Drilling Rig Systems, Components and their Functions (2)

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Course Name & Code: Petroleum Drilling Engineering I (PTR 316)

5th Semester (3rd Grade Fall Semester)

Week #8/Lecture #7 (Theory)

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Previous Lecture

- Rotary Drilling Rig Systems.
  - Hoisting
  - Rotary System
- Rotary Drilling Rig Components.
- Functions of Rotary Rig Components.

Lecture Learning Outcomes

By the end of this lecture, you will be able to:

- List the main rig components and understand their functions.
- Define the 5 main rig systems and their role within the drilling process with Listing their individual components.
- Comprehend the composition of drilling string, Define its components and Differentiate between their roles.

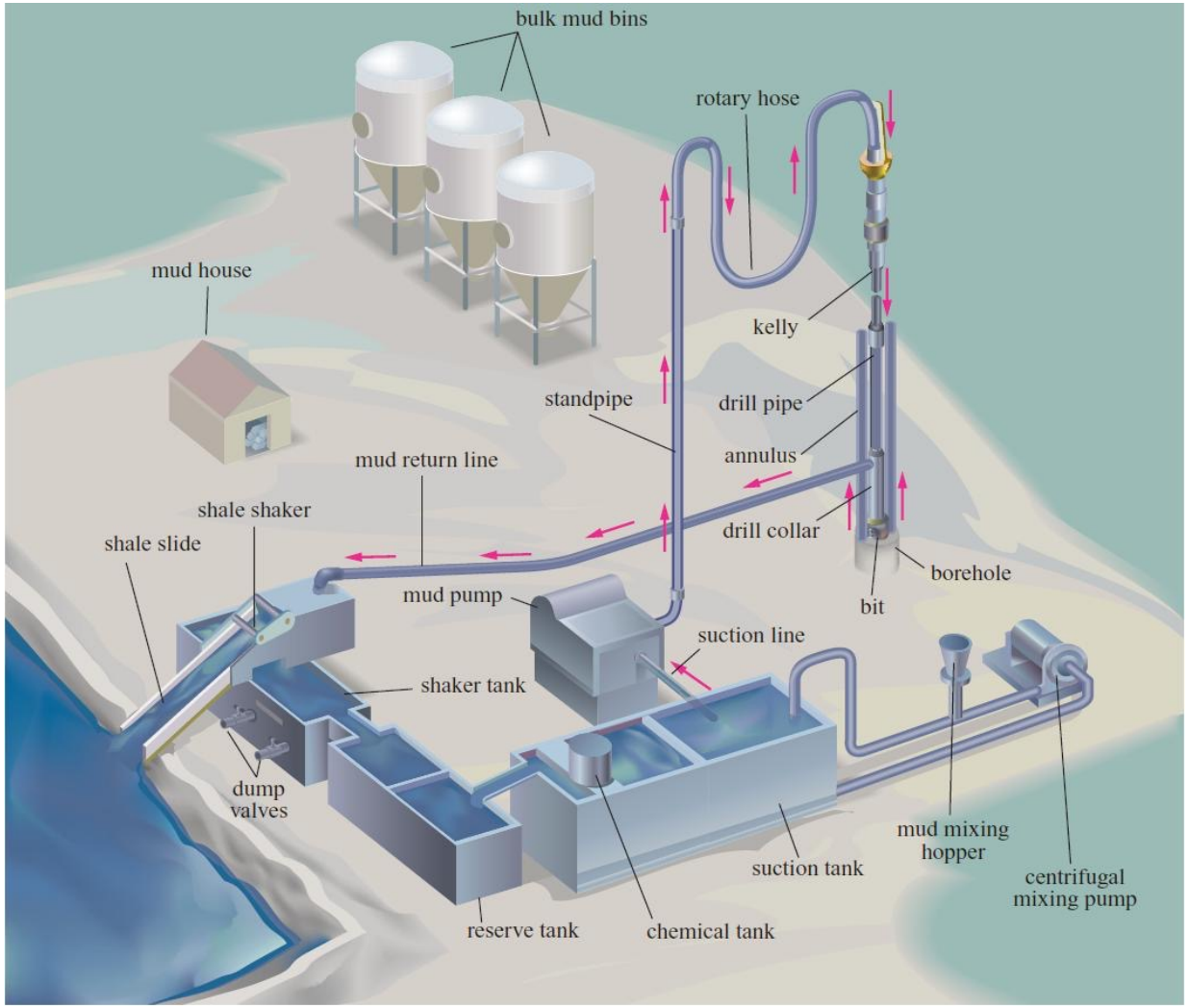
Content

- Rotary Drilling Rig Systems,
  - Circulation System
  - Well Control System
  - Power System
- Rotary Drilling Rig Components
- Functions of Rotary Rig Components
- Drill String Components.
- Types of Drill Bits.

Circulation System

Circulating equipment includes:

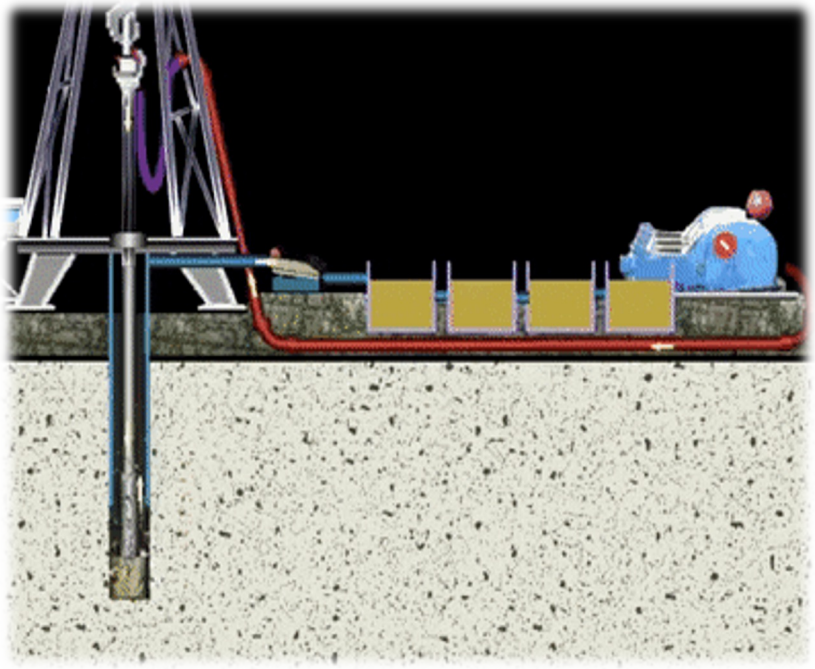
- Mud tanks
- Suction line
- Mud pump
- Discharge line
- Stand pipe
- Rotary hose
- Swivel (or top drive)
- Kelly (on rigs with a rotary-table system)
- Drill pipes, drill collars and Bit
- Annulus
- Mud return line
- Shale shaker, desilter and desander
- Others...



