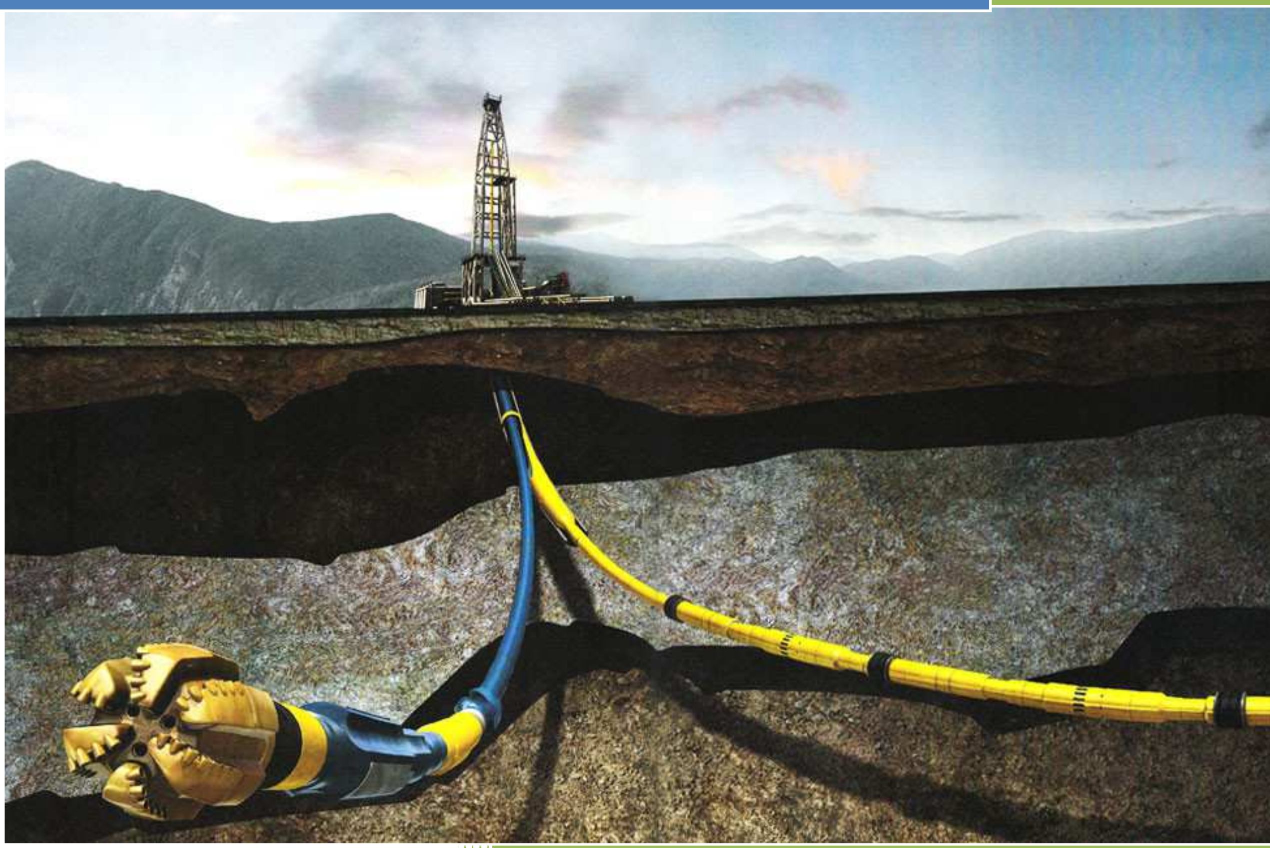
Lecture Note on Advanced Drilling Technology



TAPAS SUTAR

Dept. of Drilling Engineering.

OSME, Keonjhar

Advance Drilling Technology

Directional Drilling

What is directional drilling (only defination)

To Control the feed, direction, rotation of the drillstring to follow the Pre-determine path of the bore-hole to hit the target.

Application of directional drilling

Controlled directional drilling is the process of deviating a well bore along a predetermined Course to a target whose location is given at a lateral distance from the vertical. Following applications Can be enumerated on the basis of this defination.

1. Drilling of inaccessible location :-

A target zone lying vertically beneath a surface location that is impractical to be caused as a rig site (e.g - residential location, rivers beds, harbours etc.) Can be penetrated by drilling a directional well.

2. Multiple wells drilling from a single platform :-

Offshore platforms are the most Common application of directional drilling. Where multiple wells Can be drilled through various slots installed in the same platform. Clusters drilling is also an application on onshore due to the land limitations.

3. Side tracking :-

Directional drilling Can be used to deviate the well bore around and away from an obstruction in the origional well bore. (e.g - stuck drill string left in the hole).

4. Relief well drilling :-

This is one of the most important application of directional drilling to intersect a blow out well near the bottom so that mud and water Can be pumped in to the blowing well.

5. Multiple targets :-

Sometimes it may be necessary to drill through one target and alter the direction of the well to reach the next target.

6. Troublesome geological conditions :-

Drilling through geological faults or troublesome formations like saltdome etc. can be avoided by directional drilling method. Practically the well planning is made in such a way that these ~~parabolic~~ problematic structures/formations are avoided from the drilling path.

Directional Drilling Terminology :-

1. Measured depth (MD) - Actual depth of the well measured through drillstring.
2. Course length (CL) - Measured length between two survey station
3. Drift angle or Inclination angle - Deviation from vertical in degrees.
4. True vertical depth (TVD) - True vertical depth as calculated from the directional survey.
5. Departure or Course deviation - Horizontal distance the well has achived.
6. Drift direction (azimuth) - The well direction from north measured in degrees.
7. Buildup angle - The buildup angle is given in degrees per unit length.
8. Kick off point (KOP) - The well depth at which deflection of the hole is initiated.
9. Monel drill Collar - A non magnetic drill Collar in which Compass is positioned for measuring hole inclination & direction.
10. Course of horizontal drift - Closure - Horizontal distance and direction of any ~~Compass is~~ specified point in the hole. (drill)
11. Lead angle (Angle difference betn proposed well path & actual well path) - The practice of anticipating the normal direction and angle at which the bit will drill.
12. Dogleg - Total change in hole angle due to the deviation from vertical and a change in hole direction.

13. Bottom hole orientation (BHO) - Method used to orient directional tool in the desired direction.

14. Declination - Angular difference betw magnetic north & true north direction

15. Bottom hole assembly (BHA) - The Connection of stabilizer & reamers used to Control hole deviation & direction.

Factors govern planning of directional well

The following factors to be considered for planning of directional well

1. Target location
2. Target zone
3. Formation Characteristics
4. Availability of deflecting tools
5. Location of adjucent well bore.
6. Choise of buildup rate
7. Types of Profile

1. Target Location

For the purpose of planning and monitoring of all measurements must be taken from a Common referance Point. If the target co-ordinates (northing, easting) is given. Then this must be Converted and refered back to the referance point. Normally this reference point is taken as the rotary table as the drillstring passes through it and it is situated on the platform. All depth are measured from the elevation of the rotary table.

2. Target Zone

The point to be Penitrated is called target & the area around the target is called target zone. The target zone allows the driller (directional) some tolerance on the final positioning of the well. Target zone radius 50m 50M

3. Formation charecteristics

The type of formation to be drilled Can affect the planning of the directional ~~drill~~ well. The hardness of the formation is important for selection of the kick-off point. In soft to medium hard formation a sucessful kick off is done.

4. Avialability of deflecting tools :-

The available deflecting tool capabilities and the technique of their application in a particular situation well influence the shape of the well path. The directional behaviour of the tools and bottom hole assemblies also to be considered when planning a directional well.

5. Location of adjacent well bore

In offshore platforms, distance between the adjacent conductors is small. In this situation precise control is required to locate the kick-off point and this is chosen in varying depth to give some separation to avoid collision directly beneth the platform.

6. Choice of Buildup rate

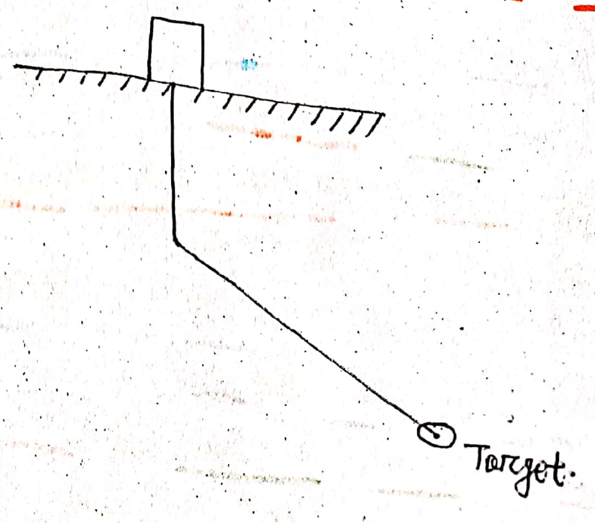
If the change in angle (buildup angle) occurs too quickly severe dog legs can occur in the trajectory. These doglegs make it difficult for drilling assemblies to pass through & also cause more wear on the drill string. To obtain a resonable curvature a buildup rate of 2-3° per 30 meter is commonly used.

