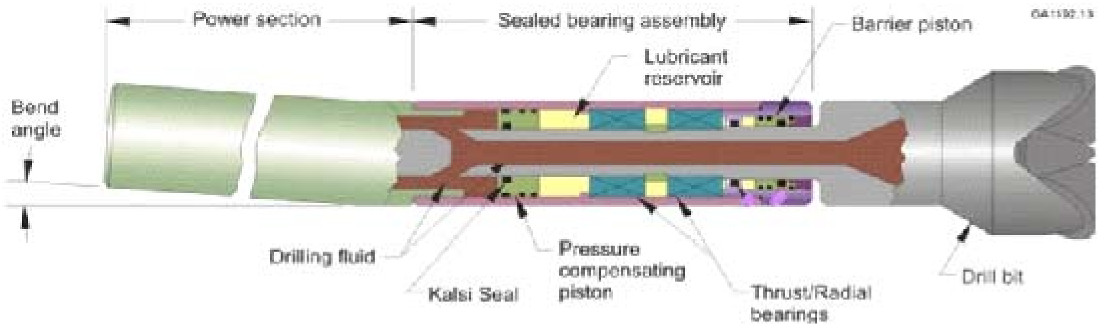

Fig. 16. Positive Displacement Motor

For efficient operation, a pressure-tight chamber must exist between the rotor and stator, but at the same time, the shaft must rotate without causing excessive wear. The helical shaft is made of steel alloy and its surface is treated to increase its wear resistance. The choice of material for the stator is critical. Various rubber and elastomer materials have been tried and tested. Most of the elastomer components are susceptible to high temperatures. They are also affected by oil-based mud, which cause swelling.

Universal Joint

Since the shaft is rotating eccentrically, the lower end must be connected to a universal joint. This joint converts the eccentric motion to concentric motion, which is then transmitted to the bit. Various types of flexible joints can be used, but the simplest design is a ball joint lubricated by grease. A rubber sleeve around the joint prevents contamination by mud. The universal joint is then connected to the drive shaft, which rotates within the bearing assembly.

Applicationsof PDMs

Although the positive displacement motor was first introduced for straight hole drilling, the major applications are now in directional wells. Kick offs and correction runs When used with a bent sub, PDMs are widely used as a deflecting tool. The bent sub can be oriented in the required direction and the drill string is not rotated. An MWD tool or steering tool will provide continuous monitoring of the toolface while drilling. Generally, a low-speed, high-torque motor is best for this application. The length of the motor should be as short as possible to allow for the curvature of the wellpath. Performance drilling Improvements in the design of motors have made them more competitive with rotary methods. In particular, better bearing design has enabled motors to operate down-hole for longer periods, which improves the overall economics of the bit run. More powerful multistage motors have been introduced for drilling straight sections of hole. These tools, however, are also competing against turbo-drills, which are generally more powerful and have higher rotational speeds than PDMs. As with turbo drills, the drill .string is rotated for performance drilling to reduce the risk of stuck pipe.

Orientation of Deflecting Tool

When planning a trajectory change, it is essential to have the deflecting tool pointing in the required direction before drilling begins. Although the bent sub or whipstock can be turned on surface, actual down-hole orientation must be checked by surveying instruments.

Toolface Setting

To set the toolface properly the directional driller must have certain information:

(a) The present inclination and azimuth of the hole;

(b) The required change in inclination or azimuth to correct the trajectory or kick off the well.

(c) The expected rate of change (i.e. the dog-leg) that the deflecting tool can provide.

The “Toolface” of a deflection tool, or a steerable motor system, is the part (usually marked with a scribe line) which is oriented in a particular direction to make a desired deflection within the wellbore. There are two ways of expressing toolface orientation:

Magnetic or Gyro Toolface is the toolface orientation measured as adirection on the horizontal plane. If measured by a “magnetic” type surveytool, it is called magnetic toolface, it is called gyro toolface. Toolface orientation is measured and expressed in this way at low inclinations, generally less than 5°.

