Fundamentals Of Petroleum Engineering

DRILLING OPERATIONS

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COURSE CONTENTS

- Introduction
- Types of Oil Rigs
- Rotary Drilling
- Well Control
- Drilling Procedure
- Directional Drilling
- Drilling Problems

Introduction – Drilling Team

Comprises of:

- Drilling contractor's personnel –Noble or Trident or Forex.
- Operating company representatives – Petronas Carigali, ExxonMobil, Shell, Murphy.
- Service companies –Halliburton, Schlumberger, BJ Services .
- Supply companies –catering services, supply boat, etc.

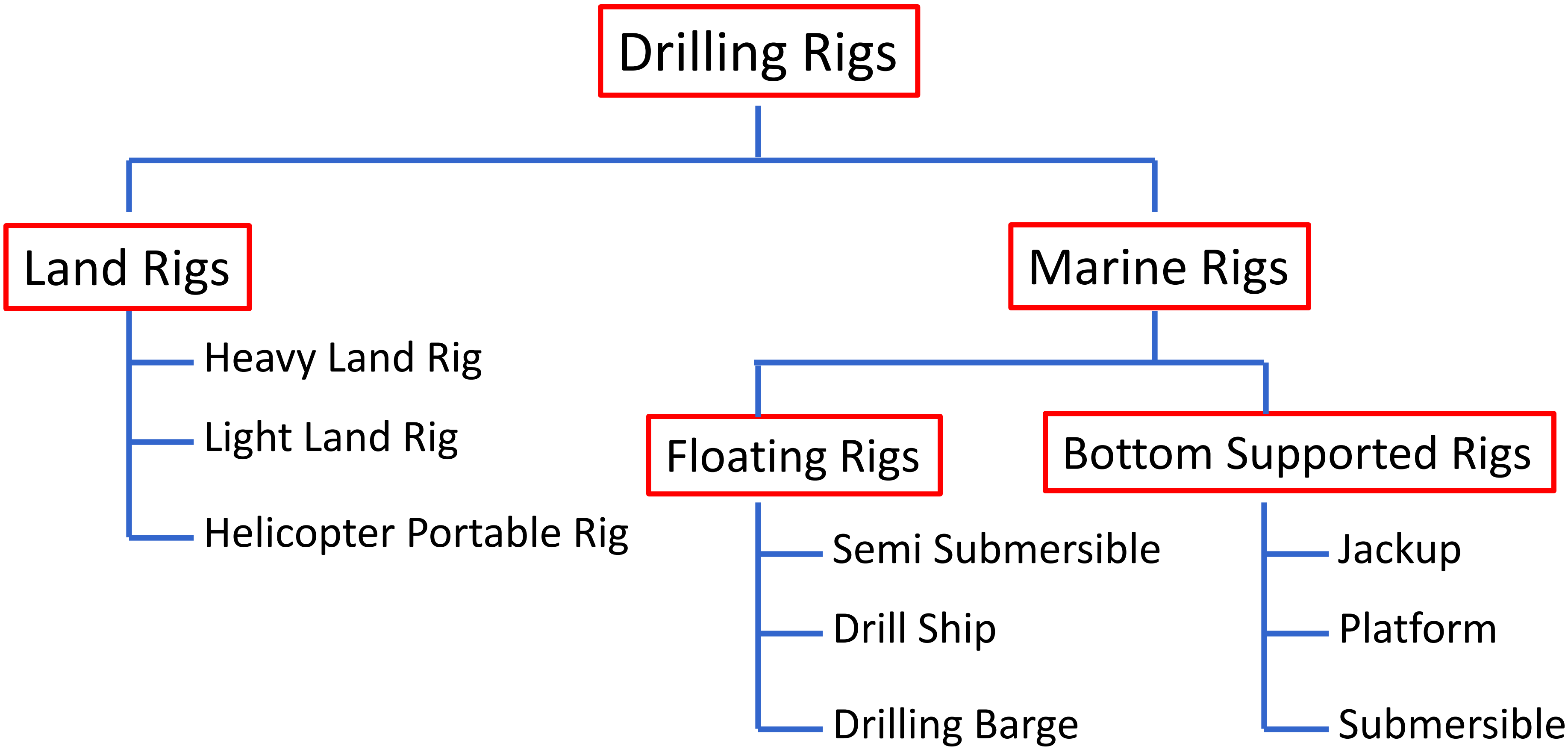
Introduction – Function of Drilling Engineer

- To prepare drilling programs; modified drilling program cost estimates including AFEs (Authorization for Expenditure); bid specification for drilling contractor; drilling contracts.
- There are various drilling contracts: daily rate, turnkey, footage rate, and incentive.
- To work with geologist (on logging program), and other specialists such as directional engineers, mud engineer, service and supply personnel.

Type of Drilling Rigs

- All rigs have the same basic components.
- Land rigs: jackknife or cantilever rigs and portable-masts.
  - Main design features are portability and maximum operating depth. Derricks are built on locations.
- Marine (or offshore) rigs: bottom-supported offshore rigs, semi-submersible floating rig, drill- ship floating rig.
  - Main design features are portability and maximum water depth (WD) of operation.

Type of Drilling Rigs



A typical classification of rotary drilling rigs

Types of Oil Rigs – Land Rigs

The sequence of operations is as follows when a land well is drilled:

- Prepare location before rig arrives.
- Dig cellar
  - Install conductor pipe
  - Prepare support pad for rig, camp, etc
  - Build roads, fencing, dig pits
  - Sometimes drill water well.
- Move rig on to location, rig up and prepare to start drilling.

