Lecture #2 PeE3321

Rig systems
Wellbore Elements and Volumes

Rig types Re-cap from last time

Land rigs	**Land-based drilling rigs consist of engines, a drawworks, a mast, pumps to circulate mud, blowout preventers, drill stem. They can be further divided into size based on height of Mast, single, double triples, horsepower, or depth Light duty rigs 3000-5000 ft, medium duty 4000-5000 feet, Heavy duty rings 12000-15000 feet and ultra heavy rigs 18000- 250000 feet. Kelly drive or top drive.**
Jack up rigs	**Jack-up rigs are mobile, self-elevating, offshore drilling platforms equipped with legs that can be lowered to the ocean floor until a foundation is established to support the hull, which contains the drilling equipment, etc.**
Platform rigs	**A platform is a stationary offshore oil production facility. Platform rigs drilling unit provides offshore drilling at these facilities.**
Drilling barge	**For very shallow water. The barge can not handle waves and rests on the sea floor when drilling. Used in lakes and swamp lands like Louisiana.**
Submersible rigs	**Rests on the sea floor when drilling. Compartments are flooded which cause the rig to submerge and rest on bottom. When ready to move the water is removed and the rig can float and be towed to next location. Shallow inland sea submersible is called drilling barge.**
Semi-submersible	**Floating offshore rig with pontoons and columns. When flooded with water the rigs pontoons cause the unit top partially submerge to a predetermineddepth.**
Drill ships	**Special designed ships with a drilling unit onboard.**

Covered in Lecture 2

Concepts

- Know the 6 rig systems
  - ✓ Explain the hoisting system
  - ✓ Explain the Rotary system and the two types of rotary systems
- Open hole and types of wellbore sections
  - ✓ Open hole
  - ✓ Casing
  - ✓ Liner
  - ✓ Drill stem

Calculations

- Static Force on Dead line and Fast line
- Dynamic Force in Dead line
- Efficiency of motor and sheaves
- Static load on derrick
- Horsepower of hoisting system
- Volumes in open hole
- Volumes inside casing and annular spaces
- Displacement of casing and drill pipe

A rig has 6 basic components

1. Hoisting system
2. Power system
3. Rotary system
4. Circulating system (Drilling fluid System)
5. Well control system
6. Well monitoring system

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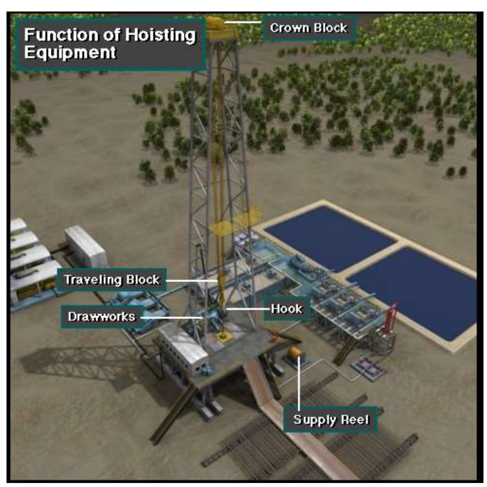
Hoisting system - Derricks and masts

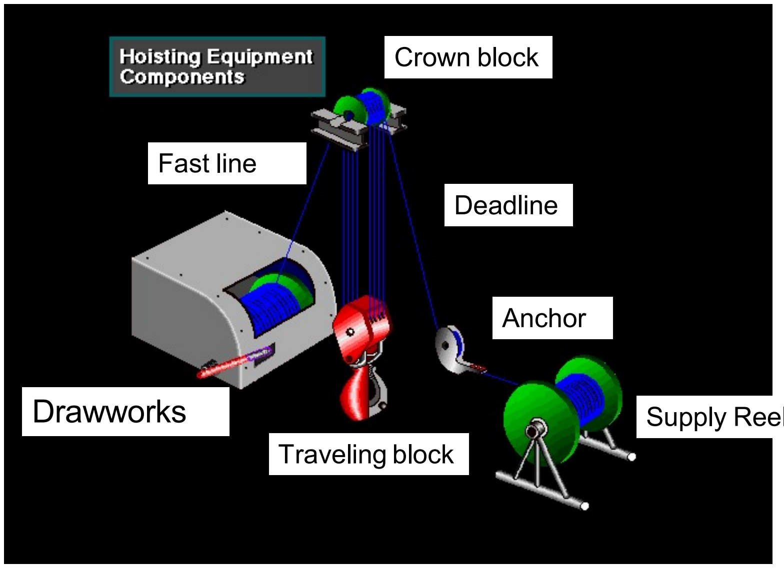
The Hoisting system is used to raise, lower, and suspend equipment in the well

