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Oil & Gas Drilling Technology – Onshore Rigs – Part 2

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OIL & GAS DRILLING TECHNOLOGY
ONSHORE RIGS – PART 2

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I. INTRODUCTION:

Oil and gas inland drilling rigs can be mobile equipment mounted on trucks, tracks or trailers or more permanent land-based, or marine-based structures (such as oil platforms, also commonly called “offshore oil rigs”). Drilling rigs can sample sub-surface mineral deposits, test rock, soil and groundwater physical properties, and also can be used to install sub-surface fabrications, such as underground utilities, instrumentation, tunnels or wells. The term “rig” or “platform” therefore generally refers to the complex of equipment that is used to penetrate the surface of the Earth’s crust.

Small to medium-sized drilling rigs are mobile, such as those used in mineral exploration drilling, blast-hole, water wells and environmental investigations. Larger rigs or oil & gas platforms are capable of drilling through thousands of meters of the Earth's surface, using large "mud pumps" to circulate drilling mud (slurry) through the drill bit and up the casing annulus, for cooling and removing the "cuttings" while a well is drilled.

Hoists in the rig can lift hundreds of tons of pipe. Other equipment can force acid or sand into reservoirs to facilitate extraction of the oil or natural gas; and in remote locations there can be permanent living accommodation and catering for crews (which may be more than a hundred). Marine rigs or offshore platforms may operate many hundreds of miles or kilometers distant from the supply base with infrequent crew rotation or cycle.

II. OIL AND GAS DRILLING RIGS:

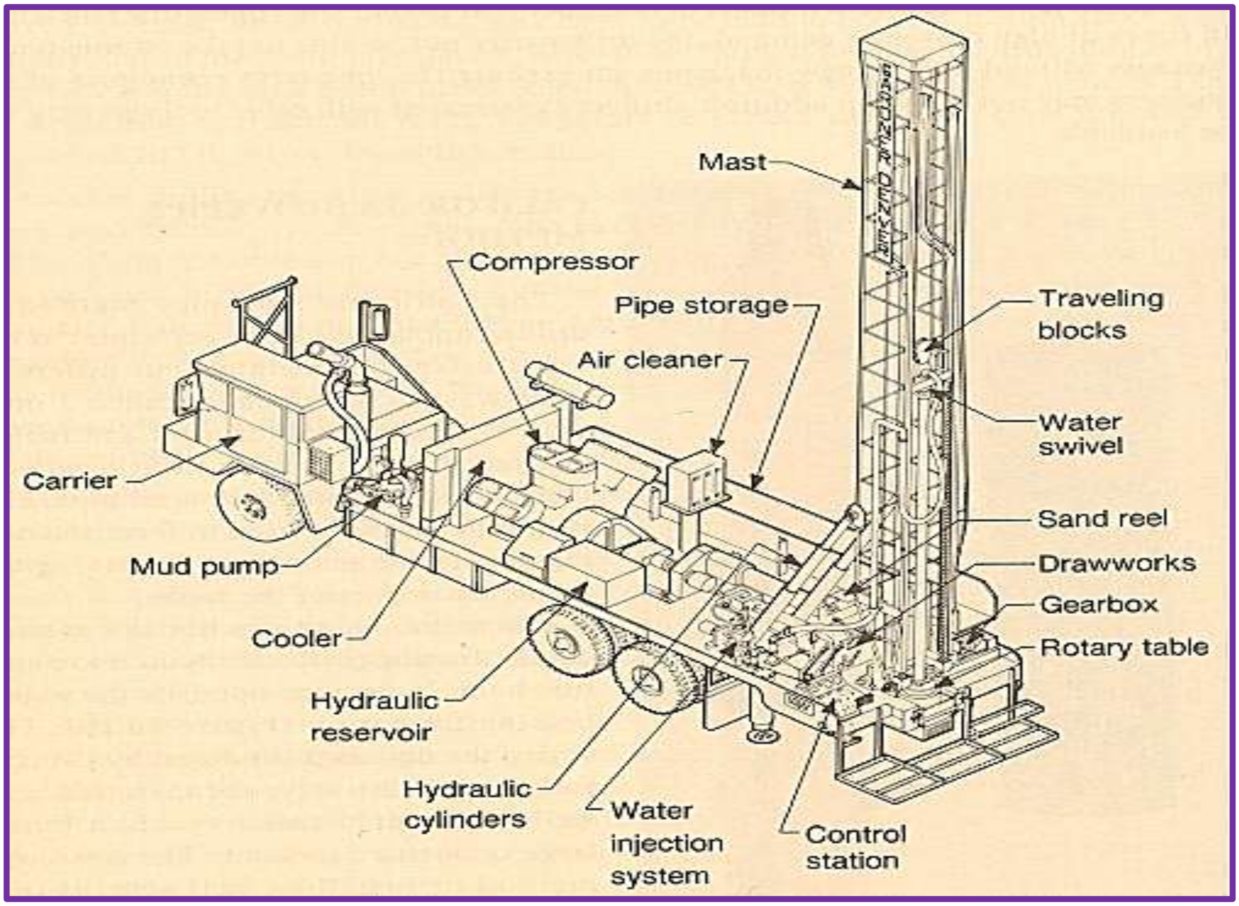
Oil and natural gas drilling rigs are used not only to identify geologic reservoirs but also to create holes that allow the extraction of oil or natural gas from those reservoirs. Primarily in onshore oil and gas fields once a well has been drilled, the drilling rig will be moved off of the well and a service rig (a smaller rig) that is purpose-built for completions will be moved on to the well to get the well on line. This frees up the drilling rig to drill another hole and streamlines the operation as well as allowing for specialization of certain services, i.e., completions vs. drilling.