Circulation System

Mud Circulation Process

- The mud pump takes mud from the mud tanks through the suction line and sends it out a discharge line to a standpipe.
- The standpipe is a steel pipe mounted vertically on one leg of the mast or derrick.
- Mud flows out of the standpipe and into the rotary hose, which is connected to the swivel on rotary-table system rigs or to the top drive.
- Mud goes down the kelly on rigs with a rotary table; on rigs with a top drive, mud goes through passageways inside it.
- Once it leaves the kelly or the top drive, mud flows down the drill stem (pipe, collars, etc.), out the bit.
- It does a sharp U turn and heads back up the hole in the annulus.
- As it flows up the annulus, the mud carries the cuttings made by the bit.



Circulation System

- Finally, the mud leaves the hole through a steel pipe called the "mud return line" and falls over a vibrating, screen like device called the "shale shaker".
- The shale shaker is appropriately named, for it rapidly vibrates or shakes as the mud returning from the hole falls over it. The shale shaker acts like a sifter and screens out the cuttings.
- Except in environmentally sensitive areas on land, the cuttings fall into the reserve pit, the earthen pit excavated when the site was being prepared.
- In areas where the contractor cannot use a reserve pit because of environmental reasons, the shaker dumps the cuttings into a special receptacle.
- Later, the cuttings are properly disposed off.
- Then the mud drains back into the mud tanks where the mud pump recycles it downhole.

Circulation System

- The circulating system is essentially a closed system. The system circulates the mud over and over throughout the drilling of the well.
- From time to time, however, crew members may add water, clay, or other chemicals to make up for losses or to adjust the mud's properties as the hole drills into new and different formations.
- Several pieces of auxiliary equipment keep the mud in good shape. The shale shaker sifts out the normal-sized cuttings.
- Sometimes, though, the bit creates particles so small that they fall through the shaker with the mud.
- So, after the mud passes through the shale shaker, the system sends the mud through desanders, desilters, degaser, and mud centrifuges. These pieces of equipment remove fine particles, or small solids, to keep them from contaminating the drilling mud.

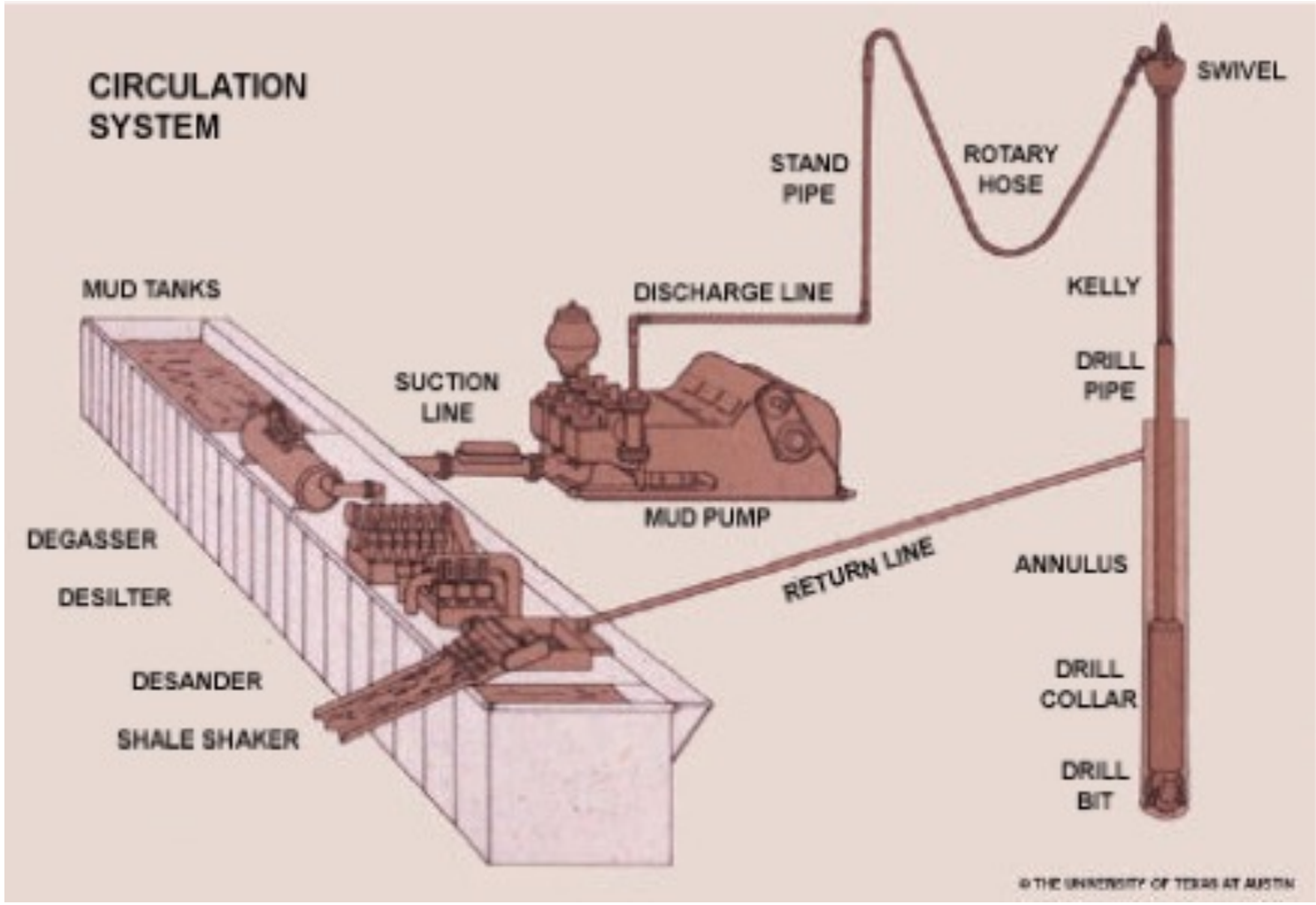
Circulation System

- A degasser removes small amounts of gas that enter the drilling mud as it circulates past a formation that contains gas.
- A degasser is used when the amount of gas is not enough to make the well a producer; instead, it is just enough to contaminate the mud.
- The driller cannot recirculate this gas-cut mud back into the hole because the gas makes the mud lighter, or less dense.
- If the mud gets too light, the well can kick (formation fluids under pressure can enter the hole). If not handled properly, a kick can lead to a blowout.

Circulation System

- To add non-corrosive and non-caustic powdered components to the drilling mud, the derrickman often uses a mud hopper.
- The derrickman opens the sack of material, places it at the top of the hopper's large funnel, and gradually adds the powder to the funnel.
- At the bottom of the hopper, a high-speed stream of mud picks up the powdered material, thoroughly mixes it, and puts it into the mud tanks.