High Side Toolface is the toolface orientation measured from the high side of the borehole in a plane perpendicular to the axis of the hole. It must be pointed out that the term toolface commonly used is a shortened version of “toolface orientation”.

Inclination is the angle between vertical and the wellbore in the vertical plane. We measure this angle by measuring the direction that gravity acts relative to the tool.

Gravity acts in a vertical direction and has a magnitude of 1g at sea level at the equator.

Azimuth is the direction of the wellbore relative to true or grid north in the horizontal plane. We measure this angle by measuring the direction of the earth’s magnetic field relative to the tool.

Measurement while drilling (MWD)

MWD is the process by which certain information is measured near the bit and transmitted to surface without interrupting normal drilling operations.

The type of information may be:

(a) Directional data (inclination, azimuth, tool face).

(b) Formation characteristics (gamma-ray, resistivity logs).

(c) Drilling parameters (downhole WOB, torque, rpm).

The sensors are installed in a special down hole tool made up as an integral part of the bottom hole assembly. Within the down hole tool there is also a transmitter to send the signals tosurface via some kind of telemetry channel. The most common type of telemetry channel currently in use is the mud column inside the drill string. The signals are detected on surface, de-coded and processed to provide the required information in a convenient and usable format. The great advantage of MWD is that it allows the driller and the geologist to effectively “see” what is happening down hole in real time. It therefore improves the decision-making process. There was therefore a need for a system that provided instantaneous and continuous monitoring of the formation while drilling. Fig 17 shows the segments of an MWD Tool.

Applications of MWD

The applications of MWD can be divided into three broad categories, which are described as follows:

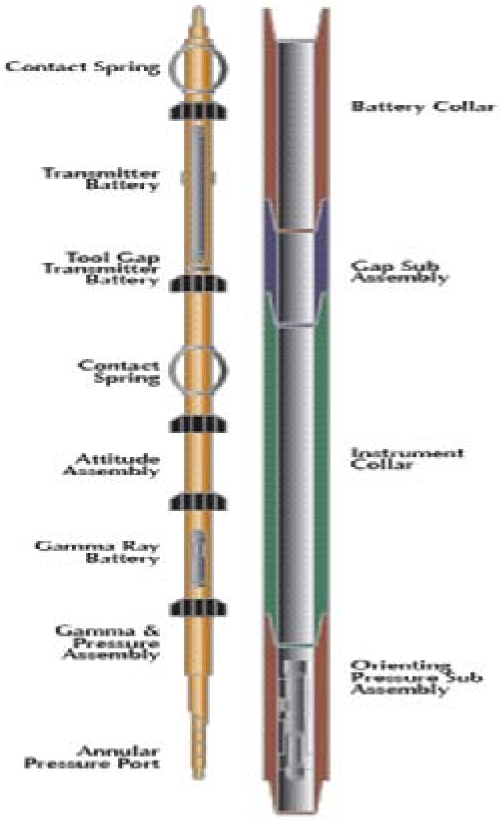

Fig. 17. Segments of an MWD tool

Directional Surveying

This accounts for approximately 70% of all MWD jobs. In the North Sea, MWD has become the standard method of monitoring the well path as drilling proceeds. The major benefits of MWD in directional drilling are that:

a) Valuable rig time is saved when taking surveys, owing to the elimination of conventional wire line techniques.
b) Orientation of tool face for steering runs is made much easier, as is monitoring of tool face while drilling with no wire line problems.
c) Less time is spent with the drill string in a stationary position, thereby reducing the risk of stuck pipe.
d) Closer density of surveys is possible without a great loss of rig time; therefore there is better monitoring of the well path.
e) The effects that changing drilling parameters or formation changes may have on the well path can be detected very much quicker, reducing the risk of severe dog-legs and the need to make correction runs.