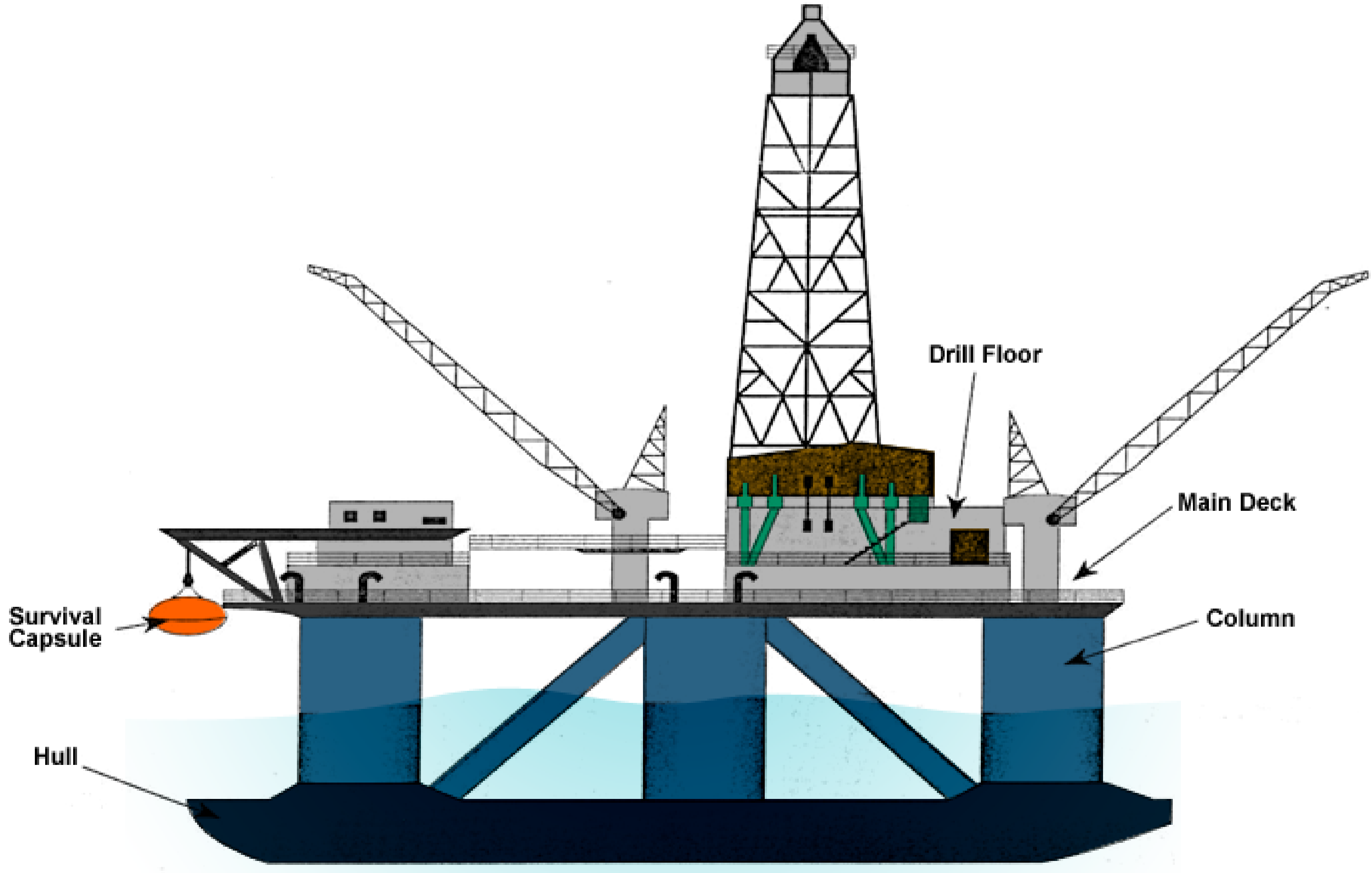
Offshore Drilling Rigs

- Two main types:
  - floating
  - bottom-supported unit
- Floating unit include: semisubmersible (bottle-type, column stabilized), barge rig and drill ship.
- Bottom-supported unit include: submersible (posted barges, bottle-type submersibles, arctic submersibles), jackups and platforms.

(1). Semi Submersible

- This floating drilling unit has columns when flooded with seawater, cause the structure submerge to a predetermined depth.
- Although it is moved by wave action, it sits low with a large part of its structure under water combined with eight huge mooring anchors, make it a very stable installation.
- This type of rig drills a hole in the seabed then it moves to the next location.
- With advancing technology some semi submersibles can drill in water depths over five thousand feet.

Semi Submersible



A COLUMN-STABILIZED SEMISUBMERSIBLE RESTS BELOW THE WATERLINE WHILE DRILING

(2). Platform

- This immobile structure can be built from concrete or steel and rests on the seabed.
- When oil or gas is located a platform may be constructed to drill further wells at that site and also to produce the hydrocarbon.

Steel Jacket Platform

- Most common type of platform
- Consist of the jacket, a tall vertical section made of tubular steel members.
- Supported by piles driven into the seabed.
- Additional sections on top of the jacket provide space for drilling rig, crew quarters, and other equipments.

Steel Jacket Platform

Concrete Gravity Platform

- Build from steel reinforced concrete
- Tall caissons, or column are the dominant feature of this platform.
- Sometime, special concrete cylinder are fixed at the base of the caissons on the sea floor to store crude oil.

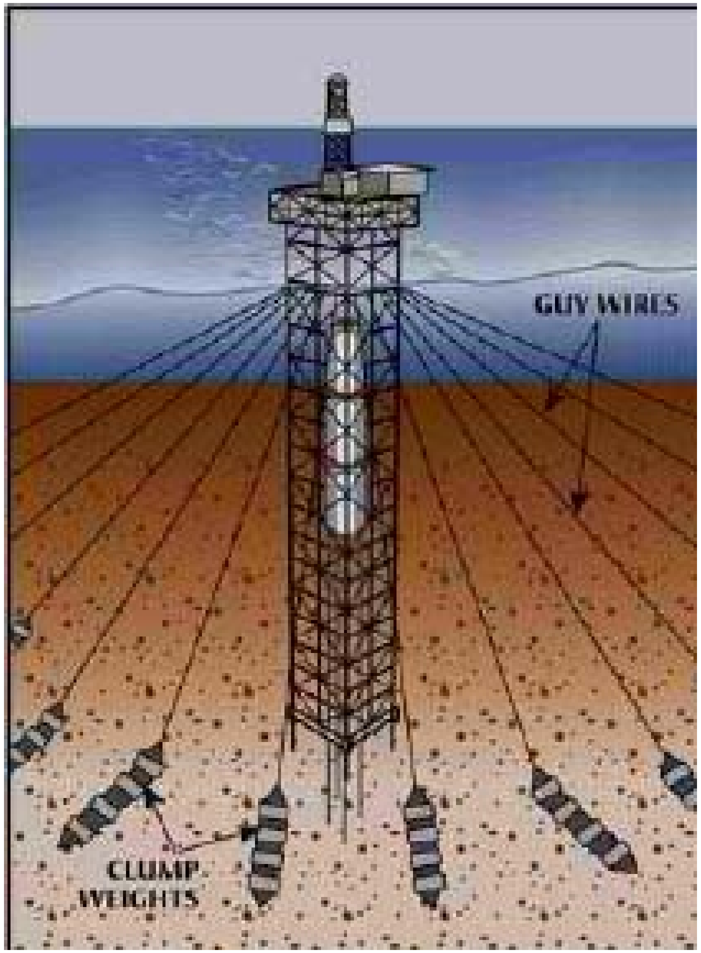
Steel-Caisson Platform

- Specifically for use in cold area – where fast-moving tidal currents carry pack of ice that can destroy steel-jacket.
- The caissons are made of two layers of thick steel to prevent ice damage.

