Introduction

This chapter is an introduction to the art and science of drilling oil wells. While this chapter focuses on well drilling in the oil and gas industry, it is important to note that wells can be drilled for a variety of purposes. Not all wells are used to extract oil and gas from the earth. Some wells are drilled into deep layers of rock to dispose of hazardous waste. Greenhouse gases, such as carbon dioxide, can be captured and injected into underground layers for permanent disposal. The same well drilling methods can be applied to all these uses.

Drilling rigs are large and noisy. They operate numerous pieces of enormous equipment. The purpose of a drilling rig is only to drill a hole in the ground. Although the rig is big, the hole it drills is relatively small. The purpose of the drill hole is to tap an oil or gas reservoir often thousands of feet or hundreds of metres below the surface of the earth. The drill hole is usually less than one foot (30 centimetres) in diameter at final depth.

1- History :

The story of modern oil well drilling began at the start of the industrial revolution. Workers wanted better ways to illuminate their homes when they returned from the factories. The steam-powered industrial machines increasingly used in factories also required good quality lubricant oils.

Responding to the demand for reliable lighting, companies began making oil lamps, which were brighter than candles, lasted longer, and were not easily blown out by errant breezes. The best source of oil to burn in the early oil lamps was sperm whale oil. Whale oil was clear, almost odorless, light in weight, and burned with little smoke.

While everyone preferred whale oil, by the mid-1800s it was so scarce that only the wealthy could afford it. Whalers in the New England region of the United States had nearly hunted sperm whales into extinction. There was a demand for something to replace whale oil.

Oil seeping out of shallow accumulations is a common, worldwide phenomenon. The area around Baku, Azerbaijan, had been known from ancient times to hold oil and natural gas seeps.

2- Methods of drilling

Cable-tool drilling and rotary drilling techniques have been available since people first began making holes in the ground. Rotary rigs dominate the industry today, but cable-tool rigs drilled many wells in the past. Over 1,600 years ago, the Chinese drilled wells with various primitive yet efficient cable-tool rigs, which they continued to use into the 1940s. To quarry rocks for the pyramids, the ancient Egyptians drilled holes using hand-powered rotating bits. They drilled several holes in a line and stuck dry wooden pegs in the holes. Then they saturated the pegs with water. The swelling wood split the stone along the line made by the holes.
Most wells today are drilled with rotary rigs based on the Hamil Brothers' design at Spindletop.

2-1 Cable-Tool Drilling

A steam-powered cable-tool rig was used by Drake and Smith to drill the Oil Creek site in Pennsylvania. The early drillers in California and elsewhere also used cable-tool rigs. The principle of cable-tool drilling is the same as that of a child's seesaw. When a child is on each end of a seesaw, it moves it up and down. The rocking motion demonstrates the principle of cable-tool drilling.

To explore the concept further, one could tie a cable to the end of the seesaw and let the cable dangle straight down to the ground. Next, a heavy chisel with a sharp point could be attached to the dangling end of the cable. By adjusting the cable's length so the end of the seesaw is all the way up, the chisel point hangs a short distance above the ground. Releasing the seesaw lets the heavy chisel hit hard enough to punch a hole in the ground. Repeating the process and rocking the seesaw causes the chisel to drill a hole. The process is quite effective. A heavy, sharp-pointed chisel can slowly force its way through rock, bit by bit, with every blow.
A cable-tool rig operates much like a seesaw with a powered *walking beam* mounted on a derrick. The walking beam is a wooden bar that rocks up and down on a central pivot. At Drake's rig, a 6-horsepower (4.5-kilowatt) steamboat engine powered the walking beam. As the beam rocks up, it raises the cable attached to a chisel, or bit. Then, when the walking beam rocks down, heavy weights above the bit, called sinker bars, provide weight to ram it into the ground. The bit punches its way into the rock, and repeated lifting and dropping make the bit drill into the earth. The driller lets out the cable gradually as the hole deepens. The derrick provides space to raise the cable and pull the long drilling tools out of the hole using one of several winches called the bullwheel.

