PDHonline Course M535 (12PDH)

Oil & Gas Production and Processes Fundamentals

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OIL & GAS PRODUCTION AND PROCESSES FUNDAMENTALS

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OBS.: This is a didactic and professional handbook. It´s highly recommended downloading and printing the course content for your study, before answering the quiz questions.

I. INTRODUCTION:

Petroleum is an oily and flammable liquid that occurs naturally in deposits, generally below the surface of the earth, also called **crude oil**. It is a natural liquid found in rock formations, consisting of a complex mixture of **hydrocarbons** and various molecular weights, with traces of nitrogen and sulfur compounds. Oil is formed by the remains of decomposing plants and animals, buried under thick layers of rock, over the last 600 million years. Small microscopic plankton organisms were responsible for the high organic carbon content of buried fossils under sedimentary rocks subjected to intense heat and pressure, distributed in some places on land and at the bottom of the sea, and then gradually transformed into oil reservoirs.

The word petroleum may come from the **Greek**: "*petra*" for rocks and "*elaion*" or from Medieval Latin, "*petra*" (or petrous) for rock and "*oleum*". The term (spelled "*petraoleum*") was found in 10th-century Old English sources and used in the treatise De Natura Fossilium, published in 1546 by the German mineralogist Georg Bauer, also known as Georgius Agricola. In ancient times, it was dug from streams or holes in the ground and used as mortar, to coat walls and boat hulls, for lighting purposes or as firearms in defensive warfare. Historically, we know stories of eternal fires where oil and gas infiltrations ignite and burn. An example is the famous fire in the oracle of Delphi, in **1000 BC**, always lit. In **500 BC**, the Chinese were already using natural gas to boil water.

II. HISTORY:

According to historians Herodotus and Diodorus Siculus, more than **4,000 years ago**, asphalt was already used in the construction of the walls and towers of Babylon. Large quantities of crude oil were found on the banks of the River Issus, one of the tributaries of the Euphrates. Ancient Persian tablets indicate medicinal and enlightening uses in the upper levels of their society. Around 350 BC, oil was produced from bamboo wells in China. Early British explorers in Myanmar (Burma) documented an oil extraction industry at Yenangyaung in 1795, with hundreds of hand-dug wells. In the past, the whale oil was used for lighting and in soap making. Demand for oil as a lighting fuel in Europe and other countries grew rapidly, to provide a cheaper alternative to scarce whale oil.

There was then a considerable search for oil in various parts of the world. In the mid-19th century, a group led by Major Alexeyev of the Bakinskii Corps of Mining Engineers, in the Baku region (Azerbaijan) in 1848, drilled a well manually. Other wells began to be dug manually in Poland in 1853, and another in neighboring Romania in 1857, in search of alternative fuels for commercial use. The process of distilling crude oil, as well as other hydrocarbon compounds, was first reported in the 9th century by the Persian Rhazes, (Abu Bakr al-Razi, 865 -935 AD), physician and alchemist. In his Book of Secrets, he described two methods for producing kerosene, called "white naphtha", using a device known today as an alembic. Kerosene is a liquid hydrocarbon fuel derived from the Greek "keros" (wax).

In the 19th century, kerosene was produced from coal oil (or shale oil) and bitumen, heating the rock to extract the oil and then distilling it, but with high extraction costs. In 1846 Abraham Gesner, a Canadian geologist, gave a public demonstration of a new kerosene extraction process in Charlottetown, Prince Edward Island, (Canada) using a mineral asphalt similar to carboniferous rock, called albertite, which takes the name after Albert County in New Brunswick, Canada, where it was first found. Albertite is a type of dark, shiny solid hydrocarbon bitumen that resembles coal, less soluble in turpentine than mineral asphalt. Abraham Gesner heated albertite in a retort and distilled a fine fluid, excellent fuel for lamps. Despite the priority of his discovery, Gesner did not obtain the first patent for kerosene. He was prevented from using albertite by producers because they had coal mining rights, and lost a court case when experts claimed that albertite was a form of coal.

Albertite

'Albertite' mine in Albert Mines, 1860

In 1847, the Scottish chemist James Young noticed a natural petroleum seepage in the Riddings coal mine at Alfreton, Derbyshire from which he distilled a light thin oil suitable for use as lamp oil, at the same time obtaining thicker oil suitable for lubricating machinery, which he named "*paraffin oil*" because at low temperatures resembled paraffin wax. In 1848, Young set up a small business refining the crude oil and became the first to patent the process of distilling the cannel coal into coal oil. In 1852 Young left Manchester to live in Scotland and that same year took out a US patent for the production of paraffin oil by distillation of coal. Both the US and UK patents were subsequently upheld in both countries in a series of lawsuits, however other producers were obliged to pay him royalties.

In 1851, Samuel Martin Kier began selling **kerosene** to local miners, under the name "*Carbon Oil*". He distilled this by a process of his own invention from crude oil. He also invented a new lamp to burn his product. The first commercial oil well in Canada became operational in 1858 at Oil Springs, Ontario (then Canada West). The businessman James Miller Williams dug several wells between 1855 and 1858 before discovering a rich reserve of oil four meters below ground. Williams extracted 1.5 million liters of crude oil by 1860, refining much of it into kerosene lamp oil. By 1859, James Miller Williams owned 800 acres of land in Oil Springs, Canada and reincorporated in 1860, the Canadian Oil Company. His company produced oil, refined it, and marketed refined products. That mix of operations qualified the Canadian Oil as the world's first integrated Oil Company. Because of Canada's unique geography, geology, resources and patterns of settlement, the discovery of petroleum applications touched off an oil boom, which brought hundreds of speculators and workers to this area.

Exploration in the Lambton County, in Southwestern Ontario, Canada, quickened the first flowing well in 1860, relied on hand pumps. The first gusher erupted on January 16, 1862, when struck oil at 158 feet (48 m). For a week the oil gushed unchecked at levels reported as high as 3,000 barrels per day, eventually coating the distant waters of Lake St. Clair with a black oil film. There is historical controversy concerning whether it was John Shaw or another oil driller, named Hugh Nixon Shaw who drilled this oil well; the local newspaper identified John Shaw.

The history of the petroleum industry in the United States goes back also to the early 19th century, when petroleum was discovered in Pennsylvania in 1859.The oil rush began in Titusville, Pennsylvania, when "*Colonel*" **Edwin Drake**, for the sole purpose of finding oil, drilled the first successful oil well in the Oil Creek Valley. The wells were shallow, less than **50 meters** (160 feet), but could give quite large production for that time. However, unfortunately for Drake, his success would not last. He had not purchased much land in the region and therefore the oil industry exploded around him outside of his control. His first well yielded only modest returns and he was fired by the Seneca Oil Company. He never **patented** the drilling method he pioneered, and lost his modest earnings from the oil business speculated on Wall Street. He would eventually die as a poor pensioner in 1880. The picture below shows the Oil Creek Valley where the oil was flowing initially at 4000 barrels per day, in October 1861.