Circulation System



Circulation System

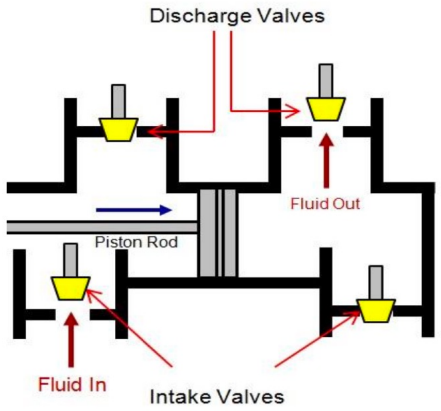
Mud Pumps

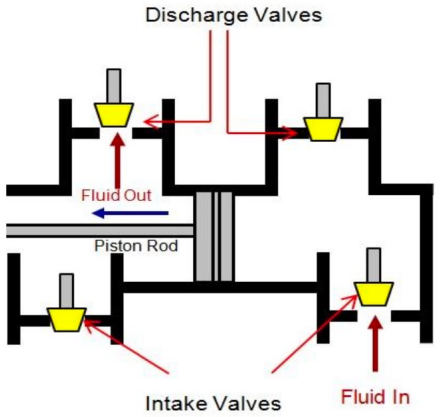
- There are two types of pumps used in the oil industry: Duplex (Two cylinders) and Triplex (Three cylinders).
- The duplex pumps generally are double-acting pumps that pump on both forward and backward piston strokes.
- The triplex pumps generally are single-acting pumps that pump only on forward piston strokes.
- Triplex pumps are lighter and more compact than duplex pumps, their output pressure pulsations are not as great and they are cheaper to operate.

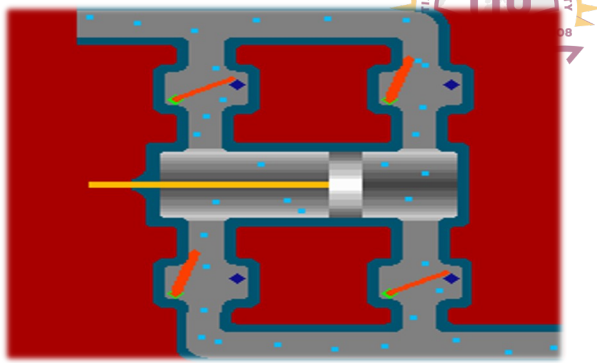
Circulation System

Mud Pumps, cont.

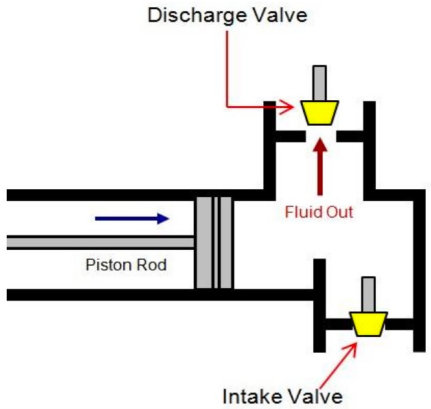
- **Duplex**

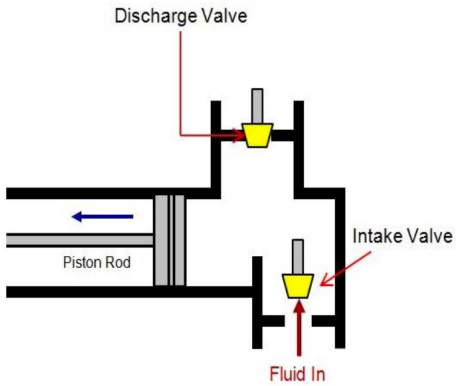


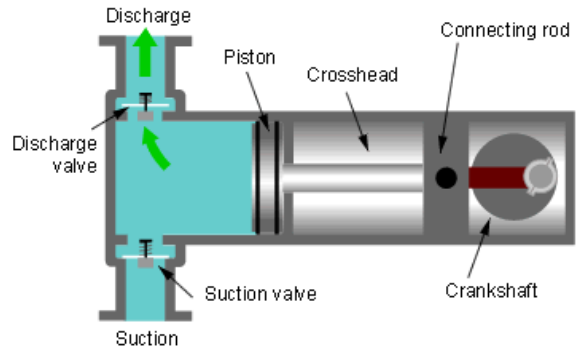


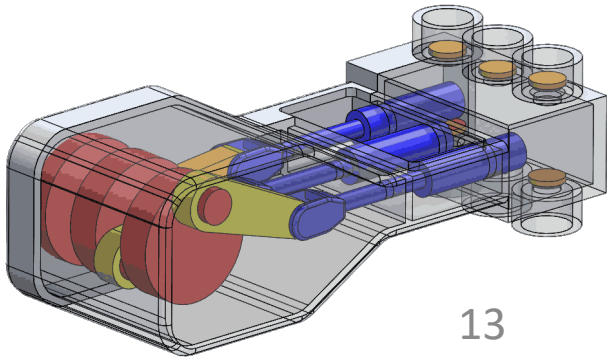


- **Triplex**





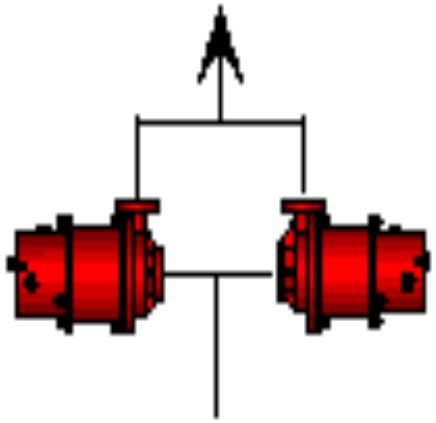


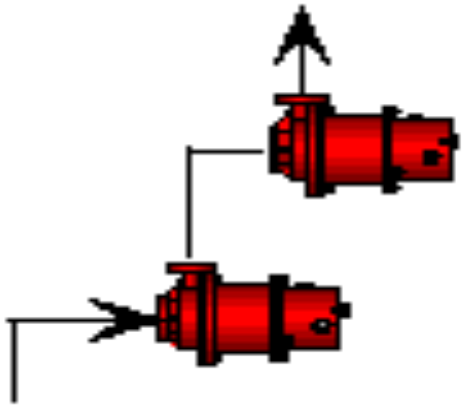


Circulation System

Pumps Arrangements

- There will be at least two pumps on the rig and these will be connected by a mud manifold.
- At shallow depths they are usually connected in parallel to deliver high flow rates. As the well goes deeper the pumps may act in series to provide high pressure and lower flow rates.





