DIRECTIONAL DRILLING OVERVIEW

DEFINITION

Directional drilling is the term used to describe the drilling and steering of a borehole along a planned route, in order to reach a pre-determined target location. It is also sometimes referred to a guided boring.

BACKGROUND

The origins of directional drilling can be found in the oil industry, where the technique was used to drill around obstacles, as well as to gain access to oil beneath shallow coastal waters from a rig located on land.

Directional drilling has now become commonplace in the oilfield, with a number of specialised service companies providing the required expertise. It is now not unusual to have wells drilled with a horizontal displacement of 2 miles and a vertical depth of 10,000 ft.

APPLICATIONS

The advantages of directional drilling have now been realised in a variety of industries, with applications which include:

1. Drilling to avoid obstructions and obstacles.
2. Controlling vertical holes.
3. Drilling underneath inaccessible locations.
4. High angle and horizontal drilling.

Within the non-petroleum industry, applications include:-

Mining

Directional drilling is used to obtain core samples, to drain hazardous methane gas contained in coal seams, as well as for coal gasification in deep seams.

Geothermal

Directional drilling is used to take advantage of the orientation of hot rock fractures.

Construction

Directional drilling is used for the installation of pipelines under river beds and other obstructions, including urban development areas. The technique is also increasingly being used by telecommunication and utilities companies, as a cost effective alternative to traditional underground construction methods.

Environmental

Horizontal directional wells, rather than vertical wells, are increasingly being used for environmental monitoring and remediation activities.

ADVANTAGES OF DIRECTIONAL DRILLING

Directional drilling of boreholes can provide a number of advantages over the more traditional excavation techniques.

These advantages include:

* More efficient and potentially less expensive.
* Increased drilling rates (feet per day).
* Less environmentally disruptive, little disturbance to overhead traffic.
* Improved borehole location accuracy.
* Improved safety and control.
* Smoother borehole profiles.
* Avoids the need for concrete weight coating.

DIRECTIONAL DRILLING TECHNIQUES

One of the major problems associated with directional drilling is controlling and predicating the amount of deviation that occurs as the well is drilled. The deviation is caused by a combination of formation effects and the behaviour of the bottom hole assembly (BHA). Drilling parameters such as weight on bit, RPM and hydraulics will also affect the amount of deviation that occurs.

All directional drilling techniques consist of a drilling unit to form the borehole and a survey system which is used to locate the drill bit.

There are principally two types of BHA commonly used. The first involves a rotary drilling assembly, which does not contain a downhole motor. These assemblies can be designed to build, hold or drop the angle of inclination in the well by using the weight of the drill pipe and carefully positioning stabilisers along the drill string.

Techniques used in conjunction with rotary drilling assemblies to change borehole azimuth include deflection elements within the borehole, as well as Jetting, which is commonly used in softer formations. This technique relies on the hydraulic power of the drilling fluid to initiate deflection, using a special nozzle within the drill bit. The nozzle must be oriented in the required direction, using a survey tool. The formation is then cut by small diameter high pressure jets of water or liquified clay (bentonite), which provides borehole stability.

The second deflection technique involves the use of a downhole motor (positive displacement motor), which is driven by the drilling fluid and rotates the drill bit. The deflection is provided by a special bend sub which is placed above the motor. The bend angle is usually between $1/2^{o}$ and 2^{o} (depending on the required deflection) and forces the bit to drill in a specific direction. The direction of the deflection depends on the orientation of the bend and this is measured using a survey tool.

Geometry of a Directional Drilled Well

A directional borehole is drilled from the surface to reach a target area along a planned path. Owing to changing rock properties, the hole path rarely follows a single plane but, instead, changes its inclination and direction continuously. Thus, the deviated well should be viewed in three dimensions, such that hole inclination and hole direction are specified at each position. The following parameters define a directional well:

(1) **Inclination** is the angle between the horizontal and tangent to the well path at any point (referenced to the vertical in the oilfield applications).

(2) **Azimuth** (direction) is the angle measured in a horizontal plan between the Direction of north and a point on the well path.

(3) **Depth** is the measured depth of the drill bit from the point of entry, usually based upon the length of drill string inserted into the borehole.

SURVEY AND STEERING INSTRUMENTS

It is a basic requirement of directional drilling to be able to locate the wellbore's present position, track the path it took to get there, and project where it is going.

To confirm that the wellbore is infact achieving the desired profile requires some measurement of borehole position while drilling. This may be achieved with either a "snapshot" of the well at a given position, or by a steering tool which provides continuous measurements during the drilling process.

In addition, several high accuracy gyro and magnetic survey systems are available for use in these drilling control applications.
These tools offer greater accuracy than conventional survey technology, plus advanced centralisation and support computer programs.

When planning a change in direction of a borehole, the directional driller must also know the orientation of the deflecting tool. To do this, a directional survey instrument is required.

Equipment Available

A variety of guided boring systems are now available. These instruments provide survey information which includes borehole azimuth and inclination, as well as orientation of the survey tool and deflecting device.

Walkover System

These instruments have position sensors placed close to the drilling head and a surface locator. These systems are inexpensive, but they do require surface access to the borehole path and are limited to shallow borehole depths.

Single/Multi-shot Survey Instruments

These instruments can be put into the drill string periodically to record either single or multiple surveys of the borehole. The instrument and therefore survey data, is retrieved after pulling the drill string out of the hole.

Steering Tools

Steering tools provide the added advantage over conventional multi-shot instruments by providing continuous survey measurements while drilling (MWD) the borehole. This enables the driller to continuously steer the drill bit in the desired direction, with survey results being continuously updated on a drillers display panel.

Steering tools are usually connected to a surface computer and display unit by cable or wireline. Wireless alternatives are available, however, their performance is formation dependant.

The steering tools contains rugged solid state sensors which measure the earth's gravitational field (accelerometers) and earth's magnetic (magnetometers) in order to calculate borehole inclination, azimuth and orientation.

Factors Influencing Survey Tool Selection

With the wide range of technologies now available, there are a number of option for obtaining the borehole information required. Selection of appropriate survey equipment is increasingly influenced by accuracy and cost of survey operations, while considerations such as location, target size and rig cost also remain important selection criteria.
In the end, it is the application which, increasingly, determines what survey equipment is used, and how, based on the following criteria:

* **Target Size**: The size of the target determines, in part, the accuracy requirements and the survey instrument required.

* **Type of Drilling Installation**: Magnetic interference is inherent in some installations and will determine survey procedure.

* **Rig Costs**: Rig costs will affect the cost-effectiveness of survey instruments.

* **Formation and Hole Conditions**: Hole size and formation type limit the use of some tools.

* **Well Budget**: Like rig cost, this factor determines in part the cost-effectiveness of some survey tools.

* **Survey Cost**: Calculated in terms of survey time, drilling impact and accuracy.

* **Borehole Length & Depth**: Affects both survey accuracy and instruments available.

THE NEXT STEP

Dataflonw Measurement Systems Limited is a quality focused manufacturer of high reliability borehole survey and directional drilling instruments. The company has been designing equipment for the oil and gas industry for many years. We have recognised that the sophisticated guided drilling systems, which have been used extensively within the oil and gas industry are usually too expensive for use in non-oilfield markets, which has meant that most contractors could not justify the purchase of such a system and consequently they relied on service companies to provide the steering and location services.

However these steering and survey systems do provide a number of operational advantages, in terms of accuracy, reliability and continuous measurements while drilling.

We have therefore developed a range of cost effective, easy to use instruments to meet all the potential requirements of this market. We also provide a comprehensive backup and support service to our customers on a worldwide basis.

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