The Drake Well, Titusville, PA, 1859

In Europe, Ignacy Lukasiewicz, a Polish pharmacist residing in Lwów, was experimenting different kerosene distillation techniques trying to improve the Gesner's process, using local seep oils. On the night of 31 July 1853, doctors at the local hospital needed to perform an emergency operation, impossible using candlelights. They sent a messenger for Lukasiewicz to try his new lamps. The **lamps** burned so brightly and cleanly that the hospital officials ordered several lamps plus a large supply of fuel. Lukasiewicz quit the pharmacy and travelled to Vienna to register his technique with the government. Then, moved to the Gorlice region of Poland in 1854, and sank several **wells** across southern Poland over the following decade, setting up a refinery near Jaslo in 1859.

By the end of the 19th century, the Russian Empire, particularly the Branobel Company in Azerbaijan had taken the lead in production. Access to oil was, and still is, a major factor in several military conflicts of the twentieth century, including the World War II, during which oil facilities were strategic assets and extensively bombed. The goal of German invasion in the Soviet Union included the capture of the Baku oilfields, to provide the necessary oil-supplies for the German military, suffering from Europe blockades. A large portion of the world's total oil exists as unconventional sources, such as bitumen in Canada and extra heavy oil in Venezuela. While significant volumes of oil are extracted from oil sands, particularly in Canada, logistical and technical hurdles remain, as oil extraction requires large amounts of heat and water, making its net energy content quite low relative to conventional crude oil. Thus, Canada's oil sands are not expected to provide more than a few million barrels per day in the foreseeable future.

In 1901, the U.S.'s first deep oil well out poured in Spindletop, near Beaumont, Texas. Captain Anthony F. Lucas's combined use of fishtail bits, water-based drilling mud, and steam-driven rotary drill rig resulted in such success that after, triggers the Texas oil boom. By the end of the 19th century, oil exploration in North America, led the US to become the leading producer. However, after 1960 the United States was surpassed by Saudi Arabia and the Soviet Union. Today, the top three oil producing countries are Russia, Saudi Arabia and the United States. About 80 percent of the world's readily accessible reserves are located in the Middle East, with 62.5 percent coming from the Saudi Arabia, UAE, Iraq, Qatar and Kuwait.

Discovery of Natural Gas: In 1859, an oil explorer, H.C. Tweedle, found a natural gas seep near Moncton, New Brunswick, Canada, what became the Dover field, but water seepage prevented production of these wells. In 1889, Eugene Coste, a young geologist who became the father of Canada's natural gas industry, brought in the first producing gas well in Essex County, Ontario. In 1891, Canada started to export natural gas from the Bertie-Humberstone field in Welland County to Buffalo, New York. Later, gas was exported to Detroit from the Essex field using 8 inches pipeline under the Detroit River.

In 1897, the pipeline stretched the Essex gas supply to its limit with the extension of exports to Toledo, Ohio, but the Ontario government revoked the license for the pipeline, and in 1907 the province passed a law prohibiting the export of natural gas and electricity. In 1909, New Brunswick's first successful gas well came in to supply customers at Stoney Creek near Moncton, although, nowadays, the city has a **propane** air plant to augment the limited natural gas supply. In 1911, a milestone for the natural gas industry was founded, when three companies using Ontario's Tilbury gas field joined to form Union Gas Company of Canada. In 1924, the Union Gas was the first company to use the new Seabord or Koppers process to remove poisonous *hydrogen sulfide* from the Tilbury gas. Union became one of the largest corporations in Canada before its acquisition by Duke Energy, a US firm.

Natural flows of oil and gas led to the successful early exploration in Alberta's foothills. Those discoveries were not unique, however. Early settlers frequently found oil and gas seeps in Western Canada, generally near rivers, streams and creeks. In 1922, at Rolla, British Columbia, the company Imperial Oil financed exploration to investigate. Then, a well was drilled and oil and gas found. By 1940, the New Brunswick Gas and Oilfields (NBGO) and its predecessors had drilled 126 wells. There were 27 exploratory and 99production wells, and from those, 73 were producers in the Stoney Creek Field.

The first large scale liquefaction of natural gas in the U.S. was in 1918 when the government liquefied natural gas to **extract helium**, which is a small component of some natural gas. Then, helium was intended for use in British dirigibles for World War I. The key patents having to do with natural gas liquefaction came in 1915 and the mid-1930s. In 1915 Godfrey Cabot patented a method for storing liquid gases at very low temperatures. It consisted of a thermos bottle type design, which included a cold inner tank within an outer tank, the tanks being separated by insulation.

In 1937, Lee Twomey received patents for a process for large scale liquefaction of natural gas. The intention was to store natural gas as a liquid so it could be used for shaving peak energy loads during cold snaps. Because of large volumes it was not practical to store natural gas, near atmospheric pressure. However, when the natural gas was converted to a liquid form, cooled to -162ºC (-260ºF) to **shrink the volume 600 times**, it could be stored in a **volume 600 times smaller**. Thus, this became a practical way to store the natural gas, stored at -260°F.

In 1938, however, with the growing importance of natural gas, concern over the monopolistic tendencies of interstate pipelines to charge higher than competitive prices due to their market power, the U.S. government began regulating the interstate natural gas industry with passage of the Natural Gas Act. The Act was intended to protect consumers from possible abuses such as unreasonably high prices. In 1989, Congress completed the process of deregulating the price of natural gas at the wellhead, which was begun in 1978 with the passage of the Natural Gas Policy Act, by passing the Natural Gas Wellhead Decontrol Act (NGWDA).

Today, natural gas is a vital component of the world's supply of energy and currently supplies more than one-half of the energy consumed by residential and commercial customers, and about 41 percent of the energy used by U.S. industry. It is one of the cleanest, safest, and most useful of all energy sources. Natural gas is the cleanest burning fossil fuel, playing an increasing role in helping to attain goals of a cleaner environment, energy security and a more competitive economy.

Since then, the two million-mile underground natural gas delivery system has an outstanding safety record. In 2004, the American Public Gas Association (APGA) consolidated the liquefied natural gas (LNG) and began to play a more prominent role in the overall gas supply picture. Although about one percent of the natural gas consumed in this country is currently imported as LNG, it is estimated that USA imports of LNG will grow to approximately **7 or 8%** by the end of this decade. This will require more than the four LNG facilities that currently exist in USA.

III. CRUDE OIL:

Crude Oil is a complex mixture consisting of up to **200** or more different organic compounds, mostly hydrocarbons. The API (American Petroleum Institute) measures the specific gravity of crude oil and compounds. The higher the API number expressed as degrees API, less dense (lighter, thinner) is the crude oil. Crude from different fields and from different formations within a field can be similar in composition or be significantly different, characterized for other non-wanted elements like sulfur which is regulated by environment rules and needs to be removed. Crude oil varies greatly in appearance depending on its composition. It is usually black or dark brown (although it may be yellowish, reddish, or even greenish). In the reservoir it is usually found in association with natural gas, which being lighter forms a gas cap over the petroleum, and saline water which, being heavier than most forms of crude oil, generally sinks beneath it. Crude oil may also be found in semi-solid form mixed with sand and water, as in the Athabasca oil sands in Canada, where it is usually referred to as *crude bitumen*.

In Canada, bitumen is considered a sticky, black, tar-like form of crude oil which is so thick and heavy that it must be heated or diluted to easily flow. Venezuela also has large amounts of oil in the Orinoco oil sands, although the hydrocarbons trapped in them are more fluid than in Canada and are usually called extra heavy oil. These oil sands resources are called unconventional oil to distinguish them from oil that can be extracted using traditional oil well methods. An oil well produces predominantly crude oil, with some natural gas dissolved in it. Petroleum includes only crude oil, but in common usage it includes all liquid, gaseous, and solid hydrocarbons.

