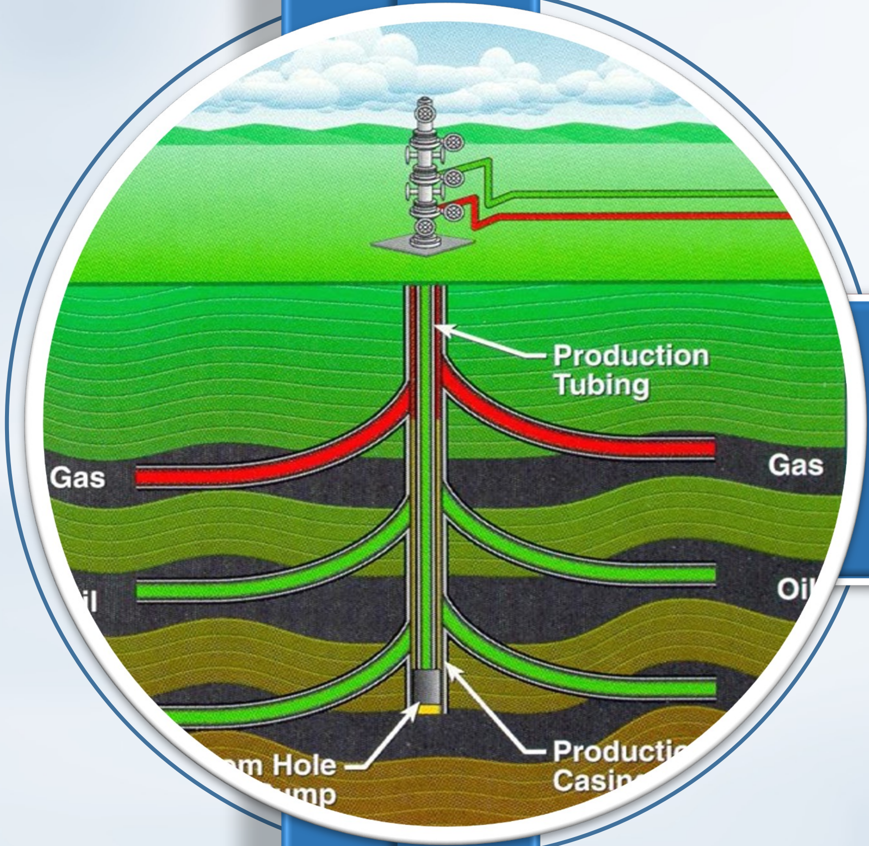


DRILLING ENGINEERING CONCEPTS

Drilling Engineering Concepts
Current Scope

A. Why Drill (not the only W ?)
B. Types of Rigs
C. Rig Systems
D. BHA
E. Casing

F. Cementing
G. Drilling Fluids
H. Basic Logging
I. Introduction to directional drilling

Introduction to Directional Drilling

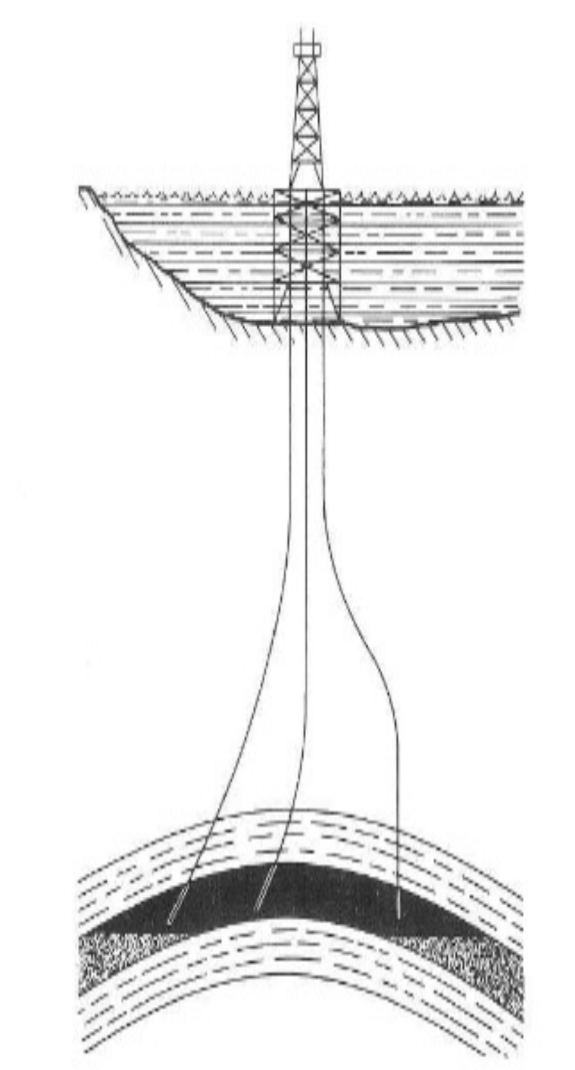
Directional drilling has grown to be an integral part of the well planning process. Directional drilling was initially used as a remedial work, either to sidetrack around stuck tools, bring the wellbore back to vertical, or in drilling relief wells to kill blowouts.