In early oil exploration, drilling rigs were semi-permanent, and the derricks were often built on site and left in place after the completion of the well. In more recent times drilling rigs are expensive custom-built machines that can be moved from well to well. Some light duty drilling rigs are like a mobile crane and are more usually used to drill water wells. Larger land rigs must be broken apart into sections and loads to move to a new place, a process which can often take weeks.

Small mobile drilling rigs are also used to drill or bore piles. Rigs can range from 100 ton Continuous Flight Auger (CFA) rigs to small air powered rigs, used to drill holes in quarries, sands, etc. These rigs use the same technology and equipment as the oil drilling rigs, just on a smaller scale. The drilling mechanisms outlined below differ mechanically in terms of the machinery used, but also in terms of the method by which drill cuttings are removed from the cutting face of the drill and returned to surface.

Archeological records show that as early as 3000 B.C, the Egyptians may have used a similar rotary drilling technique. Leonardo da Vinci, in 1500, developed a design for a rotary drilling mechanism that bears much resemblance to actual technology. Although rotary drilling was patented in 1833, most attempts with rotary drilling consisted of little more than a mule, attached to a drilling device, walking in a circle.

The success came through the efforts of Captain Anthony Lucas and Patillo Higgins when they drilled the first “Spindletop” well in Texas in 1901. While the concept for rotary drilling, using a sharp spinning drill bit, is quite simple, modern rigs became very complicated. Basically, the rotary drilling system consists of *four groups of components*; the *prime movers*, *drilling and hoisting apparatus*, *rotating equipment*, and *mud circulating systems*, as described below:



1. Prime Movers: The prime movers in a rotary drilling are the driving systems that provide energy power to an entire rig. Generally, steam engines supplied power to the early drill rigs, but currently gas and diesel engines connected with generators, became a standard after World War II. Natural gas or steam is commonly used in reciprocating turbines, which also generate electricity to provide incidental lighting, pumping water, and air compression requirements for the wellsite.

2. Drilling and Hoisting Apparatus: These processes consist by the tools used to raise and lower whatever equipment is inserted into or come out from the wellbore. The most visible part of the hoisting equipment is the derrick, which is a tall tower structure that extends vertically from the wellbore, to serve as support for the cables (drilling lines) and pulleys (drawworks) to raise or lower tools into the borehole. As an example, in rotary drillings, the holes are dug with a high resistant steel rotary drill bit and then lined with long strings of pipes (drill pipes) extending from the surface down to the borehole. When a drill bit needs to be changed or replaced, the whole string of pipes must be raised to the surface.

