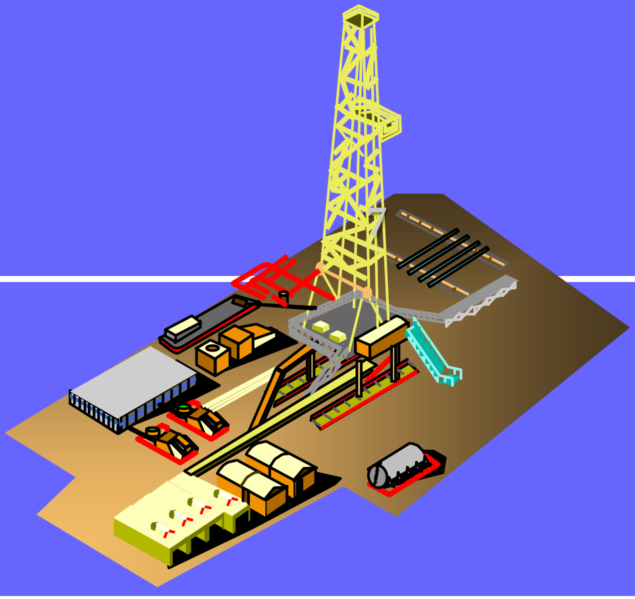
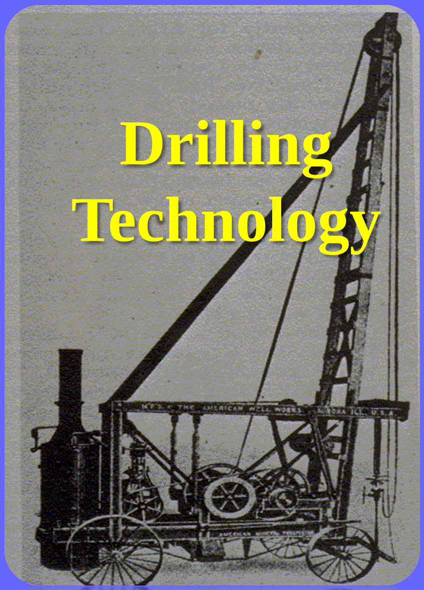
Chapter Six
Petroleum Well Drilling Engineering



Introduction to Petroleum Engineering
PGE 251

The Primary Purpose of the Drilling Process is to Gain Access to Subsurface Hydrocarbon Fluids and to Provide a Flow Path for Bringing Those Fluids to the Surface



Petroleum Well Drilling Engineering

Major Drilling Techniques

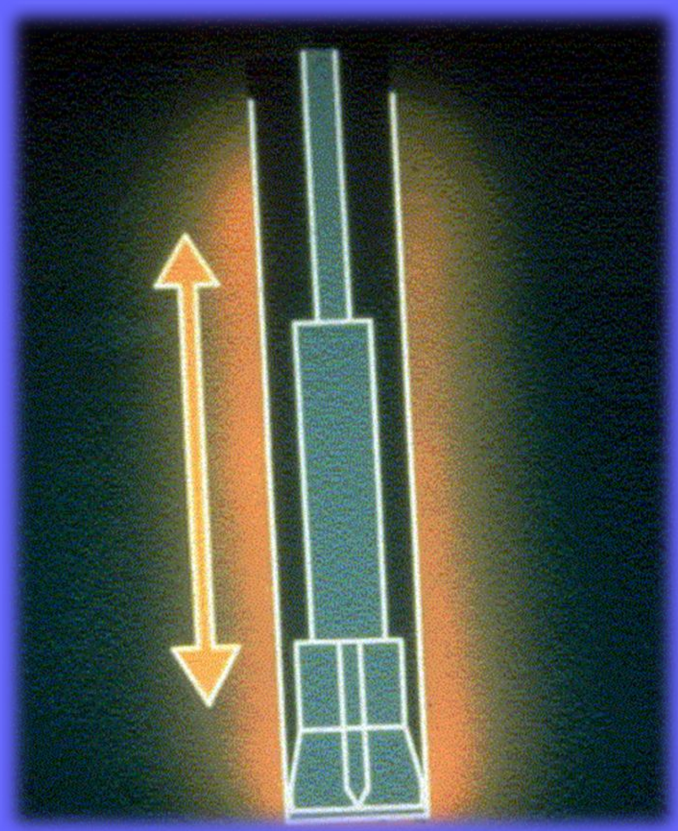
- Cable Tool Drilling
- Conventional Rotary Drilling