Types of Profile

Generally 3 type of profile for well path is considered depending upon the target, formation being drilled etc. These are as follows -

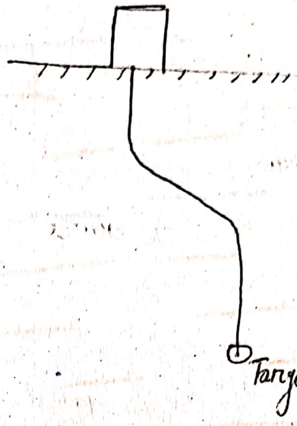
(a) Type-I (Build and hold)

In this type shallow kick off point (KOP) is selected. This profile is used when large displacement is required; The hole is drilled down vertically to the kick off point (KOP) and from there the well is deviated to the required inclination.



(b) Type-II / S-type (Build, hold and drop)

This profile is similar to the type-I drawn to the lower tangential section until a drop off section where the inclination is reduced and is some cases it becomes vertical as it reaches the target. This profile is used when the target is deep but the horizontal displacement in relatively small.



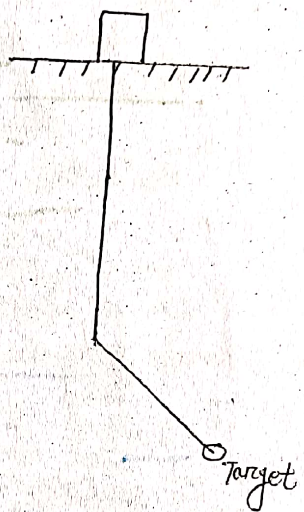
(c) Type-III (Deep kick off and build)

This type of profile is only used in particular situation such as salt dome drilling, final well positioning on side tracking. In this profile the KOP is deep, so it has certain disadvantage such as.

(i) Formation will probably be harder and less responsive to deflection.

(ii) More tripping time to change out BHA while deflecting.

(iii) Buildup rate is more difficult to control.



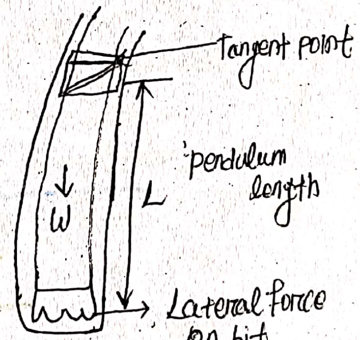
Forces acting on bit

In deviated well the drill collar make contact with the lower side of the bore hole.

If no stabiliser in used in the BHA. Then the collars will make contact with the bore hole at a distance 'L' from the bit.

'L' is known as tangent length.

The unsupported length of collars below the tangent point creates a pendulum effect that exerts side force in the bit.



(Pendulum effect causing a drop in inclination due to weight of all drill collars)

The maximum side force can be determined by the formula.

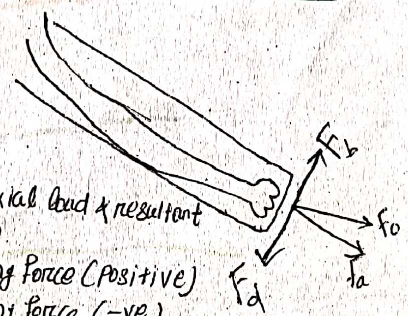
$$F = \frac{L W_c \sin\alpha}{2}$$

where F = Max^m side force (lb)

L = Tangent length (ft)

W_c = weight per unit length of drill collar lb/ft

α = Angle of inclination.



resolving axial load & resultant side force.

F_b = Building force (Positive)

F_d = Dropping force (-ve)

F_a = Axial force

F_o = Resultant force

Placement of stabiliser on BHA well affect the ... will find whether the BHA will build or drop the angle.

A stabiliser placed just over the bit acts as a fulcrum or pivot. The weight of the drill collars above the stabiliser acts as a lever to make the bit build up angle.

As the distance between the bit & stabiliser increase the upward force on the bit reduces if it place higher up the string. The tangential length will increase and it produces a pendulum effect on the bit.

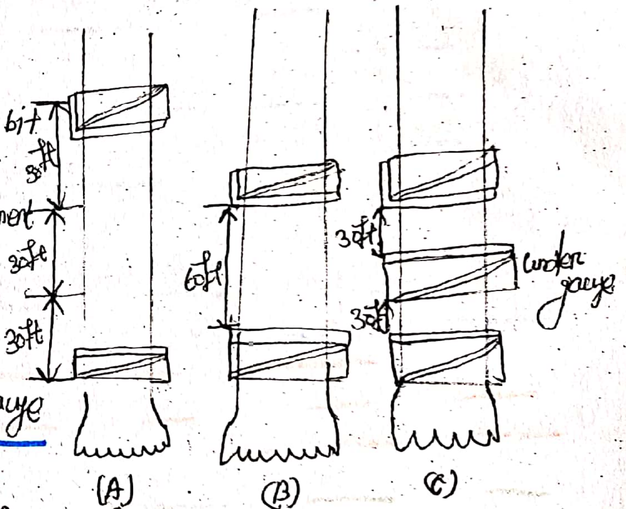
When an angle is to be maintained a holding assembly must be designed. This assembly is designed to cancel the fulcrum and pendulum effect. So here more stabilisers are used and these extra stabilisers provide extra stiffness and resist bending.

Rotary Assemblies (Bottom hole assemblies)

Rotary assembly is a BHA, which is solely driven by rotary table at the surface.

No downhole motors or turbines are used. Rotary assemblies can be designed to build, hold or drop the angle of inclination.

1. Building Assembly



(i) Run just after kick off started.

(ii) A single stabiliser placed above the bit well cause building due to fulcrum effect. In addition further attachment of stabilisers modify the rate of build to match the well trajectory. (20m or 30m)

(iii) If the near bit stabiliser undergauge the sideforce on bit reduces.

(iv) The assembly A & B suitable for soft and medium formations. The assembly 'C' will build slightly less angle as one undergauge stabiliser is added which less this pendulum effect. By bringing the 2nd stabiliser closer to the near bit stabiliser, the building tendency is increased.

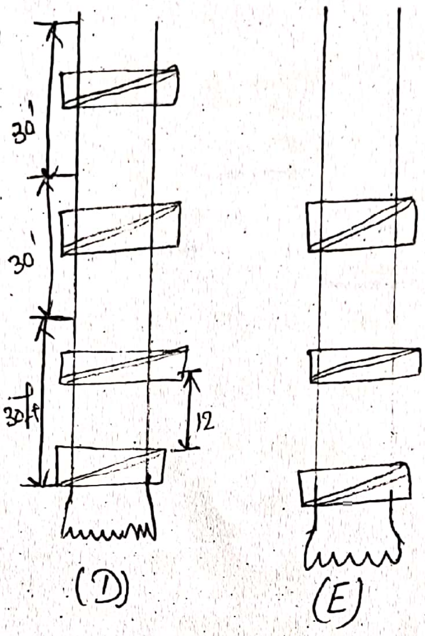
(v) To maintain proper gauge hole the near bit & 2nd stabiliser should be replaced to roller reamers.

(vi) During buildup of directional well. The build up angle rate should kept below 2° per 100 ft to reduce risk of dg leg.

Too much was also cause rapid build up. So WOB should keep low during build-up of a directional well.

2. Holding Assembly

(i) Once the inclination of the borehole achived to the requested angle. Then the borehole is drilled with a holding assembly. The purpose to use the holding assembly to just maintain the build up angle, rather than reduce the tendency of BHA to build or drop angle.



(ii) In a holding assembly. Stabilisers should be placed at close intervals Sometimes Pony collars are used.

(iii) 'D' type assembly is suitable for soft formations where as in 'E' type assembly an undergauge stabiliser is used to counter the gravitational effect.

(iv) In general 3 stabilisers should be used in a holding assemly unless differential sticking is expected.

(v) In harder formation the near bit stabiliser is replaced by a reamer.

(vi) WOB doesn't affect the directional behaviour of this type of assembly so optimum WOB can be applied to get max^m penitration.

3. Dropping Assembly

(i) In directional drilling only in type-III/S-type well profile requires a drop in angle.

(ii) The other application of a dropping assembly is when the inclusion of bore hole has been increased ~~trajectory~~ beyond the proposed trajectory. It must be reduced to bring the well back to the course.

(iii) In general the dropping of angle is done in softer formation as the pendulum effect in harder formation is very slow.

(iv) In dropping assemblies, the near bit stabilizer is not used. The first stabilizer used in BHA is 60' to 90' away from the bit. Both the 'I' and 'G' type assemblies are used in high angled hole.