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 (3 1/2 inch, 4 inch, 5 inch, 5 1/2 inch, 5 7/8 inch, 6 5/8 inch). The tool joint connections are threaded to make each drill pipe segment to the next segment. Drill pipes are hollow to allow drilling fluid to be pumped through them, down the hole, and back up the annulus.

Drill strings may be manufactured in 30-foot lengths (range 2 or single drill pipe); although sections of drill pipe can also be manufactured 60–90-foot (18–27 m) stands (range 3 or double-triple respectively). Each 30-foot component is referred to as a joint, and typically 2, 3 or 4 joints are joined together to make a *stand*. When the derrick is tall enough, multiple joints of drill pipe may be removed and put down at once, speeding the drilling process. The advantage of a top drive is that it allows the drilling rig to use longer sections of a stand of drill pipes.

Standard Derricks: Generally, are four sided steel structures that must be assembled and disassembled when transported, using special vehicles.

Portable Derricks: There are two models; *telescoping and jackknife types*. The telescoping derrick is raised and lowered in an extending and collapsing fashion, erected in one piece, but may be disassembled after being lowered. According to capacity, the derricks are classified as:

- **Single**: Has the capacity of pulling 30 feet stands of pipe (only one 30-ft joint);
- **Double**: Has the capacity of pulling 60 feet stands of pipe;
- **Triple**: Has the capacity of pulling 90 feet stands of pipe.

3. Rotating Equipment: Are the tools that actually serve to rotate the drill bit, as the Kelly, swivel, and the part of the drill string, which connects the rotary hose to the drill string and allows circulation and rotation at the same time. Below the drill pipe are also the drill collars, which help to add weight to the drill string, and ensure enough pressure to the rotary bit to dig through hard rocks.

4. Mud Circulating Systems: The main objectives are; cooling and lubricating the drill bit, removing debris and cuttings and coating the walls of the wellbore with a mud type-cake, through the drilling fluid, which circulates down the borehole during drilling process. The main components of the circulating system include the fluid pumps, air compressors, plumbing and specialty injectors for addition of additives to the fluid flow stream. The main procedures of circulating systems are:

- ✓ **Direct Circulation**: In this method, the *mud pit* is the starting point, where the drilling fluid ingredients are usually stored. Then, a drum or a mixer is used to purpose of mixing the mud. After addition of additives and mixed, the fluid is pumped up to the swivel and down all the way, through the drill pipe, and emerging back through the drill pipe to the surface. At the surface the fluid falls back in the mud pit or tanks to settle down the cuttings. Clean fluid is picked and the process is repeated until drilling is completed.

- ✓ **Reverse Circulation:** In this method, fluid is pumped from the mud pit down to the bore-hole, passes upward through the bit, and carry the cuttings back into the mud pit. However, this system requires a lot of water. The main difference is that additves are seldom mixed, and occasionally, low concentrations of polymeric and clay additives are used to reduce water loss. Rotary rigs designed for reverse circulation, usually have larger capacity mud pumps and air bigger air compressors developed for larger boreholes, which allow increase pressures and insure the removal of cuttings and debris from the wellbore.

- ✓ **Direct Rotary Air Drilling**: Is performed as a path for fluid circulation when using direct rotary air for drilling, which is somewhat the same for fluid rotary drilling. A large compres-sor provides air to the swivel hose connected to the top of the Kelly, and when is forced down the drill pipe, the air scapes through small ports at the bottom of the bit, lifting the cuttings and the cooling the bit. Drill nozzles for air rotary drilling bits are available in sizes to suit the down-hole conditions, velocity requirements and compressor capacity.