Major Drilling Techniques

- **Cable Tool Drilling**

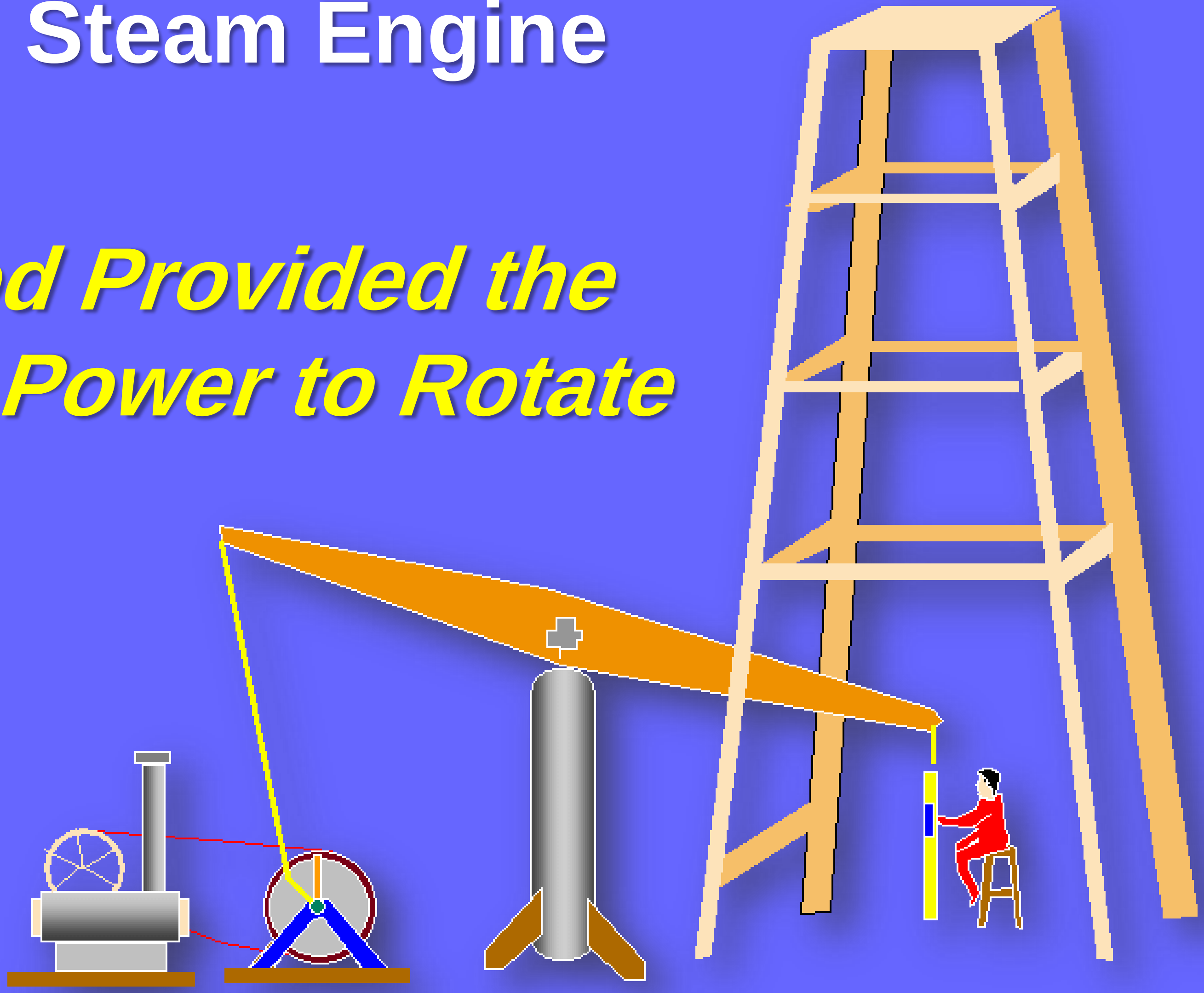
Impact or Percussion

Drilling Concept

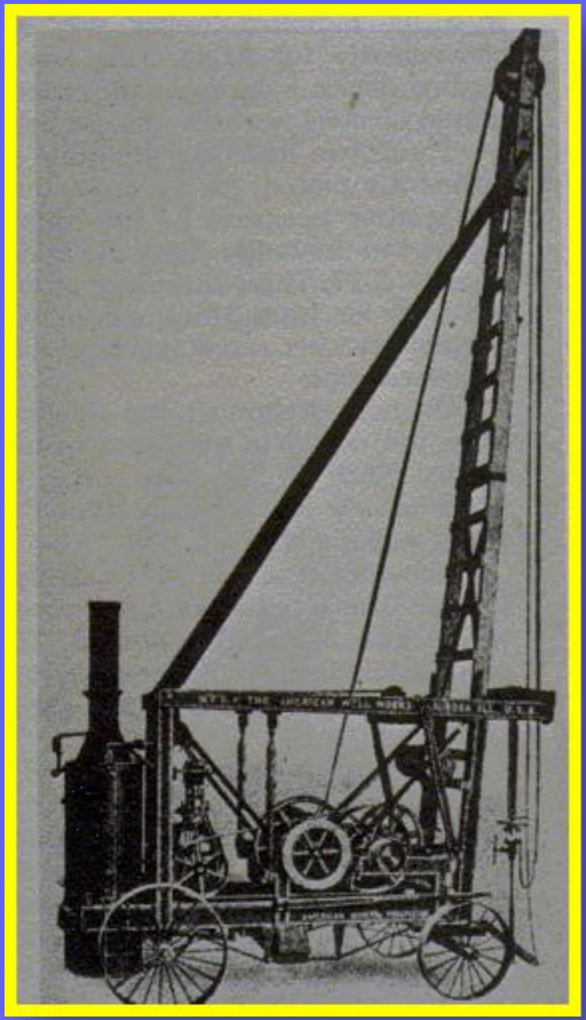


Mechanization of the Impact Process Using Cable Tool Drilling & the Steam Engine

This Method Provided the Necessary Power to Rotate



Cable Tool Drilling & The Steam Engine



Major Drilling Techniques

- ## Cable Tool Drilling

The limitations of this method are:

- ✓only for shallow wells of small and invariable diameters.
- ✓only vertical wells can be drilled.
- ✓There is no system to control the flow of formation fluids.

Major Drilling Techniques

- **Conventional Rotary Drilling**

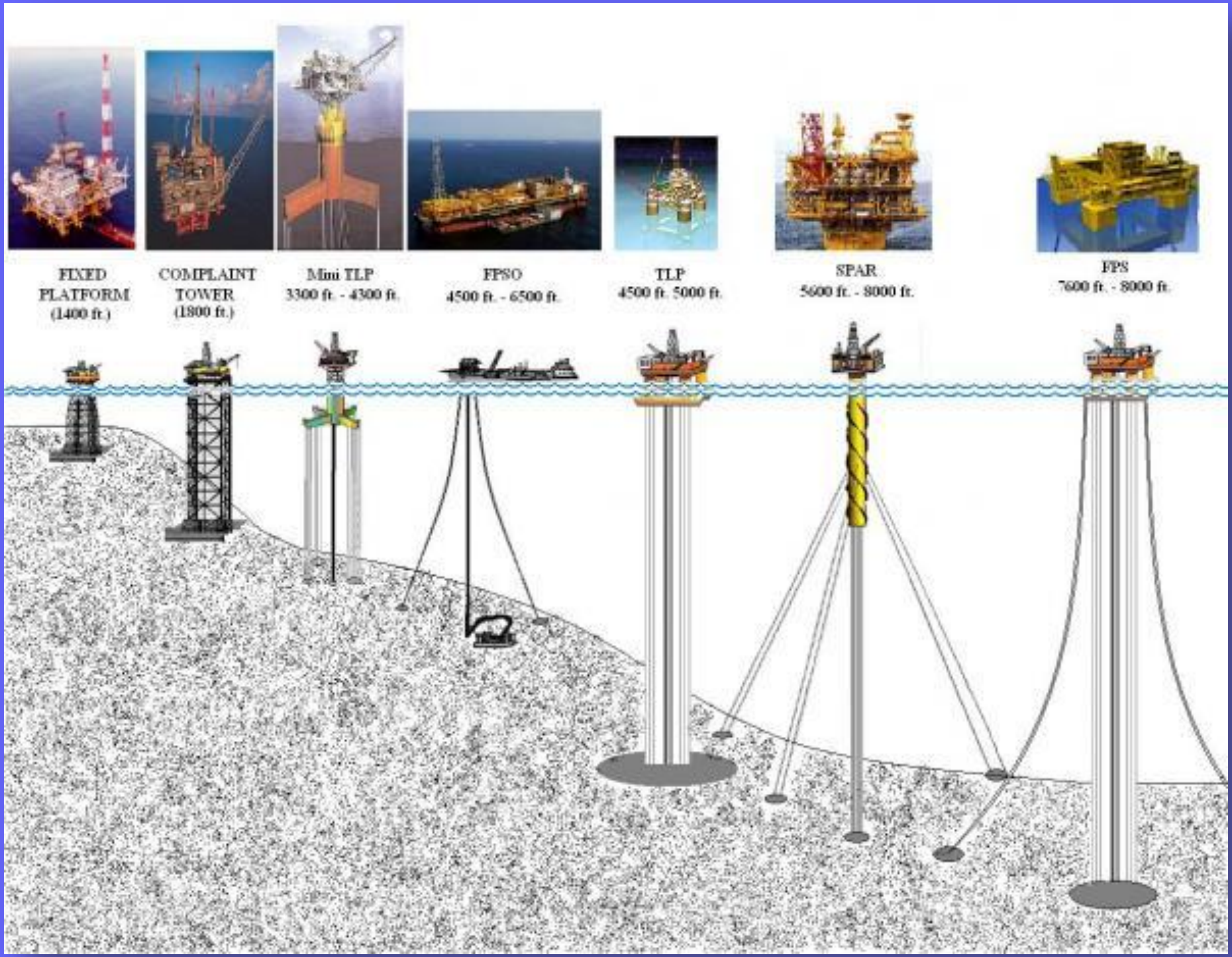
  The advantages of rotary drilling method are:

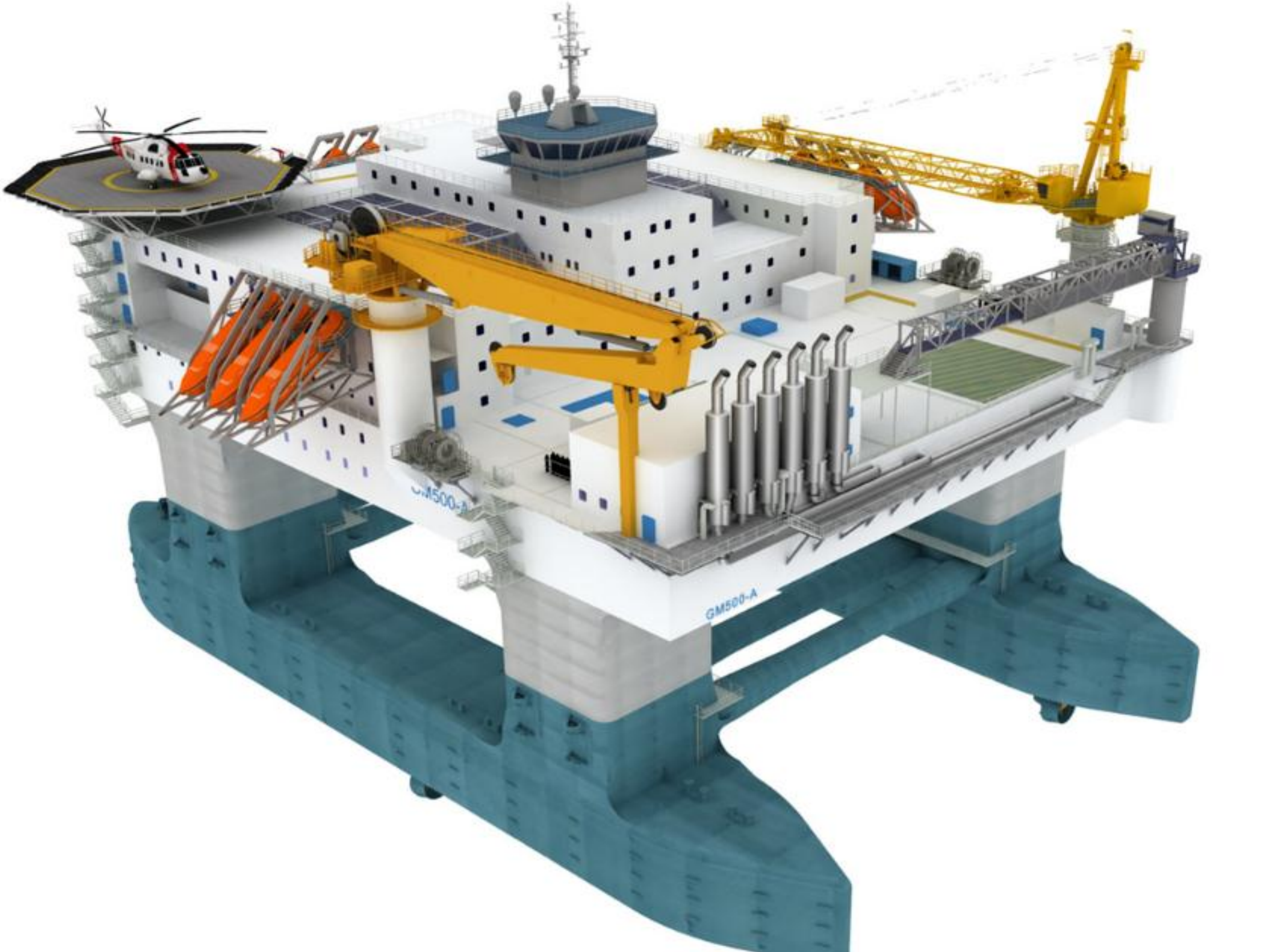
  - ✓ **for both shallow and deep wells of variable diameters.**
  - ✓ **Vertical, directional and horizontal wells can be drilled.**
  - ✓ **The flow of formation fluids into wellbore can be controlled.**

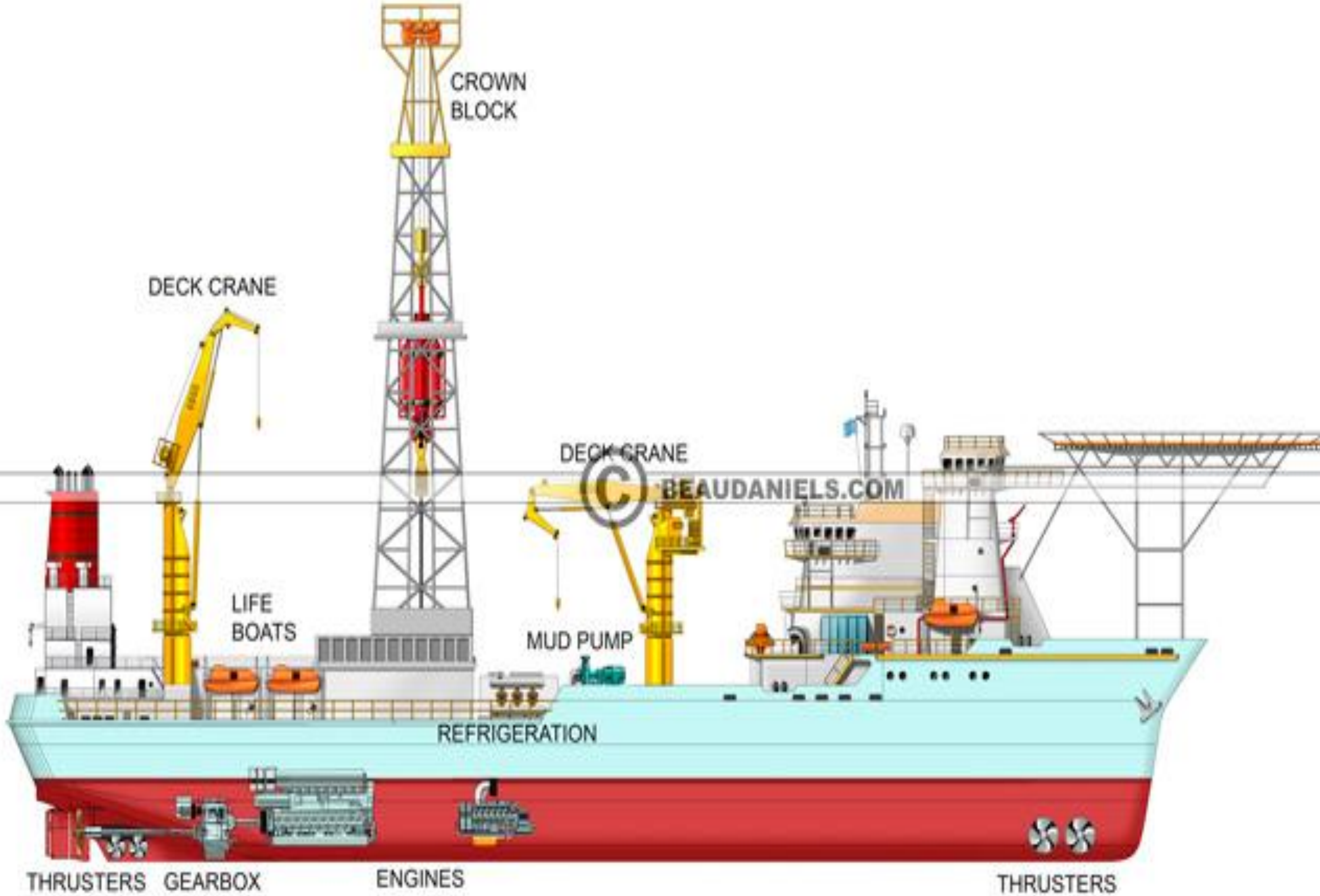
Conventional Rotary Drilling

Onshore rotary drilling rigs	Offshore rotary drilling rigs
• Light rigs (3000 ft – 5000 ft).	• Jack up rigs.
• Medium rigs (4000 ft – 10000 ft).	• Platform rigs.
• Heavy rigs (12000 ft – 16000 ft).	• Submersible rigs.
• Ultra-heavy rigs (18000 ft – 25000 ft).	• Drill ships.