Circulation System

Pump Horsepower

- The flow rate (Q) of the pump is obtained by multiplying the pump factor by N (number of cycles or strokes per unit time).
- The Power output of a mud pump is measured in Hydraulic Horsepower. The horsepower delivered by a pump can be calculated from the following:

$$HHP = \frac{P\,Q}{1714}$$

- Where:

HHP: horsepower

Q: flow rate (gpm)

P: discharge pressure (psi)

Circulation System

Example 2:

Calculate the power requirement for the following pump:

Flow rate = 800 gpm

Pressure = 1500 psi

Mechanical Efficiency = 0.9

Solution:

$$HHP = \frac{PQ}{1714} = \frac{1500 \times 800}{1714} = 700.12\ hp$$

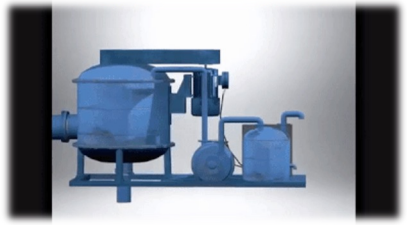
The requirement power = 700.12/0.9 = 777.91 hp.

Circulation System

Circulation System: Solid Control

Shake Shaker

Vacuum Degasser



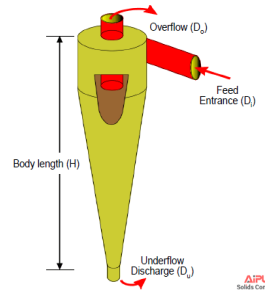
Decanter Centerfuge

Mud tank

Desilter

Desander

Hydrocyclones



Circulation System: Solid Control

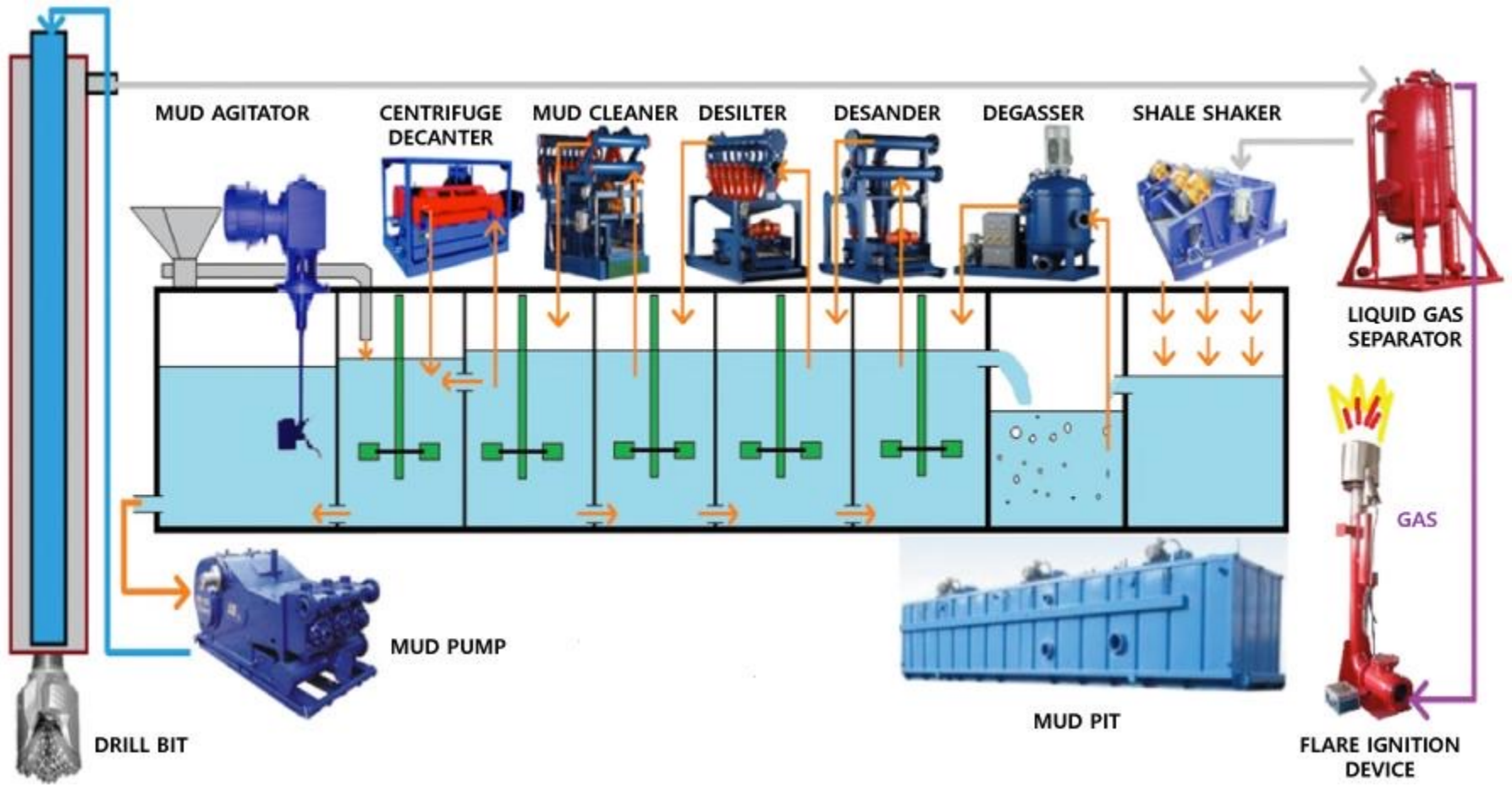
Solids Control Methods

- There are Three basic methods used to control the solids content of a drilling fluid:

A. Screening

B. Settling

C. Dilution



Well Control System

- The function of the well control system is to detect, prevent, remove the uncontrolled flow of formation fluids from the wellbore.
- When the drill bit enters a permeable formation, the pressure in the pore space of the formation may be greater than the hydrostatic pressure exerted by the mud column. If this is so, formation fluids will enter the wellbore and start displacing mud from the hole. Any influx of formation fluids (oil, gas or water) into the borehole is known as a Kick
- The well control system is designed to:
  - Detect a kick.
  - Close-in the well at surface.
  - Remove the formation fluid which has flowed into the well.
  - Make the well safe.
- Failure to do this results in the uncontrolled flow of fluids – known as a blow- out - which may cause loss of lives and equipment, damage to the environment and the loss of oil or gas reserves.