Under surface pressure and temperature conditions, lighter hydrocarbons, such as **methane, ethane, propane and butane** occur as gases, while **pentane** and heavier hydrocarbons are in the form of liquids or solids. The hydrocarbons in crude oils are mostly alkanes, cycloalkanes and various aromatic hydrocarbons while the other organic compounds contain **nitrogen, oxygen, sulfur**, and trace amounts of metals, such as **iron, nickel, copper and vanadium**. However, in an underground oil reservoir the proportions of gas, liquid, and solid depend on subsurface conditions and on the phase diagram of the petroleum mixture.

Petroleum is extracted mostly through oil drilling, after tiresome studies of structural geology (at the reservoir scale), sedimentary basin analysis, reservoir characterization (mainly in terms of the porosity and permeability of geologic reservoir structures). Then, it is refined and separated, most easily by distillation, into a large number of consumer products, from gasoline (petrol), kerosene to asphalt and chemical reagents used to make plastics and pharmaceuticals. The proportion of light hydrocarbons in the petroleum mixture varies greatly among different oil fields, ranging from **97 percent** by weight in the lighter oils, to as little as **50 percent** in the heavier oils and bitumen.

API Gravity: The American Petroleum Institute (API) fluid gravity is a measure of how heavy or light a petroleum liquid is compared to water. When its API gravity is **greater than 30**, it is lighter and floats on water, if **less than 10**, it is heavier, and sinks. Thus, API is used to compare the relative densities of petroleum liquids. Crude oil API gravities typically range from **7 to 52** corresponding from about 750 kg/m³ (46.8 lb/ft³) to 970 kg/m³ (60.5 lb/ft³), but most fall in the **20 to 45 API** gravity range. Although the light crude (i.e., 40-45 degree API) is good and lighter crude (i.e., 46 degree API and above) is not necessarily better for a typical refinery.

Crude lighter than **40-45 degrees API** contains shorter molecules, or less of the desired compounds, useful as *high-octane gasoline and diesel fuel* that maximize the production of most refineries. On the other side, heavy crude oil less than **25 degrees API** contains longer and bigger molecules that are not useful as *high-octane gasoline and diesel fuel*, more difficult for further processing. Heavy crude can be processed in a refinery by cracking that reduces the carbon number to increase the high value fuel yield.

API Classification: Oil with API gravity between **40 and 45** commands the highest prices. Above 45 degrees, the molecular chains become shorter and less valuable to refineries. Crude oil is classified as *light, medium or heavy*, according to its measured API gravity, as shown below:

- ✓ **Light crude oil**: API gravity higher than 31.1° API (less than 870 kg/m^3);
- ✓ **Medium crude oil**: API gravity between 22.3°API and 31.1°API (870 to 920 kg/m^3);
- ✓ **Heavy crude oil**: API gravity below 22.3° API (920 to 1000 kg/m^3);
- ✓ **Extra heavy oil**: API gravity below 10.0° API (greater than 1000 kg/m^3).

Crude oil with API gravity less than 10º API is referred to as *extra heavy oil or bitumen*. Bitumen derived from the oil sands deposits in Alberta, Canada, has an API gravity of around 8° API. It can be diluted with lighter hydrocarbons to produce diluted bitumen, with an API gravity of lower than 22.3º API, or further "upgraded" to an API gravity of 31° API to 33°API as synthetic crude.

For example, consider 1 barrel of tar dissolved in 3 barrels of naphtha (lighter fluid) to produce 4 barrels of a 40º API mixture. When this 4 barrel mixture is fed to a distillation column of a refinery, 1 barrel of tar, and 3 barrels of lighter fluid is all that will come out from the still. On the other hand, when 4 barrels of a naturally occurring 40º API South Louisiana sweet crude is fed to the distillation column at a refinery. Then these could **come out** as 1.4 barrels of gasoline and naphtha, 0.6 barrels of kerosene (jet fuel), 0.7 barrels of diesel fuel, 0.5 barrels of heavy distillate, 0.3 barrels of lubricating stock, and 0.5 barrels of residuum (tar).

This example above illustrates weight percent distributions of three different hypothetical petroleum stocks that could be fed to a refinery with **catalytic cracking capacity**. The chemical composition is generalized by the carbon number which is the number of carbon atoms in each molecule. The medium blend is desired because it has the composition that will yield the highest output of high octane gasoline and diesel fuel in the cracking refinery. Though the heavy stock and the light stock could be mixed to produce a blend with the same API gravity as the medium stock, the composition of the blend would be far different from the medium stock.

Extra heavy crude are hydrocarbons with an API grade of about **15º or below**. The most extreme heavy crude currently extracted is in eastern Venezuela (Orinoco basin), 8º API. In other areas, such as Canada, the reservoir temperature is lower, and steam injection must be used to stimulate flow form the formation. When reaching the surface, the crude must be mixed with a diluent (often LPGs) to allow it to flow in pipelines. Syncrude Canada is one of the world's largest producers of ***synthetic crude oil*** from oil sands and the largest single source producer. It is located just in the Athabasca Oil Sands, and has a capacity of 350,000 barrels per day (56,000 m^3/d) of oil, equivalent to about 13% of Canada's consumption.

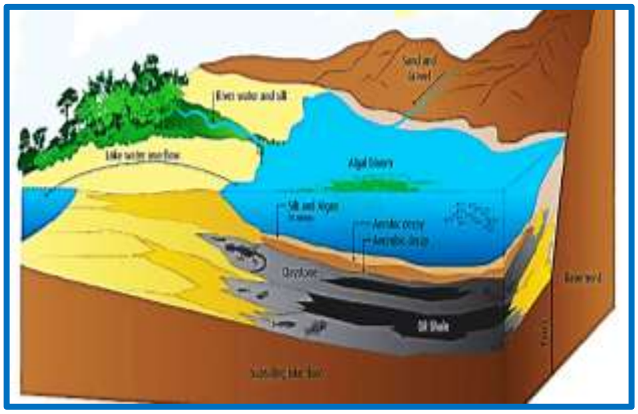
Tar Sands: Also referred to as oil sands are a **combination** of clay, sand, water, and bitumen (heavy black viscous oil). Tar sands can be mined and processed to extract the oil-rich bitumen, which is then refined. Basically two tons of tar sands may produce approximately one barrel of oil. Typical tar sands contain sand grains with a water envelope, covered by a bitumen film that may contain **70% oil**. Various fine particles can be suspended in the water and bitumen and can be processed through water extraction. Hot water is added to the sand, and the resulting slurry is piped to the extraction plant where it is agitated and the oil is skimmed from the top.

The bitumen froth floats to the top of separation vessels, further treated to remove residual water and fine solids, transported and processed the same way as for extra-heavy crude. It is estimated that around 80% of tar sands are too far below the surface, for the current open-pit mining technique. Techniques are being developed to extract the oil below the surface, using a massive injection of steam into a deposit to liberate the bitumen underground, and channeling it to extraction points where it would be liquefied before reaching the surface. Tar sands of Alberta, Canada and Venezuela are estimated at **250 billion barrels**, equivalent to the total reserves of Saudi Arabia.