In 1930, the first controlled directional well was drilled in Huntington Beach, California, USA. The well was drilled from an onshore location into offshore oil sands. Controlled directional drilling had received rather unfavourable publicity until it was used in 1934 to kill a wild well near Conroe, Texas, USA.

As a result, directional drilling became established as one way to overcome wild wells, and it subsequently gained favourable recognition from both oil companies and contractors.

Directional Drilling these days is also used for increasing reservoir exposure, when a long horizontal section is drilled in a thick layered reservoir, particularly for limestone reservoir.

Introduction to Directional Drilling

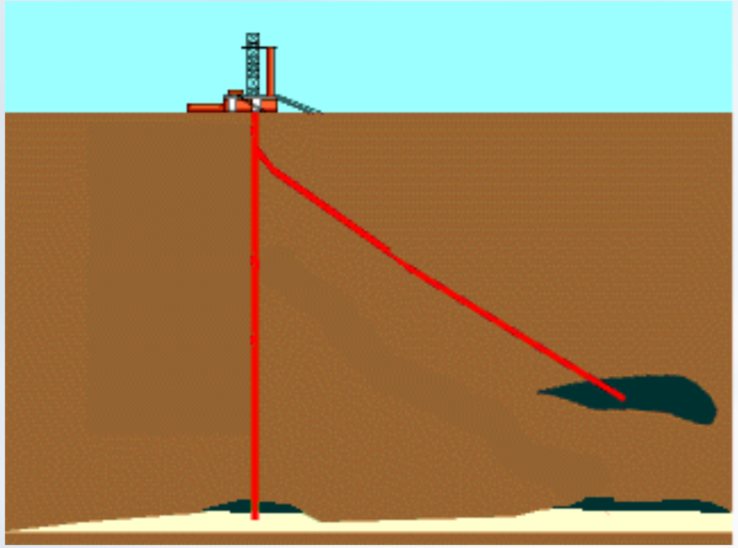


Controlled directional drilling is the process of deviating a wellbore a long and pre determined course to a target whose location is given as lateral distance from the vertical. This definition is the basis for all controlleddirectional drilling, whether to maintain the wellbore as nearly vertical as possible or as a planned deviation from the vertical. Vertical drilling, although considered fundamental in most areas, can be very difficult to achieve in some regions due to steeply dipping formations.

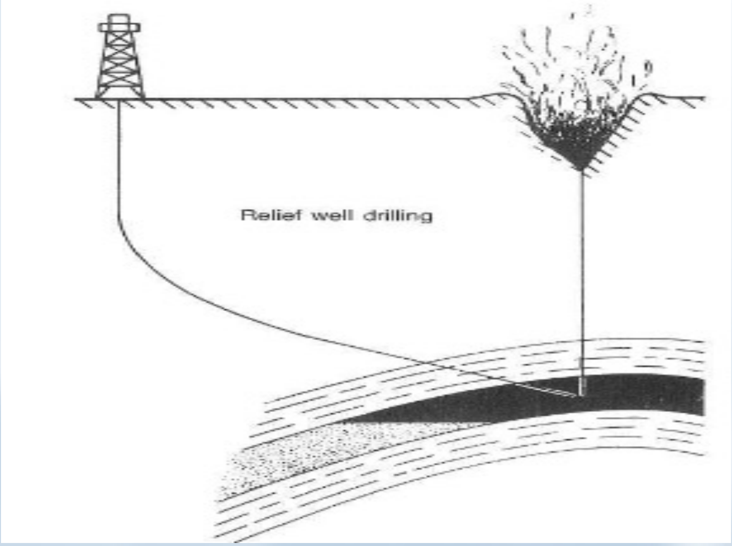
Inaccessible Locations. Quite often, a target pay zone lies vertically beneath a surface location that is impractical as a rig site. Common examples include residential locations, riverbeds, mountains, harbours, and roads. In these cases, a rig site is selected and the well is drilled directionally into the target zone.

Multiple wells Drilling from a Single Site. Perhaps the most common application for directional drilling is associated with offshore production plat- forms. It is more economical, in most cases, to drill a number of directional wells from a single platform than to build individual platforms for vertical wells. Some North Sea platforms have the capability to drill as many as 60 wells from the single structure