Formation Evaluation

Logging-while-drilling with gamma-ray and resistivity sensors is becoming more popular, but it is much more difficult to justify in strict economic terms. This is because the operator will probably wish to run a complete suite of wire line logs in any case. Some of these benefits are listed as follows:

1. Selection of casing points using gamma ray log to identify shale zones.
2. Picking the top of the reservoir to begin coring operations.
3. Correlation with other neighboring wells as drilling proceeds.
4. Identification of troublesome zones.
5. Ability to run logs in high-angled wells where wire line methods may not be suitable.
6. At least some formation data is available if the hole is lost before wire line logs are run.
7. Resistivity logs can detect the presence of shallow gas zones.
8. Formation pressures can be evaluated while drilling using data from gamma ray and resistivity logs.

The increasing credibility of MWD logs is such that in some areas MWD has replaced some intermediate wire line logs. One major drawback now is the absence of an MWD porosity sensor. There has also been much debate over the comparison between MWD logs and wire line logs.

a) The logging speeds are very different (MWD may be 10-100 ft/h, wire line may be 1800 ft/h). The resolution of the logs will therefore also be different.
b) The condition of the hole may have changed owing to the effects of mud invasion.
c) The centralization of the tools may be different.
d) There may be a difference in the type of sensor used (e.g. Geiger-Muller tube in MWD as opposed to scintillation counter in wire line tool).
e) Signal attenuation due to the drill collar will affect results.
f) The MWD-GR log is measured in counts per second, while the wire line log is in API units.

Drilling Parameters

Of the three main applications of MWD, the use of sensors to measure down hole drilling parameters is perhaps the most difficult to justify in terms of cost-effectiveness. This is because these sensors are not replacing some other system, which was more expensive to run, such as survey tools, or logging tools.The major benefit of having down hole sensors for WOB, rpm or torque is that the measurements are actually being made where it matters-at the bit. Surface indicators cannot be assumed to be reliable in certain circumstances (e.g., in a highly deviated hole, down hole WOB may be as low as 20% of the value indicated on surface, owing to wall friction). This discrepancy between down hole and surface measurements may give some indication of hole problems (e.g., surface torque being much greater than bit torque suggests possible stuck-pipe problems as opposed to a locked cone at the bit). Apart from providing useful indicators to the driller as the hole is being drilled, these sensors have a wider application in providing the input to optimization programs, rather than taking inaccurate surface data. In some instances (e.g. turbo drilling) an MWD sensor is the only available method of optimizing drilling operations

Limitations

Retrieving a tool using wire line is not necessarily faster than pulling the tool out of the hole. For example, if the tool fails at 1,500 ft (460 m) while drilling with a triple rig (able to trip 3 joints of pipe, or about 90 ft (30 m) feet, at a time), then it would generally be faster to pull the tool out of the hole than it would be to rig up wire line and retrieve the tool, especially if the wire line unit must be transported to the rig. Wire line retrievals also introduce additional risk. If the tool becomes detached from the wire line, then it will fall back down the drill string. This will generally cause severe damage to the tool and the drill string components in which it seats, and will require the drill string to be pulled out of the hole to replace the failed components, thus resulting in a greater total cost than pulling out of the hole in the first place. The wire line gear might also fail to latch onto the tool which would require the drill string to be pulled out of the hole to replace the failed components, thus making the wire line operation a waste of time.

CONCLUSION

In the past, it was assumed all oil and gas wells were essentially vertical or the bottom of the hole was directly under the drilling rig. The petroleum industry was not fully aware of the advantages of directional drilling until the recent times. Directional drilling has seen a rapid development after the invention of MWDs in 1970s.The uses of directional drilling have been proven to reduce environmental impacts in India as well in other countries like U.S. where approximately 40% of the oil and gas wells are directionally drilled. Directional drilling also facilitates more wellheads to be grouped together on one surface location that leads to less surface area disturbance and an easier as well as a cheaper way to complete and produce wells. Thus, directional drilling can be a beneficial technology when executed properly.

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