In northern Alberta, mostly foreign-owned oil companies are aggressively extracting bitumen from tar sands, which they turn into one of the dirtiest and most destructive forms of energy on the planet. In the process, they are creating serious social, economic and environmental problems in North America and all over the world. Tar sands development **infringes** on the constitutional rights of aboriginal peoples that have lived in the Northern Alberta, destroying wildlife habitat, polluting air and water with toxins and carcinogens, and rendering traditional food sources, such as caribou and fish, extinct or inedible. It also obliterates forests, rivers and wetlands from an area the size of Florida, destroying an internationally recognized **ecosystem** and reducing the amount of habitat available for a number of sensitive and endangered wildlife species.

Oil Shales: Is an organic-rich fine-grained sedimentary rock containing **kerogen** (a solid mixture of organic chemical compounds) from which liquid hydrocarbons, called shale oil, contain amounts of oil and combustible gas that can be extracted by destructive distillation. One of the largest known locations is the oil shale locked in the Green River Formation, Colorado, Utah, and Wyoming. Oil shale differs from coal, as the organic matters in shales have higher atomic **Hydrogen to Carbon ratio**. Coal has an organic to inorganic matter ratio of more than **4.75 to 5.0,** while oil shales have a higher content of sedimentary rock. Sources estimate the world reserves of Oil Shales as more than 2.5 trillion barrels.

Oil shales are **substitutes** for conventional crude oil; however, extracting is more costly than the production of conventional crude oil, both financially and in terms of its environmental impact. Oil shales were formed when algae and sediment deposit in lakes, lagoons and swamps, where an-aerobic (oxygen free) environment, thus allowing to be accumulated in thick layers, with overlying rocks baked under high temperature and pressure. The shale oil can be strip mined and processed with distillation. Extraction with fracturing and heating is still relatively unproven. Companies are experimenting direct electrical heating and scarcely using steam injection. Extraction cost is currently around 25-30 USD per barrel.



Oil Shales – Sedimentary rock | Shale rock

Oil Barrels: An ***oil barrel*** (abbreviated as *bbl*) is a unit of volume, whose definition has not been yet universally standardized. In the United States and Canada, an ***oil barrel*** is defined as ***42 US gallons***, which is about ***159 liters** or 35 imperial gallons.* Oil companies typically report their production in terms of volume and use the units of **bbl, Mbbl** (one thousand barrels), or **MMbbl** (one million barrels). Since medieval times, the term barrel has various meanings throughout Europe, ranging from about 100 liters to 1000 liters, or more in special cases.

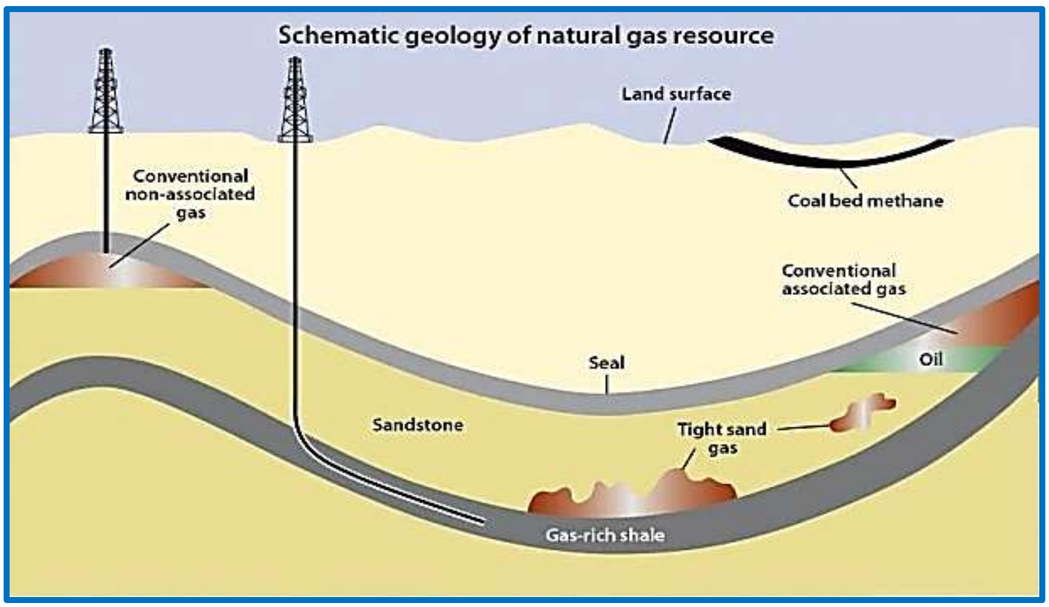
A barrel is one of several units of volume applied in various contexts; there are **dry barrels**, fluid barrels (such as the UK beer barrel and US beer barrel), and oil barrels. Outside the United States and Canada, volumes of oil are usually reported in **cubic meters** (m^3) instead of oil barrels. For example, one ton of heavy distillates might occupy a volume of 256 US gallons (6.1 bbl). In contrast, one ton of crude oil might occupy 272 gallons (6.5 bbl) and one ton of gasoline will require 333 gallons (7.9 bbl).

Other terms are used when the discussing only oil. One common term is *barrels per day* (BPD, BOPD, bpd, bd, or b/d), where 1 BPD is equivalent to 0.0292 gallons per minute or 49.8 tons per year. At an oil refinery, production is sometimes reported as *barrels per calendar day* (bc/d or bcd), which is total production in a year divided by the days in that year. Likewise, *barrels per stream day* (BSD or BPSD) are the quantity of oil product produced by a single refining unit during continuous operation for 24 hours. Lastly, the terms "**mbd and mmbd**" are sometimes used to denote one thousand or *one million barrels per day*, respectively.

IV. NATURAL GAS:

Liquefied Natural Gas (LNG) is a clear **natural gas** colorless, non-toxic and non-corrosive liquid (predominantly methane, CH_4) that has to be converted to liquid form, cooled to -162ºC (-260ºF) to shrink the volume of the gas 600 times, making it easier for storage and transport when pressure is set at around 25 kPa (4 psi). The liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty downstream. The gas may contain heavier hydrocarbons such as pentane, hexane, and heptane in the gaseous state.

An oil well also produces natural gas. At ambient conditions the gas condensates and form natural gas. This *condensate* resembles petrol in appearance, which is similar in composition to some volatile light crude oils, and because of the underground temperature-pressure is higher than at the surface. The exact molecular composition varies widely and the proportions of chemical elements vary over narrow limits. One of the risks of **LNG** is a rapid phase transition explosion (RPT), which occurs when cold LNG is exposed to water.



LNG has a greater volume reduction than **Compressed Natural Gas** (CNG). The density of LNG is **2.4 times** higher than CNG and 60% that of diesel, which makes the cost of LNG more efficient for transport over long distances, where there are no gas pipelines. Specially designed cryogenic sea vessels or cryogenic tanker trucks are commonly used for transportation. Then, LNG is transported to storage facilities, where it is degassed and then distributed to users, through natural gas pipelines. There are, basically, **two processes** for liquefying natural gas in large quantities. One of them is a cascade process, in which natural gas is cooled by another gas, which in turn has already been cooled by another gas, hence a cascade. The other method is the Linde process, and its variation is called the Claude process, which is also used. In this process the gas is cooled regeneratively, passing it continuously through an orifice until it is cooled to temperatures where it liquefies. The gas cooling by expansion through an orifice was developed by James Joule and William Thomson, well known in this process, as the **Joule-Thomson** effect.