Introduction to Directional Drilling



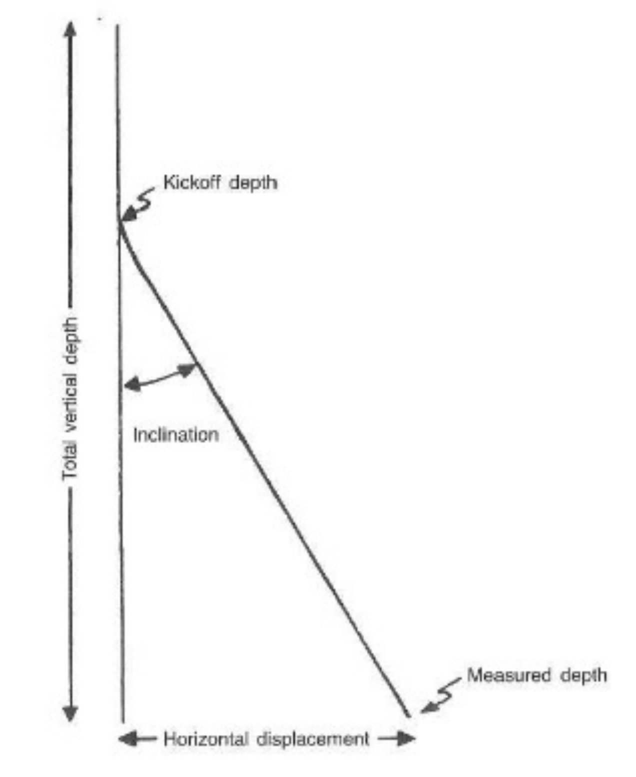
SideTracking : A frequently occurring cause for directional drilling is sidetracking. The primary purpose is to deviate the wellbore around and away from an obstruction in the original wellbore, such as a stuck drillstring. Generally, sidetracking cannot be defined as controlled directional drilling because it does not have a predetermined target. Side tracking can be done using setting a Whipstock, cutting a Window in already cemented casing or the casing can be retrieved and then a separate access to the zone can be achieved by shallower kick off point using a cement plug.



Relief Well Drilling : Possibly the most appropriate application of directional drilling is drilling a relief well to intersect a blowout well near the bottom so that mud and water can be pumped into the blowout well .

Directional control in this type of drilling is stringent due to the extreme accuracy required to locate and intersect the blowout well. Quite often, special logging tools are required in locating the blowout well.

Introduction to Directional Drilling



Design Considerations :

Assuming that a target and rig site have been selected, the directional planning considerations. The values that must be identified are as follows:

- Lateral, or horizontal, displacement from the target to a vertical line from the rig site
- Kick off point (KOP)
- Desired build angle rate
- Final drift angle
- Profile : Straight kick vs S curve

If an S curve is selected as the plan type, the engineer must also select a drop angle rate and a depth at which the hole must return to vertical.

Based on the kick off point depth, a shallow kick off / deeper kick off profiles can also be classified.

Based on the target depth and horizontal drift the directional wells also can be classified as short / medium radius.

Horizontal / multi lateral wells also require directional drilling services

Introduction to Directional Drilling

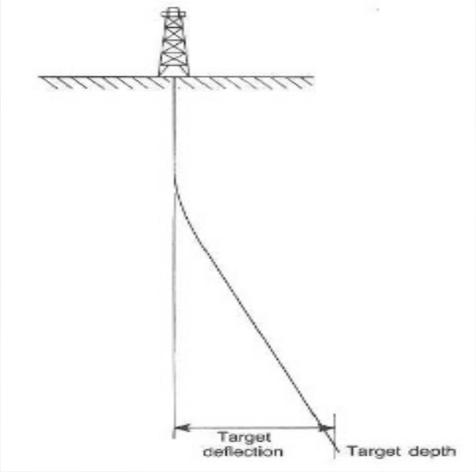
Drift, or Inclination, Angle. The drift, or inclination, of the wellbore is the angle, measured in degrees, between the actual well path at some depth and a vertical line below the rig site. This measurement is independent of the azimuth or course heading. Typically, this value will range from 15°_35°. A minimum acceptable drift angle of approximately 12°_15° is de sired by many industry personnel.

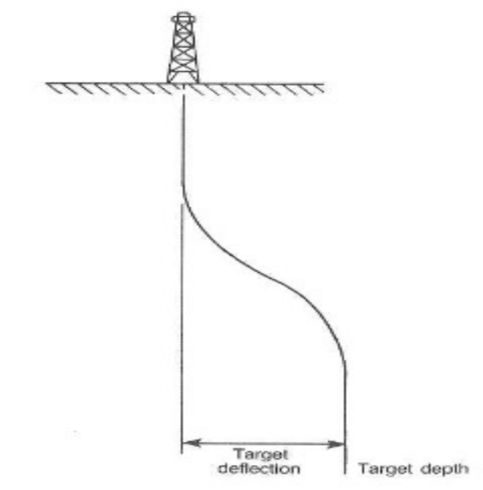
Drift angles less than this range are slightly more difficult to control. In other words, it is usually easier to control a 20° well than a 10°well. Although wells have been drilled in the 70°_80° range, common upper restraints are 45°-48°.

Hole angles greater than 45°-48° begin to encounter problems such as increased torque and drag as well as pump down requirements for some logging operations. Many operators establish 35° as the upper limit.

The typical planning procedure is to establish minimum and maximum acceptable drift angles and a KOP (kickoff point). A well course is computed. If the calculated drift angle required to reach the target falls outside the drift angle constraints, a new KOP is selected. In some cases, compromises are required between optimum KOP and drift angles.

Introduction to Directional Drilling





Kickoff Point (KOP).
The KOP is the depth at which the wellbore path will be intentionally diverted from the vertical position. The KOP is usually selected in soft, shallow formations where directional drilling is easier. In addition, the KOP is often selected so the final angle build up can be achieved prior to setting surface casing. This approach minimizes key seat problems in the hole section.