- ✓ **Reverse Air Drilling**: Is performed when a tremie pipe is inserted inside the drill pipe with a check valve on its bottom. When the formation produces water, the *reverse air drilling* begins. If drill rods are added, the tremie length may be submerged more then 20 ft, which aerates the column of water within the drill rod. The air assists in the transport of cuttings up the drill pipe, creating a partial vaccum, which helps to draw the water and cuttings in suspension. This method is generally used in sedimentary rocks and unconsolidated sand and gravel, and also requires adequate water to be successful, as the water is drawn from the wellbore producing zones that have been accessed.

Oil & Gas Drilling Preparation: Once the site has been selected, scientists survey the area to determine its boundaries, and conduct environmental impact studies if necessary. The oil company may need environmental agreements, titles and the right-of way accesses before drilling the land. For offshore sites, maritime standards and legal jurisdiction must be determined. After the legal issues are settled, the crew goes about preparing the land, as described below:

- The land must be cleared and leveled, and access roads may be built;
- Because water is used in drilling, there must be a source of water nearby. If the drilling is inland and there is no natural source, the crew drills a water well;
- The crew digs a reserve pit, which is used to dispose of rock cuttings and drilling mud dur-ing the drilling process, and lines it with plastic to protect the environment;
- If the site is an ecologically sensitive area, such as a marsh or wilderness, the cuttings and mud must be disposed of offsite and trucked away, instead of placed in a pit.

Once the land has been prepared, the crew digs several holes to make way for the rig and the main hole. A rectangular pit, called as *cellar* is dug around the location of the actual drilling hole. The cellar provides a work space around the hole for the workers and drilling accessories. The crew then begins drilling the main hole, often with a small drill truck rather than the main rig. The first part of the hole is larger and shallower than the main portion, and is lined with a large-diameter conductor pipe.

The crew digs additional holes off to the side to temporarily store equipment, when these holes are finished, the rig equipment can be brought in and set up. Depending upon the remoteness of the drill site and its access, it may be necessary to bring in equipment by truck, helicopter or barge. Some rigs are built on ships or barges for work on inland water, where there is no foundation to support a rig (as in marshes or lakes).

Oil & Gas Drilling Processes: The crew sets up the rig and starts the drilling operations. First, from the starter hole, the team drills a surface hole down to a pre-set depth, which is somewhere above where they think the oil trap is located. There are six basic steps to drilling the surface hole:

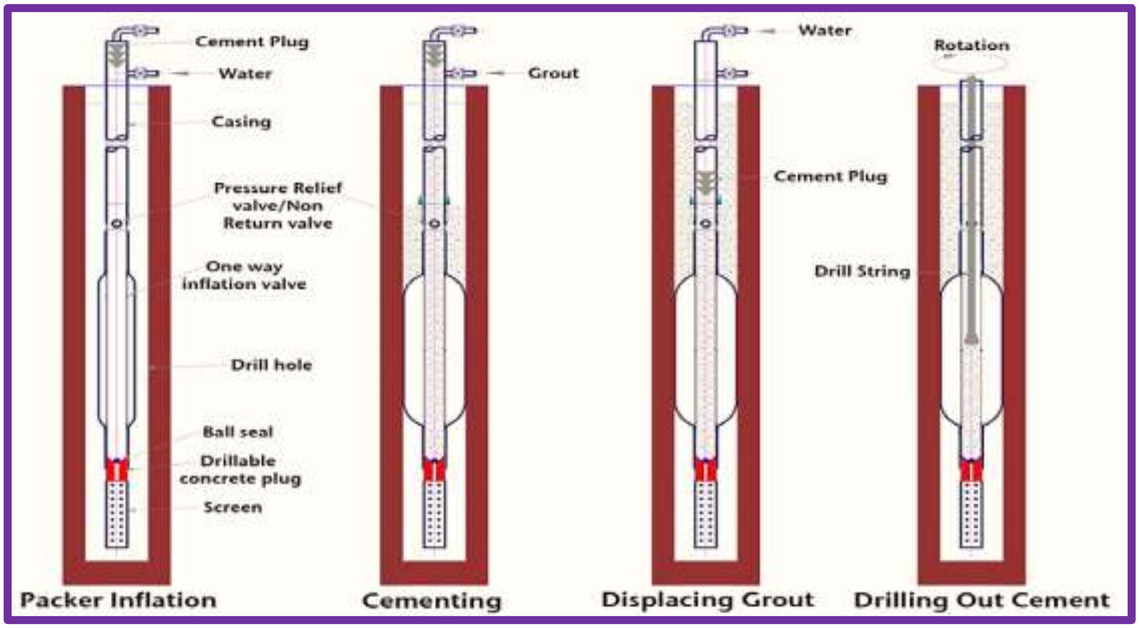
- ✓ The drill bit is placed, collar and drill pipe in the hole, the Kelly and turntable are attached, and drilling begins;
- ✓ As drilling progresses, the mud must circulate through the pipe and out of the bit to float the rock cuttings out of the hole;
- ✓ As the hole gets deeper, new sections (joints) of drill pipes are added, the drill pipe, collar and bit are removed (trip out) when reaches the pre-set depth (anywhere from a few hundred to a couple-thousand feet);
- ✓ When the pre-set depth is reached, the casing are cemented, casing-pipe sections are placed into the hole to prevent it from collapsing by itself. The casing pipe has spacers around the outside to keep it centered in the hole.
- ✓ The casing crew puts the casing pipe in the hole. The cement crew pumps cement down the casing pipe using a bottom plug, a cement slurry, a top plug and drill mud. The pressure from the drill mud causes the cement slurry to move through the casing and fill the space between the outside of the casing and the hole.
- ✓ Finally, the cement is allowed to harden and then tested for such properties, as hardness, alignment, and a proper seal.