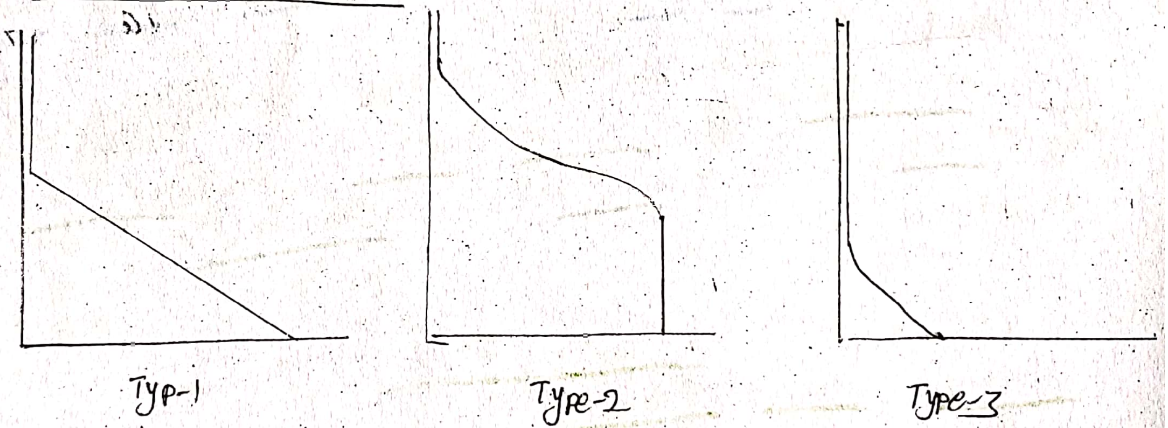
(v) Using a dropping assembly of the hole angle doesn't reduce. The WOB can be reduced to increase the pendulum effect to achive optimum dropup.

Deflecting tools

Although rotary assemblies (BHA) can be designed to alter the path of the well bore. There are certain circumstances (e.g. kick off & side tracking) in which it is necessary to use special tools which are called deflecting tools.

Some of the deflecting tools are-

1. Whipstocks
2. Knuckle joint
3. Spudding bit
4. Jet bit
5. Rebel tool
6. Down hole motor & bent sub
7. Down hole turbines



Directional drilling Techniques

1. Whip-stock Technique

Whip stock is a concave type of wedge about 3 meters long and inclined at an angle up to 3° maximum as shown in figure. It has a hollow neck through which drill pipe & subs can move & there is a shear pin hole in this neck. A shear pin sub is made up above the bit and shear pin is inserted into the hole to hold the

Sub & the bit in position. This assembly is then run to bottom and concave face of whipstock is oriented. Weight is applied on it so that it is embedded into the formation. Additional weight is applied which shears the pin and frees the bit for drilling down the whip stock face. An interval of 5 to 6 meters is drilled at low weight & less RPM & then retrived the whip stock. Latter on this smaller hole is enlarger to full gauge by using a hole opener.

2. Jet deflection Technique.

This technique is best suited for soft formations. The hydraulic power of the drilling fluid is used to wash away a packet of formation & initiate deflection. A specially modified bit is used which has one large nozzle and two blinds. The bit is run on an assembly which includes an orienting sub & full gauge stabilizer near the bit. Once on bottom, the large nozzle is oriented in the required direction. The Jet deflection technique is limited to soft formation & can not be used on smaller rigs where enough pump capacity is not available.

3. Down hole motor & bent sub technique.

~~The most common deflection technique in current for circuit deflection a bent ~~ housing can be installed within the motor itself. The bent housing introduces the deflection much closer to the bit & provides a larger turn.~~

The most Common deflection technique in current use involves running a positive displacement motor to drive the bit without rotating the drill string. The deflection is provided by the bent sub which forces the bit & motor to drill in a ~~specific~~ specific direction. The amount of deflection is a function of the offset provided by the bent sub, the stiffness of the downhole motor & the hardness of the form". For difficult deflection a bent, housing can be installed within the motor itself. The bent housing introduces the deflection much closer to the bit & provides a larger turn.

The main advantage of this thechnique is to achive a full gauge hole with smooth curvature having less risk of severe dogleg.

4. Downhole turbine technique

A down hole turbine can be used in the same way as a positive displacement motor to deflect the well bore in the long tangential section of directional well bore. Turbines are more cost-effective than conventional rotary methods.

5. Steerable downhole mud motor with MWD Technique

This is the latest and highly efficient method used to kick off directional wells. Since this system is a "Steerable system", the motor can be used either in the 'rotary mode' or in the 'Steerable mode'. The greatest advantage of this system is that it doesn't require a BHA change even after the kickoff operation is accomplished. Further drilling can be continued simply by changing the mode.

ORIENTATION OF DEFLECTION TOOLS

Orientation of deflection tool is defined as the placement of the tool in any predefined position w.r.t the reference point.

Survey instruments can be used to determine the present orientation of the deflection tool at the bottom of the hole. Then the bottom hole assembly must be rotated from the surface to orient deflection tool.

The amount of orientation can be obtained by the use of a graphical method called Ragland vector diagram. The ragland diagram can be constructed from the following data.

(a) Initial bore hole deviation & direction.

(b) Maximum permissible dogleg.

Ex Using graphical method determine the required orientation of the deflecting tool to change the hole direction from N 30° E to N 40° E assuming that hole deviation is 7° & maximum dog leg ~~seri~~ severity is 2°/100 ft. Also determine new hole inclination.

Given,

Initial hole inclination – 7°
Initial hole direction – N 30° E
Maximum dogleg severity – 2°/100 ft
Final hole direction – N 40° E

(i) Draw a horizontal line of 7 unit of length. It represent the hole inclination. The direcn of the line is N 30° E. Mark the starting point 'O' at zero & 'C' at 7 units.

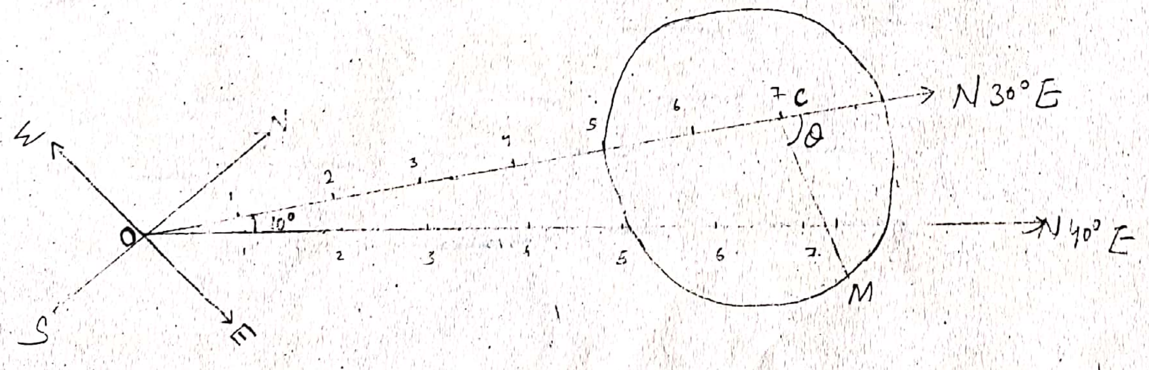
(ii) Plot a circle of 2 units in radius with its Cen be C, as the maximum allowable dog leg severity is 2°/100 ft.

(iii) From Point 'O' draw a line at 10° to OC as the difference in direction / azimuth between the initial hole dirn & final hole dirn (i.e. N 40° E – N 30° E = 10°).

(iv) The angle 'θ' between OC & radius CM gives the required orientation of the tool. Thus to obtain final hole deviation of N 40° E the deflecting tool should be oriented θ to the right of the present hole direction of N 30° E.

Hence the regular setting of the deflecting tool is N (30 + θ)° E

(v) The new hole inclination is represented by the length of line OM.



Method of orientation

Generally two methods of orientation of deflection tools are there. These are, (Although MWD is recently used)

a. Muleshoe method
b. Magnetic method

a. Muleshoe method

(i) This method uses an orienting sub is known as 'muleshoe'.
(ii) The muleshoe contains a key which can be aligned with the scribe line on the deflecting tool. (e.g. bent sub or whip stock)
(iii) A non-magnetic drill collar is connected to the orienting sub & the complete drill string is run to the bottom of the hole.
(iv) A single shot survey instrument is run to the orienting sub where it slides into the orienting sub key through a special keyway cut in it's surface.
(v) The reference line of the deflecting tool is then recorded in direct relation to the magnetic north as registered by the magnetic compass of the survey instrument.
(vi) On the surface the developed film will graphically show the relationship between the tool surface orientation, hole inclination & magnetic north. By simple arithmetic, the actual orientation of the tool is determined.
(vii) If the tool is not facing the required direction, the amount of rotation is then applied at the surface to position the tool in the appropriate dirn.

b. Magnetic method

(i) The magnetic method is suitable for hole deflection created by jetting where an orienting sub is not required

(ii) It uses non-magnetic collar containing six orienting magnets arranged in physical alinement with the deflecting tool face.

(iii) The survey instrument comprises a swinging pendulum, a regular compass and a needle type' compass, which will be locked in place by the magnets in the collar.

(iv) The survey instrument is run on a wireline inside the drill pipe until it lands on the non-magnetic drill collar, here the needle type compass will be attracted to the orienting magnets, & a camera will photograph this position which is super imposal on the regular compass. Thus the relative position of the orienting magnets (and in turn the tool face direction) & direction of the hole are determined. The hole deviation is indicated by the swinging pendulum.