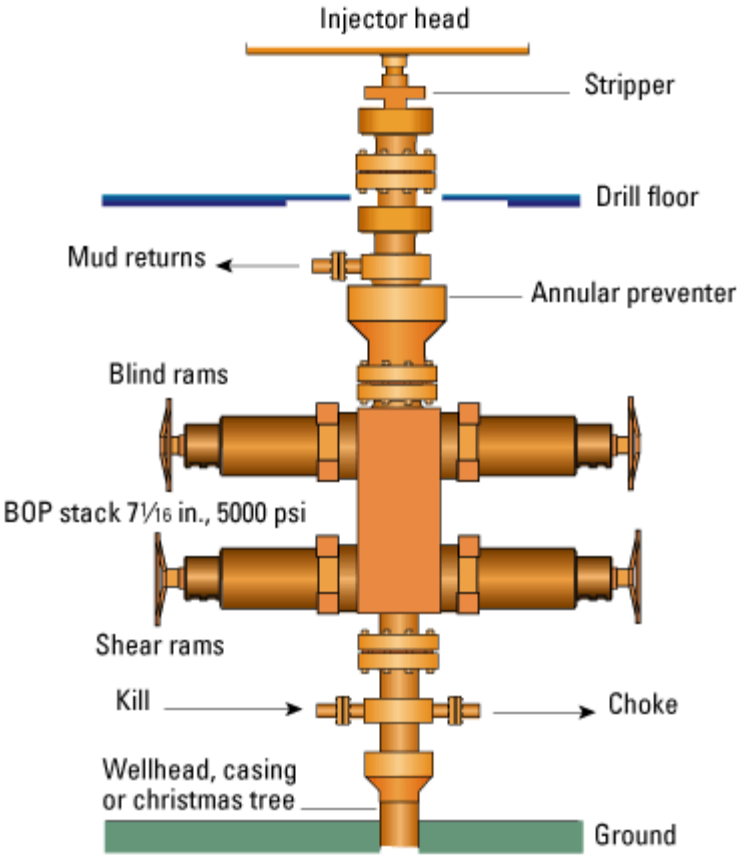
Well Control System

- Primary well control is achieved by ensuring that the hydrostatic mud pressure is sufficient to overcome formation pressure.
- And this will only be maintained by ensuring that the mud weight is kept at the prescribed value, and keeping the hole filled with mud.
- Secondary well control is achieved by using valves to prevent the flow of fluid from the well until such time as the well can be made safe.
- There are many signs that a driller will become aware of when a kick has taken place. The primary indicators of a kick are as follows:
  A. Pit volume increase
  B. Flow rate increase
  C. Flowing well with pumps shut off
  D. Pump pressure reduce

Well Control System

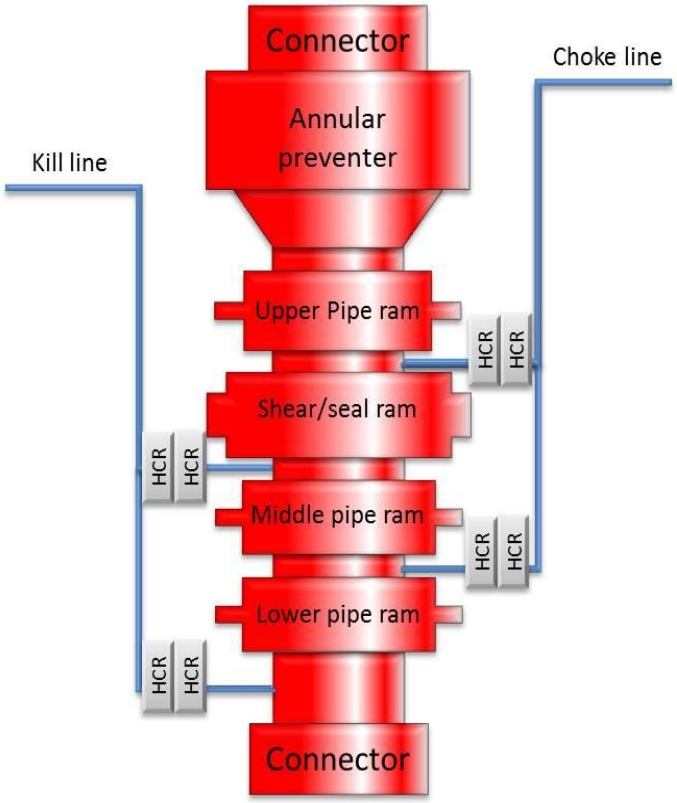
BOP Equipment

- The blowout prevention (BOP) equipment is the equipment which is used to shut in a well and circulate out an influx if it occurs.
- The main components of this equipment are the blowout preventers or BOP's. These are valves which can be used to close off the well at surface.
- In addition to the BOP's the BOP equipment refers to the auxiliary equipment required to control the flow of the formation fluids and circulate the kick out safely.



Well Control System

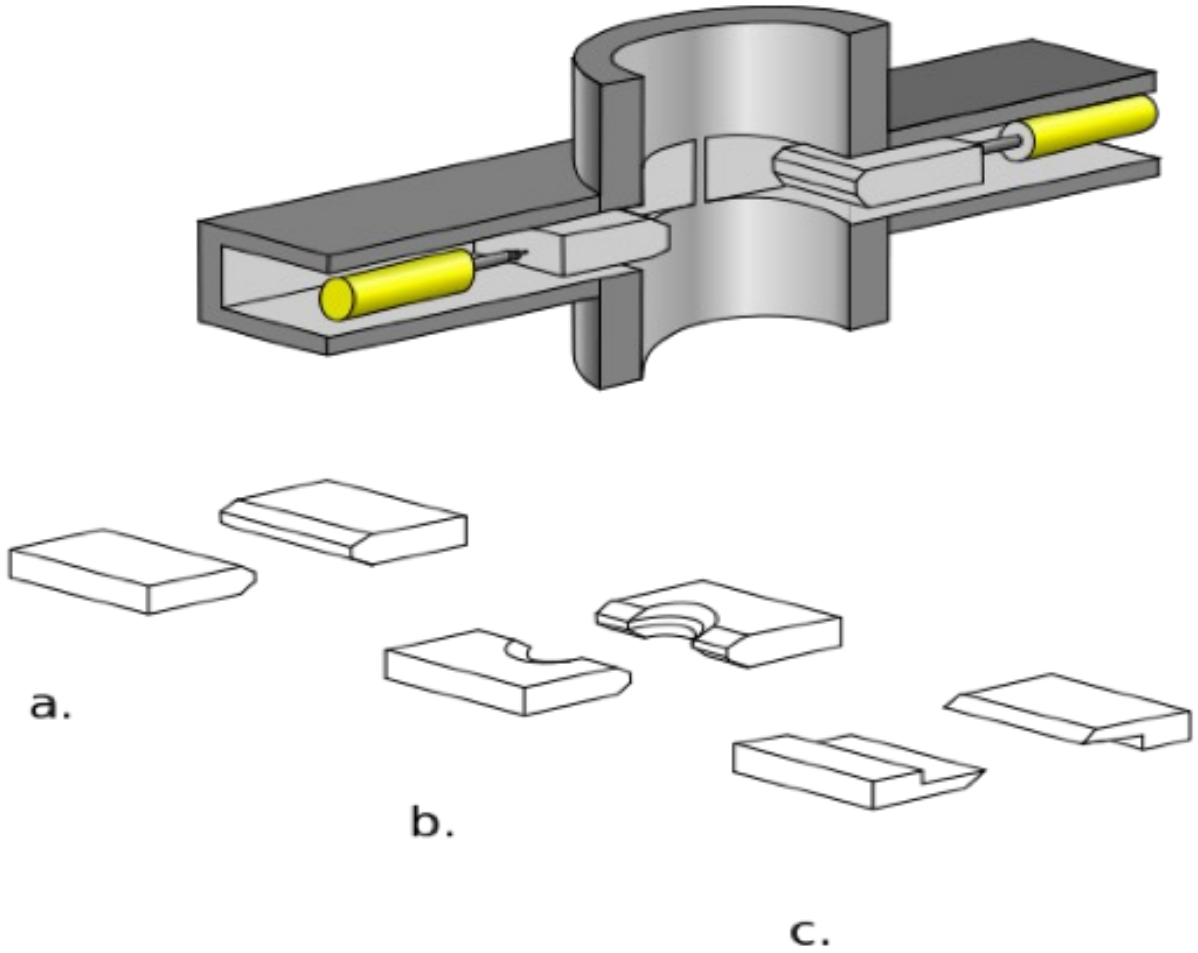
- There are two basic types of blowout preventer used for closing in a well:
  - ➢ Annular type
  - ➢ Ram type
- It is very rare for only one blowout preventer to be used on a well. Two, three or more preventers are generally stacked up, one on top of the other to make up a BOP stack.
- This provides greater safety and flexibility in the well control operation.
- For example, the additional BOPs provide redundancy should one piece of equipment fail; and the different types of ram provide the capability to close the well whether there is drillpipe in the well or not.