Drilling Stages: The crew drills and cements new casings, and goes drilling again. When the rock cuttings from the mud, reveal the oil sand from the reservoir rock, the crew may have reached the well's final depth. At this point, crew members remove the drilling apparatus from the hole and perform several tests to confirm this finding. Once they've reached the final depth, the crew completes the well to allow oil to flow into the casing in a controlled manner, as described below:

- ✓ First, they lower a *perforating gun* into the well to the production depth. The gun has explosive charges to create holes in the casing through which oil can flow. After the casing has been perforated, they run a small-diameter pipe (tubing) into the hole, as a conduit for oil and gas to flow up through the well. A *packer* device is run down the outside of the tubing.

- ✓ When the *packer* is set at the production level, it's expanded to form a seal around the outside of the tubing. A ball value is dropped into the casing to seal the bottom valve. The casing is pressurized with fluid, inflating the packer which seals the borehole wall. When the pressure rises, the burst valve opens allowing fluid to flow into the outer annulus.

- ✓ Cement grout may then be pumped down to seal the casing. The burst valve acts as a non-return valve to prevent the return of grout into the casing. Then, an assembly of valves, spools, pressure gauges and chokes fitted to the wellhead of a completed well to control production. The wellhead is normally positioned at the top of the well. The wellhead ends all the casings that are in the well, and enables pressure monitoring and pumping into each casing annulus section.



- ✓ Finally, a multi-valved structure designated as X-mas tree or Christmas tree is placed on the top of the wellhead, and the top of the casing is cemented. The Christmas tree is the assembly of gate valves, chokes, and fittings that controls the flow of oil or gas during production. Tree design is based on production pressure and/or flow rates. The Christmas tree and wellhead are usually made up and installed as a unit. The Christmas tree allows the control of the oil flow from the well.

- ✓ After the well is completed, the crew must start the flow of oil into the well. For *limestone* reservoir rock, *acid* is pumped down the well and out the perforations. The acid dissolves channels in the limestone that lead oil into the well.

- ✓ For *sandstone* reservoir rock, a specially blended fluid containing *proppants* (sand, walnut shells, aluminum pellets) is pumped down the well and out the perforations. The pressure from this fluid makes small fractures in the sandstone that allow oil to flow into the well, while the proppants hold these fractures open. Once the oil is flowing, the oil rig is removed from the site and production equipment is set up to extract the oil from the well.