HORIZONTAL DRILLING TECHNOLOGY

Definition of horizontal drilling :-

A horizontal well may be defined as a well which is drilled to an inclination of 90° & maintains thus inclination to a significant distance.

Advantage of horizontal drilling :-

As horizontal wells has increased horizontal displacement from a central platform it can reduce the number of platforms required to exploit the ~~reservoier~~ reserves in offshore area.

Another potential benifit of drilling highly deviated or horizontal wells is the increased length of competion zone through the reservoier.

Application of horizontal wells

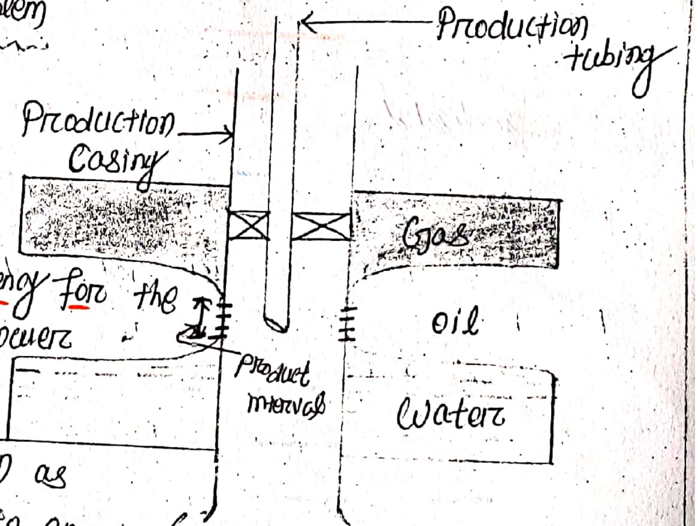
1. Increased Production from a single well

(a) The greater contact area of the well bore through the producing zone allows a much longer completion interval than would be possible in a less deviated well with more of the formation contributing directly to the production, higher flow rate can be expected.

(b) The productivity index (PI) of a horizontal well may be 5 times than that of a conventional well. Therefore horizontal wells are suited to relatively than bed that cover a large area or to formations where the permeability is low.

(c) Horizontal wells can be used as an alternative on hydraulic fracturing as a means of improving production rate from tight formations. Horizontal wells may also be used to improve water injection as a means of improving oil recovery from the reservoir.

2. Reduction in Coning problem

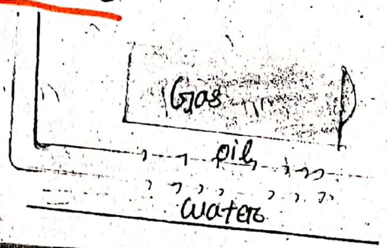


(Gas & water coning in vertical wells)

When the vertical well is drilled through a relatively thin pay zone which overlies on an aquifer. There is a tendency for the water to drawn up into the lower perforation zone of the vertical permeability in high. This is known as water coning & this leads to an increased water cut in the production well which can be reduced by cementing off the lower perforation and reperforation on the upper zone of the perforated part of the casing.

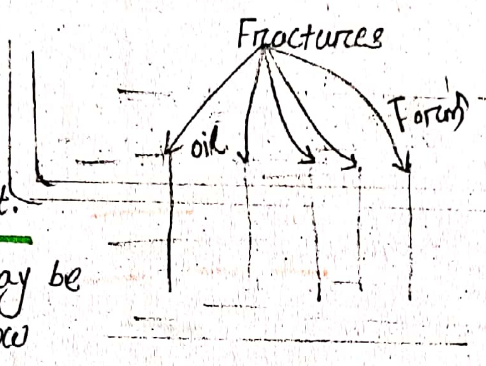
Similarly this problem exists in case there is a gas zone overlying the production zone & here the gas may be drawn down to the upper perforation zones.

This problem can be minimised by a horizontal well it can be placed away from both gas and water zone. Again due to



longer length of the perforated zone, the drawdown in the reservoir pressure around the well bore will be reduced which leads to a greater oil recovery before creating a Coning effect.

3. Intersection of vertical fractures

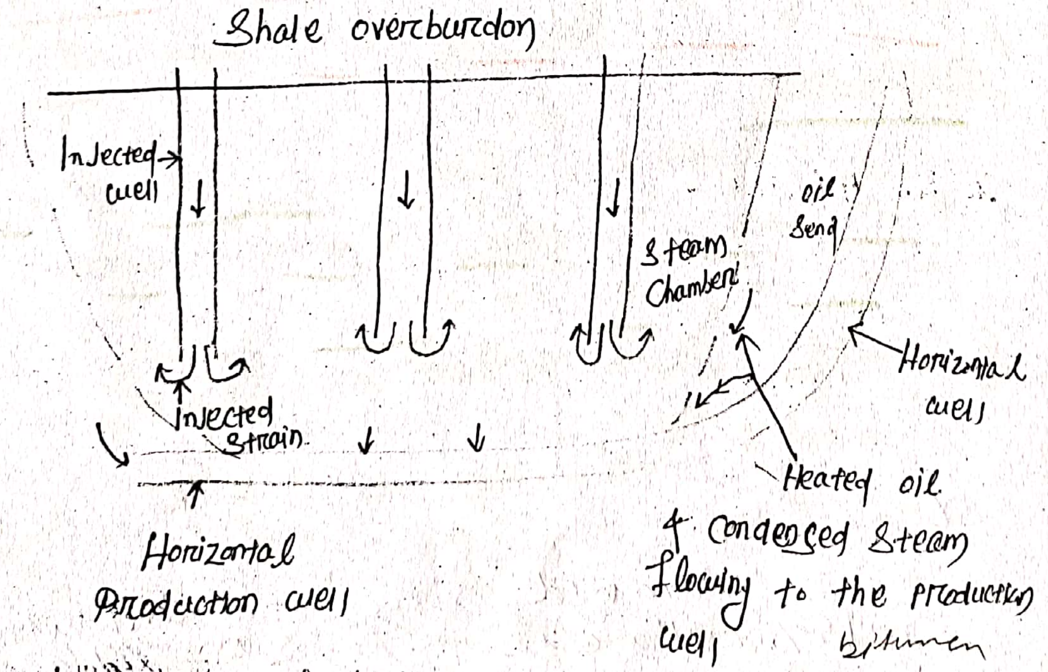


Many reservoirs contain fractures which are vertical or near vertical at a depth greater than 2000-3000 ft.

In this case of the rock may be impermeable but still the oil can flow through the fractures so in this case, a horizontal well proves a satisfactory way to drill down for recovery of oil as it can intersect so many fractures at it's well path.

4. Enhanced oil recovery

If in a zone, a highly viscous oil is present. Then the reservoir can be exploited by reducing the viscosity of the fluid and extracting it through a horizontal well.



bitumen
In this type of highly vescous oil zone or bitame zone a horizontal well can be drilled at the base of the zone & a numbers of vertical wells can be drilled above the well.

Through those vertical wells, steam can be injected to the formations. The viscosity of oil near the steam injector can be reduced and so it will drain down under gravity force towards the producing horizontal well which can be extracted there. exhausted

5. Reducing the number of wells & platforms required in an offshore field development

The reasons are

(a) The increased productivity in horizontal well which may result requirement of lesser amount of drill hole.

(b) In shallow reservoirs which cover a wide area, the extended reach horizontal well can cover most of the reservoir area which may result lesser number of platforms.

(c) In offshore fields where are large distance between bottom hole locations horizontal well may be drilled as an alternative to infill drilling, thus it reduces the number of well to be drilled.

(d) The cost of individual horizontal well might be more expensive, but it covers wide area thus reduces a number of vertical wells as well as other ancillary which working cost more so the overall project cost with the help of horizontal well is economical.

Infill drilling -

It is defined as adding new wells in an existing field within the original well pattern to accelerate recovery or to test recovery methods.

6. Development of Non-Petroleum Reservoir resources

Horizontal well can be utilised to extract entrapped methane gas from coal seam before the coal to be mined, since a concentration of 5-15% methane is air forms an explosive mixture. For this, a small diameter horizontal hole can be drilled through the coal seam.

The orientation of the horizontal hole can also be planned to coincide with the direction of maximum permeability through the coal seam.

~~The orientation of the horizontal~~
For coal deposits located at a depth beyond conventional mining methods. Coal degasification process may be used to exploit the coal reserve.
Highly deviated and horizontal wells provide a network of channels for the injection of air and oxygen and for production of the gases.

MWD

Defination

MWD is the Process by which Certain information is measured near the bit and the information is transmited to the surface without ~~ent~~ Interrupting drilling operations.