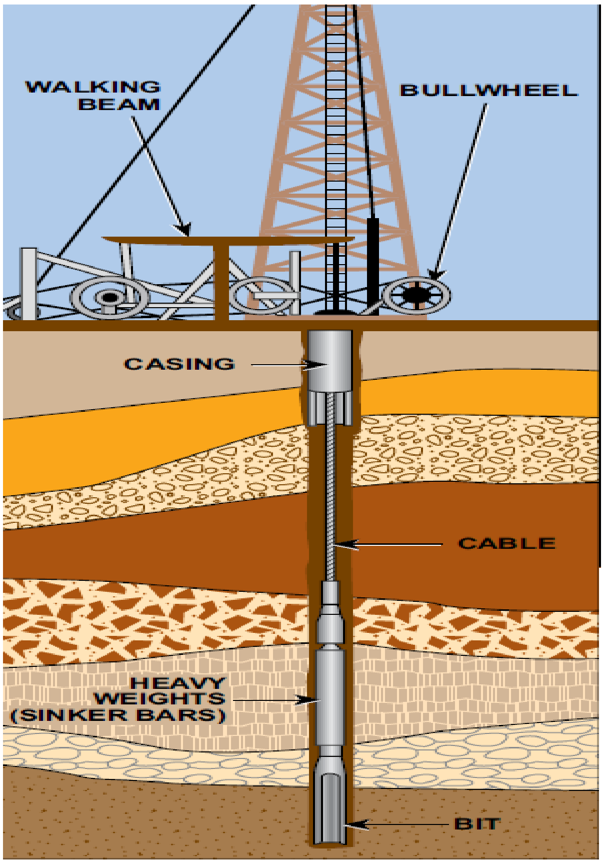

Figure 17:cabel-tool drilling

2-2 Rotary rig types

A variety rotary drilling rigs might be used depending on the location and geography of the reservoir.

Offshore, the ocean environment plays an important role in rig design. Rigs may be broadly divided into two categories: rigs that work on land and rigs that work offshore.

One type of offshore drilling facility is a platform. Although drilling occurs from platforms, most companies use platforms for production of oil and gas rather than for drilling.

If a platform is designed for drilling, the rig on the platform operates just like a land rig.

Several wells can be drilled from the same platform, and the rig is moved or skidded over to the next slot in the platform to begin a new well.

Figure 18: onshore rotary drilling

figure 19: offshore rotary drilling

3- Drilling fluids (mud)

In geotechnical engineering, drilling fluid is used to aid the drilling of boreholes into the earth. Often used while drilling oil and natural gas wells and on exploration drilling rigs, drilling fluids are also used for much simpler boreholes, such as water wells. Liquid drilling fluid is often called drilling mud. The three main categories of drilling fluids are water-based muds (which can be dispersed and non-dispersed), non-aqueous muds, usually called oil-based mud, and gaseous drilling fluid, in which a wide range of gases can be used.

The main functions of drilling fluids include providing hydrostatic pressure to prevent formation fluids from entering into the well bore, keeping the drill bit cool and clean during drilling, carrying out drill cuttings, and suspending the drill cuttings while drilling is paused and when the drilling assembly is brought in and out of the hole. The drilling fluid used for a particular job is selected to avoid formation damage and to limit corrosion.

3-1 Types of drilling fluid

Many types of drilling fluids are used on a day-to-day basis. Some wells require that different types be used at different parts in the hole, or that some types be used in combination with others. The various types of fluid generally fall into a few broad categories:

- Air: Compressed air is pumped either down the bore hole's annular space or down the drill string itself.
- Air/water: The same as above, with water added to increase viscosity, flush the hole, provide more cooling, and/or to control dust.
- Air/polymer: A specially formulated chemical, most often referred to as a type of polymer, is added to the water & air mixture to create specific conditions. A foaming agent is a good example of a polymer.
- Water: Water by itself is sometimes used. In offshore drilling sea water is typically used while drilling the top section of the hole.
- Water-based mud (WBM).
- Oil-based mud (OBM)Synthetic-based fluid (SBM) (Otherwise known as Low Toxicity Oil Based Mud or LTOBM)

3-2Function

- 1 Remove cuttings from well
- 2 Suspend and release cuttings
- 3 Control formation pressures
- 4 Seal permeable formations
- 5 Maintain wellbore stability
- 6 Minimizing formation damage
- 7 Cool, lubricate, and support the bit and drilling assembly
- 8 Transmit hydraulic energy to tools and bit
- 9 Ensure adequate formation evaluation
- 10 Control corrosion (in acceptable level)
- 11 Facilitate cementing and completion
- 12 Minimize impact on environment

3-3 Factors influencing drilling fluid performance

Three factors affecting drilling fluid performance are:

- The change of drilling fluid viscosity
- The change of drilling fluid density
- The change of mud pH

4- Rock bit :

A Drill bit, is a device attached to the end of the drill string that breaks apart, cuts or crushes the rock formations when drilling a wellbore, such as those drilled to extract water, gas, or oil.