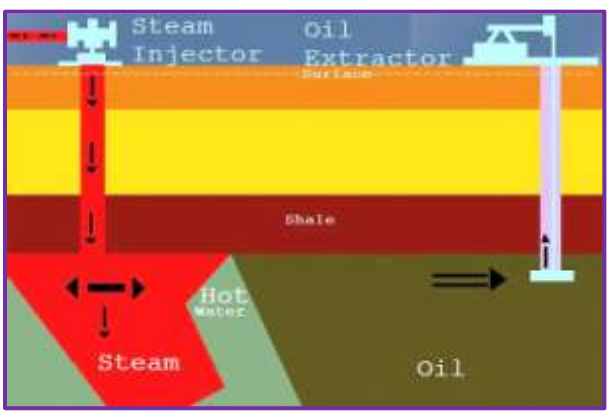
Oil Extraction and Recovery: After the rig is removed, an artificial lift pump is placed on the wellhead. The most common type of onshore artificial lift pump system is the *beam pumping (*or *sucker rod pumping*). The sucker rod pump lifts the oil from the reservoir through the well to the surface. Usually pumping about 20 times a minute, the pumping units are powered electronically or via gas engine, called as *prime mover*.

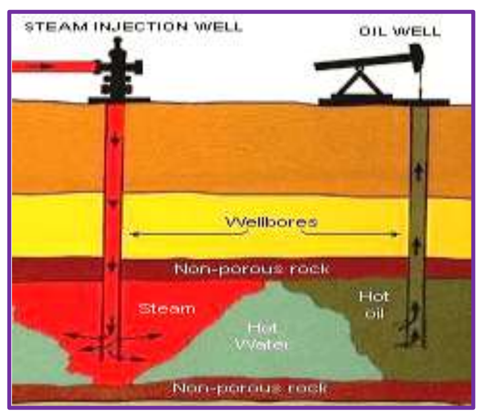
This system forces the pump up and down, creating a suction that draws oil up through the well. In some cases, the oil may be too heavy to flow. In these cases, the crew drills a second hole into the reservoir and injects steam under pressure. The heat from the steam thins the oil in the reservoir, and the pressure helps push it up the well. This process is also called Oil Recovery. Sometimes pumps, such as beam pumps and electrical submersible pumps (ESPs), are used to bring the oil to the surface; all these are known as artificial lift mechanisms.

Primary Recovery: When the underground has a high pressure in the oil reservoir to force the oil to the surface, the arrangement of valves (the Christmas tree) on the wellhead is sufficient for oil processing and production. During the *primary recovery* stage, the reservoir natural mechanisms include; natural water displacing oil downward into the well, expansion of the natural gas at the top of the reservoir, expansion of gas initially dissolved in the crude oil, and gravity drainage resulting from the movement of oil within the reservoir from the upper to the lower parts where the wells are located. These factors, during the primary recovery stages are typically 5-15%.

Secondary Recovery: Over the lifetime, the pressure of the well may fall, and there will be insufficient underground pressure to force the oil to the surface. *Waterflooding* is a typical secondary recovery method depending on the properties of oil and the characteristics of the reservoir rock. Other secondary recovery techniques to increase the reservoir's pressure are by water injection, natural gas reinjection, gas lift, air injection, carbon dioxide or some other gas, reducing the overall density of fluid in the wellbore. The injection process requires power, such as gas turbines. The factors after primary and secondary oil recovery operations are between 35 and 45%.

Tertiary Oil Recovery: Also called as "enhanced recovery", increases the mobility of the oil in order to increase extraction. The "Thermally Enhanced Oil Recovery" (TEOR) method is also a tertiary recovery technique that heats the oil, reducing its viscosity and making it easier to extract. Steam injection is the most common form of TEOR, and is often done with cogeneration plant. In this process, a gas turbine and a generator are used to generate electricity and the waste heat is used to produce steam, which is then injected into the reservoir.