Hoisting system consists of:

1. Crown Block
2. Traveling Block
3. Derrick (mast)
4. Drawworks
5. Fast line (Drilling line)
6. Deadline



Hoisting System

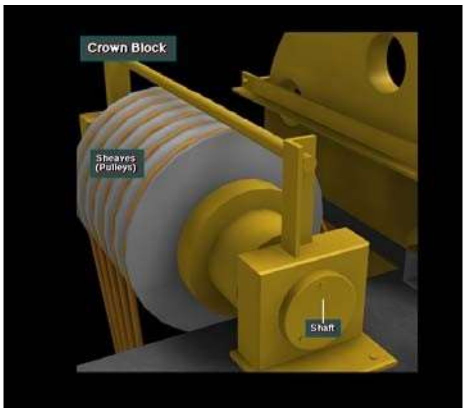


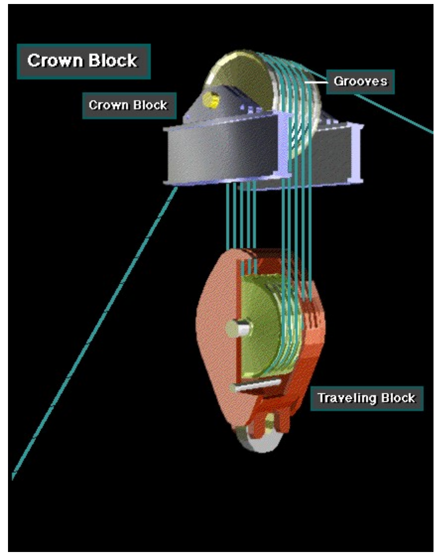
Hoisting System – Crown Block

- A series of sheaves (i.e. pulleys) fixed in the top of the derrick used to change the direction of pull from the drawworks to the traveling block.

Hoisting System- Crown and Traveling Block

The fast line is threaded many times between the crown block and the traveling block.





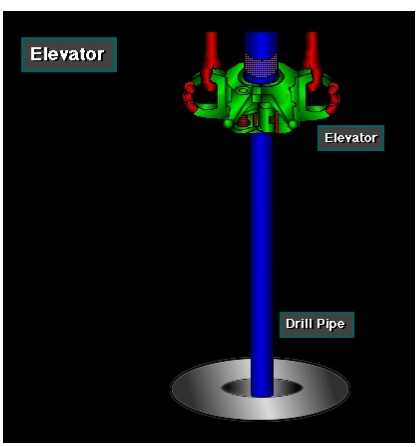
Hoisting System- Masts and Derricks

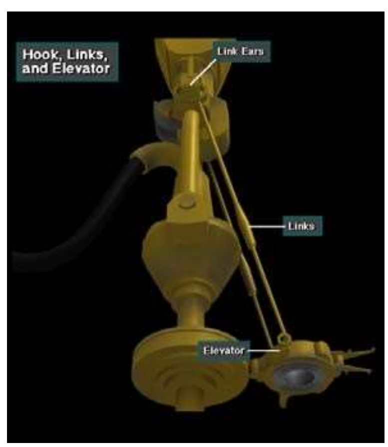
- Vertical structure that allows vertical clearance and strength to raise and lower the drill string.
- This structure withstands compressive loading and wind loading.
- A mast is a strong tower that stands independently on the rig floor and is raised as a single-piece unit.
- A standard Derrick has 4 legs that us usually bolted together and with beams to increase the strength.
- Derrick can not be raised or lowered in a single operation.

Hoisting System- Drawworks

- The principal parts of the Drawworks are the drum, the drum brakes, transmission, and cathead.
- The principal function is to convert the power source into a hoisting operation and provide braking capacity to stop and sustain the weights imposed when lowering or raising the drill string.
- The drum is housed in the Drawworks and transmits the torque required for hoisting and braking. It also stores the drilling line required to move the traveling block the length of the derrick.