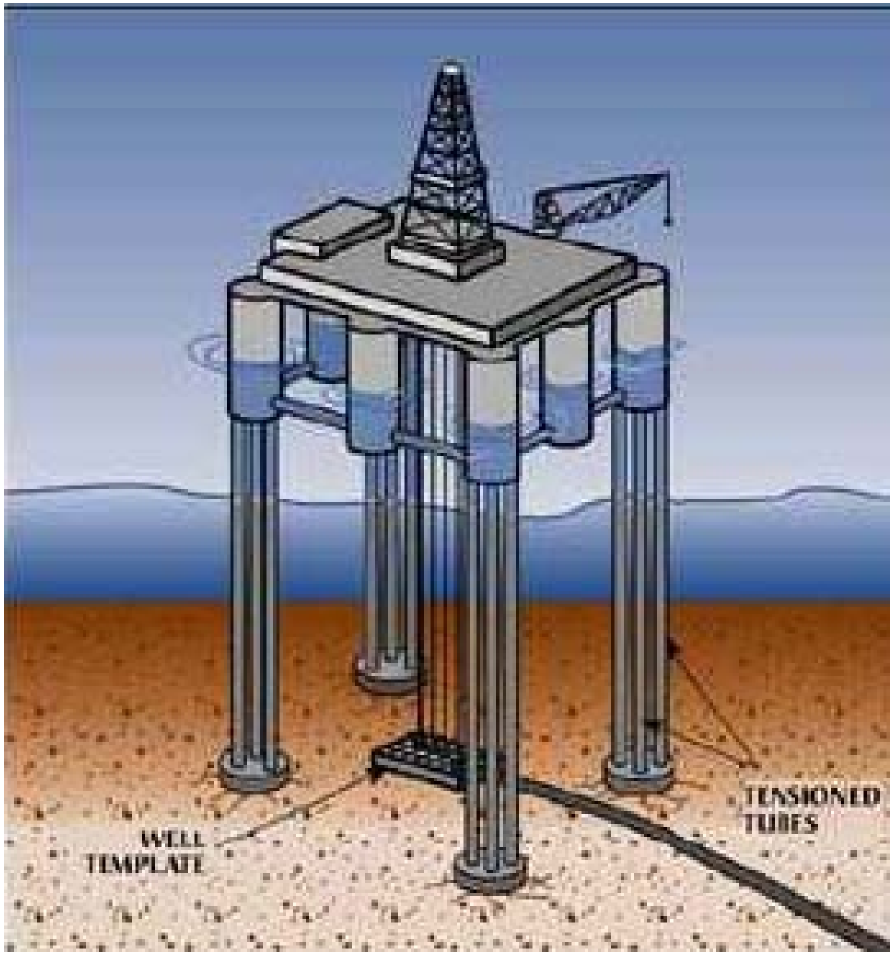
Compliant Platform

- Using rigid platform in water much over 1000 feet depth is not practical – very much expensive to build.
- In deep water, most companies use compliant platform, which contain fewer steel parts and are lighter than rigid steel-jacket.
- Guyed-tower platform and tension-leg platform.

Compliant Platform



Guyed tower platform



Tension Leg Platform (TLP)

(3). Jack up

- This is a mobile drilling rig, different from the semi submersible. Instead of floating over its drilling location the Jackup has long leg structures, which it lowers to and into the seabed raising the rig out of the water.
- The obvious limitation with this type of installation is the depth of water it can operate in.
- The maximum being five hundred feet.

(4). Drill Ship

- As the name suggests this is a ship shaped drilling vessel.
- Unlike the semi submersible and the Jackup, it does not require tugboats to tow it to location.
- Although they are not as stable as semi submersibles they also drill in very deep waters.

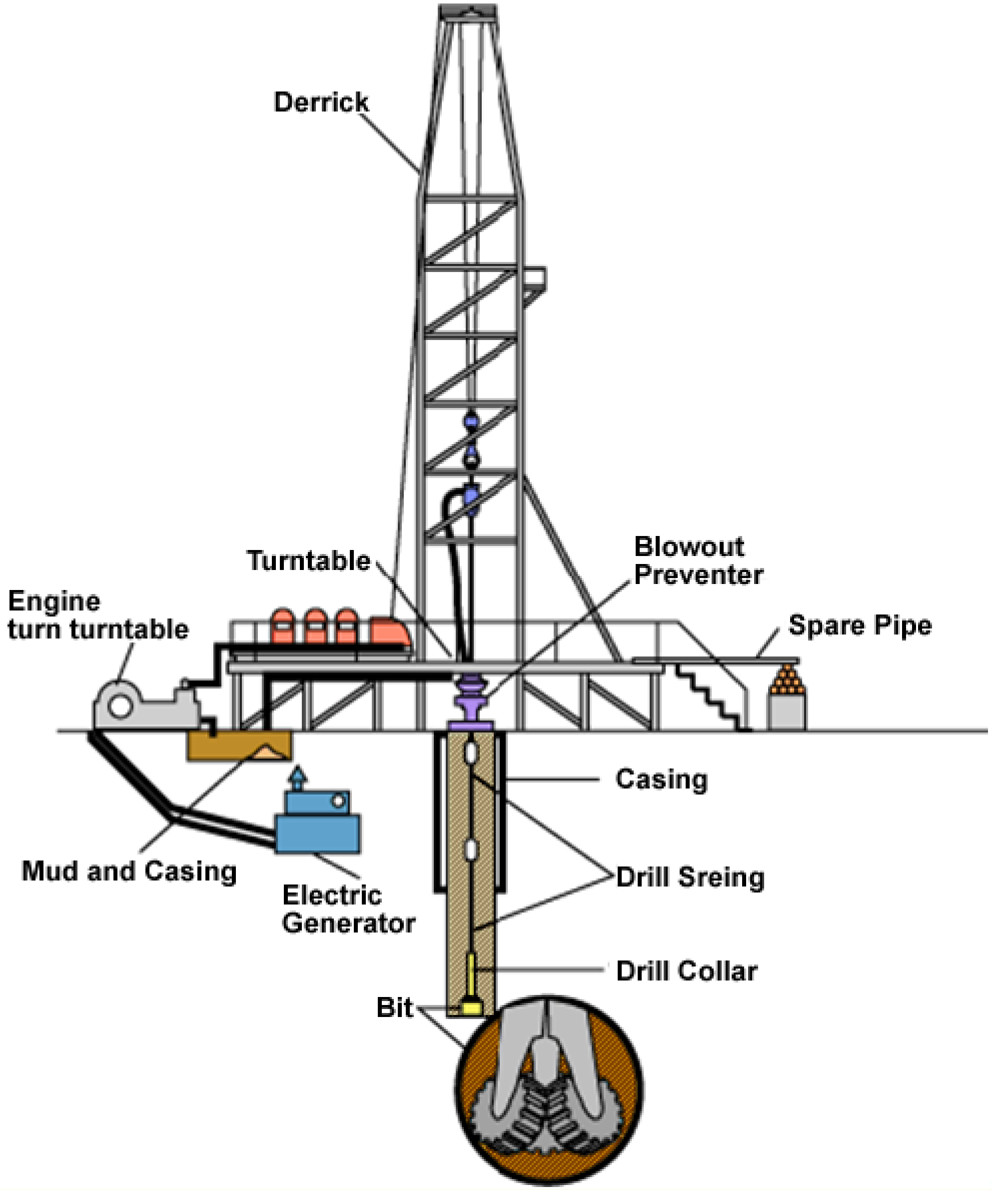
5. FPSO

- Floating Production, Storage and Offshore Loading
- They are attached to a seabed well head and they produce and store the oil until another tanker takes it from them.
- They are used to produce from small wells where it would be too expensive to build a platform.

Rotary Drilling

- Rotary drilling uses a sharp, rotating drill bit to dig down through the Earth's crust.
- The spinning of the drill bit allows for penetration of even the hardest rock.
- The actual mechanics of modern rigs are quite complicated. In addition, technology advances so rapidly that new innovations are being introduced constantly.
- A rotary drilling rig with some of its major components identified is illustrated in the next figure.