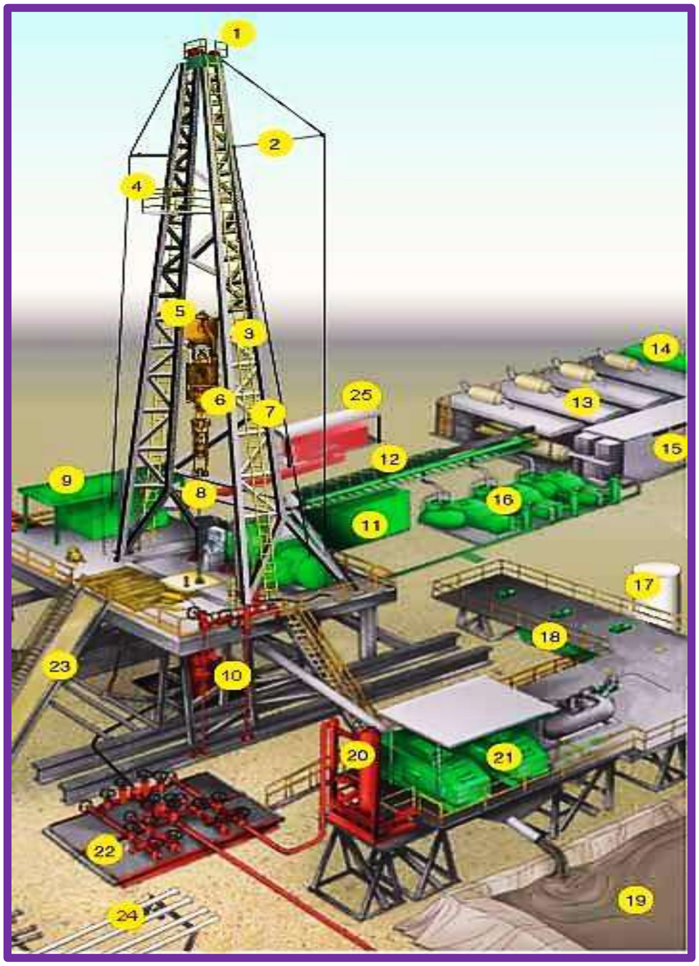




Fire flooding (In-situ burning) is another form of TEOR, where some of the oil is burned to heat the surrounding oil. Fire flooding works best when the oil saturation and porosity are high. Continuous injection of air or other gas mixture with high oxygen content will maintain the flame front. Heat from the fire reduces oil viscosity and helps vaporize reservoir water to steam.

Occasionally, surfactants (detergents) are injected to alter the surface tension between the water and oil in the reservoir, mobilizing oil which would otherwise remain in the reservoir as residual oil. Another method to reduce viscosity is using the carbon dioxide flooding.

1. DRILLING RIGS – MAIN COMPONENTS:



1. Crown Block and Water Table
2. Catline Boom and Hoist Line
3. Drilling Line
4. Monkeyboard
5. Traveling Block
6. Top Drive
7. Mast
8. Drill Pipe
9. Doghouse
10. Blowout Preventer
11. Water Tank
12. Electric Cable Tray
13. Engine Generator Sets
14. Fuel Tanks
15. Electric Control House
16. Mud Pump
17. Bulk Mud Components Storage
18. Mud Pits
19. Reserve Pits
20. Mud Gas Separator
21. Shale Shaker
22. Choke Manifold
23. Pipe Ramp
24. Pipe Racks
25. Accumulator

The PETEX picture above is *only for a reference*, but is an effective instructional tool. However, for didactic learning, a little more complete *list of the main terms*, operations and components of the petroleum drilling rig is shown below, with some improved descriptions, in alphabetical order.