- The elevators are used for latching on to the tool joint or lift sub of the drill pipe or drill collars.
- connected to the hoisting system (traveling block)





Hoisting system

Derrick or Mast Vertical structure that allows vertical clearance and strength to raise and lower the drill string. This structure with-stands two types of loading: compressive loading and wind loading. A mast is a strong tower that stands independently on the rig floor and is raised as a single-piece unit. A standard Derrick has 4 legs that us usually bolted together and with beams to increase the strength. Derrick can not be raised or lowered in a single operation. Today masts is much more common, but in practice Derrick is loosely used for both Mast and Derrick.

Types of Derricks:

Triple- has the capacity of pulling 90' stands of pipe

Double- has the capacity of pulling 60' stands of pipe

Single- has the capacity of pulling 30'stands of pipe (one 30-ft joint)

Standard Derricks - Four sided structures that must be assembled and disassembled when transporting.

Portable Derricks - Telescoping and jackknife types. The telescoping derrick is raised and lowered in an extending and collapsing fashion and lowered in one piece, but has to be disassembled to some degree after being lowered.

Deadline - The drilling line strung through the traveling block and to the drawworks is secured by the deadline, which is wrapped around the deadline reel and clamped. This prevents the line from slipping and the traveling block from falling.

Anchor – Anchors the deadline to the rig floor. A weight indicator is attached to the anchor. **Drilling**

line supply reel. A reel with spare drilling line which is attached to the deadline and anchor. **Fast**

Line (Drilling line)- is a wire rope or a steel cable used in the hoisting system.

Traveling Block - The block and tackle which is rigged with the crown block by multiples of drilling line strung between the crown block and the traveling block

Hook The hook is located beneath the traveling block. This device is used to pick up and secure the swivel and kelly.

Cathead –The cathead is a shaft with a lifting head that extends on either side of the drawworks and has two major functions. It is used in making up and breaking out tool joints in the drill string. It is also used as a hoisting device for heavy equipment on the drill floor. This is done by wrapping the catline (catline is generally made of rope and is connected to a piece of chain used to tie on to equipment) around the lifting head.

To be covered in today lecture

Concepts

- Know the 6 rig systems (continued)
  - ✓ Explain the Rotary system and the two types of rotary systems
- Open hole and types of wellbore sections
  - ✓ Open hole
  - ✓ Casing
  - ✓ Liner
  - ✓ Drill stem

Calculations

- Static Force on Dead line and Fast line
- Dynamic Force in Dead line
- Efficiency of motor and sheaves
- Static load on derrick
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- Volumes in open hole
- Volumes inside casing and annular spaces
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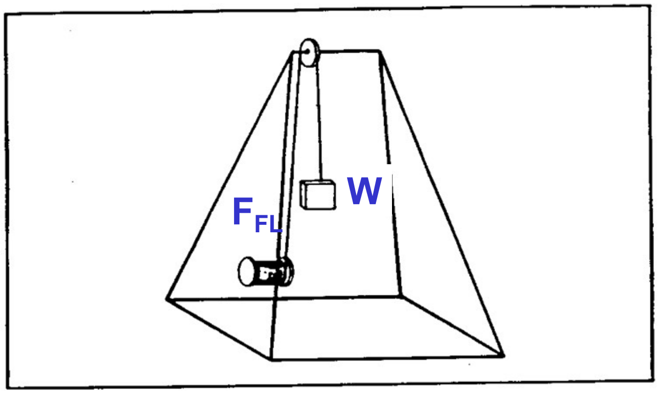
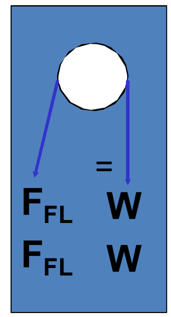
Simple Pulley System

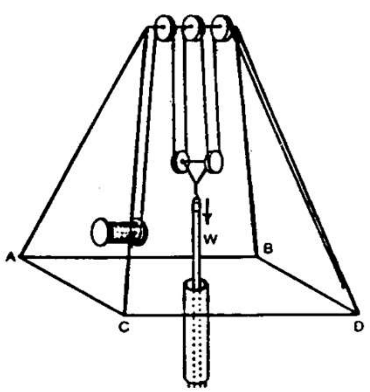




Force on fast line: $F_{FL} = W$

Load on Derrick: $L_D = F_{FL} + W$ (no friction)

Block and Tackle System (no friction)