Well Control System

Three types of ram preventers are available:

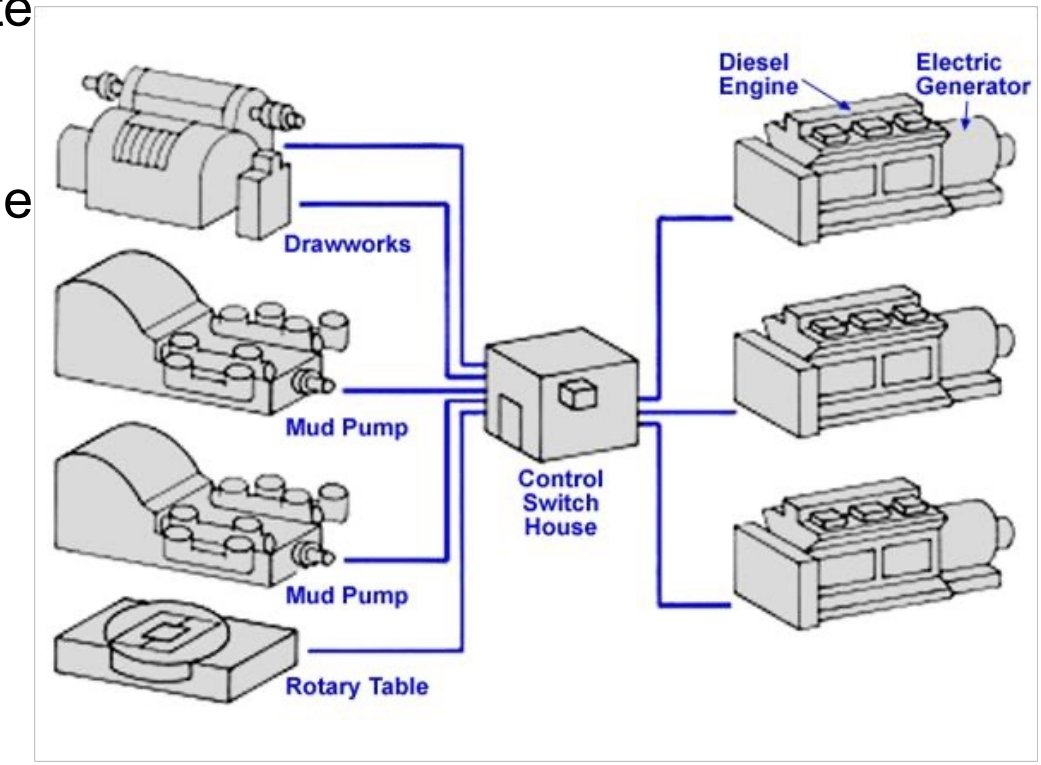
1. Blind rams: which completely close off the wellbore when there is no pipe in the hole.
2. Pipe rams: close around a drill pipe, restricting flow in the annulus, but do not obstruct flow within the drill pipe.
3. Shear rams: which are the same as blind rams except that they can cut through drillpipe for emergency shut-in but should only be used as a last resort.



Power System

- Most drilling rigs are required to operate in remote locations where a power supply is not available.
- They must therefore have a method of generating the electrical power which is used to operate:

1. Drawworks.
2. Mud pumps.
3. Rotary system
4. Auxiliary power requirements for lighting etc.
5. Life support systems.



Power System

- The power system on drilling rig usually consists of a prime mover as the source of raw power and some means to transmit the raw power to the end-use equipment.
- The prime movers used in the current drilling industry are diesel engines.
- Steam boilers are rarely used in present operations due to the difficulty in transporting the boilers and the fact that greater widespread knowledge of diesel units exists among crewmen.
- The rig may have (depending on its size and capacity) up to 4 prime movers, delivering more than 3000 horsepower.

Power Transmission

- Raw power is transmitted via one of the following systems:

A. Mechanical drive.

B. Direct current (DC) generator and motor.

C. Alternating current (AC), silicon controlled rectifier (SCR), direct current motor.

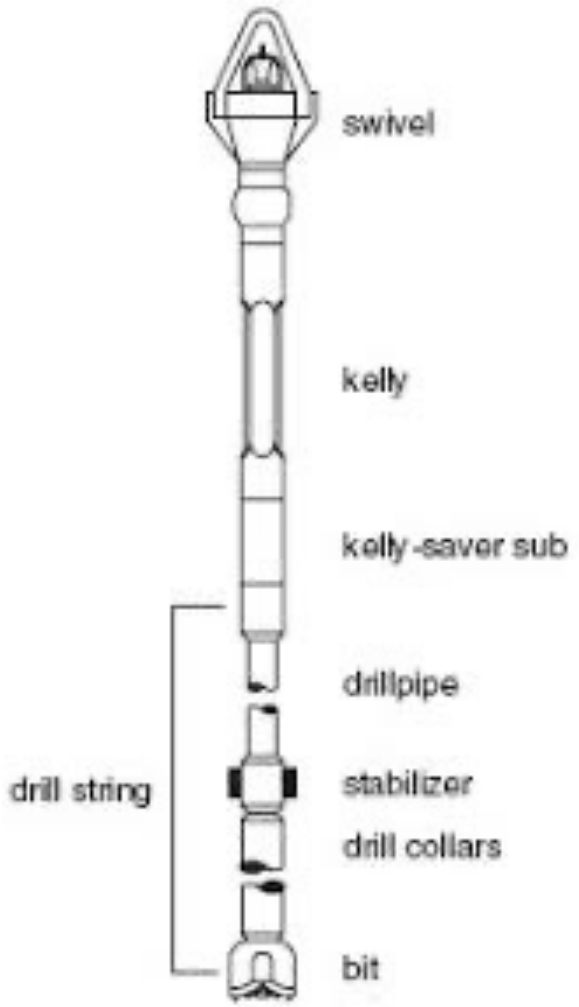
- The most widely used system on new rigs is the AC-SCR system.