Information gathered by MWD

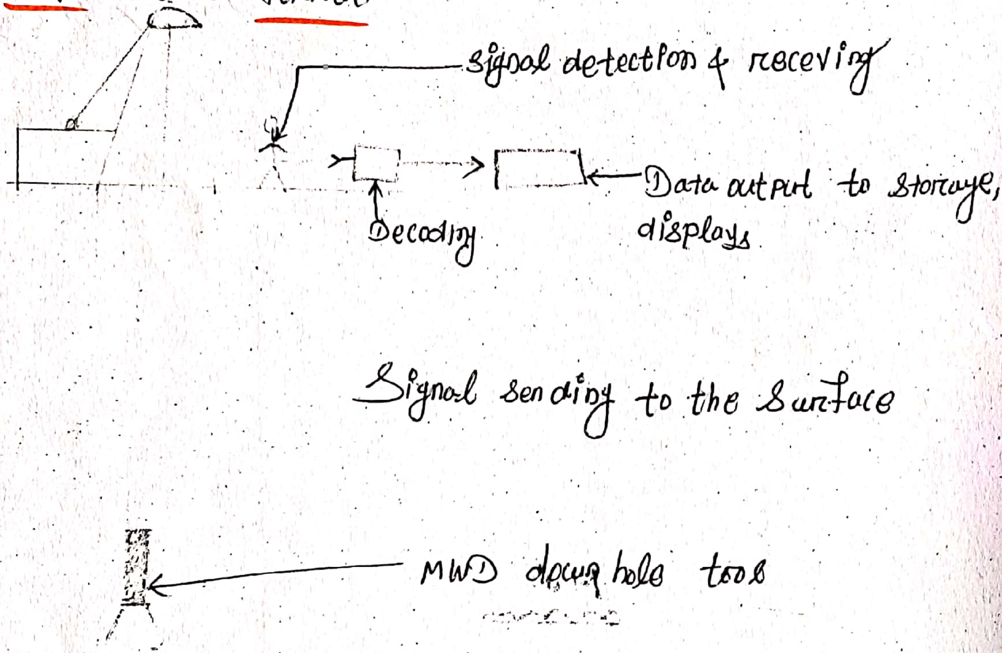
The type of informations gattered by MWD are
a. Directional data (i.e. Inclination, Azimuth)
b. Formation Charecterstics
c. Drilling Parameters (i.e. WOB, Torque, RPM)

Working Procedure

(a) In MWD the sensors are installed in a special down hole tool which is an integeral part of the bottom hole assembly. The sensors record data ~~without~~ about inceination, azimuth and drilling parameters

(b) Within the down hole tool, there is also a transmeter which sends the data as signals to surface via somekind of telemetry channel.

(c) The signals are ~~detached~~ detacted on the surface by a receiving device, and other systems are there which decodes the signals. process these and provide required data in a convinent and useable format.



Advantag of MWD

a. MWD allows the driller & the geologist to effectively see what's happening in the hole in real time.

b. It also improves the decision making process as there is a delay of only few minutes between measuring the parameters and receiving the data on the surface.

Systems associated in MWD

Generally 3 systems are associated in MWD. These are-

(a) Measuring system which measures the data at the downhole. Generally it Comprises a down hole tool.

(b) The telemetry system, that transmits the data to the surface.

(c) The surface system, those decodes the data & Converts it to useable format.

System of MWD
- Measuring System
- Telemetry system
- Surface system

Measuring system

The measuring system of a MWD is generally incorporated in a downhole tool. It has 3 parts
- MWD sensor
- Power source
- Transmission system

Down hole tool
- MWD Sensor
- Power source
- Transmission system

MWD Sensor

The sensor used in the downhole tool must be rugged enough to withstand harse environment.

Different type of sensors used in the downhole tool are.
- Directional sensor.
- Gamma ray sensor
- Resistivity Sensor
- Temperature Sensor
- Down hole WOB/ Torque Sensor
- Turbine RPM sensor

Directional Sensor

a. The directional sensors used in MWD tool are magnetometers + accelerometers.

b. The sensors are powered up after some kind of signal has been sent from the surface.

c. A Perselucer or motion sensor within the downhole tool recognises the signal & initiates the survey.

d. During the time when the sensor actually taking the measurements. The drillstring must remain stationary for accurate results to be obtained. The period is generally less than 2 minutes after which normal drilling resumes. The data are transmitted to the surface while drilling is ahead.

(e) The measurement of inclination azimuth & toolface are sent in a predetermined order. It generally takes 2-4 minutes for transmission of a complete directional survey.

(f) The accuracy of the result is usually given as ±0.25° for inclination, ±2° for azimuth & ±3° for tool face.

Gamma Ray Sensor

(a) Gamma rays are emitted by radioactive elements such as isotopes of potasium, thorium & uranium. These elements are found more commonly in shales than in other rocks. By measuring gamma ray emissions from a sequence of rocks it is possible to identify shale zones.

(b) A gamma ray sensor mounted in an MWD tool can detect this radiation as the bit through the formn.

(c) To be most effective in detecting the changes in lithology. The gamma ray sensor should be positioned as close to ~~feet of~~ new formn are the bit as possible. So that only a few feet of new formn are drilled before the tool responds. For practical reason the distance between the bit & gamma ray sensor is about 6'.

Resistivity Sensor

a) Resistivity is a measure of formn resistance to flow of electric current.

b) The response from the formation will depend upon the fluid content of the pore space (oil & gas act as insulator, while brine is a conductor).

c) In a resistivity sensor two electrodes are mounted on an insulated rubber sleeve on the outside of the MWD tool. The electric current emitted by the upper electrode passes through the formation & is detected by the lower

The actual response is affected by borehole dimensions mud invasion & bed thickness.

d) This type of sensor will not be effective in boreholes where oil base mud is being used. For this an induction type sensor can be incorporated in the MWD tool.

e) Like Gamma-ray sensor the resistivity sensor also should be installed close to the bit to give a fast response to formation changes.

Temperature Sensor

a) The temperature sensor usually mounted on the outside of the drill collar & it monitors the annular temperature.

b) The sensing element may be a step of metal (i.e. platinum) whose electrical resistance changes with temperature.

c) The sensor can be calibrated to measure temperature ranging from 50 to 350° F.

Downhole WOB/Torque Sensor

a) Downhole WOB & torque are measured by a system of strain gauges mounted on a special sub placed close to the bit.

b) The strain gauges will detect axial forces for WOB and torsional forces for torque.

c) By placing pair of gauges on opposite side of the sub any stresses due to bending can be eliminated.

d) The sub must also be designed to compensate the effect of tempt. & pressure.

Turbine RPM Sensor

a) To know the actual speed at which the bit is turning a turbine tachometer is linked to the MWD system to provide real time data.

b) The sensor consists of a 2" diameter probe that is placed very close to the top of the rotating turbine shaft on the top of the shaft, there are two magnets mounted 180 apart. As the shaft rotates, an electric coil with in the probe picks up voltage pulses due to the magnets. By counting the number of pulses over a certain interval. The turbine speed in rpm is calculated. This information is encoded as a series of mud pulses that are transmitted at intervals to surface to let the driller know the rpm is changing

(B) Power Source

The power source to operate the MWD tool is located on the downhole.

Generally the forms of power source is being used such as

a) Batteries
b) Turbine Alternator.

a) Batteries

i) These are compact & reliable since contains no moving parts.
ii) They have finite operational life & are temperature dependant.
iii) They have been successfully used where only directional data is required.
iv) The disadvantage of these are due to limited power output they doesn't meet the requirement of multisensor tools.

b) Turbine Alternator

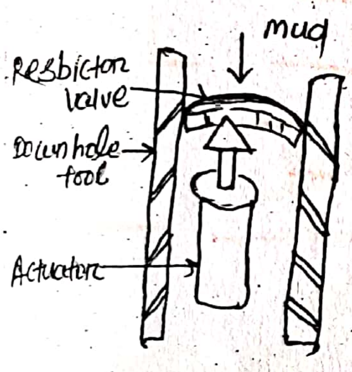
i) For multisensor tools turbines are readily used to provide power to the MWD tool.
ii) Here an alternator is connected to the shaft of the turbine & the alternator generates current.
iii) The electrical power generated by the alternator is controlled by a voltage regulator.
iv) The advantage of this system is it provides more power & longer operating life than battery power.
v) The disadvantage of this system is that power failure can occur when the turbine is damaged. To prevent this any debris should be filtered out from mud & this is done by installing a screen on the top of the drillstring which would be easier to be emptied whenever requires

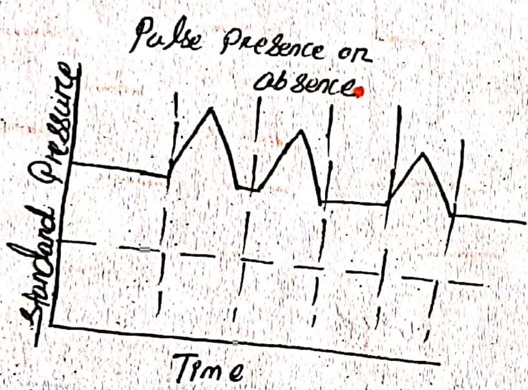
c) Transmission system

Generally 3 methods are used encode the data received by the sensors & prepare the data to transmit to the surface. These systems are applied in mud telemetry system. These systems are -

a. Positive pulse system
b. Negative pulse system
c. Continous wave system.

a) Positive pulse system



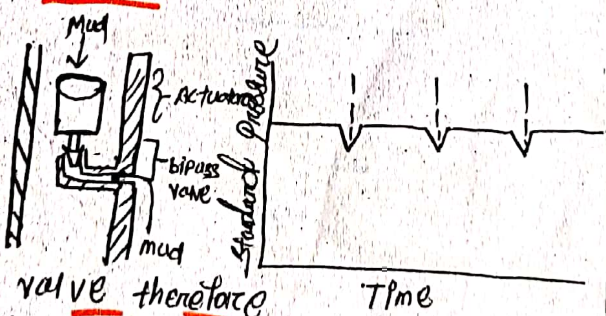


i) In Positive pulse system, generally a restriction valve is situated within the downhole tool & the valve is operated by hydraulic actuator.

ii) When the valve is operated it forms a temporary barrier in the flow of mud through the drill string which causes increase in Stand pipe Pressure.

iii) To transmit data to the surface. This valve is operated several times creating a source of pulses that are detected by transducer at the surface & is decoded by the surface Computer.

b) Negative pulse system



i) In this system the transmitter consists of a valve which when opened, allow a small volume of mud to escape from the drill string to the annulus.