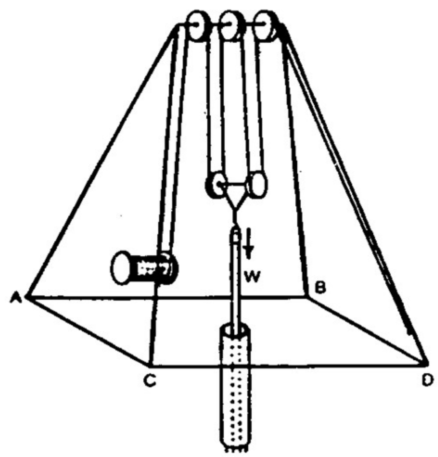
For an ideal, frictionless system the tension in the drilling line is the same throughout the system

Mechanical advantage

To pull the drill string up the force needed on the fast line is only ¼ of the weight of the drill string. That is the mechanical advantage of a block and tackle system

Force fast line: $F_{FL} = W/4$

Block and Tackle System (With Friction)

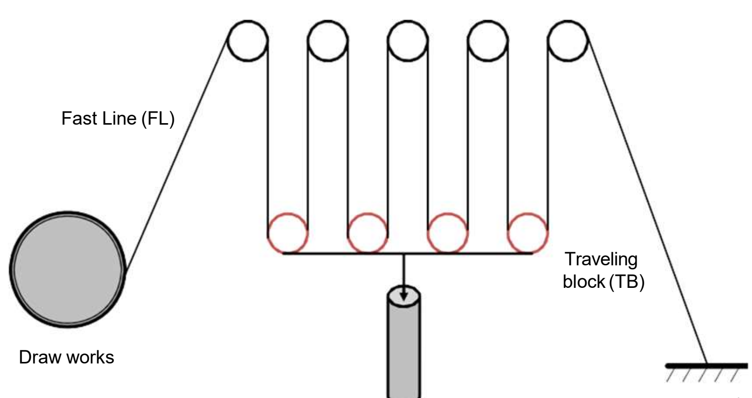


For an actual system, efficiency has to be taken into account

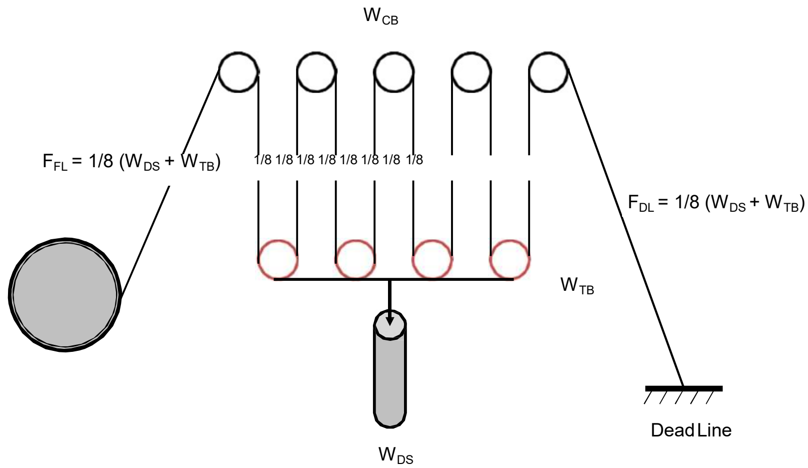
Overall efficiency of a block and tackle system (or any engine)

$$\text{Efficiency (\%)} = \frac{\text{Output power}}{\text{Input power}} \times 100$$

Schematic of the hoisting system



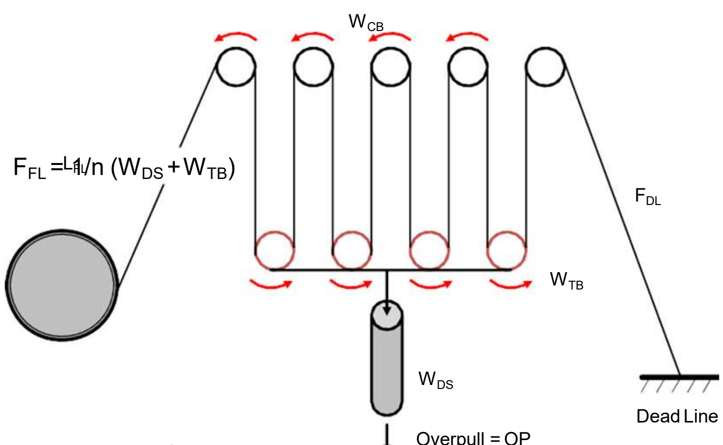
Load on the fast line and dead line



Load on the fast line = F_{FL} = 1/n (W_{DS} + W_{TB})