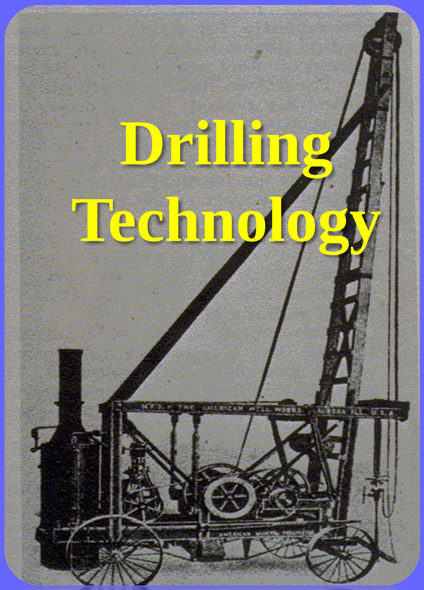
Conventional Rotary Drilling




GM500-A


CROWN
BLOCK
DECK CRANE
DECK CRANE
© BEAUDANIELS.COM
LIFE
BOATS
MUD PUMP
REFRIGERATION
THRUSTERS
GEARBOX
ENGINES
THRUSTERS

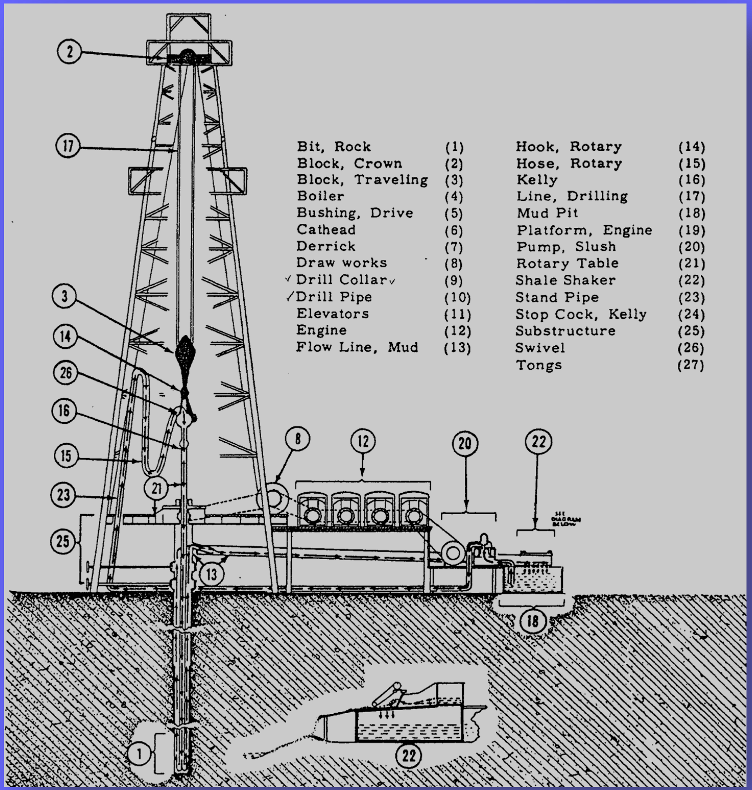
DRILL SHIP



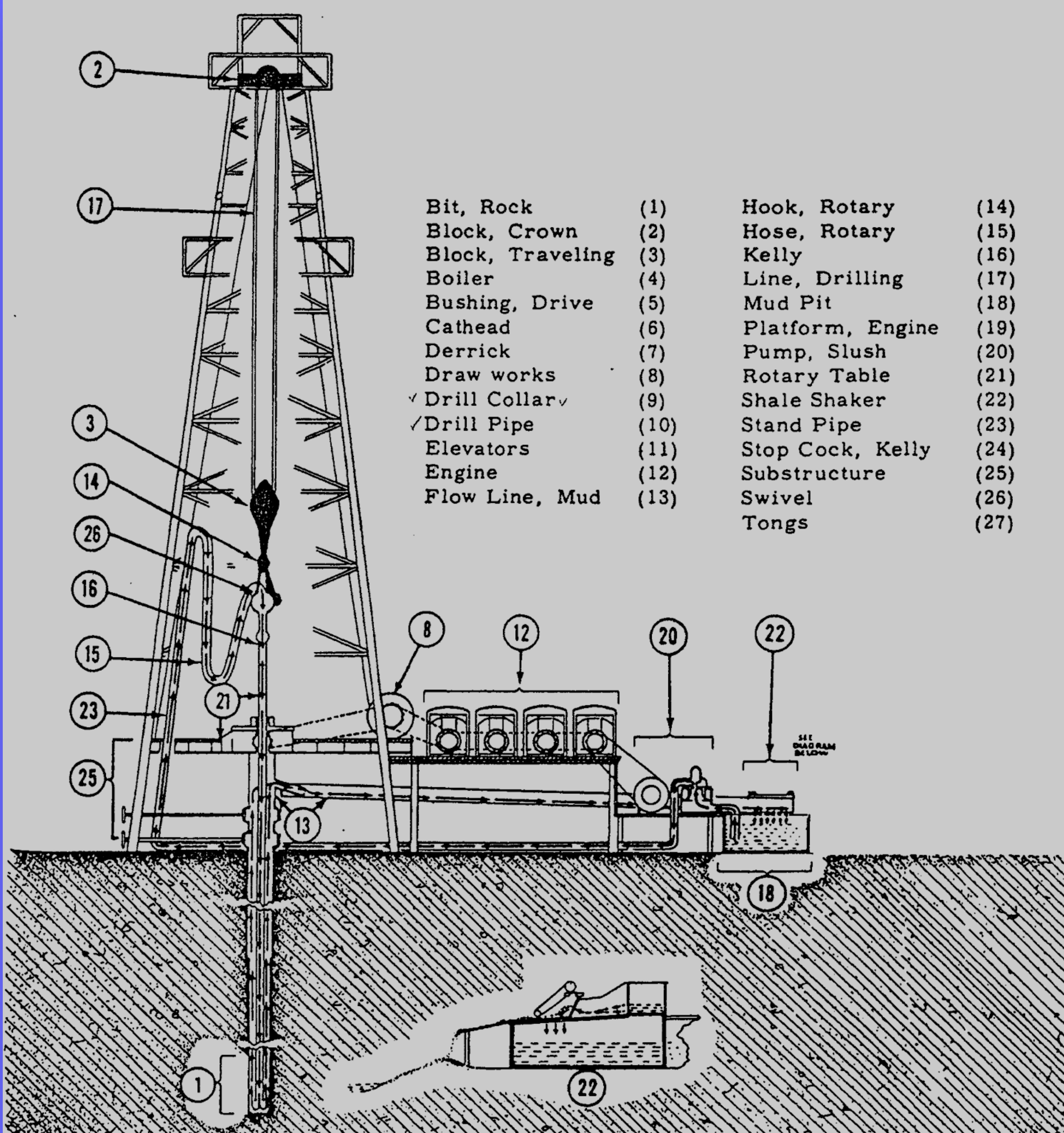
Petroleum Well Drilling Engineering

Basic Rotary Drilling Rig Components

- The Rig (Derrick)
- Hoisting System
- Rotating System
- Mud Circulating System
- Pressure Controlling System