Modern LNG storage tanks are typically full containment type, which has a pre-stressed concrete outer wall and a high-nickel steel inner tank, with extremely efficient insulation between the walls. Storage pressure in these tanks is very low, less than **10 kPa** (1.45 psig). Smaller quantities as **700 m³** (190,000 US gallons) and less, may be stored in horizontal or vertical, vacuum-jacketed, pressure vessels. These tanks may be at pressures anywhere from less than 50 kPa to over 1,700 kPa (7 psig to 250 psig).

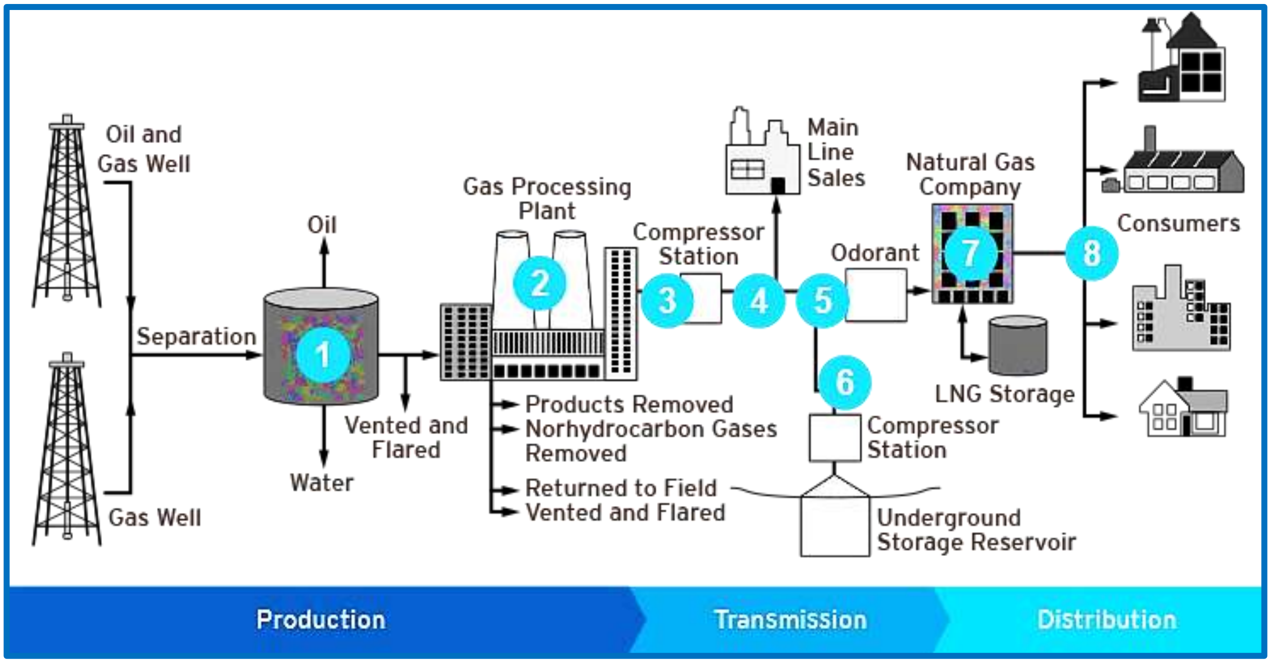
The insulation, as efficient as it is, may not keep the LNG cold enough by itself, as heat will warm and vaporize the LNG. Industry practice is to store LNG as a boiling cryogen, that is, the liquid is stored at its boiling point for the atmospheric pressure. When the vapor boils off, the heat for the phase changes and cools the remaining liquid. The insulation must be very efficient and only a relatively small amount of boil off is necessary to maintain temperature, also called auto-refrigeration. The LNG storage tanks is compressed and fed to natural gas pipeline networks.

Natural gas is **combustible**. To ensure safe and reliable operation, particular measures are taken in the design, construction and operation of LNG facilities. The natural gas used by consumers is composed almost entirely of methane. However, natural gas found at the wellhead, although still composed primarily of methane, is by no means as pure. Raw natural gas comes from **three types** of wells: *oil wells, gas wells, and condensate wells*. Natural gas that comes from oil wells is typically termed "*associated gas*". This gas can exist separate from oil in the formation (free gas), or dissolved in the crude oil (dissolved gas).

Natural gas from gas wells, in which there is little or no crude oil, is called "*non-associated gas*". Gas wells produce free natural gas along with a semi-liquid hydrocarbon condensate. Whatever the source of natural gas, once separated from crude oil, it normally exists in mixtures with other hydrocarbons; mainly ethane, propane, butane and pentane. Additionally, raw natural gas contains water vapor, hydrogen sulfide (H2S), carbon dioxide, helium, nitrogen and other compounds.

Electricity from Natural Gas: The natural gas power production process begins with the extraction of natural gas. Then, it is treated at gas plants to remove impurities, such as hydrogen sulfide, helium, carbon dioxide, hydrocarbons, and moisture. Pipelines transport the natural gas from the gas plants to power plants, which have combustion in boilers and turbines to generate electricity. Natural gas-fired boiler and combined cycle systems require water for cooling purposes; however, the combustion turbines requires very little water, and the use of natural gas to create electricity does not produce substantial amounts of solid waste.

In order to meet the demand for petroleum and natural gas, refined products are stored, and aboveground storage tanks are constructed as an integral part of the pipeline systems. This requires that storage capability be available near the production facilities, at refining and processing plants, at loading facilities, and near distribution points. The LNG storage tanks are normally spherical in shape to allow an even distribution of pressure within the tank. Power plants use several methods to convert gas to electricity. One method is to burn the gas in a boiler to produce steam, which is used by a steam turbine to generate electricity. Another technology, growing in popularity, is to burn the natural gas in a combustion turbine and use the hot combustion turbine exhaust to make steam to drive a steam turbine. This technology is called "*combined cycle*" and achieves a higher efficiency by using the same fuel source twice.