Rotary Drilling



Rotary Drilling

- The basic rotary drilling system consists of four groups of components.
  - Prime movers
  - Hoisting equipment
  - Rotating equipment
  - Circulating equipment

Prime Movers

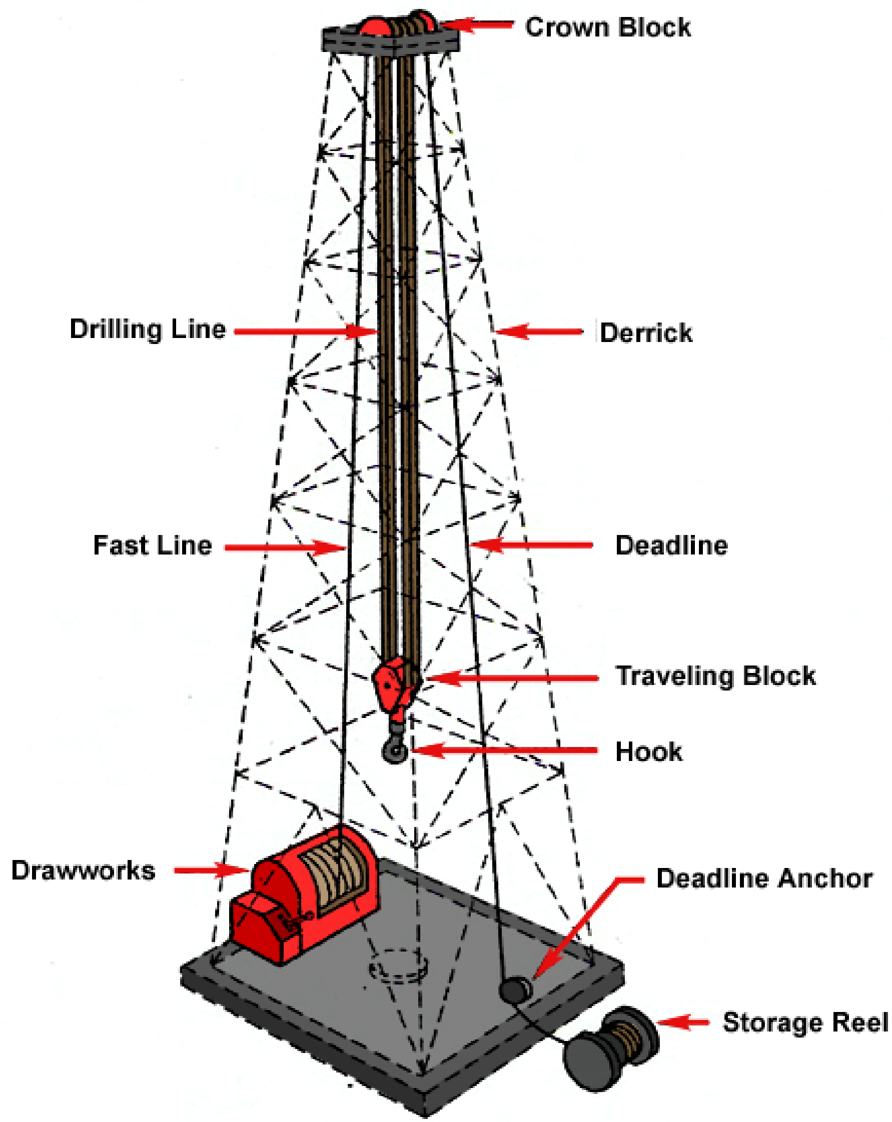
- The prime movers in a rotary drilling rig are those pieces of equipment that provide the power to the entire rig.
- Recently, while diesel engines still compose the majority of power sources on rotary rigs, other types of engines are also in use.
- Some rotary rigs may use electricity directly from power lines. Most rotary rigs these days require 1,000 to 3,000 horsepower, while shallow drilling rigs may require as little as 500 horsepower.
- The energy from these prime movers is used to power the rotary equipment, the hoisting equipment, and the circulating equipment.

Hoisting Equipments

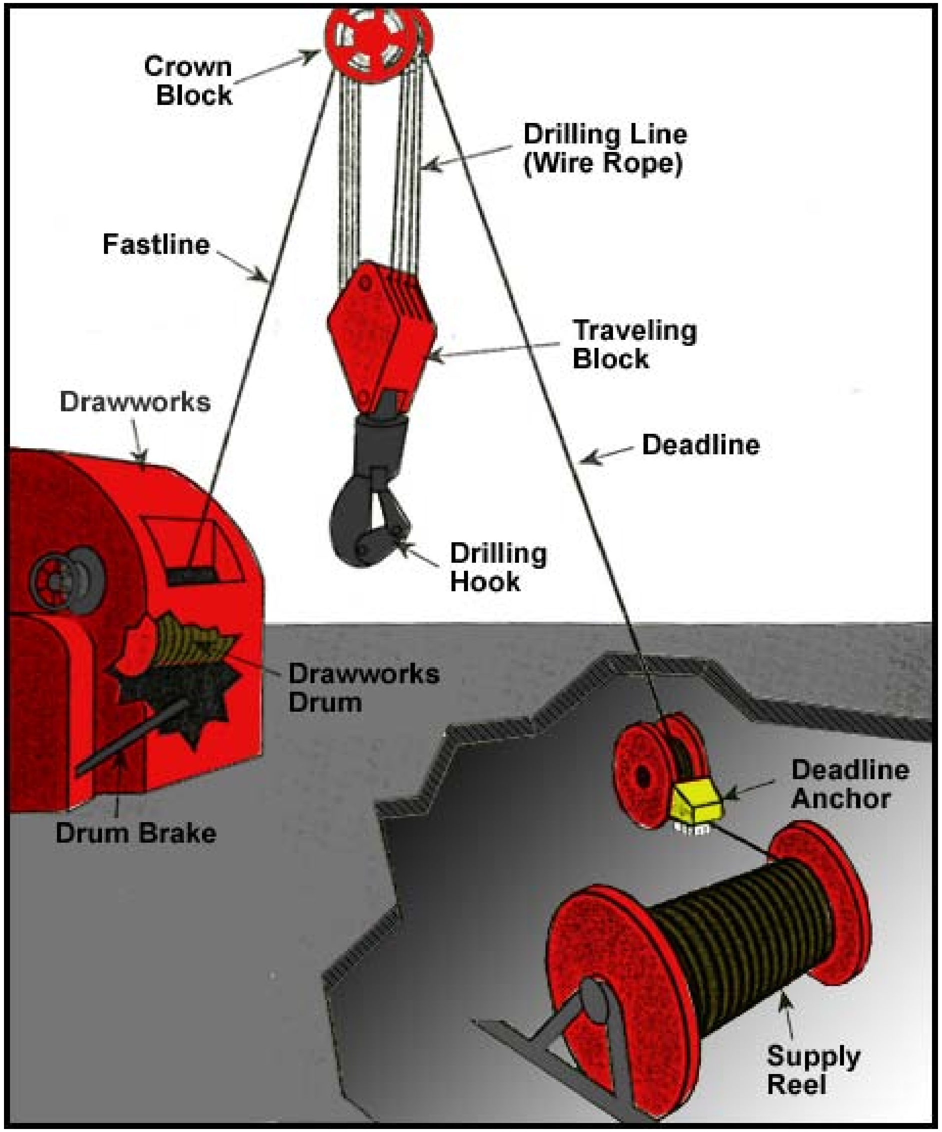
- The hoisting equipment on a rotary rig consists of the tools used to raise and lower whatever other equipment may go into or come out of the well.
- The most visible part of the hoisting equipment is the derrick, the tall tower-like structure that extends vertically from the well hole.
- The hoisting system is made up of the drawworks, derrick, crown block, traveling block, hook and wire rope.
- If a drill bit needs to be changed, either due to tear or a change in the subsurface rock, the whole string of pipe must be raised to the surface.