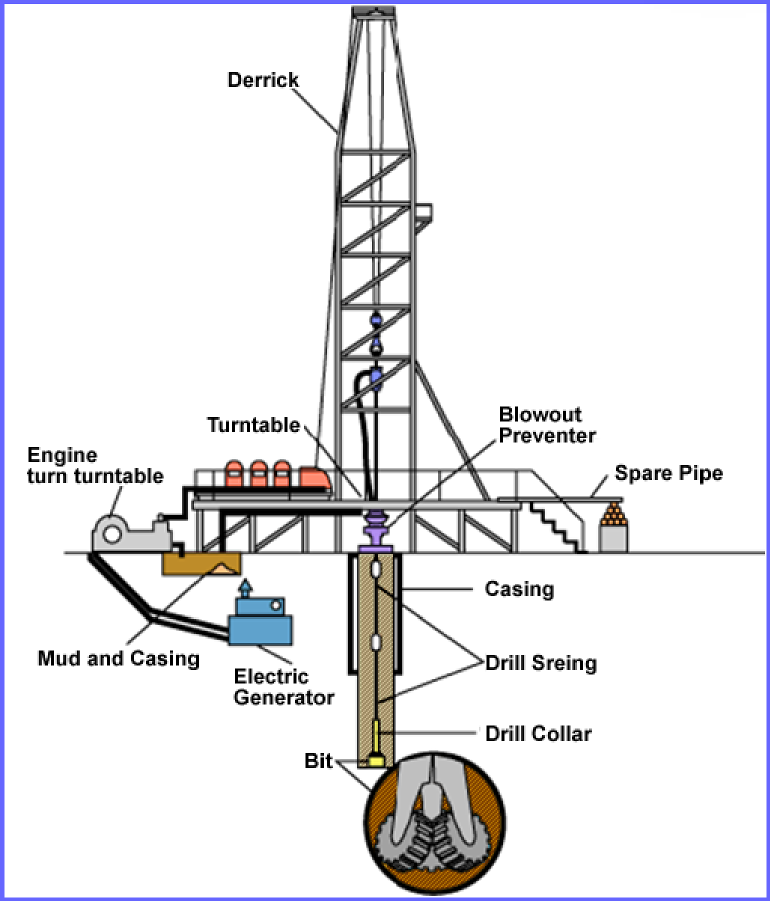


Drilling Technology



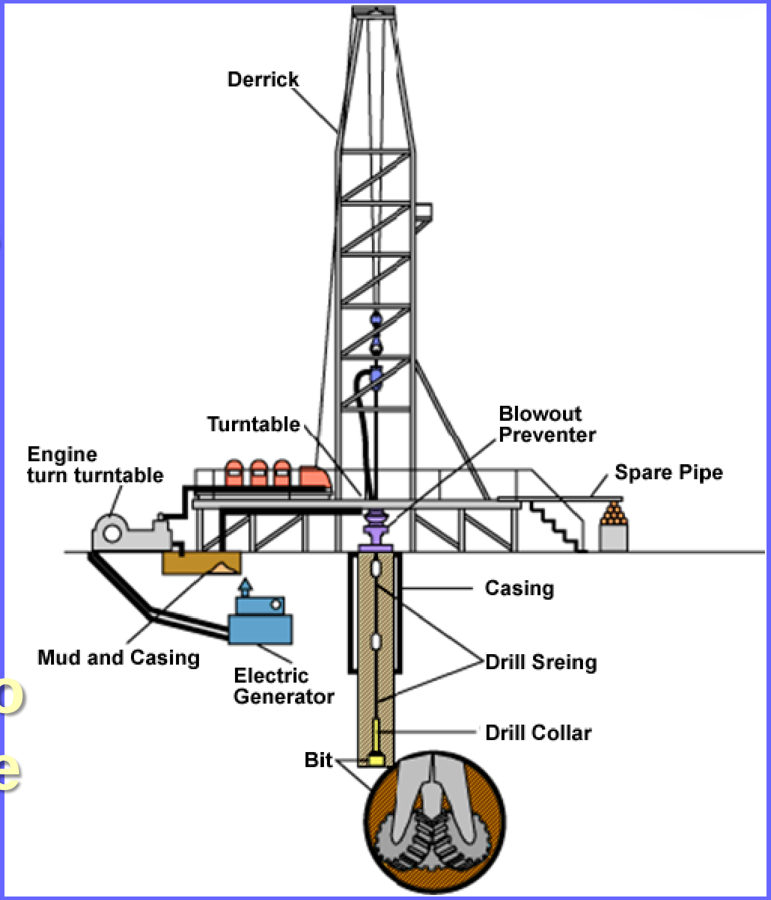
Basic Rotary Drilling Rig Components

- **The Rig (Derrick)**
  - **Masts and derricks are tall structural towers that support the blocks and drilling tools.**
  - **They provide height to allow the driller to raise and assemble the drill string.**



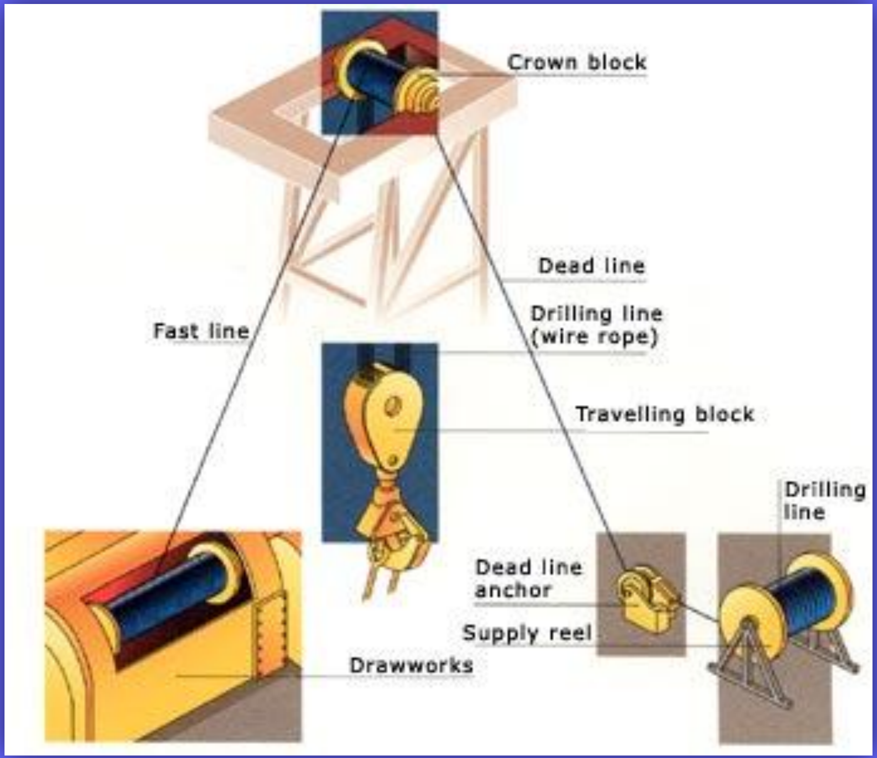
Basic Rotary Drilling Rig Components

- **The Rig (Derrick)**
  - **Some of the specifications used to rate derricks and masts are: height, vertical load, side wind load.**
  - **for example, a mast may be 42 meters tall, be able to support 250 tonnes, and be capable of withstanding 160km/hour winds.**