Load on the dead line = F_{DL} = 1/n (W_{DS} + W_{TB})

Dynamic Load on the fast line



Dynamic load on the fast line

$F_{FL\text{-}DYN}$ = (F_{FL})/ e_{sh}^n

e_{sh} = individual sheave efficiency

$F_{FL\text{-}DYN}$ = (F_{FL})/E_n

E_n = Overall Hoisting efficiency

Friction in the Sheaves

The block and tackle which is rigged with the crown block by multiples of drilling line strung between the crown block and the traveling block. The efficiency, E_n, can be computed as

$$E_n = e_{sh}^{\,n}$$

where

- E_n is the overall hoisting efficiency
- e_{sh} is the efficiency of each sheave
- n is the number of lines strung between the crown block and traveling block

Example:
Given $e_{sh} = 0.98$; $n = 8$ Then $E_n = 0.851$

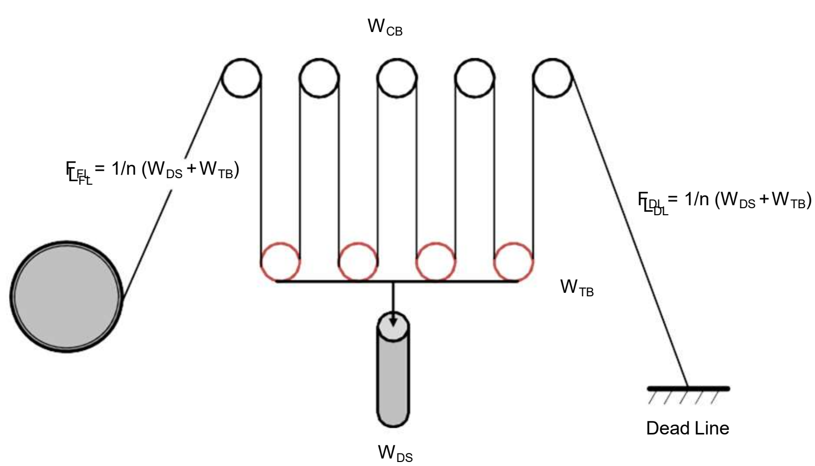
When the drill stem is stuck

$$F_{FL\text{-}DYN} = (F_{FL} + OP)/e_{sh}^{\,n}$$

OP = Over pull

OP = 0 in normal drilling operations

Static Load on the Derrick - L_D



Load on the Derrick = $L_D = W_{DS} + W_{TB} + F_{FL} + F_{DL} + W_{CB}$

Load on the Derrick = $L_D = ((n+2)/n) * (W_{DS} + W_{TB}) + W_{CB}$

Load on the substructure

Substructure of the rig is supported on a foundation which is in turn supported by the earth's surface (or ocean surface). The substructure supports the Derrick (mast).

$$L_{ss} = L_{RT} + L_{SB}$$

L_{SS} is the load acting on the substructures
L_{SB} is the set back load of the drill string.
L_{RT} is the maximum load supported in the rotary table

Derrick load (no friction) Example L2-1

The total weight of 9,000 ft of 9 5/8-inch Casing string for a deep well is determined to be 380,000 lbs, the traveling block weighs 20,000 lbs.

Calculate the maximum Derrick load.

Since this will be the heaviest casing string run, the maximum mast load must be calculated.

Assuming that 10 lines run between the crown and the traveling blocks (i.e. n = 10) and neglecting buoyancy effects.

A rig has 6 basic components

1. Hoisting system
2. Power system
3. Rotary system
4. Circulating system (Drilling fluid System)
5. Well control system
6. Well monitoring system

Power on the rig

- Prime movers are the main power source on the rig.
  - Prime movers power the drawworks and rotary table.
  - The power is used to:
    - Rise and lower equipment into the well
    - Turn the drill string
    - Pump mud
  - Prime movers are need to power auxiliary equipment like, solids control, shale shakers, lighting, heating, BOP systems, laboratory equipment, etc…

Hoisting Horsepower

The hoisting Horsepower needed to lift the hook load at a given velocity is

$$HP_{hoist} = \frac{L_{hoist} * V_{hook}}{33,000}$$

L_{hoist} is the total hoisting load (lb)

V_{hook} is the hook velocity (ft/m)

Maximum hoisting horsepower conditions generally occur when setting surface or intermediate casings strings.