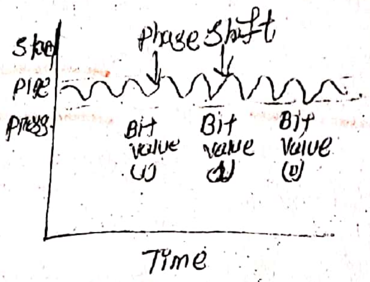
ii) The rapid opening & closing of this valve therefore creates a drop in standpipe pressure that can be detected by pressure transducer.

iii) The presence & absence of a pulse within a timeframe or the time interval.

iv) ~~Be~~ between successive pulses are used to interpret the data.

C) Continous Wave System

i) In this system the transmitter as a rotary valve when consist of a pair of slotted discs which are mounted at right angles to the mud flow. one of the disc is stationary while the other is driven by a motor.



ii) The constant speed of the motor creates a regular & continous variation of pressure that creats a standing wave. This wave is used as a carrier to transmit data to surface.

iii) When an information is to be transmitted the speed of the motor is reduced so that the phase of the carrier wave is reversed. The carrier wave is therefore modulated to represent the data required.

iv) The surface equipments detect these phase changes in the pressure signal & transmit this into a bearing code.

5) Telemetry system

Telemetry system are used useful to transmit data from measuring device from the bottom hole to the surface system to decode it.

Different telemetry methods used to transmit data are -

1. Hard were method
2. Electromagnetic method
3. Seismic(Acoustic) "
4. Mud pulse "

1 Hard were method →

i) This is the most direct method to transmit electrical signals to the surface via a conductor.

ii) This method is first, proposed in 1930.

iii) 2 different methods are used in Hard were method such as-

a) Insulated conductor attached to drill pipe.
b) Conductor cable running through drillstring.

(a) Insulated Conductor attach to drill pipe :-

This method employs a continous conductor that forms in integral part of the drill pipe.

Special connectors built in to the tool joint provides conductivity throughout the length of the drill string.

The sensor are located on a special drill collar. The armoured cable connects this collar the with the lower end of the drill pipe.

The length of the armoured cable must be equal to the length of the BHA to ensure correct tension is mounted.

At this other end of the system there is an insulated slip ring which is mounted on the top of the kelly & then it is connected to the surface equipment that process the signals & give the final result. The major disadvantages of this system is

i) It takes additional cost for a special type of drillpipe.
ii) It is difficult to achive a continous circuit at connections.

b) Conductor cable running through cable

Here a armoured type conductor cable runs through the drillstring to collect the data.

To overcome the shortage of cable when the hole gets deeper extra cable in spooled inside the drill pipe.

Electrical, mechanical latches built into the system allow the cable to be temporarily disconnected while the new joint is added.

Advantage of hardware method over other telemetry method:-

Although there are serious operational problems to overcome hardware system do offer some advantages over other telemetry methods such as-

a. Higher data rates allow more information to be transmitted in real time.
b. No need to incorporate a downhole power source.
c. Two way communication is possible (i.e. signals could also be sent down to activate certain components such as an adjustable bent sub or a downhole BOP)
d. Unlike some other methods there is effectively no depth limitation since signal weaken is not a problem.

Electromagnetic method

i) This system is developed from 1940.
ii) A wave transmitter is mounted within the BHA. generates signals that can be modulated to send the required data in the form of a binary code. Then these signals are detected at surface by antenas which are placed on the ground around the rig site.

The advantage of this system are-

a. No disruption to normal drilling operation
b. Simpler rigup than other method
c. Data can be transmitted while tripping.

The disadvange of this system is due to weakning of signals only low frequency waves can be transmitted effectively, & these are sometimes difficult to distingush from a the frequencies emitted by electrical equipment on the rig.

3. Seismic (Acoustic method)

i) In this system, seismic waves through the drillpipe provides the telemetry channel.

ii) To overcome background noise due to drilling operation a large seismic generators would be required in the BHA.

iii) Again weakens of the signals along the drillstring also makes it difficult to pick the signal at the surface so to overcome this, repeater stations are also required which may be installed at intervals of drill string to amplify the signal.

4. Mud pulse method

i) Now a days most MWD system transmit data on this system.

ii) The major components in the system are incorporated in a non-magnetic drill collar. This special drill collar is supplied by the MWD Company. Its ~~Cent~~ internal diameter is greater than the internal size since it has to accomodate the MWD tool components. The major components are -

a. A power source to operate the tool
b. Sensor to measure required information.
c. A transmitter to send the data to the surface.
d. A microprocessor or control system to co-ordinate the various fun^n of the tool.

iv) The major advantage of mud telemetry system over other systems are its relative simplicity. In this method no special drillpipe is required and also there is no completion due to wireline in the hole. The pressure pulses travel through the mud column at around 4000 to 5000 ft

Surface system

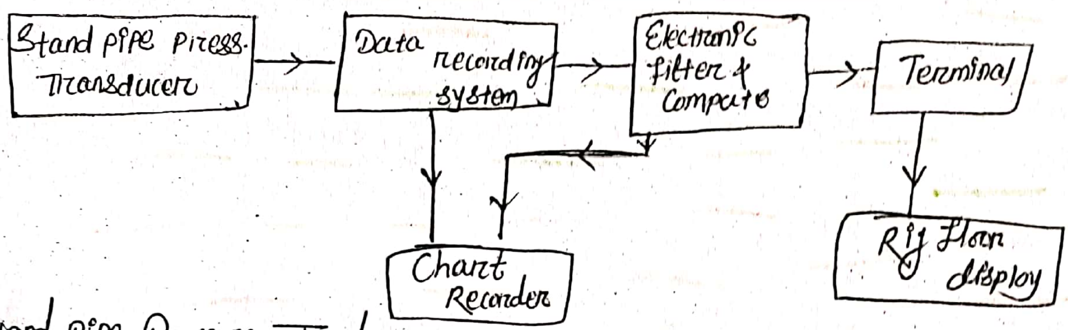
The surface system decode the data sent by the transmitter & makes it user readability. The system ~~transmitter & makes it use~~ consist of some equipments which are follows :-

a) A stand pipe pressure transducer to detect variation in pressure & converts these to electrical ~~ee~~ signals.

b) An electronic filtering device to reduce & eleminate interferance from the pump or downhole motors that may ~~be~~ also pressure variation

c) A surface computer to interpret the results.

d) A rigfloor display to ~~ee~~ communicate to results to the driller or plotting device to produce ~~ee~~ continous log.



Stand pipe Pressure Transducer

i) The transducer can be installed in the stand pipe manifold.
ii) Inside the transducer there is a sensitive diaphragm that detect variation in pressure & convert those hydraulic pulses to electrical pulses.
iii) The voltage output is relayed to the rest of the surface equipment by means of an electrical cable.

Electronic Filter, Amplifiers, Surface Computer

i) As well as detecting the MWD pulses, the transducer also responds to pressure variation caused by rig pumps & down hole motors. The background noises makes it difficult to identify the MWD pulses so to make it identify. The speed of the rig pump should be altered ~~and/or~~ altered pulsation dampners should be used on the pump.
ii) The signal from the transducer can further be ~~comp~~ improved by the help of electronic filters which are used to filter any other frequences above or below the preset range. //

ACID BOTTLE

- It is used in mining indust. from about 1870.

In this particular instrument the container is a glass cylinder & the liquid is hydrofluoric acid. If the instrument is allowed to rest in an inclined position for a certain period of time the acid will react with the glass & leave a mark on the side of the cylinder indicating the horizontal surface. The dist. between the mark & the acid's original position when the cylinder was level can be used to calculate inclination angle. The strength of the acid must be chosen carefully to etch a sharp distinct line on the glass within a reasonable length of time.