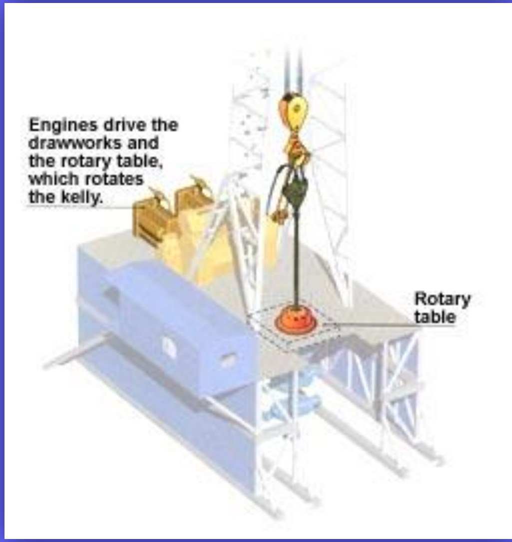
Basic Rotary Drilling Rig Components

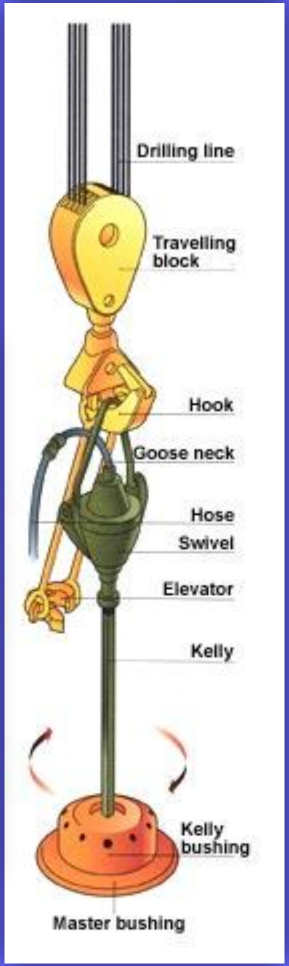
- **Hoisting System**
  - It is responsible for handling up and down drillpipes, drillcollars and drillbit during drilling operations. It includes drawworks, crown block, traveling block and the drilling string lines.



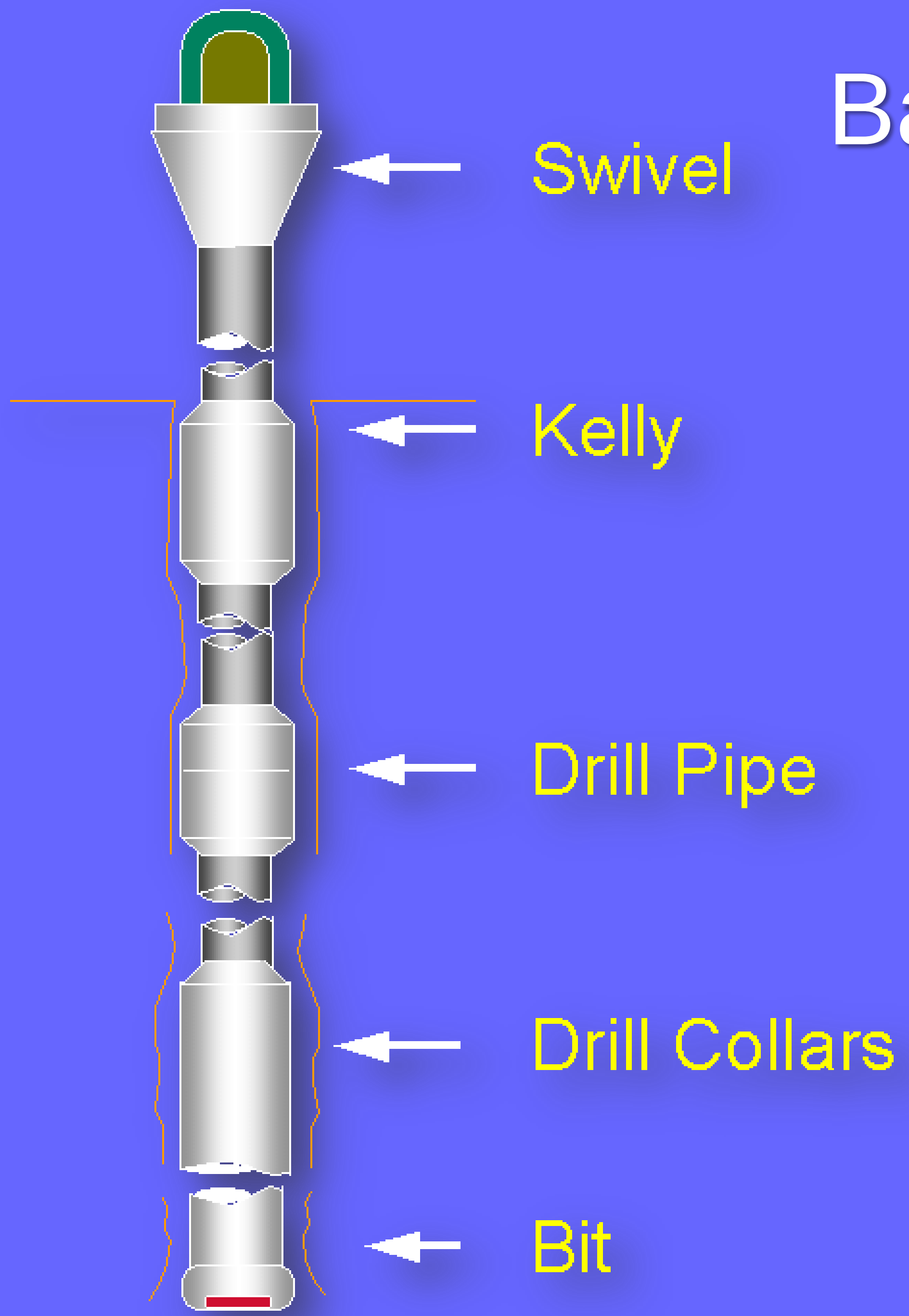
Basic Rotary Drilling Rig Components

- **Rotating System**
  - This system is responsible for the rotation of the drillstring (Bit, drillcollar and drillpipes) during drilling operations.