The drill bit is hollow and has jets to allow for the expulsion of the drilling fluid, or "mud", at high velocity and high pressure to help clean the bit and, for softer formations, help to break apart the rock. A tricone bit comprises three conical rollers with teeth made of a hard material, such as tungsten carbide. The teeth break rock by crushing as the rollers move around the bottom of the borehole. A polycrystalline diamond compact (PDC) bit has no moving parts and works by scraping the rock surface with disk-shaped teeth made of a slug of synthetic diamond attached to a tungsten carbide cylinder.

The tricone bit is an improvement on the original bit patented in 1909 by Howard R. Hughes, Sr. of Houston, Texas, father of the famed billionaire Howard R. Hughes, Jr..

PDC bits, which first came into widespread use in 1976, are used for gas and oil exploration in the North Sea. They are effective at drilling shale formations, especially when used in combination with oil-base drilling muds.

Figure 20:drill pits

4-1 Types of Drill Bits

Drill bits are broadly classified into two main types according to their primary cutting mechanism. **Rolling cutter bits** drill largely by fracturing or crushing the formation with "tooth" shaped cutting elements on two or more cone-shaped elements that roll across the face of the borehole as the bit is rotated.

Figure 21:rolling cutter bit

Fixed cutter bits employ a set of blades with very hard cutting elements, most commonly natural or synthetic diamond, to remove material by scraping or grinding action as the bit is rotated.

Figure 22:fixed cutting bit

Modern commercial rolling cutter bits usually employ three cones to contain the cutting elements, although two cone or (rarely) four cone arrangements are sometimes seen. These bits mainly fall into two classes depending on the manufacture of the cutting elements or "teeth". Steel-tooth bits have cones that have wedge-shaped teeth milled directly in in the cone steel itself. Extremely hard tungsten carbide material is often applied to the surfaces of the teeth by a welding process to improve durability. Tungsten carbide insert (TCI) bits have shaped teeth of sintered tungsten carbide press-fit into drilled holes in the cones. Some types of steel-tooth bits also have TCI elements in addition to the milled teeth. The cones rotate on roller or journal bearings that are usually sealed from the hostile down-hole drilling fluid environment by different arrangements of o-ring or metal face seals. These bits usually also have pressure compensated grease lubrication systems for the bearings.

Fixed cutter bits were the first type of drill bit employed in rotary drilling, and they are mechanically much simpler than rolling cutter bits. The cutting elements do not move relative to the bit; there is no need for bearings or lubrication. The most common cutting element in use today is the polycrystalline diamond cutter (PDC), a sintered tungsten carbide cylinder with one flat surface coated with a synthetic diamond material. The cutters are arranged on the blades of the bit in a staggered pattern with the diamond coated cutter surface facing the direction of bit rotation to provide full coverage of the borehole bottom. Other fixed cutter bits may employ natural industrial-grade diamonds or thermal stable polycrystalline diamond (TSP) cutting elements.

There is also currently available, a “hybrid” type of bit that combines both rolling cutter and fixed cutter elements.

5- drill string

A drill string on a drilling rig is a column, or string, of drill pipe that transmits drilling fluid (via the mud pumps) and torque (via the kelly drive or top drive) to the drill bit. The term is loosely applied as the assembled collection of the drill pipe, drill collars, tools and drill bit. The drill string is hollow so that drilling fluid can be pumped down through it and circulated back up the annulus (the void between the drill string and the casing/open hole).