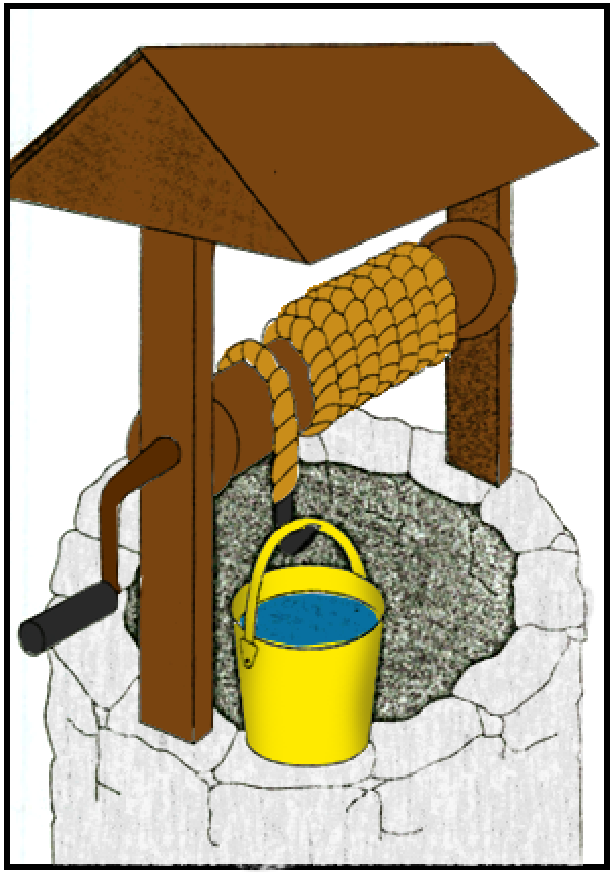
Hoisting Equipments

- The hoisting equipment is used to raise all of this equipment to the surface so that the drill bit may be replaced.



Hoisting Equipments





A Windlass hoists water from a well

Hoisting Equipments

Derrick or Mast

- Whenever the drillstem is suspended by the traveling block and drill line, the entire load rests on the derrick.
- The standard pyramid derrick is a structure with four supporting legs resting on a square base.
- In comparison, a mast is much more slender and may be thought of as sitting on one side of the rig floor or work space.
- The derrick is erected on a substructure which supports the rig floor and rotary table and provides work space for the equipment on the rig floor.

Hoisting Equipments: Derrick

- The derrick and its substructure support the weight of the drillstem at all times, whenever it is suspended from the crown block or resting in the rotary table.
- The height of the derrick does not affect its load-bearing capacity, but it is a factor in the length of the sections of drillpipe that can be removed.

Hoisting Equipments

- Travelling Block, Crown Block, Drill Line & Hook
  - Use to connect the supporting derrick with the load of drillpipe to be lowered into or withdrawn from the borehole. During drilling operations, this load usually consists of the weight of the drillpipe, drill collars and drill bit.
  - The drill line passes from the drawworks to the top of the derrick. From here is sheaved between the crown block and traveling block to give an eight, ten or twelve-line suspension. It is then clamped to the rig floor by the deadline anchor.

Hoisting Equipments: Blocks, Drill Line & Hook

- Suspended from the travelling block, on standard drilling systems, is the hook which when drilling carries the swivel and kelly and when tripping it lifts the drillstring.

Hoisting Equipments

- **The Drawworks**
  - The drawworks is a mechanism commonly known as a hoist. The main purpose of the drawworks is to lift the drillstring out of and to lower it back into the borehole.
  - The drill line is reeled (spooled) on a drum in the drawworks.
  - When engaged, the drum turns and either reels in the drill line to raise the traveling block, or lets out the drill line to lower it. Because the drillstem is attached to the block, it is raised or lowered.
  - One outstanding feature of the drawworks is the brake system, whichenables the driller to easily control a load of thousands of pounds of drillpipe or casing.

Hoisting Equipments: Drawworks

- An integral part of the drawworks is the gear (transmission) system. This gives the driller a wide choice of speeds for hoisting the drillstring.
- The drawworks also has a drive sprocket that drives the rotary table by means of a heavy-duty chain. In some cases, however, the rotary table is driven by an independent engine or electric motor.
- Another feature of the drawworks are the two catheads. The make-up cathead, on the drillers side, is used to spin up and tighten the drillpipe joints. The other, located opposite the driller's position on the drawworks is the breakout cathead. It is used to loosen the drillpipe when the drillpipe is withdrawn from the borehole.

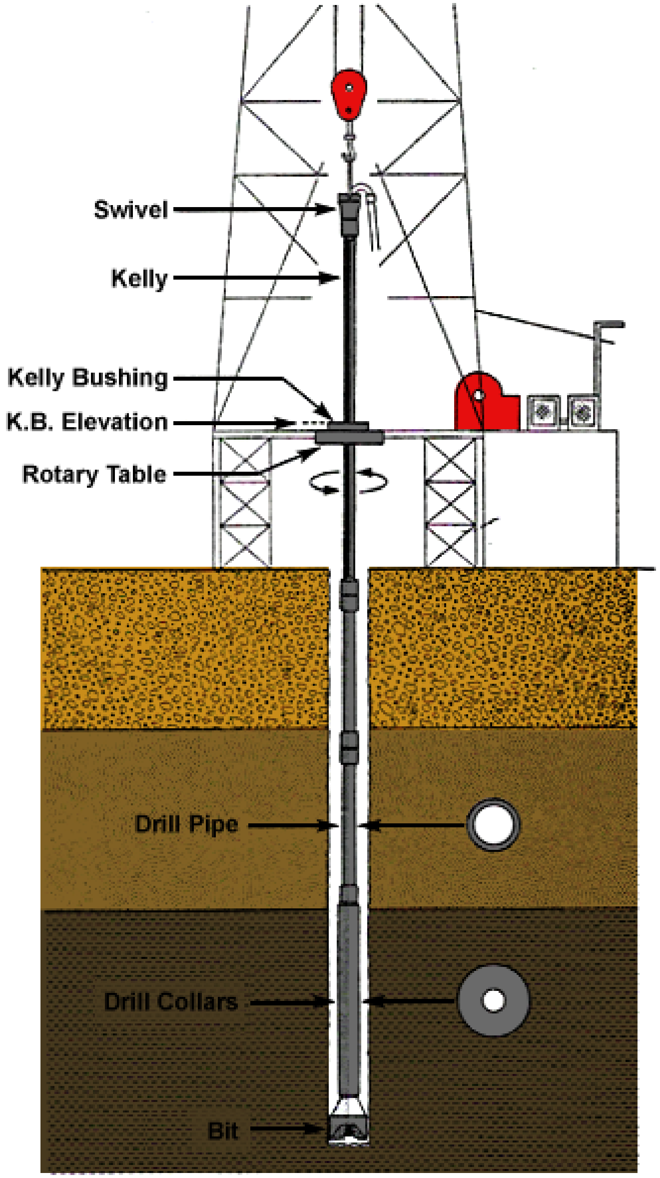
Rotating Equipments

- The rotating equipment consists of components that actually serve to rotate the drill bit.
- Rotating equipment from top to bottom consists of swivel, a short piece of pipe called the kelly, rotary table/topdrive, drill string and bit.
- A component called the swivel, which is attached to the hoisting equipment, carries the entire weight of the drillstring, but allows it to rotate freely.
- The drill bit is located at the bottom end of the drillstring, and is responsible for actually making contact with the subsurface layers, and drilling through them.

Rotating Equipments

- There are four main types of drill bits, each suited for particular conditions.
  - Steel Tooth Rotary Bits (most basic type).
  - Insert Bits (tungsten carbide inserts).
  - Polycrystalline Diamond Compact Bits (diamond inserts).
  - Diamond Bits (diamonds implanted in them).
- Diamond bits are forty to fifty times harder than traditional steel bits.

Rotating Equipments



Rotating system; the figures at bottom left indicate the comparative sizes of the drill pipe and drill collar.