Basic Drill String Components



Basic Rotary Drilling Rig Components

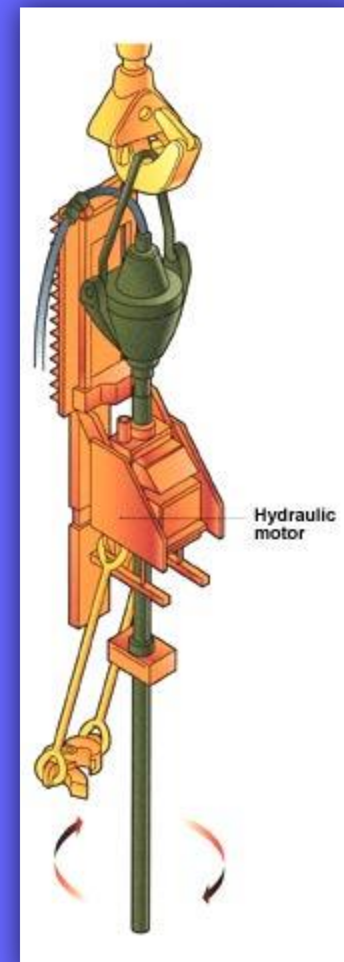
- ## Rotating System

➢ **The rotation action is done by:**

I. **A rotary table for shallow vertical wells drilling or**

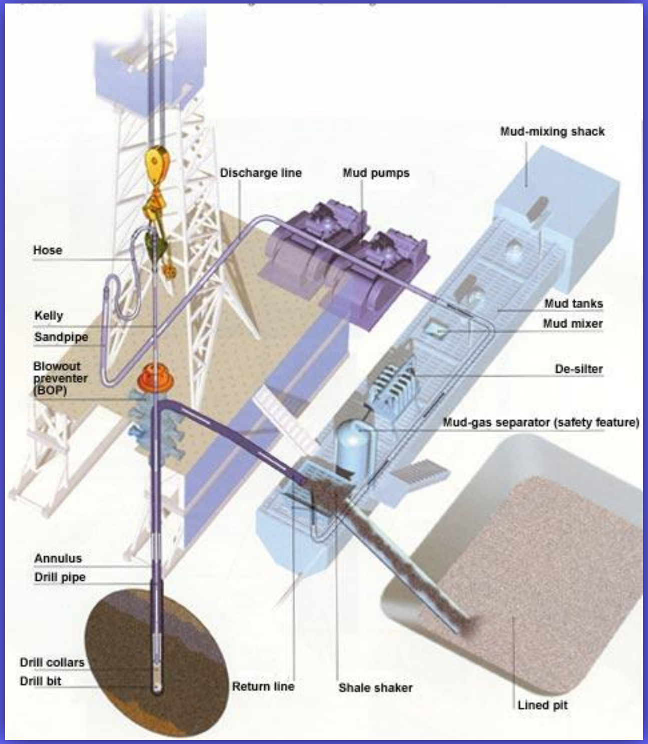
II. **A top-drive motor in case of deep vertical wells drilling or**

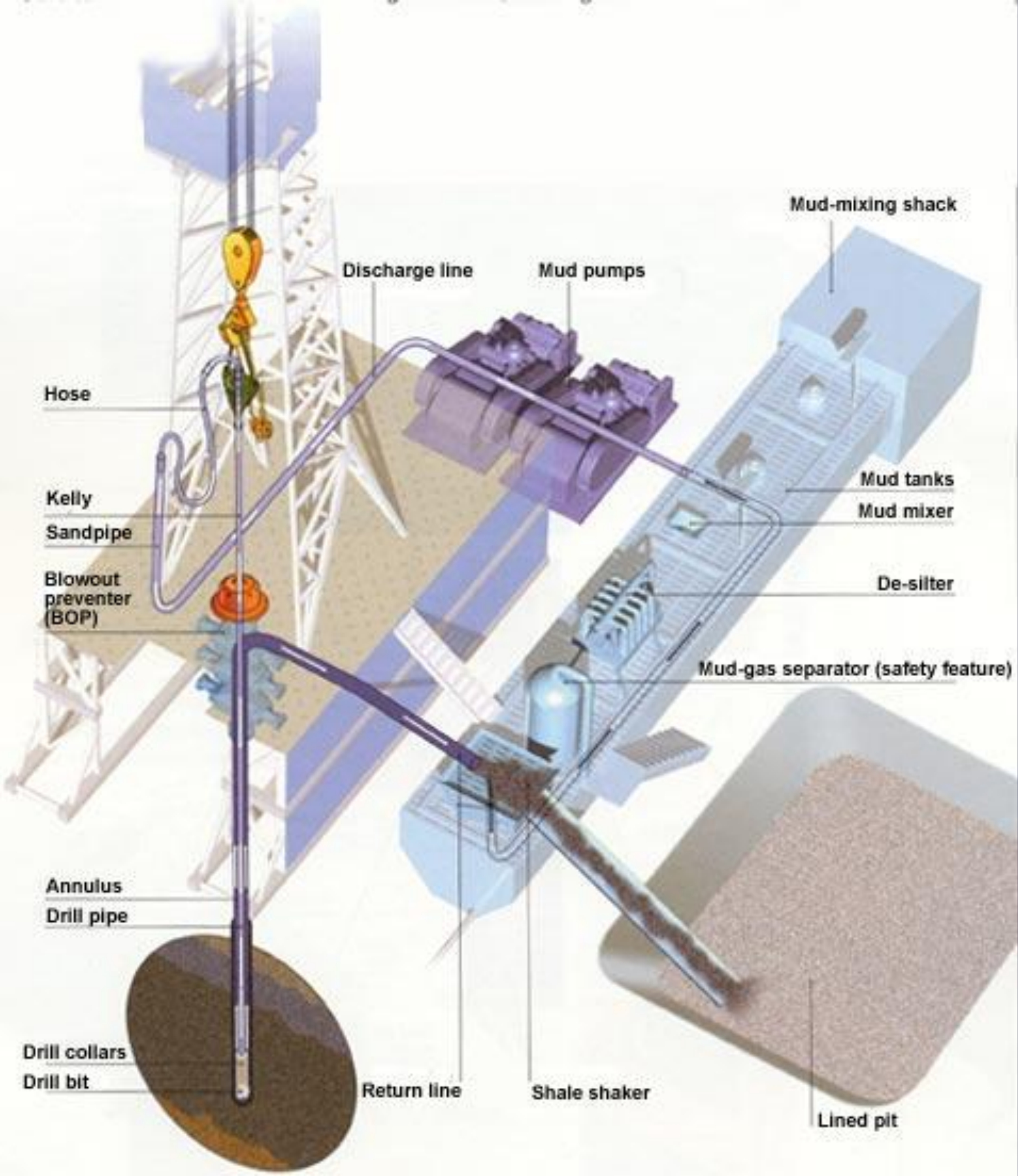
III. **A downhole motor in case of highly deviated or horizontal well drilling.**



Basic Rotary Drilling Rig Components

- **Mud Circulating System**
  - This system is responsible for the circulation of a drilling fluid necessary for carrying drilled cuttings from the borehole up to surface. Cooling and lubricating the drilling bit is important functions of any rotary drilling rig. It includes mud tank and pit, mud pump and shale shakers.





Mud-mixing shack
Discharge line
Mud pumps
Hose
Kelly
Sandpipe
Blowout preventer (BOP)
Mud tanks
Mud mixer
De-silter
Mud-gas separator (safety feature)
Annulus
Drill pipe
Drill collars
Drill bit
Return line
Shale shaker
Lined pit

Basic Rotary Drilling Rig Components

- ## Basic Functions of Drilling Fluid

The general functions of drilling fluids (mud) are:

- ✓ **to cool and lubricate the drillbit and the drillstring.**
- ✓ **to remove and transport rock cuttings from the bottom of the hole to the surface.**

Basic Rotary Drilling Rig Components

- **Basic Functions of Drilling Fluid**

The general functions of drilling fluids (mud) are:

- ✓ to suspend rock cuttings during non-circulation periods.
- ✓ to control encountered subsurface pressure.