Plan / Profile Type. Two types are used in directional drilling. The straight kick builds angle and drills directionally through the target, and S Curve. The S curve drops angle prior to drilling into the target so entry is vertical. S curve requires careful consideration prior to its implementation. Since the angle change will occur deeper in the well where the formations are harder, directional control may be more difficult. In addition, since angle dropping requires fewer stabilizers in the bottom-hole assembly (BHA), azimuth control problems may occur. If a high-angle hole is returned to the vertical position, key seating may develop if a long section of vertical hole is drilled. The S curve will usually require 10-20% more drilling time than a straight kick. S curves usually are vertical at target depth for managing completion and improved cement bond.

Introduction to Directional Drilling

Build (and Drop)Angle Rates. The buil dangle rate describes the amount of angle buildup below the KOP until the drift angle reaches the desired value.

Drop angle rates, which apply only in S plans, describe the rate of angle decrease prior to returning to vertical.

The rates are measured as degrees per 100 ft of wellbore path.

Typical ranges for build and drop angle rates are 1°-4°1100 ft with 3°/100 ft being perhaps the most common.

Values above 4°/100 ft can create dogleg and keyseat problems. Computer programs are used for planning the well with build angle rates of 2° and 4°/100 ft. If the KOP remains constant, the final drift angle is altered.

The results of the computer are either published as Tables / are given a graphical representation

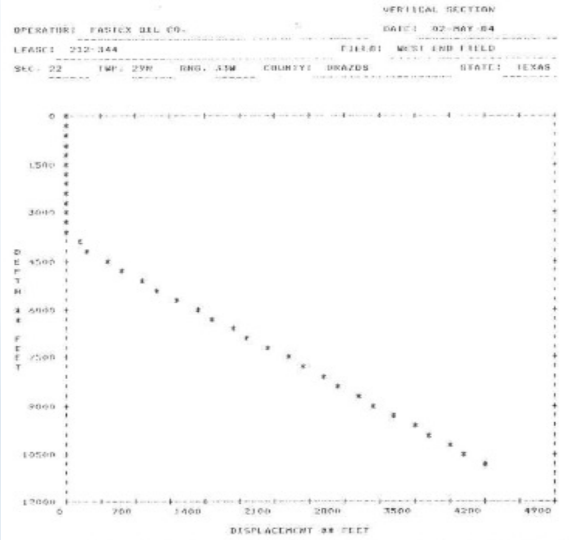
2° build angle rate

MEASURED (FT)	DRIFT (DEG)	TVD (FT)	DISPLACEMENT (FT)	NORTH/SOUTH (FT)	EAST/WEST (FT)
.0	.0	.0	.0	.0	.0
3000.0	.0	3000.0	.0	.0	.0
3100.0	2.0	3100.0	1.7	1.2	1.3
3200.0	4.0	3199.6	7.0	4.6	5.2
3300.0	6.0	3299.5	15.7	10.5	11.7
3400.0	8.0	3398.7	27.9	18.6	20.8
3500.0	10.0	3497.5	43.5	29.0	32.5
3600.0	12.0	3595.6	62.6	41.7	46.7
3700.0	14.0	3693.1	85.1	56.7	63.5
3800.0	16.0	3789.6	111.0	73.9	82.6
3900.0	18.0	3885.3	140.2	93.4	104.6
4000.0	20.0	3979.8	172.8	115.1	128.9
4100.0	22.0	4073.2	208.6	138.9	155.6
4200.0	24.0	4165.2	247.7	165.0	184.7
4300.0	26.0	4255.8	289.9	193.1	216.3
4400.0	28.0	4344.9	335.3	223.3	250.1
4500.0	30.0	4432.4	383.8	255.6	286.3
4559.5	31.2	4483.6	414.1	275.8	308.9
11008.0	31.2	10000.0	3753.7	2500.0	2800.0
12177.0	31.2	11000.0	4359.1	2903.2	3251.6

4° build angle rate

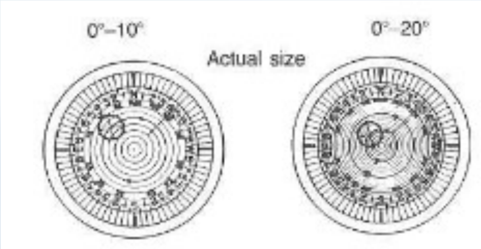
MEASURED (FT)	DRIFT (DEG)	TVD (FT)	DISPLACEMENT (FT)	NORTH/SOUTH (FT)	EAST/WEST (FT)
.0	.0	.0	.0	.0	.0
3000.0	.0	3000.0	.0	.0	.0
3100.0	4.0	3099.9	3.5	2.3	2.6
3200.0	8.0	3199.4	13.9	9.3	10.4
3300.0	12.0	3297.8	31.3	20.8	23.3
3400.0	16.0	3394.8	55.5	37.0	41.4
3500.0	20.0	3489.9	86.4	57.5	64.4
3520.0	24.0	3582.6	123.8	82.5	92.4
3700.0	28.0	3672.5	167.7	111.7	125.1
3738.6	29.5	3706.3	186.3	124.1	138.9
10973.0	29.5	10000.0	3753.7	2500.0	2800.0
12122.5	29.5	11000.0	4320.5	2877.5	3222.8