Rotating Equipments

- **Swivel**
  - The swivel hangs from the drilling hook by means of large bail, or handle. The swivel is not rotate, but allow everything below it to rotate.
  - Drilling fluid is introduced into the drillstem through a gooseneck connection on the swivel, which is connected to the rotary hose.

Rotating Equipments

- ## Power Swivel

  - When a ‘top-drive’ system is used, the swivel is replace by power swivel.
  - The power swivel performs the same functions as the ‘normal swivel’, but it is also associated with a transmission system used to rotate the drill string, instead of the rotary table transmitting this motion.

Rotating Equipments

- **Kelly**
  - The kelly is approximatel 40 feet long, square or hexagonal on the outside and hollow throughout to provide a passage way for the drilling fluid.
  - Its outer surfaces engages corresponding square or hexagonal surfaces in the kelly bushing.
  - The kelly bushing fits into a part of rotary table called master bushing. Powered gears in the rotary table rotate the master bushing, and thus the kelly bushing.
  - The kelly bushing will rotate the kelly and everything below it to rotate

Rotating Equipments

Drill String

- The drillstring is made up of the drillpipe, drill collars, and specialized subs through which the drilling fluid and rotational power are transmitted from the surface to the bit.
- Drill pipe and drill collar come in sections, or joints, about 30 feet long.
- The most commonly used diameters of drill pipe are 4, 4½, and 5 inches OD.
- The purpose of drill collars is to put extra weight on he bit, so they are usually larger in diameter than drill pipe and have thicker walls.

Rotating Equipments: Drill String

- Drill pipe and drill collars have threaded connection on each end.
- On drill pipe the threaded connection are called tool joints. Tool joints are steel rings that are welded to each end of a joint of drill pipe. One tool joints is a pin (male) connection, and the other is a box (female) connection.
- Specialized Subs: The word “sub” refers to any short length of pipe, collar, casing, etc., with a definite function.

Rotating Equipments

Drill Bit

- At the bottom of drillstring is a the bit, which drills the formation rock.
- Most common types are roller cone bits and diamond bits.
- The bit size: range from 3¾ inches (9.5 cm) to 26 inches (66 cm) in diameters. The most commonly used sizes are 17½, 12¼, $7^7/_8$, and 6 ¼ inches (44, 31, 20, and 16 cm).
- Roller cone bits usually have three cone-shaped steel devices that are free to turn as the bit rotates.

Rotating Equipments: Drill Bit

- Several rows of teeth, or cutters, on each cone scrape, gouge, or crush the formation as the teeth roll over it.
- Two types: milled teeth and tungsten carbide inserts.
- Most roller cone bits are jet bits: drilling fluid exits from the bit through nozzles between the cone, thus create high velocity jets of mud. This will help lift cuttings away from the bit.

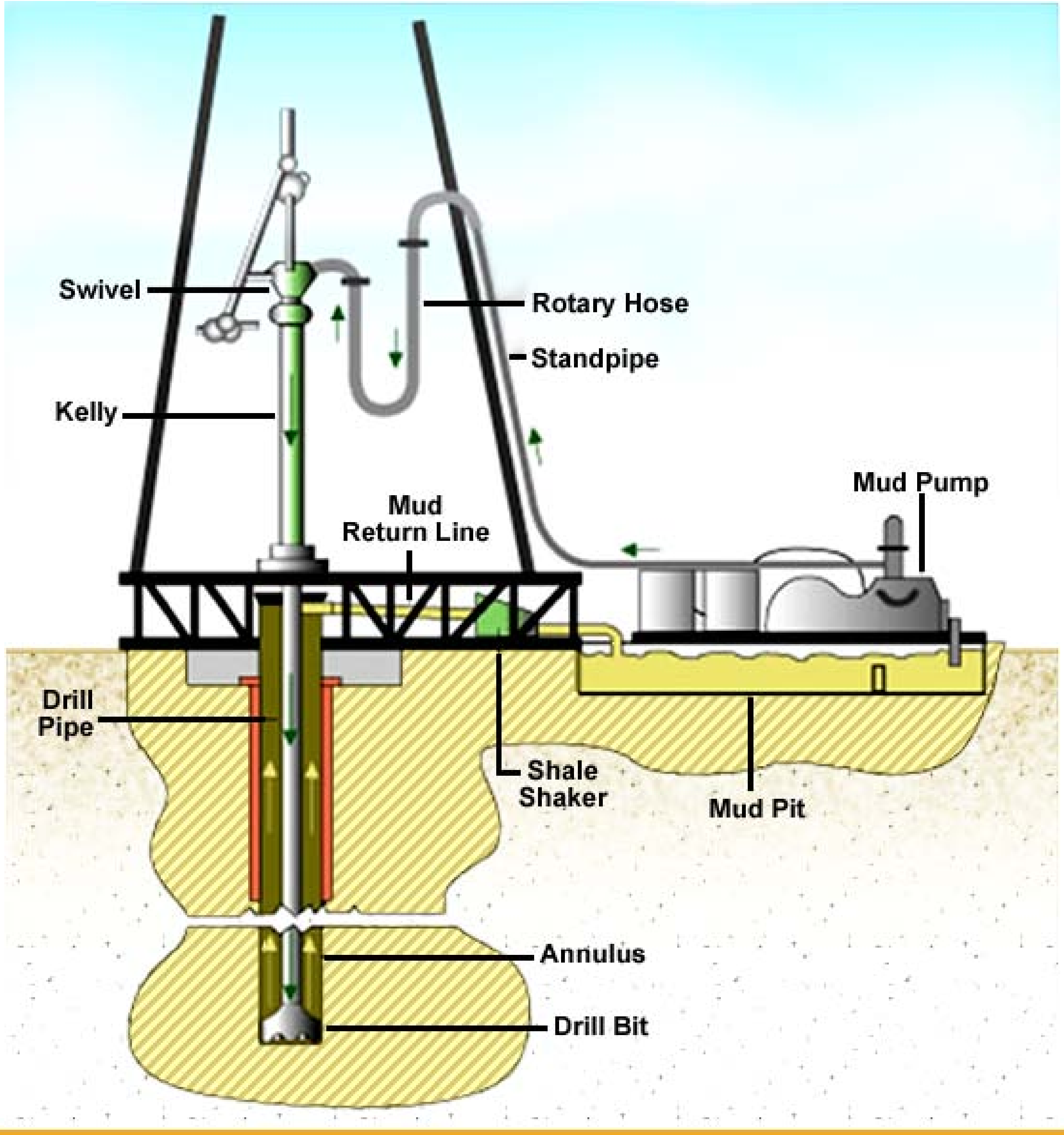
Circulating System

- There are a number of main objectives of this system:
  - Cooling and lubricating the drill bit.
  - Controlling well pressure.
  - Removing debris and cuttings.
  - Coating the walls of the well with a mud cake.
- The circulating system consists of drilling fluid, which is circulated down through the well hole.
- The most common liquid drilling fluid, known as 'mud', may contain clay, chemicals, weighting materials, water and oil.
- The circulating system consists of a starting point, the mud pit, where the drilling fluid ingredients are stored.

Circulating System

- Mixing takes place at the mud mixing hopper, from which the fluid is forced through pumps up to the swivel and down all the way through the drill pipe, emerging through the drill bit itself.
- From there, the drilling fluid circulates through the bit, picking up debris and drill cuttings, to be circulated back up the well, traveling between the drill string and the walls of the well (also called the 'annular space').
- Once reaching the surface, the drilling fluid is filtered to recover the reusable fluid.