Hoisting Horsepower (cont.)

The required minimum prime mover horsepower to the hoisting system is

$$HP_{hoistin} = \frac{L_{hoist} * V_{hook}}{33,000 * e_{sh}^{n} * e_{draw}}$$

L_{hoist} is the total hoisting load (lb)

V_{hook} is the hook velocity (ft/min)

Maximum hoisting horsepower conditions generally occur when setting surface or intermediate casings strings.

e_{sh}^{n} = drilling line efficiency

e_{draw} = is the mechanical coupling efficiency (0.8-0.9) (Drawworks mechanical efficiency)

Example L2-2

A rig must hoist a load of 300,000 lb (including the traveling block weight). The draw works can provide an input power to the block and tackle system as high as 500 hp. Eight lines are strung between the crown block and traveling block. Sheave efficiency is .98 and mechanical efficiency is 0.9. Calculate;

1. The static tension in the fast line when upward motion is impending,
2. the maximum hook horsepower available,
3. the maximum hoisting speed

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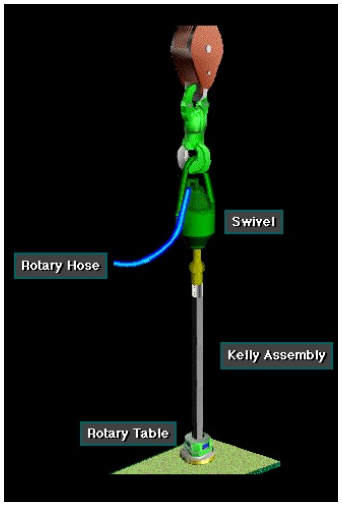
Rotary System

- Generally, bits can be rotated in one of 3 ways:
  - **Rotary table system**
  - **Top drive system**
  - **Downhole motor**

Rotary Table System

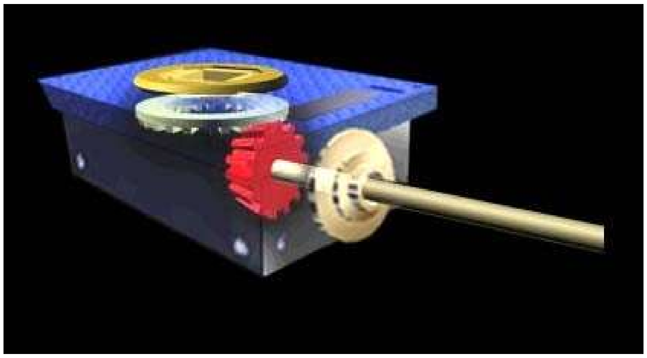
The **Rotary Table system** consists of:

1. **Rotary table with a turntable:** the turntable rotates the master bushing
2. **Master bushing:** that rotates the kelly drive bushing
3. **Kelly drive bushing:** that rotates the kelly
4. **Kelly:** that rotates the attached pipe and bit
5. **Swivel:** that suspend the pipe and allows it to rotate. The swivel has a passage that allows the drilling fluid to enter the kelly and the pipe.

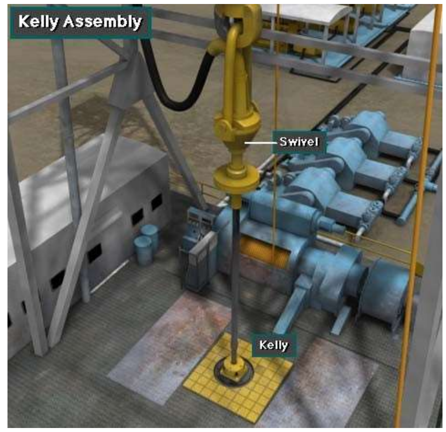


Rotary table

- The rotary table is turned by the prime mover (motor) which turns the kelly drive bushing and then the kelly which again turns the drill string and the drill bit.