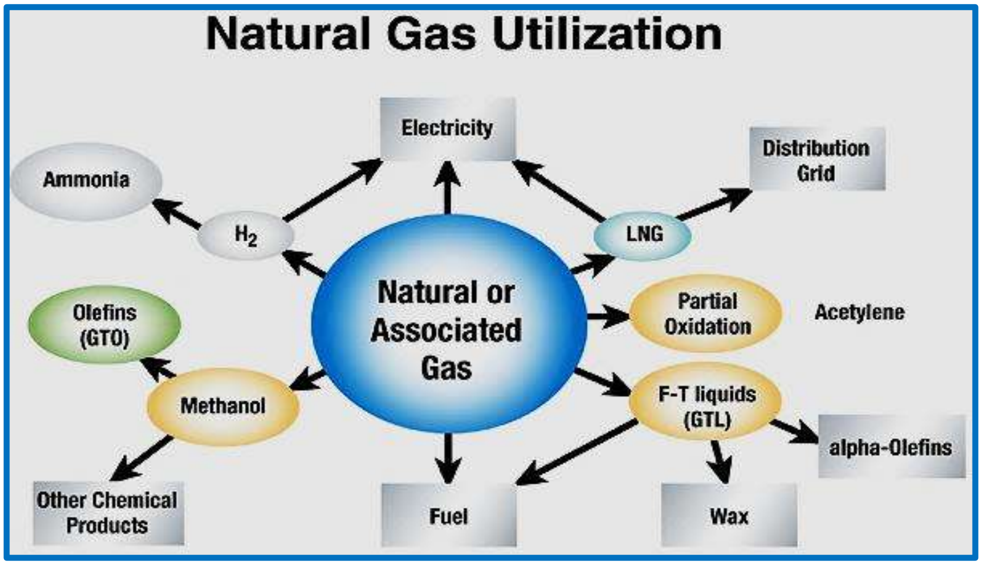
New Applications for Natural Gas: The fast growth of natural gas production from unconventional sources is creating a need to develop technologies for its efficient use. There is a clear goal to find solutions for reduced flaring and venting, and enhanced gas conversion may play a key role in this respect. The most efficient use of natural gas is **direct conversion to electric power** or use as a fuel for domestic needs, such as home heating. Once these needs are met, or the excess gas is in the area where infrastructure is not available, supplier companies may consider alternatives.

Chemical conversion to acetylene, ammonia, methanol and refinery hydrogen is widely practiced but, although there are large markets for these base chemicals, in terms of gas consumption, it represents only approximately **5 percent** of global annual gas consumption. Alternatives for use of large amounts of natural gas include Liquefied Natural Gas (LNG), conversion to liquid fuel products (GTL), conversions to olefins (GTO) and further to polymers (GTP). Of these products, polymers are the largest value added products.

Liquefied Petroleum Gas (LPG): Is derived **60%** from natural gas and **40%** from refining crude oil. LPG is marketed as propane, butane or a combination of the two, and can be used in a number of applications; also known as *common kitchen gas*, used for warming domestic water and space heating. Additionally, LPG can be used in power generation and industrial applications, such as burners and welding. Considered a clean-burning fossil fuel, LPG burns completely, leaving no waste and emitting significantly less pollutants into the environment than other hydrocarbons.

LPG for Cars and Buses: LPG is also used to power internal combustion engines. Millions of cars and buses in Europe and Brazil are actually powered by LPG today, where there are filling stations that provide LPG to domestic users. Although no passenger cars fueled by LPG have been produced commercially in the United States since 2004, gasoline and diesel cars and trucks can be reworked to run on LPG. Recent development makes it economically to **convert** methanol to ethylene and propylene, and then convert to polyethylene and polypropylene for the ultimate end-use in numerous fibers, plastics and polymer products.

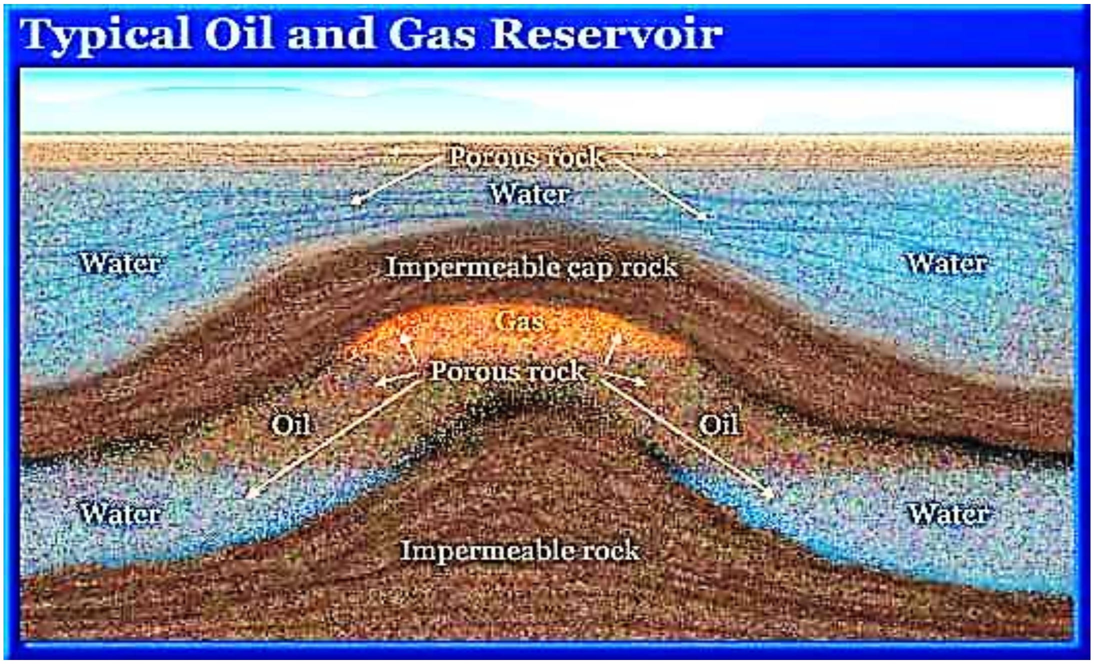
The conversion of methanol to olefins and other hydrocarbons has been widely studied. Initial work in the 1970s and early 1980s focused on conversion of methanol to gasoline range products employing zeolites (hydrated alumino-silicates of sodium, potassium, calcium, and barium), that can be readily dehydrated and rehydrated, used as cation exchangers and molecular sieves. More recently, China has taken a lead in conversion of coal to chemicals, and two commercial plants came on employing coal to methanol and several more units are in design and construction.



V. OIL RESERVOIRS:

There are **three conditions** to be investigated for oil reservoirs: source rocks rich in hydrocarbons buried deep enough for underground heat to transform them into oil, reservoir rocks that are porous and permeable to accumulate, and cover rocks that prevent the oil to escape to the surface. These conditions allow geological research for well drilling. The "*natural lift*" is a production method that relies on natural reservoir pressure to force oil to the surface. The structure that contains oil and gas is typically made of porous rocks, such as sandstone or washed limestone. The sand was deposited as sand dunes on the surface or on the bottom of the sea. Oil and gas deposits form as organic material (small plants and animals) deposited in geological periods about 100 or 200 million years ago, and developed conditions for sand or silt to be transformed into hydrocarbons by high temperature and pressure.

For an oil reservoir to form, the porous rock must be covered by a non-porous layer, such as salt, shale, chalk or mud, which prevents hydrocarbons from leaking out of the structure. As rock structures become elevated as a result of tectonic movements, hydrocarbons migrate up and out of the deposits, and accumulate in ridges beneath the non-permeable rock, with gas at the top and oil and fossil water at the bottom. A young reservoir (60 million years old) generally contains heavy oil, less than **20 API**. In some areas, severe uplift, erosion and fissuring of rocks have allowed hydrocarbons to leak out, leaving reservoirs of heavy oil or pools of tar. Oil and gas are pressurized in the pores of the porous rock formation. When a well is drilled, the hydrostatic pressure pushes hydrocarbons out of the rock and into the well. When the well flows, gas, oil and water are extracted. The challenge is to plan the drilling, so that the use of the reservoir can be maximized.