The instrument was lowered down the drillstring on wireline until it rested on top of the bit or on a baffle plate at some point above the bit. Acid bottle was left in this position for about 20 minutes to allow the reaction to take place. The motion of the acid during running in and pulling out prevented any other lines being etched on the glass. The glass was inspected back at the surface & the angle inclination was determined.

The measure of the hole direction, an additional Compartment was required containing gelatine + a magnetic compass needle. The compass needle was free-floating + aligned itself with magnetic North. It was held in this position by the gelatine. The direction of the deviated well could therefore be referenced to Magnetic North.

The major disadvantage of the acid bottle technique was that the acid did not always leave a distinct line to show the interface. In reading the mark some allowance had also to be made for capillary effect.

Formulas

Note

(1) – Tangential Method

True vertical depth (TVD) = $\cos I_1 \times$ Measured depth (MD)

Horizontal displacement (HD) = $\sin I_1 \times MD$

Northing (N) = $\cos A \times HD$

= $\Delta MD \sin I \times \cos A$

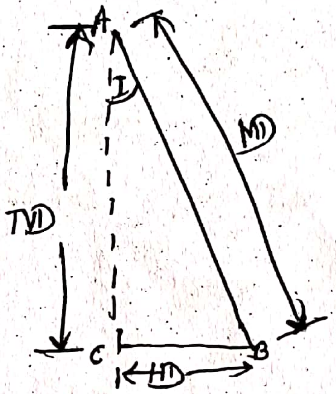
Easting (E) = $\sin A \times HD$

= $\Delta MD \sin I \times \sin A$

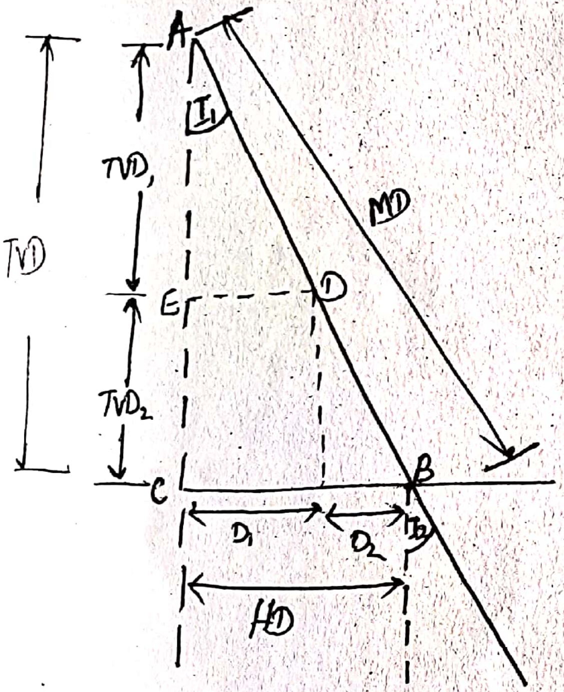
Note

I = Angle of inclination

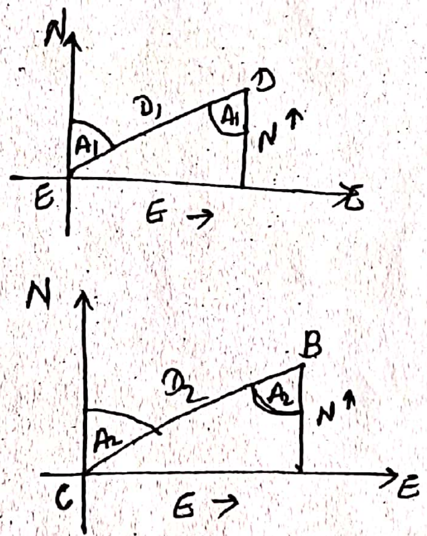
A = Azimuth



(2) – Balance tangential method



(Front view)



(Top view)

$TVD_1 = \cos I_1 \; MD/2$

$TVD_2 = \cos I_2 \; MD/2$

- $TVD = TVD_1 + TVD_2$

$D_1 = \sin I_1 \; MD/2$

$D_2 = \sin I_2 \; MD/2$

- $HD = D_1 + D_2$

$N_1 = MD/2 \sin I_1 \cos A_1$

$N_2 = MD/2 \sin I_2 \cos A_2$

- $N = N_1 + N_2$

$E_1 = MD/2 \sin I_1 \sin A_1$

$E_2 = MD/2 \sin I_2 \sin A_2$

- $E = E_1 + E_2$

(3) - Average Angle method

$$TVD = \cos\left(\frac{I_1+I_2}{2}\right) MD$$

$$HD = \sin\left(\frac{I_1+I_2}{2}\right) MD$$

$$N = MD \sin\left(\frac{I_1+I_2}{2}\right) \cos\left(\frac{A_1+A_2}{2}\right)$$

$$E = MD \sin\left(\frac{I_1+I_2}{2}\right) \sin\left(\frac{A_1+A_2}{2}\right)$$

Bore Hole Surveying. (Directional)

Defn :- The process of collecting data regarding the well bore position (ie inclination and direction of the bore hole) relative to the reference point at the surface is called bore hole surveying.

Objective of Borehole Surveying

The objective of bore hole surveying in directional drilling are as follows :-

(a). To monitor actual wellpath as drilling continues to ensure that the target will be reached.

(B) To orient deflection tools in the required direction when making correction to the well path.

(c). To ensure that the well being drilled is in no danger of intersecting an existing well nearby.

(d) To determine true vertical depths of the various formations that are encountered to allow accurate geological mapping.

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(e) To determine the exact bottom hole location of the well for the purpose of monitoring reservoir performance, and also for relief well drilling.

(f) To evaluate dog-leg severity along the course of the well bore.

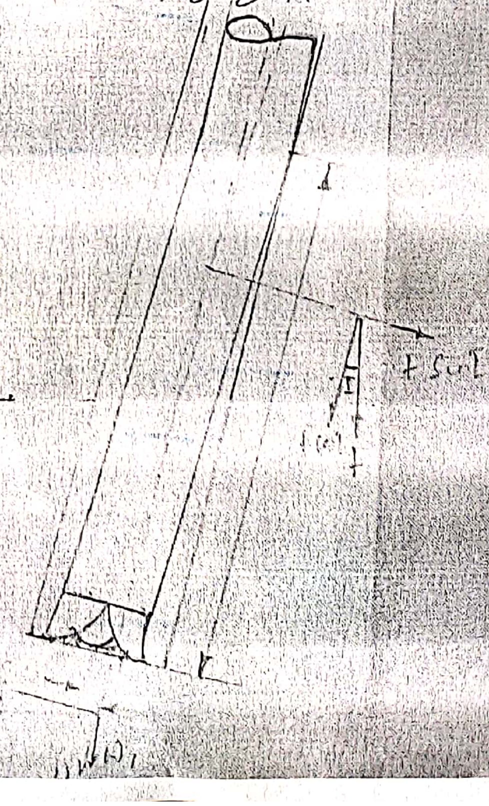
Causes of Bore hole Deviation

Generally 2 factors causes the borehole deviation. Those are as follows

- Mechanical factors
- Formation characteristics.

Mechanical Factors

i) The mechanical factors which contribute to hole deviation include the axial load (W) and the pendulum force (F)



①. The axial load 'W' is the total weight of on the bit and is compressive in nature. As the drillstring is elastic in nature, it will buckle under the action of load 'W'. So here as the drillstring buckles, as a result the [illegible] 'W' which has to act along the axis is displaced from the Centreline/axis of the hole.

(iii) Near bit the load 'W' can be resolved into 2 components 'W₁' along the axis of the hole and 'W₂' perpendicular to the axis of the hole. The component 'W₂' is responsible for hole deviation. The magnitude of force W_2 increases with increasing clearance betn the hole and drill collars & with increase in weight on bit. The figure shows deviation due to W_2 is towards left.

(iv) The pendulum forces arises due to gravity and hole inclination; its magnitude is dependant on the active length of drill collars betn the drill bit and the point of tangency to the hole wall.

Here the force 'F' can also be resolved into two components.

F cos I along the axis of the hole

F sin I which is perpendicular to the hole axis

On the above diagram, the deviation due to F sin I is towards right.

(v). So, the final magnitude and ~~deviation~~ direction of the resultant hole deviation due to the mechanical factors is dependant on the difference between W_2 and F sin I.