VERTICAL SECTION BEARING: N48.24E



Introduction to Directional Drilling

Survey Techniques. The magnetic compass is widely used in making directional well surveys.
Magnetic survey instruments are available as 1) single- shot instruments that take only one reading on a single photographic disc film during one run into a well or 2) multiple-shot instruments recording many readings on a motion-picture type of film during one run. The compass unit in both single and multi shot instruments is substantially the same.
Since magnetic instruments are susceptible to the magnetic influence of steel drillpipe and collars, they are generally run inside a nonmagnetic drill collar (NMDC) to get true magnetic reading (of earth's) for the direction and angle of the borehole at the depth. A sufficient length for NMDC should be used.
Another means of obtaining a directional survey is by the gyroscopic method. Since a gyroscope is not influenced by magnetic disturbances the Instrument using this principle can be used for determining the direction in both cased and uncased holes and adjacent to magnetic bodies. The only limitation placed upon gyro use is its size (OD), which restricts its application in certain drill- strings. The single-shot survey instrument is a precision instrument ruggedly con- structed and easy to operate. It records the inclination and direction of the borehole on a film.



Introduction to Directional Drilling

Calculation Techniques.

Various procedures have been developed to estimate the wellbore 'trajectory as it is being drilled. Although eighteen methods are known for computing surveys, only six appear to be distinct and commonly used.

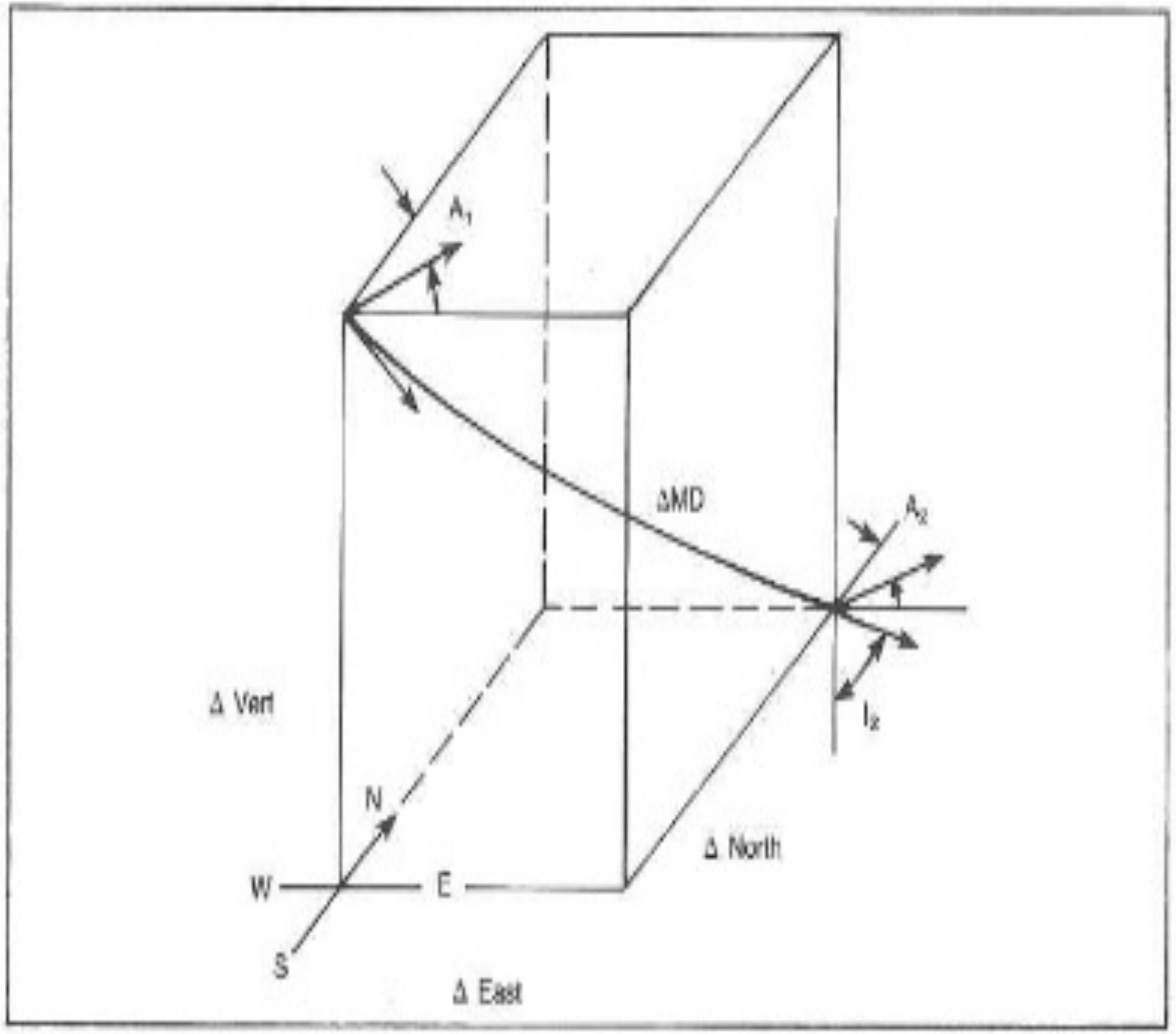
The three most widely used methods are the tangential, angle-averaging, and radius-of-curvature methods.