Circulating System



Drilling Fluid

Major direct function of drilling fluid:

- To keep hole free of cuttings.
- To exert sufficient hydrostatic pressure on the formation.
- To prevent walls from caving.
- To cool & lubricate the drill string.
- To reduce friction between the hole and the drill string.
- To help suspend the weight of the drill string and casing.
- To deliver hydraulic energy to the formation under the bit.

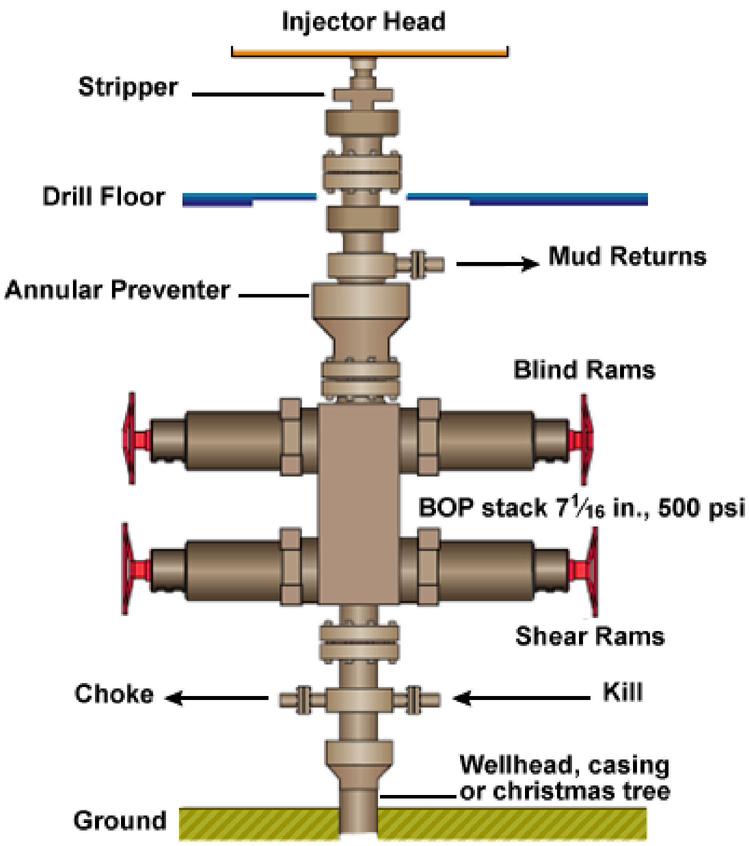
Drilling Fluid

One critical function of drilling fluid:

- When formation pressure is more than hydrostatic pressure, a kick occurs. An uncontrollable kick may cause a catastrophic blowout - perhaps the worst disaster during drilling operation.
- The effects of blowout are:
  - Loss of life.
  - Loss of drilling equipment (including the rig).
  - Loss of the well.
  - Loss of oil and gas reserves.
  - Damage to the environment.

Well Control

- Drilling fluid provides the first line of defense against blowouts.
- A hole full of mud that weighs the right amount or proper density will not blowout but sometimes the unexpected occurs.
- The second line of defense against blowout is blowout preventer (BOP).
- When closed, they form a pressure-tight seal at the top of the well and prevent the escape of fluids.



Drilling Procedure

- First, surface pipe is set. A shallow hole is drilled ofte several hundred feet deep.
- A string of surface casing is inserted into the hole and cemented in place.
- The surface casing is 10 to 20 inches in diameter, which allow the drill string and bit to pass through it for deeper drilling.
- After surface casing has been set, deeper drilling begins. A smaller bit is run inside the surface casing and continue drilling to the desired depth.
- The same process is repeated for intermediate and production casing.

Casing Accessories

- **Casing Accessories includes:**
  - Centralizer – keep the casing in the centre of the hole so that the cement distributes evenly around the outside of the casing.
  - Scratchers – help remove wall cake so that the cement can form a better bond.
  - Casing shoe, or guide shoe – fits onto the end of the last joint. It prevents the casing from snagging in irregularities in the borehole as it is lowered.
  - Float collar – a special coupling used one or two joints above the guide shoe. Contains one way valve which prevent drilling mud from entering the casing, and also prevent cement from flowing up the casing.

Cementing the Casing

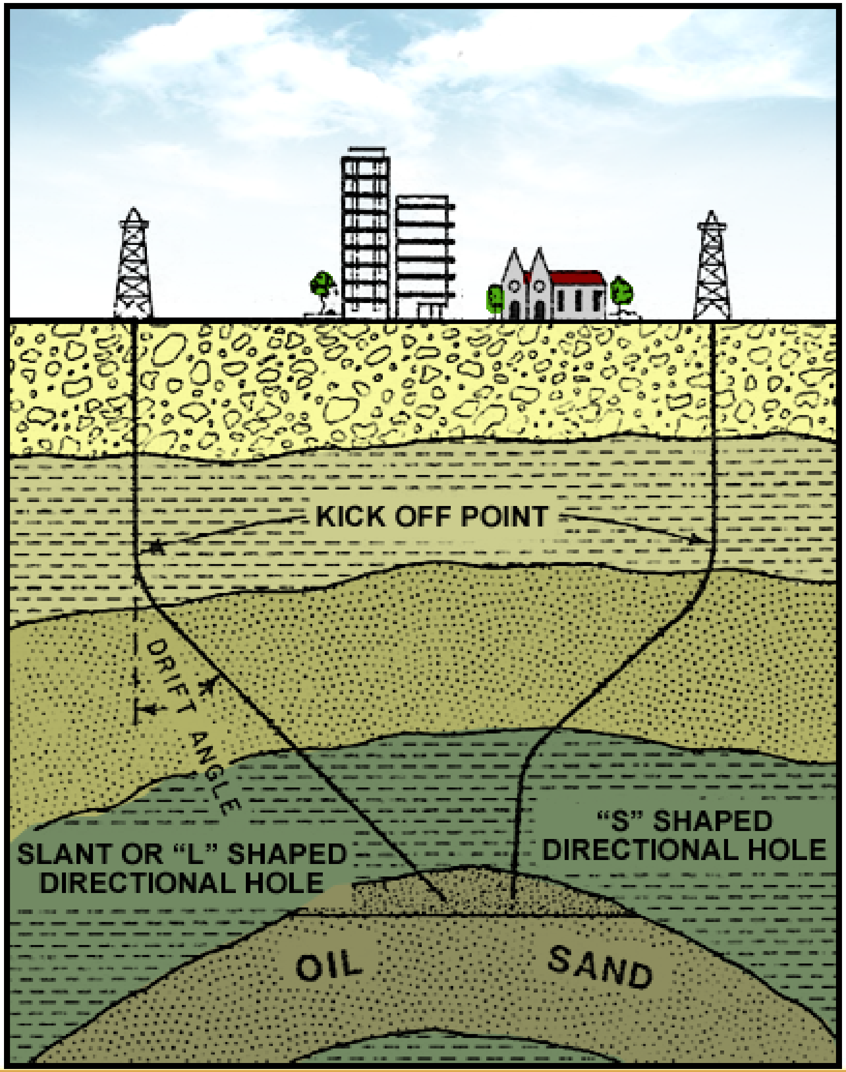
- Cement used in oilwell cementing is *portland cement*. It usually contains special additives to make it suitable for cementing a particular well. For example: A retarder required to slow down the setting time of cement.
- The cementing crew mixes the dry cement with water, to form *cement slurry*.
- The powerful cementing pumps move the slurry through a pipe to a special valve made up on the topmost joint of casing – *cementing head*, or *plug container*.
- As the slurry arrives, the *bottom plug* is released, which precedes the slurry down the casing. This plug will keep mud from contaminating the cement slurry.