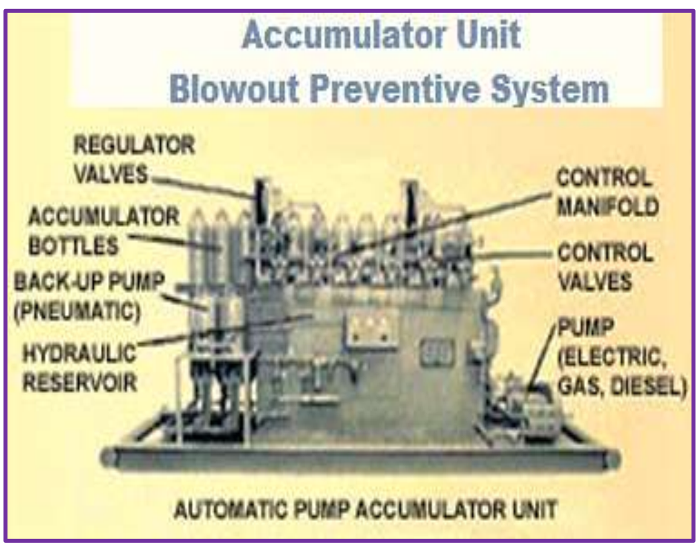
Acid Fracturing: A combination of oil, acid and water under high pressure pumping to separate hard limestone formations. In general, acid fracturing is best applied in shallow, low-temperature carbonate reservoirs, in which the reservoir temperature is less than 200°F and the maximum effective stress on the fracture will be less than 5,000 psi. Low temperature reduces the reaction rate between the acid and the formation, which allows the acid to penetrate deeper into the fracture.

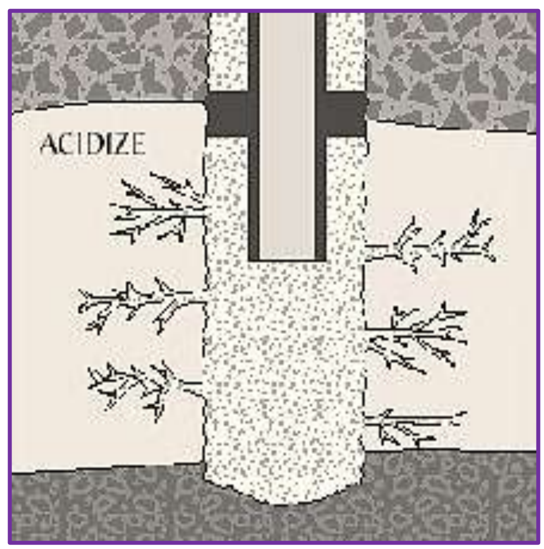
The most commonly used fluid in acid fracturing is 15% hydrochloric acid (HCl) or 28% HCl to obtain more acid penetration and more etching. Formic acid (HCOOH) and acetic acid (CH_3COOH) are also used because these acids are easier to inhibit under high-temperature conditions. However, acetic and formic acid cost more than HCl. Hydrofluoric acid (HF) should never be used during an acid fracturing treatment in a carbonate reservoir.

Acidizing Stimulation: Is a type of stimulation treatment, performed below the reservoir fracture pressure, to restore the natural permeability of the reservoir rock. Well acidizing is achieved by pumping acid into the well to dissolve limestone, dolomite and calcite cement between the sediment grains of the reservoir rocks. There are two types of acid treatment; *matrix acidizing* and *fracture acidizing*.

In a *matrix acid* the job is performed when acid is pumped into the well and into the pores of the reservoir rocks. In this form of acidizing, the acids dissolve the sediments and mud solids that are inhibiting the permeability of the rock, enlarging the natural pores of the reservoir and stimulating flow of hydrocarbons.

Accumulator: Is a device used in a drilling rig hydraulic system to store energy or, in some applications, dampen pressure fluctuations. Energy is stored by compressing a pre-charged gas bladder with hydraulic fluid from the operating or charging system. Depending on the fluid volume and pre-charge pressure of the accumulator, a limited amount of hydraulic energy is then available independent of any other power source. Well pressure-control systems typically incorporate sufficient accumulator capacity to enable the blowout preventer to be operated with all other power shut down. This storage device may use nitrogen pressurized hydraulic fluid, in operating the blowout preventers.





Air Drilling: It is a drilling technique whereby gases (compressed air or nitrogen) are used to cool the drill bit and lift cuttings out of the wellbore, instead of the more conventional use of liquids. The advantages of air drilling are that it is usually much faster than drilling with liquids and it may eliminate lost circulation problems. The disadvantages are the inability to control the influx of formation fluids into the wellbore and the destabilization of the borehole wall in the absence of the wellbore pressure typically provided by liquids.