The tangential method uses only the inclination and direction angles measured at the lower end of the course length. The wellbore path is assumed to be tangent to these angles throughout the section length. Although this method has probably been the most widely used approach, it is the most inaccurate of the available methods.

The angle-averaging method is the simple average of the angles at the top and bottom of the course length. The wellbore is calculated tangentially using these two average angles over the course length. The method is simple and accurate.

The radius-of-curvature method uses sets of angles measured at each end of the course length to generate a space curve representing the wellbore path. It has the shape of a spherical arc passing through the measured angles at both ends of the course. Although this approach is perhaps the most accurate means of survey calculations, it is difficult to do manually and is better suited for computer solution.

Introduction to Directional Drilling



Tangential

$$\Delta north = \Delta MD \cdot \sin(I_2) \cdot \cos(A_2)$$
$$\Delta east = \Delta MD \cdot \sin(I_2) \cdot \sin(A_2)$$
$$\Delta vert = \Delta MD \cdot \cos(I_2)$$

Angle-Averaging

$$\Delta north = \Delta MD \cdot \sin\left(\frac{I_1 + I_2}{2}\right) \cdot \cos\left(\frac{A_1 + A_2}{2}\right)$$
$$\Delta east = \Delta MD \cdot \sin\left(\frac{I_1 + I_2}{2}\right) \cdot \sin\left(\frac{A_1 + A_2}{2}\right)$$
$$\Delta vert = \Delta MD \cdot \cos\left(\frac{I_1 + I_2}{2}\right)$$

Radius of Curvature

$$\Delta north = \frac{\Delta MD \cdot [\cos(I_1) - \cos(I_2)] \cdot [\sin(A_2) - \sin(A_1)]}{(I_2 - I_1) \cdot (A_2 - A_1)}$$
$$\Delta east = \frac{\Delta MD \cdot [\cos(I_1) - \cos(I_2)] \cdot [\cos(A_1) - \cos(A_2)]}{(I_2 - I_1) \cdot (A_2 - A_1)}$$
$$\Delta vert = \frac{\Delta MD \cdot [\sin(I_2) - \sin(I_1)]}{(I_2 - I_1)}$$

Introduction to Directional Drilling

Dogleg Severity (DLS) : Large angle changes occurring over a short course length can place high bending stresses on the pipe. In addition, these doglegs can cause key seating problems. Most operators place a limit on the amount of angle change allowable over a 100-ft segment. Generally, the limit is 4°-6° per 100ft. (3)

Doglegs that occur at shallow and deep intervals are concerns for different reasons. Although shallow doglegs tend to wash out and enlarge in softer formations, they can cause increasing problems due to high string weights hanging at the doglegs as the well deepens. Deeper doglegs do not have the same high levels of string weight acting on the dogleg, but the dogleg does not tend to wash out, which would reduce the severity of the problem. Greater allowable doglegs occur in deeper intervals due to the lower string weight at the depth of interest.

Numerous methods are available for computing dogleg severity. Most are based on the survey calculation techniques. In some cases, charts and tables have been prepared for this purpose. A dogleg calculation technique based on the tangential method:

$$DL = \frac{100}{(L)\left[(\sin I_1 \sin I_2)(\sin A_1 \sin A_2 + \cos A_1 \cos A_2) + \cos I_1 \cos I_2\right]}$$

Where:

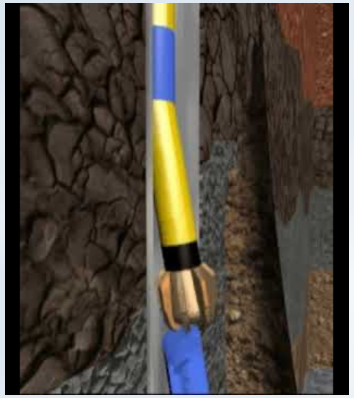
DL	=	dogleg, °/100 ft
L	=	course length, ft
I_1, I_2	=	inclination at upper and lower surveys, °
A_1, A_2	=	direction at upper and lower surveys, °

Doglegs exceeding the maximum value must be controlled. Shallow, soft formations such as those in the Gulf of Mexico usually wash out, which alleviates the dogleg.

A hole reamer placed in the drillstring opposite the dogleg is used for harder formations. This string reamer is repositioned in the drillstring as the well deepens so it continues to ream the dogleg area.