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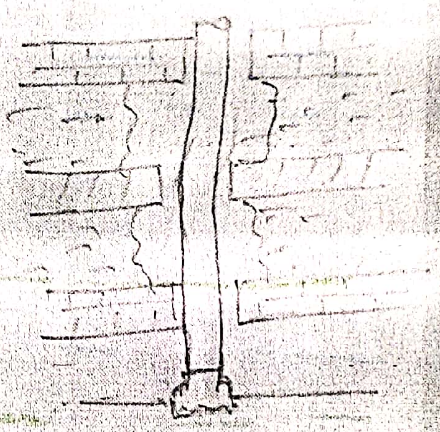
4)

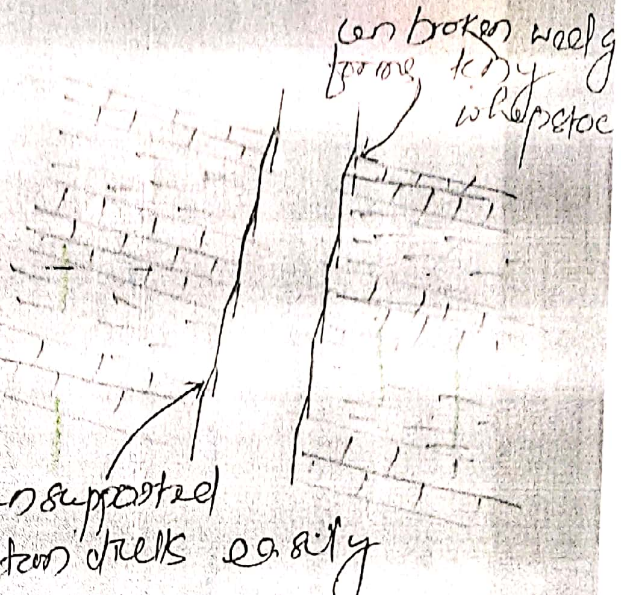
Formation Characteristics

(i) The major source of natural hole deviation is formation characteristics. Generally all hydrocarbon deposits are found in sedimentary deposits which might be composed of alternate hard and soft formation.

(ii) During drilling the soft bands are easily drilled and may be washed out due to the action of drilling fluid. Therefore an oversize hole might be produced. In this oversized portion of the borehole, the drill collar will deflect the bit laterally before the next band is approached. So continuous drilling in soft and hard bands and bit deflection with in the washout zone alternately produce a deviated borehole in the hard band. Thus an unwanted deviation is produced with possibly a severe dogleg.



(iii) Again Lamination in sedimentary rocks is another factor which ~~contris~~ contributes to natural hole deviation. In homogeneous horizontally bedded formations the bit will cut equal chips on both sides of the bit teeth and it will drill a straight hole. But in dipping laminated formations the drill bit tends to cut unequal chips on each side of the teeth, which results in lateral movement of the bit and the hole is deviated



(iv) It has been noted that the bit deflection is related to the angle of dip. When the angle of dip is greater than 45° the bit tends to drill down-dip. When the angle of dip is less than 45°, the bit tends to drill down dip. Also practical experience has shown that the angle of deviation is always less than the angle of dip.

(v). Other important formation characteristics which contribute to the hole deviation are fault, fracture, fissures and drillability.

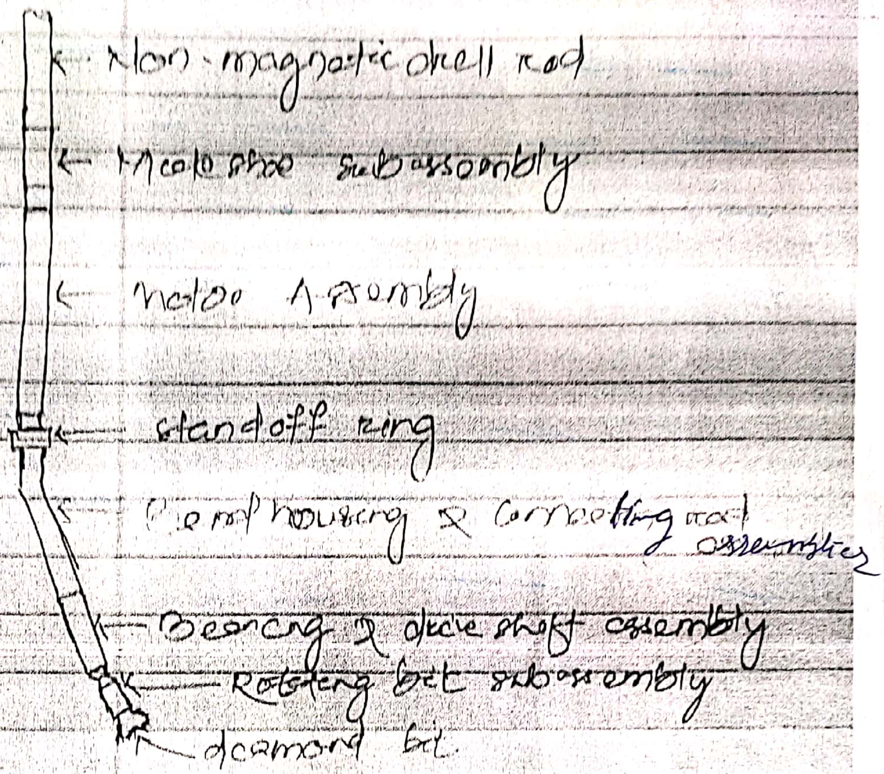
(vi). Formation tendency to deviation is known as "crooked hole tendency".

The degree of crooked hole tendency are classified as mild, medium and severe. Mild crooked hole tendency produces little or no hole deviation and normally associated with drilling of hard and isotropic formations. Medium and severe crooked hole tendency are associated with medium and soft formations respectively. These medium and soft rocks normally has a great degree of dipping, fracturing and variation of strength.

Bit walk :- Bit deflection is often referred as bit walk.

Dyna-Drill (How hole deviation is can be achieved by Dyna drill)

(i) Dyna Drill is ideally suited tool for directional drilling.



(Dyna drill tool Assembly)

(ii) The Dyna-Drill tool is essentially positive displacement mud motor which is encased in a housing and attached to a drill bit.

(iii) The drill bit is driven by the downhole motor without drill rod rotation.

(iv) Because the drill pipe does not turn, it is possible to orient the drill pipe and the attached Dyna-Drill tool to control the direction of the bore hole.

(v) The amount of deviation achieved by Dyna-Drill can be varied by using either interchangeable bent sub or housing of various angles. The higher the sub or housing angle, the greater amount of deviation can be achieved.

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(vi) A stand-off ring also can be attached as a part of the Dyna-Drill tool above the bent assembly, which is used to hold the tool slightly off bottom on the low side and thereby increase the penetration angle.

(vii) Control of direction (Azimuth) can be obtained by turning the bent housing (Tool) to the left or right.

Special Application of Dyna-Drill.

Due to the special features of the Dyna-Drill concept it has some special applications which are as follows.

(a) Micro-slim special purpose tool:-

(i) The micro-slim Dyna-Drill tool is available in 1.75" (44mm) and 2.375" (60.3 mm) sizes.

(ii) The micro-slim Dyna-Drill tool can be used to drill out cement which has hardened in a string of drill pipe while the drill string remains suspended in the hole during clean out.

(iii) This type Dyna-Drill tool is used in tubing or other production string to eliminate sand bridges, paraffin or scale build up. ~~[illegible]~~

(iv) Since using this tool, no pipe is required and also support equipments, thus makes the workover job more efficient and gets the well back on production as quickly as possible.

(b) Mineral Exploration:-

(i) In mineral exploration drilling, when directional drilling is carried out, sometimes the hole is tend to drift off course for which the Dyna-Drill can be used to correct the angle & azimuth of the course path and directs the hole towards the target.

(ii) The techniques and equipments used in such operation are similar to oil field but special care must be taken because of size limitations and support equipments available.

(c) Horizontal Drilling :-

(i) As horizontal drilling is widely used in area of soil investigation in mines & tunnels. Dyna-Drill can be used there for the horizontal drilling.

(ii) In Coal mines multilateral drillholes are done for methane - de-gassification. A Dyna-Drill tool is proved suitable to drill multilateral drillhole in the field.

(d) Pipe-line placement :-

(i) A new concept for pipeline placement has been developed which allows work to proceed without the normal obstruction of surface features and facilities, without disruption of surface traffic and without the need for ongoing bank or dike restorations.

(ii) In this technique a pilot hole is drilled from the surface location on one side of a river or road and back to the surface on the other side of the river or road. This pilot hole serves as a guide for further reaming to receive the pipeline.

(iii) This pilot hole is drilled with the help of the Dyna-Drill tool as it have provision to change angle and direction (azimuth) of bore hole.

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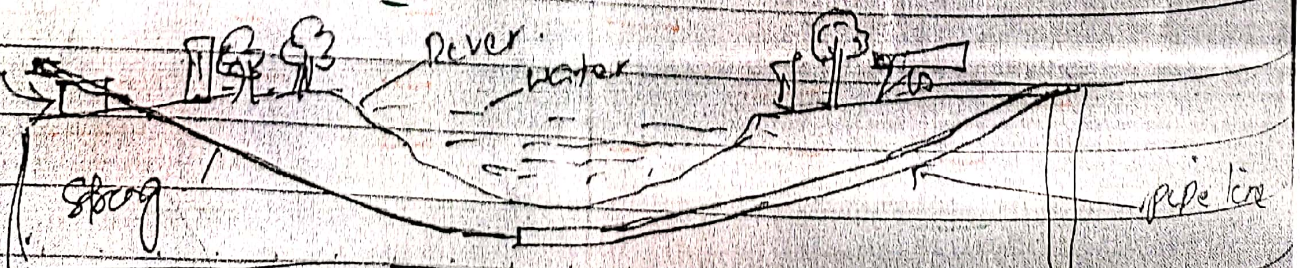

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