Cementing the Casing

- The plug will stop in the float collar. Continued pump pressure will breaks a seal in the plug and allows the slurry to pass through it. The slurry flows out through the float collar and guide shoe and starts up the annulus until the annulus is filled.
- The crew releases a top plug and pumps a liquid, called displacement fluid (normally salt water) behind the top plug.
- When the top plug comes to rest on the bottom plug, the crew shut down the pumps and allows the slurry to harden.

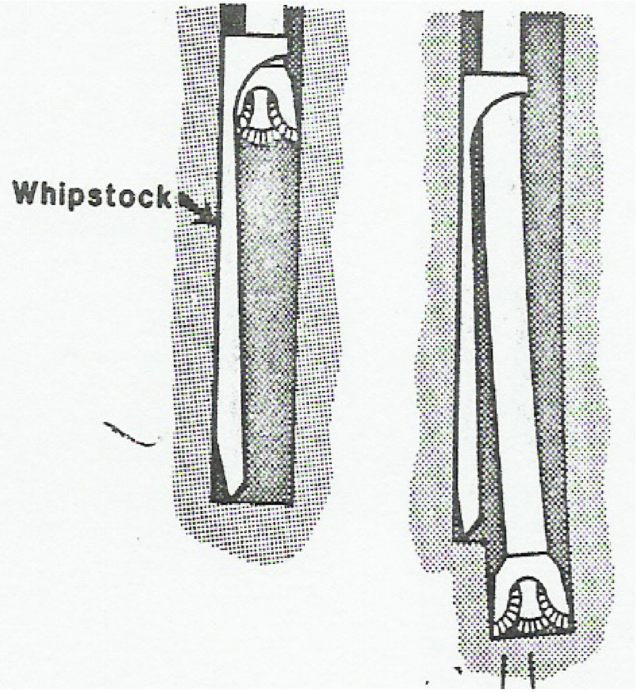
Directional Drilling

- It is often difficult to place a drilling rig directly over the spot where a well should be drilled.
- This is particularly true offshore, where a number of wells must be drilled from the same location.
- Directional drilling is the process of drilling a curved well, in order to reach a target that is not directly beneath the drill site.



Directional Drilling

- The techniques for directional drilling have become more sophisticated.
- The earliest method used was whipstock, which involves placing a wedge-shaped piece of steel at the bottom of the hole to force the bit off at desired angle.
- A more recent development in directional drilling has been the use of downhole motor.



Drilling Problems

- Stuck pipe
- Lost circulation
- Borehole instabilities
- Mobile formation
- Undergauge hole
- Kicks and blowout

(1). Stuck Pipe/Pipe Sticking

- Definition: When part of the drill pipe or collars are stuck in the hole
- If pipe cannot be rotated or pulled and circulation is good, then pipe is probably wall stuck
- Causes of pipe sticking:
  a. Differential/wall sticking
  b. Mechanical sticking
  c. Key seating

(a). Differential/Wall Sticking

- Definition: A pressure differential around the circumference of drill collars or pipe
- Wall sticking is caused by:
  - pipe is held by suction force resultant from overbalance hydrostatic pressure forcing filtrate into a permeable zone which leaves a thick mud cake on the wall of the hole
  - porous and permeable formation
  - motionless drill string

(b). Mechanical Sticking

A drill pipe can be stuck mechanically when:

- Cuttings and sloughing formations pack off the annular space around the drill string (especially during a pump shutdown period)
- Drill through several layers of formation of different hardness
- Junk dropped from surface
- The drill string is run too fast until it hits a bridge, a tight spot or the hole bottom

(c). Key Seating

- Definition: a phenomenon happens at the dogleg where a new hole is created by drill string until the drill pipe is stuck to the wall.
- When it passes through a dogleg, it tries to straighten and thus, creating a lateral force which causes the drill pipe joint to dig into the formation at the dogleg bow.
- A key-seat can only be formed if the formation is really soft and the hanging weight below the dogleg is big enough to create a substantial lateral force.
- This problem can be identified when the drill string can be moved downwards but not upwards.

(2). Lost Circulation

- One of the major problems in drilling operation.
- Occurred in almost every formation and at virtually all depths.
- Occurs when hydrostatic pressure of mud exceeds the breaking strength of the formation.
- Definition: Partial or complete loss of drilling fluid during drilling, circulating or running casing.

Type of Lost Circulation

- Those types inherent in the formation:
  - porous, permeable, and unconsolidated formations
  - cavernous or irregular formations
  - natural fractures in formations (faults, joints, fissures)
- Those openings caused by poor drilling practices:
  - induced fractures caused by high mud weights or pressure surges

(3). Shale Problem/Borehole Instability

- Shale:
  - sedimentary rock form by deposition and compaction of sediments
  - contain clays, silt water, quartz, feldspar
  - compact or unconsolidated rock depend on water content
- Definition of shale problem/borehole instability:
  - a condition where the shale section containing bentonite or other hydratable clays which continually absorb water from the mud, expands, swell & slough into the hole
  - hole instability resulting from drilling shale sections
- Other terms: sloughing shale, heaving shale, running shale

Prevention of Sloughing Shale

- Use suitable mud system to inhibit hydration (high Ca & K content, OBM, oil-emulsion, ...) to decrease the tendency of mud to hydrate water sensitive clays
- Increase circulation rate for more rapid removal of particles
- Increase mud density for greater wall support ($P_{hyd} > P_f$)
- Decrease water loss of mud
- Avoid fast trips or swabbing of the hole
- Keep flow properties & annular velocity at such a level as to insure good hole cleaning

(4). Mobile Formation

- A salt or shale can squeeze into the well bore because it is being compressed by the overburden forces
- The deformation results in a decrease in the well bore size, causing problems running BHA's, logging tools and casing and stuck pipe
- A deformation occurs because the mud weight is not sufficient to prevent the formation squeezing into the well bore
- Once broken, the hole will become enlarge

Prevention Action

- Identify salt dome
- Monitor mud chlorides and mud resistivity
- Maintain sufficient mud weight
- Select an appropriate mud system that will not aggravate the mobile formation
- Plan frequent reaming/wiper trips particularly for this section of the hole
- Slow trip speed before BHA enters the suspected area
- Minimize the open hole exposure time of these formations

(5). Undergauge Hole

- Drilling hard abrasive rock wears the bit and the stabiliser gauge and results in a smaller than gauge hole
- When a subsequent in-gauge bit is run, it encounters resistance due to the undergauge section of hole
- If the string is run into the hole quickly without reaming, the bit can jam in the undergauge hole section
- This mechanism normally occurs:
  - After running a new bit
  - After coring
  - When a PDC bit is run after a roller cone bit
  - When drilling abrasive formations

(6). Kick and Blowout

- Kick: An entry of formation fluids (gas, oil or water) into the wellbore during drilling
- Blowout: Uncontrolled flow of formation fluids (gas, oil or water) from the wellbore
- Kick and blowout can occur when hydrostatic pressure of mud is lower than the formation pressure

Causes of Kick/Blowout

- Drilling into high pressure zones (abnormal pressure)
- Swabbing when coming out of the hole
- Improper hole fill-up on trips
- Lost circulation during drilling or cementing