Introduction to Directional Drilling

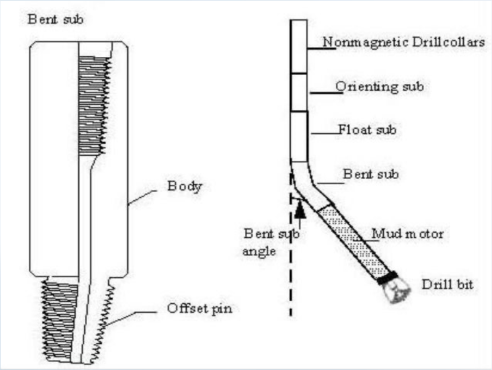
Directional drilling equipment and techniques have become an involved discipline. In addition to a variety of available equipment, other variables such as bits, mud, and geology must be considered. Service companies experienced in directional drilling are usually required to prepare adequately for the upcoming well. Following categories must be well understood for directional drilling concepts.



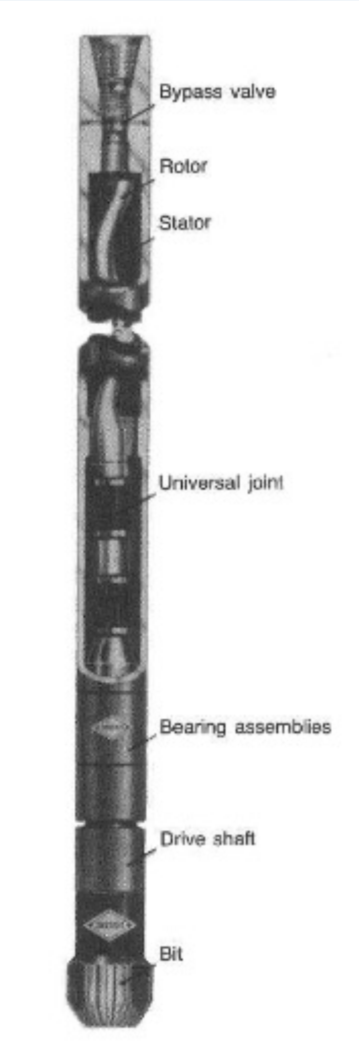
Kickoff Equipment : Hole angles are usually kicked off by jetting, whip- stocks, or some type of bent sub, downhole motor tool. Geology affects the decision as well as the desire to use a steering tool. Jetting was a widely used technique several years ago. It involved the use of a large bit jet and two smaller jets. The bit was oriented so the large jet faced in the desired direction of the wellbore. The jetting action of the mud from the large jet would wash a small cavern into the formation that the drillstring would tend to follow. After washing 6-8 ft of hole, the rotary was used to drill the rest of the joint. A survey was taken at this point and jetting was restarted until the desired well path was achieved.

The whipstock is a very simple device used to kick off the well. It is a wedge-shaped tool that forces the bit in the desired direction. The whipstock is oriented and drilling is initiated. After drilling 12-15 ft below the whipstock, the entire assembly is removed and a regular drillstring assembly is run into the well.

Bent subs are used with downhole motors. The sub has *Y2°-2Y2°* of bend in it that will deflect the motor in the desired direction (Fig. 10-11). A steering tool is commonly used with the bent sub.