5-1 Drill string components

The drill string is typically made up of three sections:

a) Bottom hole assembly (BHA)

The BHA is made up of: a drill bit, which is used to break up the rock formations; drill collars, which are heavy, thick-walled tubes used to apply weight to the drill bit; and drilling stabilizers, which keep the assembly centered in the hole. The BHA may also contain other components such as a downhole motor and rotary steerable system, measurement while drilling (MWD), and logging while drilling (LWD) tools. The components are joined together using rugged threaded connections. Short "subs" are used to connect items with dissimilar threads.

b) Transition pipe

Heavyweight drill pipe (HWDP) may be used to make the transition between the drill collars and drill pipe. The function of the HWDP is to provide a flexible transition between the drill collars and the drill pipe. This helps to reduce the number of fatigue failures seen directly above the BHA. A secondary use of HWDP is to add additional weight to the drill bit. HWDP is most often used as weight on bit in deviated wells. The HWDP may be directly above the collars in the angled section of the well, or the HWDP may be found before the kick off point in a shallower section of the well.

c) Drill pipe

Drill pipe makes up the majority of the drill string back up to the surface. Each drill pipe comprises a long tubular section with a specified outside diameter (e.g. 3 1/2 inch, 4 inch, 5 inch, 5 1/2 inch, 5 7/8 inch, 6 5/8 inch). At each end of the drill pipe tubular, larger-diameter portions called the tool joints are located. One end of the drill pipe has a male ("pin") connection whilst the other has a female ("box") connection. The tool joint connections are threaded which allows for the make of each drill pipe segment to the next segment.

6- Drill pipe DP

Drill pipe, is hollow, thin-walled, steel piping that is used on drilling rigs and horizontal drilling to facilitate the drilling of a wellbore and comes in a variety of sizes, strengths, and weights but are typically 27 to 32 feet in length. Longer lengths exist up to 45 feet. They are hollow to allow drilling fluid to be pumped through them, down the hole, and back up the annulus.

Because it is designed to transfer drilling torque for combined lengths that often exceed 1 mile down into the Earth's crust, the tempered steel tubes are expensive, and owners spend considerable efforts to reuse them after finishing a well. Used drill stem is inspected on site, or off location. Modified instruments similar to the spherometer are used at inspection sites to identify defects in the metallurgy, in order to prevent fracture of the drill stem during future wellboring. New drill pipe is classed as new (N class), becoming premium (P-class) and finally down to C (C 1 to 3) as the body outside diameter is worn down by usage. Eventually the drill pipe will be graded a scrap and marked with a red band.

Drill pipe is a portion of the overall drill string. The drill string consists of both drill pipe and the bottom hole assembly (BHA) which is the tubular portion closest to the bit. The bottom hole assembly will be made of thicker walled heavy weight drill pipe (HWDP) and drill collars which have a larger diameter and smaller internal diameter and provide weight to the drill bit and stiffness to the drilling assembly. Other BHA components can include mud motor, measurement while drilling collar (MWD), stabilizers, and other speciality downhole tools. The drill stem includes the entire drill string and the kelly which provides rotation and torque to the drill pipe.

7- Directional Drilling

No well is ever perfectly vertical. Even wells meant to be drilled vertically will wander a few degrees from vertical and move in different directions. Routine measurements are taken during drilling to determine if a well is deviating from vertical by more than the allowed amount (normally less than 5 degrees). If so, careful drilling practices, such as changing the placement of stabilizers in the BHA or adjusting the rotary speed or weight on bit, will bring the well back within the tolerances normally allowed for vertical wells.

Directional drilling is used when a well is intentionally deviated to reach a bottomhole location (BHL) that is different from the surface location (SL). Directional drilling is done for many reasons. The BHL might be under an obstruction such as a building or lake where rigging up over the required BHL is not possible. It might be necessary to drill several wells from a fixed place, such as an offshore platform or an onshore drilling island, to different bottomhole locations.

Part of an existing well might become blocked with lost drilling tools that are unrecoverable, or a well might have been drilled into an unproductive part of the reservoir. It is possible to set a plug in the lower part of the well and deviate, or kick off, the well to a new BHL. Some reservoirs are more efficiently produced by wells drilled at a very high angle. These wells are known as horizontal wells because the inclination angle from vertical reaches 90 degrees or more.

Older directional drilling methods placed inclined wedges, called whipstocks, in the well to force the bit to move in the desired direction. In soft sediments, it is possible to place a large bit nozzle or jet in the desired direction and simply erode the well’s starting path. Although time consuming, these methods are still used at times.