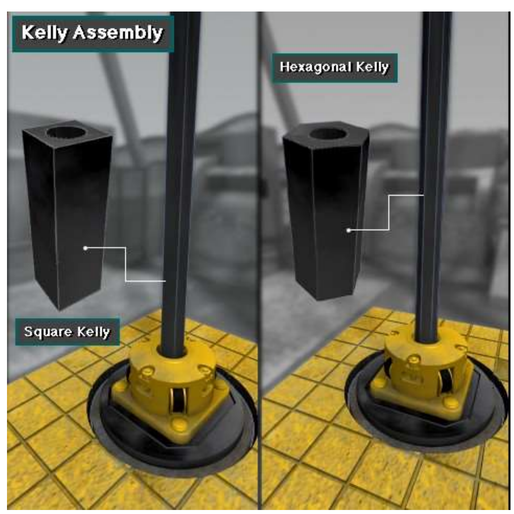


Kelly assembly



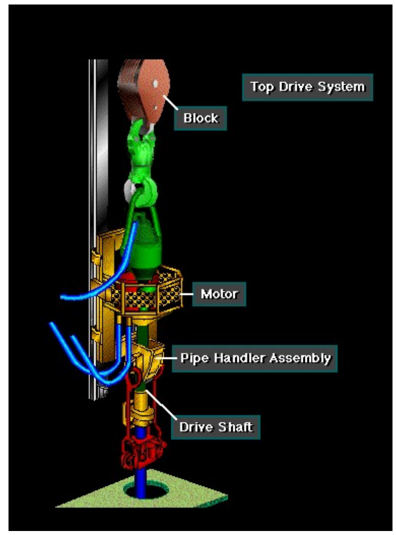
Kelly

- The kelly is a square or hexagonal tubing that is connected at the top to the travelling block through a swivel.
- At the bottom, the kelly is connected to the drill pipe.
- The kelly moves through a square (or hexagonal) opening in the kelly drive bushing.
- The kelly drive bushing can be attached to the master bushing in the rotary table.



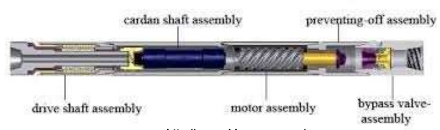
Top drive system

- A powerful engine with a motor and gear box attached to the rigs traveling block.
- The top drive rotates the drill string and bit.
- Safer and easier for the rig crew to handle the pipe.
- Top drive system can add three joints at a time.
- In the rotary table, the crew can add one joint at a time.



Downhole Motors

- Does not rotate the drill pipe
- Rotates only the bit
- Drilling fluids powers most downhole motors
- As the rotors are forced to turn, the drive shaft is
- also forced to turn, causing the bit sub and the bit to rotate
- Often used for directional drilling



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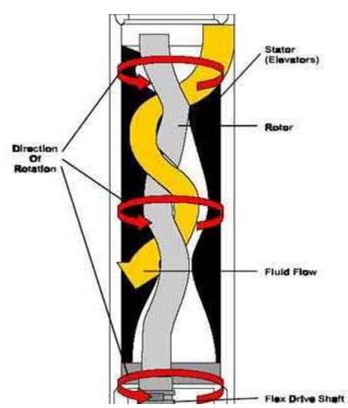

Rotary Horsepower

The rotary horsepower needed to rotate the drill string in either a rotary table or a top drive is;

$$HP_{rotary} = \frac{T * N}{5250}$$

$$HP_{rotaryin} = \frac{T * N}{5250 * e_{com} * e_{mech}}$$

T is the Torque on the top of the drill string (ft-lb)

N is the rotational speed rpm (revolution per minute)

Maximum rotary conditions generally occur near the bottom of the well, particularly in highly deviated wellbores.

e_{com} = is the mechanical compound efficiency (0.8-0.98)

e_{mech} = is the mechanical coupling efficiency (0.8-0.9)

Pump Horsepower

Hydrostatic horsepower to force the fluid through the pump; and required minimum prime mover input horsepower

$$HP_{hydro} = \frac{p*q}{1714}$$

$$HP_{hydroin} = \frac{p * q}{1714 * e_{vol} * e_{mech}}$$

p is the pressure in lb/in^2 (psi)

q is the flow rate in gal/min

Maximum HP conditions occur near the bottom of the well.

e_{vol} = is the pump volumetric efficiency (0.8-0.98)

e_{mech} = is the mechanical coupling efficiency (0.8-0.9)