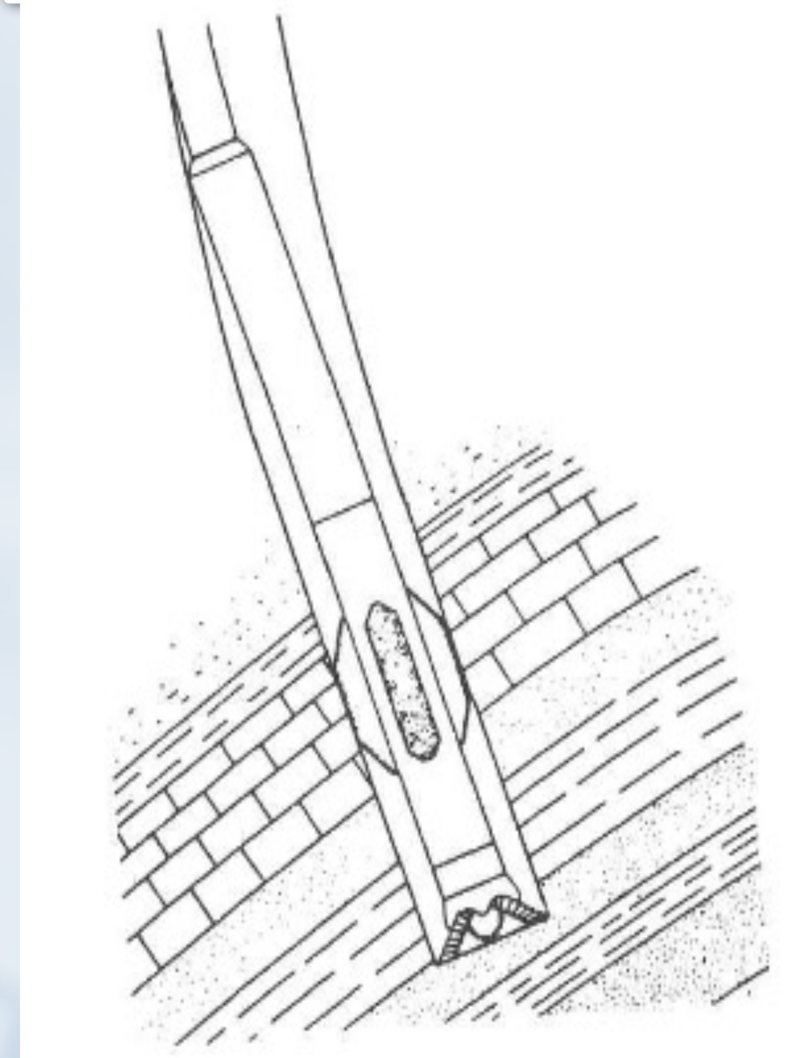
Introduction to Directional Drilling



Rotating Systems. In directional drilling, as with all types of rotary drilling, the bit is turned with the rotary system or a downhole motor device. The conventional rotary system has the bit connected directly to the drillstring, and the entire combination is rotated from the surface. Downhole motors, used with a stationary drillstring, turn the bit via rotation induced by mud flow within the motor.

Downhole motors/turbines are receiving a significant amount of use be- cause they can be used in connection with bent subs and steering tools. Motors and turbines are provided by service companies in a wide range of sizes, operating speeds, and torque characteristics for various types of bits and drilling conditions.

Introduction to Directional Drilling



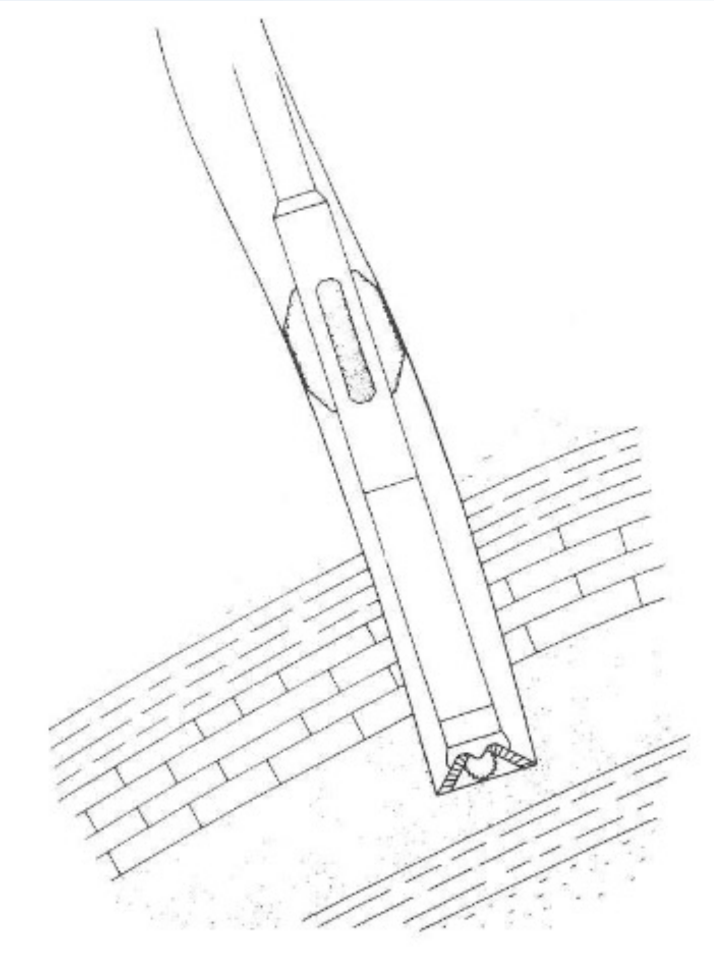
Fulcrum Effect

Drillstring Considerations. The drillstring and bottom-hole assembly play an important role in directional drilling. A packed-hole assembly uses a sufficient number of stabilizers so that hole angle changes are difficult to achieve, which is desirable after the final hole angle has been obtained. Likewise, proper stabilizer positioning can increase the hole angle via the fulcrum principle, or it can decrease via the pendulum principle.

With the fulcrum principle, a string of drill collars under torsional strain and compression is not generally subject to helical buckling, although it is subject to the same bending as a column under static load.

The bend will normally seek the low side of the hole. At a certain distance above the bit, the collars touch and rub the sidewall. This point of tangency distance from the bit depends on the collar OD and stiffness, the diameter of the hole, and the amount of bit weight. When a stabilizer is run below the point of tangency, it has a fulcrum effect, which causes the hole to pick up angle.

Introduction to Directional Drilling



Pendulum effect

The point of contact usually is on the low side of the hole in high-angle holes. The result is that the change in deflection is additive, which tends to increase the hole deflection.

This tendency is reduced by increasing drill sizes and utilizing properly located stabilizers, moderate bit weights, and higher rotary speeds. Small drill collars and high bit weights are often used to increase drift tendencies.

The reverse of the fulcrum effect caused by the drillstring is the pendulum principle. When a stabilizer is run at or above the point of tangency, the stabilizer produces a plumb bob or pendulum effect. Gravity pulls the mass below the stabilizer to the low side of the hole, which decreases the hole angle

Introduction to Directional Drilling

https://youtu.be/4b6bRBRjFPI?t=21

Thank You

Thank You for your undivided attention !

We are now open to questions.

EDVANTAGE INDIA