Drill String

The drill string consists of:

- Drill Pipes
- Drill Collars
- Drill Bit
- Optional Attachments

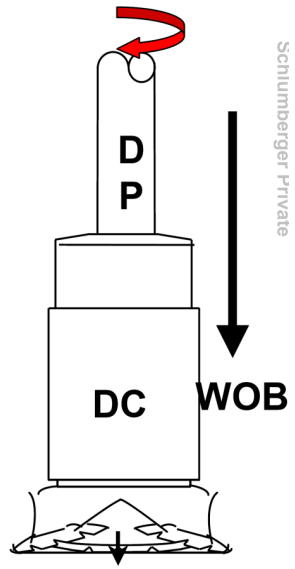
Drill Stem: is a another term used in place of drillstring in some sources. It describes all the drilling components from the sweivel down to the bit.



Drill String

- The drill string is:
  - An expensive component
  - Must be replaced periodically; consequently
  - Every care should be exercised to insure its long life
- Most drill string failures are due to material fatigue which has been aggravated by corrosion and improper care and handling.
- **Drill String Functions:**

1. To lower and raise the bit in the well.
2. To transmit rotary torque from the rotary table to the bit.
3. To provide a conduit for circulating drilling fluid to the bit.
4. To allow weight to be set on the bit.



Drill String

The drill string consists of:

1. **Drill Pipes:** is the main component of the drill string, which forms the upper part of the drill string. It is a seamless pipe which is used to rotate the bit and circulate the drilling fluid.

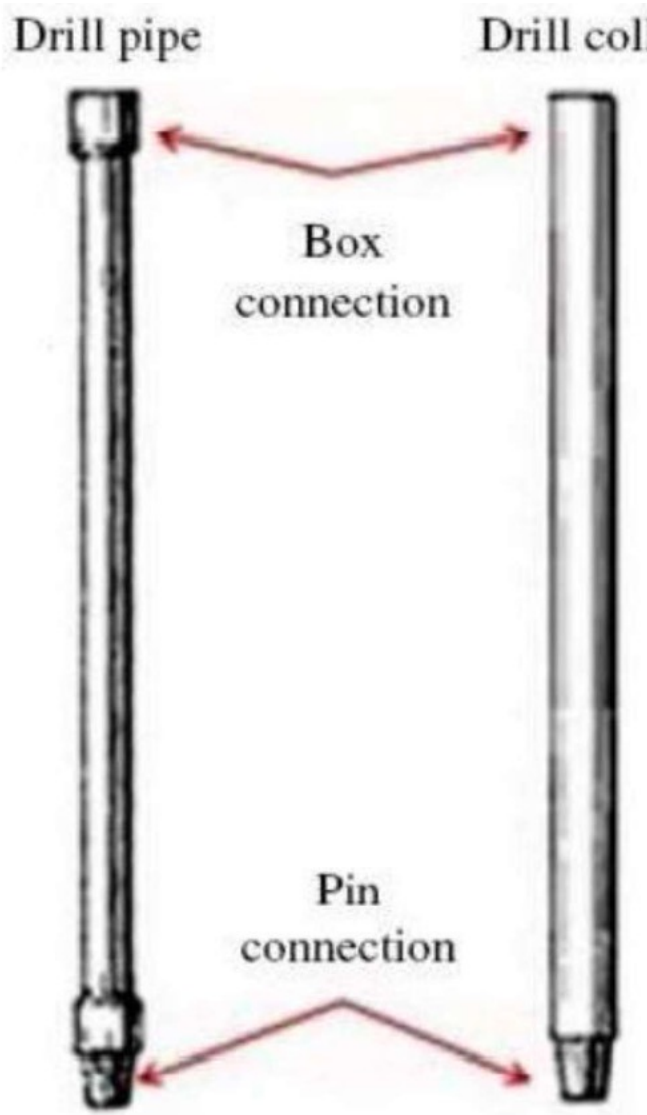
   Function:

- furnishes the length necessary for the drill string
- serves as a conduit for the drilling fluid

2. **Drill Collars:** are heavy-walled pipes that:

   Function:

- place weight on the drill bit during drilling.
- keep the drill pipe in tension to prevent bending and buckling of the drill pipe



Drill String

Drill pipes and collars are rated by:

- ❑ Size (outside diameter).
- ❑ Weight per unit of length.
- ❑ Grade (steel material and manufacturing process).
- ❑ Connections.

Reminder:

Kelly: is the topmost joint connected to the drill string which is commonly square or may be hexagonal.

Function: transmitting rotary table's rotation to the entire drill string.