The two faster and often more reliable methods of directional drilling are:

• Slide drilling with a motor

• Drilling with a rotary steerable assembly

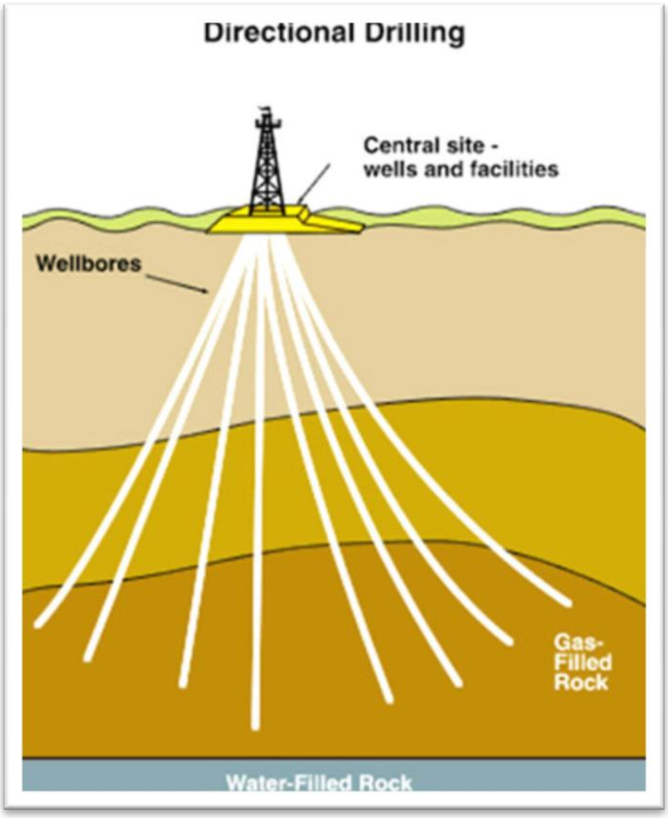

Figure 23 : directional drilling

8- Horizontal drilling

8-1 Definition and Immediate Technical Objective

A widely accepted definition of what qualifies as horizontal drilling has yet to be written. The following combines the essential components of two previously published definitions:

Horizontal drilling is the process of drilling and completing, for production, a well that begins as a vertical or inclined linear bore which extends from the surface to a subsurface location just above the target oil or gas reservoir called the "kickoff point," then bears off on an arc to intersect the reservoir at the "entry point," and, thereafter, continues at a near-horizontal attitude tangent to the arc, to substantially or entirely remain within the reservoir until the desired bottom hole location is reached.

Most oil and gas reservoirs are much more extensive in their horizontal (areal) dimensions than in their vertical (thickness) dimension. By drilling that portion of a well which intersects such a reservoir parallel to its plane of more extensive dimension, horizontal drilling's immediate technical objective is achieved.

That objective is to expose significantly more reservoir rock to the wellbore surface than would be the case with a conventional vertical well penetrating the reservoir perpendicular to its plane of more extensive dimension (Figure 1). The desire to attain this immediate technical objective is almost always motivated by the intended achievement of more important objectives (such as avoidance of water production) related to specific physical characteristics of the target reservoir. Several examples of these are discussed later on.

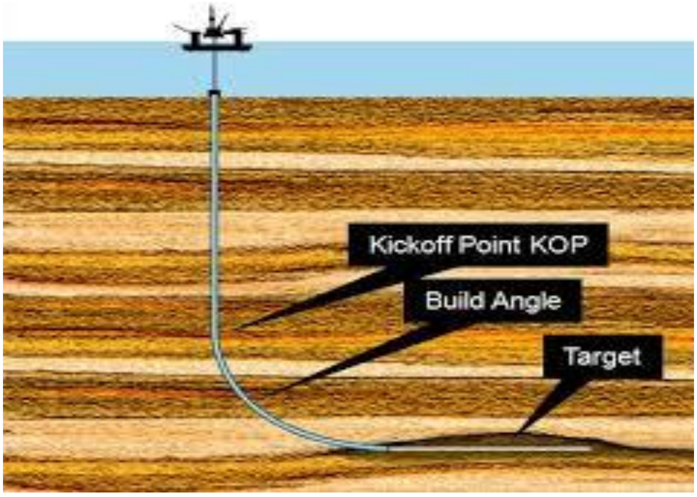

Figure 24: explaining draw of horizontal drilling

8-2 Drilling Methods and Some Associated Hardware

The initial linear portion of a horizontal well, unless very short, is typically drilled using the same rotary drilling technique that is used to drill most vertical wells, wherein the entire drill string is rotated at the surface. The drill string minimally consists of many joints of steel alloy drill pipe, any drill collars (essentially, heavy cylinders) needed to provide downward force on the drill bit, and the drill bit itself.