Basic Rotary Drilling Rig Components

- **Type of Drilling Fluids**

Drilling fluids are classified as follows:

- ✓ air or mist.
- ✓ clear water (Fresh or Sea water).
- ✓ water-base mud:
  - fresh water + Bentonite + Additives.
  - seawater + Attapulgite + Additives.
  - water + Polymers + Additives.
- ✓ oil-base mud (Emulsion or Invert emulsion).

Basic Rotary Drilling Rig Components

- **Pressure Controlling System**

It is responsible for controlling the subsurface pressure that may encountered while drilling by means of a system called blowout preventer (BOP

Basic Rotary Drilling Rig Components

- **Pressure Controlling System**

  The BOP is a series of powerful sealing elements designed to close off the annulus between the pipe and hole, where the mud is normally returning to the surface.

Basic Rotary Drilling Rig Components

- **Pressure Controlling System**

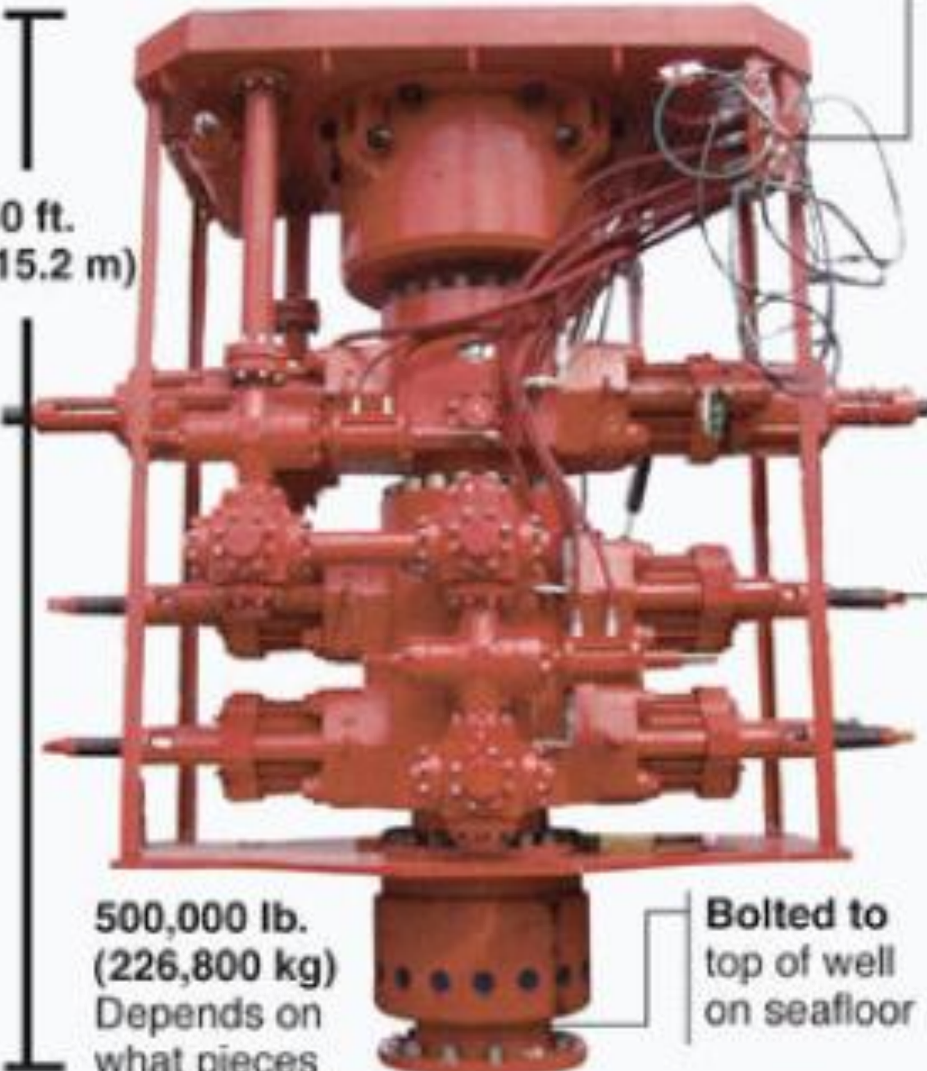
By closing off this rote, the well can be shut-in and the mud/or formation fluids forced to flow

through a controllable choke.

Blowout preventer

Investigators are trying to determine why the Deepwater Horizon blowout preventer failed.

50 ft.
(15.2 m)



Controlled by electrical, fiber-optic and hydraulic networks; can be activated manually with switches on rig floor and automatically when well pipe or rig is badly damaged

Massive pistons slam together to stop the flow of oil or natural gas; some pistons are fitted with cutting edges to shear through drill pipe and well casing if necessary

500,000 lb.
(226,800 kg)
Depends on what pieces are included

Bolted to top of well on seafloor

Source: Sentinel research, octnet.org
Graphic: Orlando Sentinel

Basic Rotary Drilling Rig Components

Basic Rotary Drilling Rig Components

- **Optimum Drilling Fluid Density Design**

Mud density design is a vital element in the overall drilling program design.

Any miscalculation in mud density will cause series unrecoverable problems such as kick or in worst cases blowouts.

Basic Rotary Drilling Rig Components

- **Optimum Drilling Fluid Density Design**

Usually, pore pressure of a subsurface formation is slightly different from values calculated based on the above assumptions. When impermeable rocks such as shales are compacted rapidly, their pore fluids cannot always escape and must then support the total overlying rock column, leading to abnormally high formation pressures.

Excess pressure, called abnormal pressure, overpressure or geopressure, can cause a well to blow out or become uncontrollable during drilling.

Basic Rotary Drilling Rig Components

- **Optimum Drilling Fluid Density Design**

Severe under pressure or subnormal pressure can cause the drillpipe to stick to the under-pressured formations.

Basic Rotary Drilling Rig Components

- **Optimum Mud Density Calculation**

Step 1: Optimize formations pore fluid pressure using the following equation:

$$P_p = 14.7 + (W_g \times TVD)$$

W_g less than (0.433 psi/ft) for subnormal pressure.

W_g between (0.433 psi/ft - 0.465 psi/ft) for normal pressure.

W_g between (0.465 psi/ft and 1.0 psi/ft) for abnormal pressure.

Basic Rotary Drilling Rig Components

- **Optimum Mud Density Calculation**

Step 2: Calculate optimum drilling mud pressure using the following equation:

$$P_m = P_p + (\text{Safety margin})$$

100 - 200

Basic Rotary Drilling Rig Components

- **Optimum Mud Density Calculation**

Step 2: Calculate optimum drilling mud pressure using the following equation:

$$P_m = P_p + (\text{Safety margin})$$

100 - 200

$$P_p \leq P_m \leq P_f$$

Basic Rotary Drilling Rig Components

- **Optimum Mud Density Calculation**

Step 3: Optimum mud density can be calculated as follows:

$$\rho_m = P_m / (0.052 \times TVD)$$