Drill String

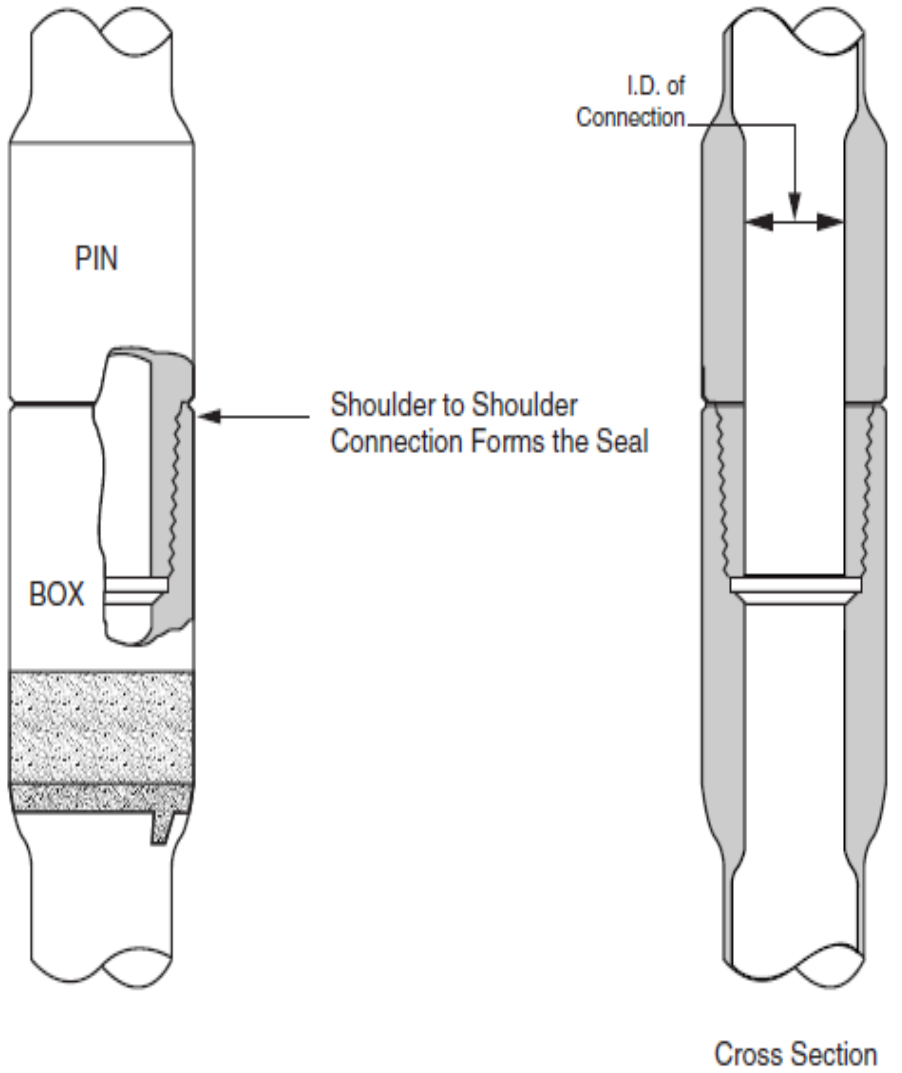
Heavy Weight Drill Pipe

- Heavy weight drill pipe is another component of the drill string and is used in conjunction with the drill pipe and drill collars. Most commonly it is used as a transition between the drill pipe and the heavier drill collars. In some applications, heavy weight also can be used instead of the drill collars.
- The extreme stress and vibrations that drill collars are made to withstand is usually also passed on to the tubulars that are a few hundred feet above the drill collars.
- Standard drill pipe is not made to withstand the majority of these conditions, so heavy weight drill pipe is used in this portion of the drill string.
- In some applications, heavy weight drill pipe may also be used in place of the drill collars. This is most common in directional oil well drilling.
- Heavy weight drill pipe is made of the exact same material as a drill collar, which allows more flexibility than a drill collar.
- The flexibility of the heavy weight drill pipe allows for a sharper change in the drilling direction, while the weight on the drill bit can still be maintained.

Drill String

Tool Joints

- The tool joint or coupling are short and cylindrical pieces attached to each end of drill pipe joint.
- Tool joints are threaded either externally or internally.
- The externally threaded end of drill pipe tool joint is described as the “Pin”.
- Internally threaded end of drill pipe tool joint is called “Box”.



Cross Section

Drill String

3. **Drill Bit:** the cutting element at the bottom of the drillstring, used to grind, break, or shear the rock at the bottom of the well.

Rotary bits are either:

- Drag Bits/Fixed cutter bits
- Roller-cone bits

Roller Cone bit

Drag (PDC) bit

Drill String

1. **Drag Bits:** have no moving parts and drill by shovelling action of their blades on the encountered formation.

- ❑ The water courses, are placed such that the drilling fluid is directed on blades, keeping them clean.
- ❑ They were once widely used for drilling soft, sticky foromations
- ❑ But, later they have been replaced largely by rolling cutter bits

Drill String

Drag bits can be:

PDC (Polycrystalline Diamond Compact) discs bounded to tungsten carbide posts mounted on the surface of the bit. PDC bits are good for drilling hard formations.

Diamond Bits such as NDB (Natural Diamond Bits), TSP (Thermally Stable Polycrystaline), Impregnated Diamond bits.

Drill String

- Diamond bits drill by scarping, drag-bit action of the stones.
- Their use is justified in many areas where their long life and the consequent trip time affords sufficient afvantage to offset the higher bit cost.
- They are normally used in hard formations.

Drill String

2. **Roller cone bits:** This bit allowed the rotary methods to compete with cable tools in hard formations which are undrillable with drag bits.

- Tooth length, spacing, and pattern are balanced to obtain the fastest penetration rate with a minimum balling between teeth. For instance, for soft formation, three cone bits have relatively long, and widely spaced teeth. For harder formation, bits have shorter, and more closely spaced teeth.

❑ Each nozzle directs a high velocity fluid jet directly on the hole bottom which rapidly removes the cuttings.
❑ So, this allows each bit tooth to strike new formation rather than expend some of its energy in regrinding previously loosened chips.
❑ However, the pressure losses through these nozzles are considerable and require extra pump capacity

Drill String

Roller cone bits: can be:

Mill tooth tri cone bits, steel teeth (soft formations).

Insert tooth tri cone bits, Tungsten carbide and button bits (hard formations).

Drill String

- **Optional attachements**: these are equipment that may be assebled and may include:
- **Stabilizer:** a drilling stabilizer is a piece of downhole equipment used in the Bottom Hole Assembly (BHA) of a drill string. It mechanically stabilizes the BHA in the borehole in order to avoid unintentional sidetracking, vibrations, and ensure the quality of the hole being drilled.

Stabilizer

Drill String

Stabilizers

Functions:

1. Centralize and provide extra stiffness to the BHA.
2. Allow higher WOB since the string remains concentric.
3. Increase bit life by reducing wobble (i.e. all three cones loaded equally).
4. Control hole deviation and dogleg severity.
5. Prevent differential sticking.

Drill String

- **Roller Reamers**
- Wellbores are not always as smooth as they need to be which is critical for tripping in and out of the hole, conducting wireline open hole logging, and running casing.
- Reamer is a tool used in drilling to smooth the wall of a well, enlarge the hole to the specified size, help stabilize the bit, and straighten the wellbore if kinks or doglegs are encountered.
- Roller reamers are used to replace near bit and string stabilizers in bottom hole assemblies where swelling or abrasive formations are encountered.
- A roller reamer consists of stabilizer blades with rollers embedded into surface of the blade.
- The rollers may be made from high grade carburized steel or have tungsten carbide inserts.

Drill String

- **Jars:** a (mechanical/hydraulic) device used downhole to deliver an impact load/sharp blow to another downhole component to free the pipe if it becomes stuck in the hole. Jars are usually positioned at the top of the drill collars.
- **Subs (substitutes)**

1. Lifting subs are used with drill collars to provide a shoulder to fit the drill pipe elevators;
2. A Kelly saver sub is placed between the drill pipe and the Kelly to prevent excessive thread wear of the Kelly and drill pipe threads;
3. A bent sub is used when drilling a directional hole;
4. Shock subs: are used to absorb vibrations and bit shock loads in drill collar strings. are used to reduce the effect of bit bounce and isolate it from the drill string to reduce fatigue wear of the string.

Drill String

Jars

Shock subs

Next Lecture

In the next lecture on Sunday November 26th, 2023. At 11:00 in class 214 we will take the following topics:

- Drilling Process and Operation

End of Lecture