Depending on the intended radius of curvature and the hole diameter, the arc section of a horizontal well may be drilled either conventionally or by use of a drilling fluid-driven axial hydraulic motor or turbine motor mounted downhole directly above the bit. In the latter instance, the drill pipe above the downhole motor is held rotationally stationary at the surface. The near-horizontal portions of a well are drilled using a downhole motor in virtually all instances.

It is possible to drill the arc section of the well bore because the apparently rigid drill pipe sections are, in fact, sufficiently flexible that each can be bent a distance off the initial axis without significant risk of incurring a structural failure such as buckling or twisting off. The smaller the pipe diameter and the more ductile the steel alloy, the greater the deviation that can be achieved within a given drilled distance. That is, the smaller the arc's radius can be made, or the larger the arc's build angle2 can be.

Downhole instrument packages that telemeter various sensor readings to operators at the surface are included in the drill string near the bit, at least while drilling the arc and near-horizontal portions of the hole. Minimally, a sensor provides the subsurface location of the drill bit so that the hole's direction, as reflected in its azimuth and vertical angle relative to hole length and starting location, can be tightly controlled. Control of hole direction (steering) is accomplished through the employment of at least one of the following:

• a steerable downhole motor
• various "bent subs"
• pipe stabilizers.

" Bent subs" are short sub-assemblies that, when placed in the drill string above the bit and motor, introduce small angular deviations into the string. Pipe stabilizers are short sub-assemblies that are wider than the drill pipe, but usually slightly narrower than the bit diameter. They are included at intervals along the drill string wherever precise lateral positioning of the pipe in the hole is needed. If they are symmetrical, they simply center the pipe within the drilled hole. If asymmetrical, they will induce a small angle between the pipe and the hole wall. All of these devices can be obtained in lower cost versions where the induced angular deviation can only be adjusted at the surface, or in higher cost versions that can be remotely adjusted while they are downhole. The additional cost of remote control capability may, in many instances, be outweighed by time-related savings, due to a substantial reduction of the number of trips3 needed, many of which would be made for the sole purpose of direction adjustment.

Additional downhole sensors can be, and often are, optionally included in the drill string. They may provide information on the downhole environment (for example, bottom hole temperature and pressure, weight on the bit, bit rotation speed, and rotational torque). They may also provide any of several measures of the physical characteristics of the surrounding rock and its fluid content, similar to those obtained via conventional wireline well logging methods, but in this case obtained in real time while drilling ahead. The downhole instrument package, whatever its composition, is referred to as a measurement-while-drilling (MWD) package.

8-3 Some New Terminology

The advent of commercial horizontal drilling has inevitably added new abbreviated terms to the "oil patch" lexicon. Expanding beyond the "old standard" vertical well statistic TD, denoting the total depth of a hole as measured along the length of the bore, the following terms, which appear frequently elsewhere in this article, are now widely used to quantify the results of horizontal drilling:

Abbreviated Term	**Stands for**	**Denotes**
TVD	Total Vertical Depth	Total depth reached as measured along a line drawn to the bottom of the hole that is also perpendicular to

		the earth's surface
MSD	Measured Depth	Total distance drilled as measured along the well bore. Note that in a vertical hole, MSD would equal TD.
HD	Horizontal Displacement	Total distance drilled along the quasihorizontal portion of the well bore

Table 1 : new terminology

Conclusion

The energy business is the largest business in the world. This will continue because the standard of living in most countries is now tied to the ability to find and use energy efficiently. Well drilling continues to be an important part of the efficient use of energy, regardless of whether the well is producing hydrocarbons or water, or permanently disposing wastes by injecting them into deep layers in the earth.

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