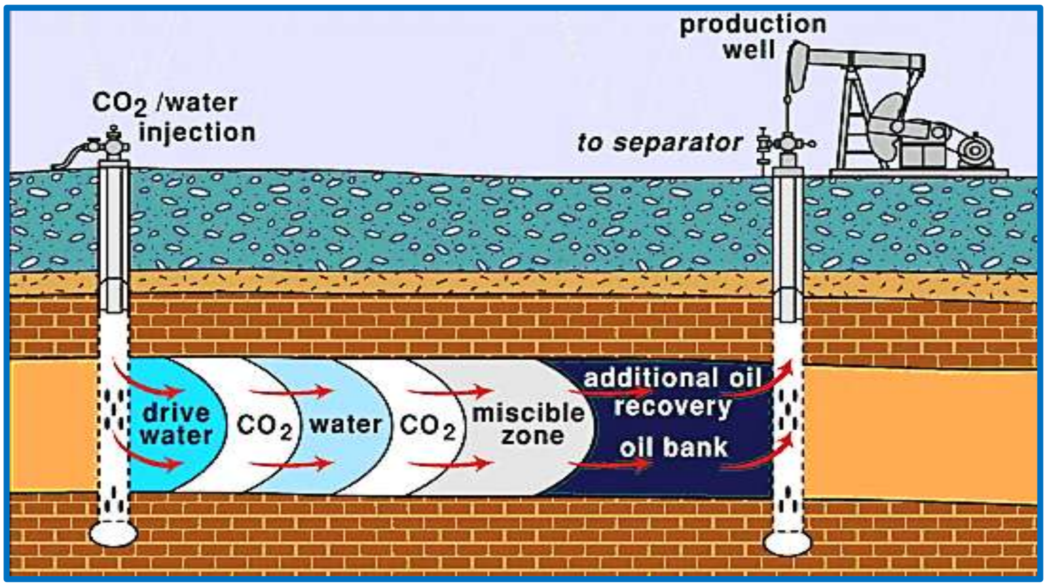


Seismic data and 3D models are typically used to plan extraction. The average recovery rate is **40%**, with **60%** of the hydrocarbons trapped in the reservoir. The best reservoirs for Enhanced Oil Recovery (EOR) allow up to **70%**. The reservoirs are quite complex, with several layers of rocks containing hydrocarbons (in some areas more than 10 layers). Wells are drilled using large horizontal displacements to reach different parts of the structure, and with multiple equipment so that a well can produce in several locations. Generally, oil is extracted through "*artificial lift*", through mechanical devices inside the well (known as a pump or velocity column) or by reducing the weight of the hydrostatic column by injecting gas into the liquid through some distance from the well. The "*artificial lift*" is necessary in wells when there is not enough pressure in the reservoir to raise the produced fluids to the surface, but it is often used in naturally flowing wells, to increase the flow rate above what would flow naturally.

A common secondary method is by "*water flooding*" or injecting water into the reservoir to increase pressure and force oil into the drilled well. Eventually, "*tertiary*" or "*enhanced*" oil recovery methods are used to increase the characteristics of the oil flow by injecting steam, carbon dioxide, other gases or chemicals into the reservoir. The extraction of oil from oil sand and shale deposits requires heating in a container or retort, or the use of injecting heated liquids into the deposit and then pumping the oil-saturated liquid. The "*gas lift*" is another widely used "artificial lift" method. As the name denotes, gas is injected in a pipe to reduce the weight of the hydrostatic column, thus reducing the back pressure and allowing the reservoir pressure to push the mixture of produce fluids and gas up to the surface. The gas lift is deployed in a wide range, from **30,000 bbl/d**

(4800 m³/d) up to **15,000 ft** (4,600 m). Gas lifted wells are equipped with side pocket mandrels and injection valves, which allows a deeper gas injection in the pipeline, but has some disavantages. There must be a source of gas, guaranteed flow, and a water source.

Oil Wells: They are divided into **injection** wells and **production** wells. The injection system uses a device that places a fluid, (which can be water, such as wastewater, salt water, or water mixed with chemicals), into the porous sandstone or limestone rock formations, or into the surface layer. In injection wells, the main objective is to maintain the reservoir's hydrostatic pressure and force the oil towards the production towers. Production wells utilize the production of natural gas, petroleum gas and crude oil. Steam, carbon dioxide, water and other substances are injected into an oil well to maintain the reservoir pressure, to heat the oil or decrease its viscosity, allowing it to flow to a nearby producing well. Gas injection is a pressure maintenance system that can be used in a reservoir, at the beginning of the production process, or used after the well's production began to decrease. Gas injection can also be a reinjection of natural gas produced as the pressure drops, and the condensates are subsequently separated in the reservoir, known as a **cycling** system.

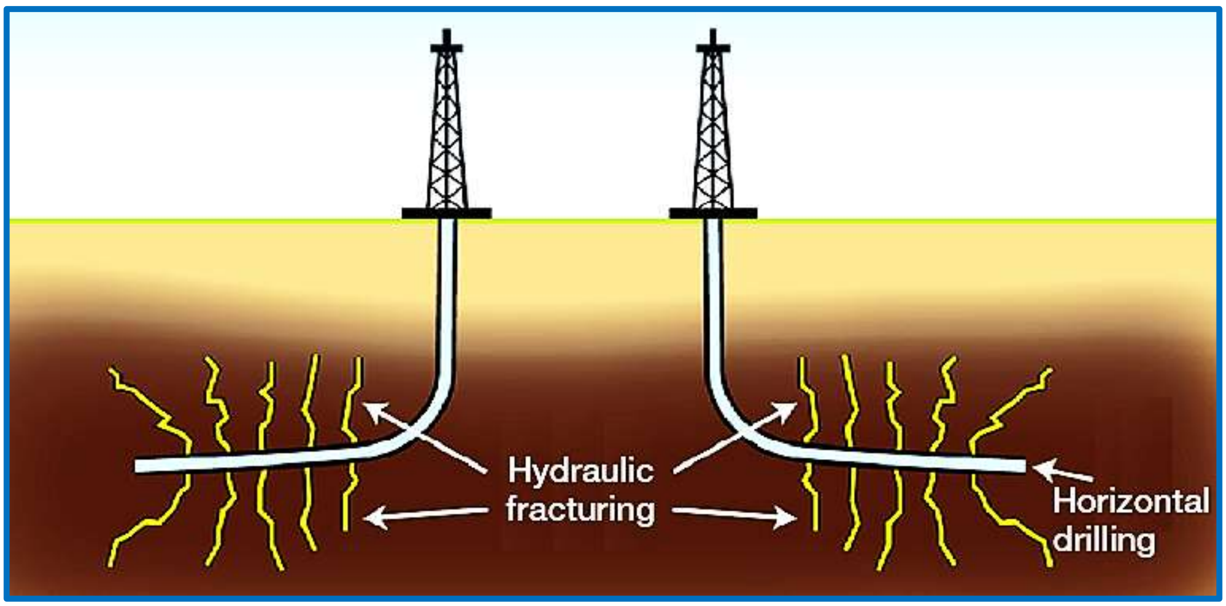


Gas Injection and Gas Lift: *Gas injection* is a secondary production method, *gas lift* is a type of artificial lift. The artificial or gas lift is used to increase production by increasing pressure within the reservoir, which includes pumping systems, such as beam pumps, hydraulic pumps and electric submersible pumps. The gas injection can also make the re-injection of produced natural gas, sometimes known as cycling, generally used to separate the condensate from the natural gas in the reservoir. In this process, the natural gas condensates are stripped from the gas on the surface after it has been extracted, and then is re-injected into the reservoir, as the pressure drops. If the oil field is highly saturated, the natural gas is injected in a gas cap; but if the oil field is undersaturated, the gas is injected directly into the oil reservoir.The United States Environmental Protection Agency (EPA) defined six classes of injection wells:

- ✓ **Class I Wells:** Are used for the injection of municipal and industrial wastes beneath underground sources of drinking water;

- ✓ **Class II Wells:** Are used for the injection of fluids associated with oil and gas production, including waste from hydraulic fracturing;
- ✓ **Class III Wells:** Are used for the injection of fluids used in mineral solution mining beneath underground sources of drinking water;
- ✓ **Class IV Wells:** Are used for the injection of hazardous wastes, injected above underground sources of water, for non-hazardous injections not covered by Classes I through IV.
- ✓ **Class VI Wells:** Are used for the injection of carbon dioxide for sequestration, or long-term storage. Currently, there are no Class VI wells in operation, expected to be in 2016.

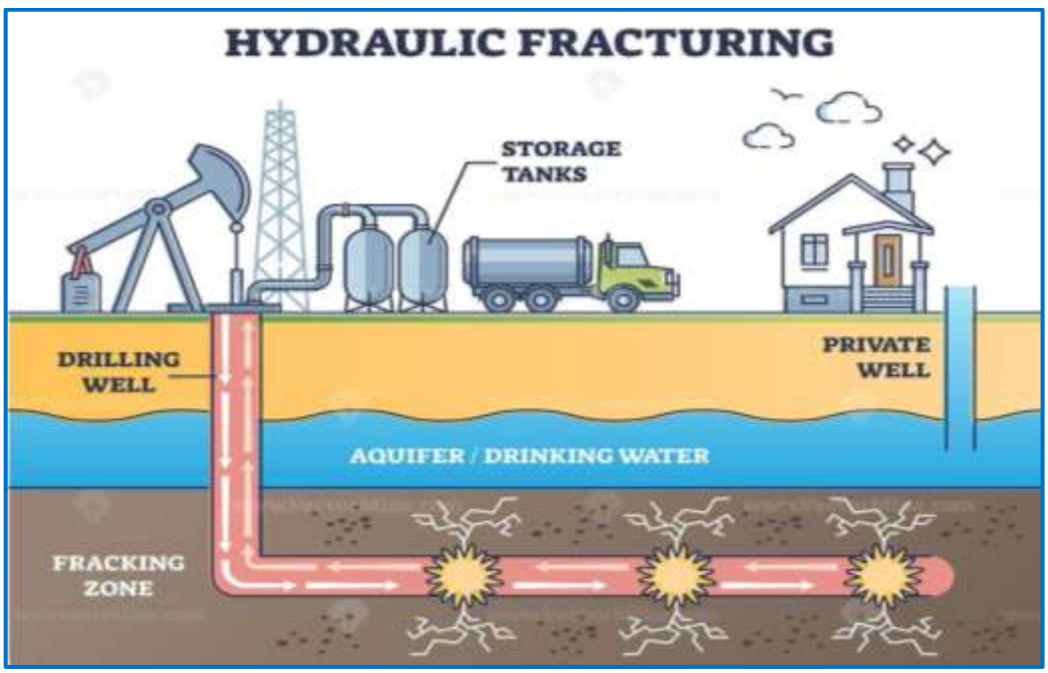
Reservoir Fracturing: Fracturing, also known as "*fracing"* (or "fracking") involves breaking the rocks, performed after the well has been drilled. It is a stimulation method, which causes a highly conductive flow path between the reservoir and the wellbore. Well fracturing breaks or splits the reservoir rock, making the way hydrocarbons flow from the rocks into the well. A fracturing makes cracks or fissures in the rocks. The orientation of the fracture can be anywhere from horizontal to vertical. Natural fractures are more common in carbonate rocks than in sandstones, and some of the best fractured reservoirs are in granite, often referred to as unconventional reservoirs.



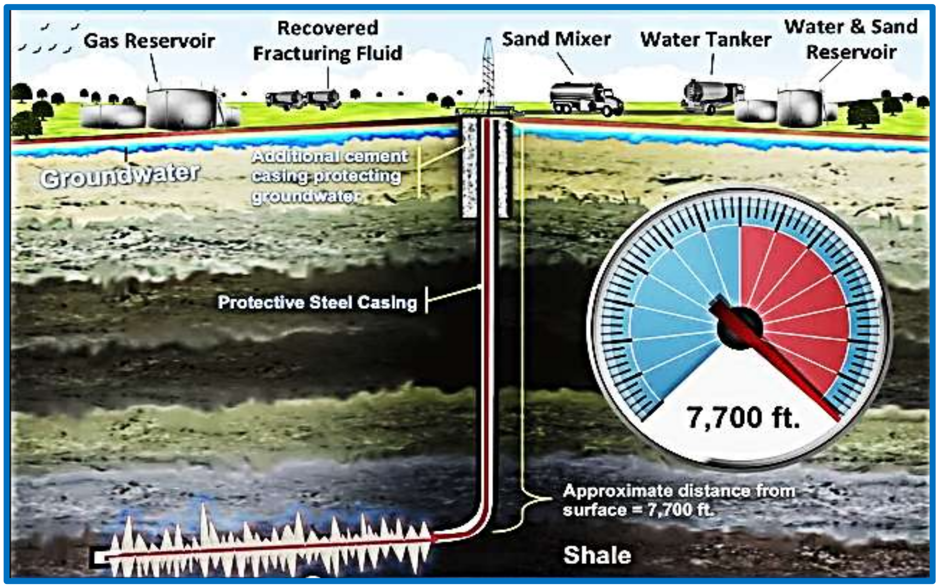
It is the process of pumping fluid into a well, by injection, causing the rock formation to fracture. The first hydraulic fracturing was done in 1947 at a gas well operated by Pan American Petroleum Corp., in Grant County, Kansas, which became a low-productivity well despite acidification being attempted. During injection, the pressure in the well increases to a value called burst pressure. After the rock formation "*breaks*", the injected fluid flows through the fracture, which can also be done using **explosives** to generate a high-velocity gas flow; a process called **propellant** stimulation. Carbonate reservoirs can also be effectively treated by acidizing. The acid dissolves carbonates and serves to enlarge fractures, the way the fractures remain open, after the oil formation has reached a new steady state. The stimulation treatment is performed in two stages. At the first stage, the formation is fractured with propellant gas generators. At the second stage, the created fractures are treated with an acid.

Explosive fracturing was the most common method of fracturing wells, which began in the 1860s until the 1940s, also known as "*well shooting*", used to detonate an explosive inside a well to break the reservoir rocks. Another method of explosive fracturing, however dangerous, introduced liquid nitrogen into the well through a tin cylinder, known as a "***torpedo***". The explosion creates a huge hole, which once cleaned, leaves the bottom of the reservoir open, through which the hydrocarbons flow out of the rock.The first hydraulic fracturing treatment was pumped in 1947 on a gas well operated by Pan American Petroleum Corp. in Grant County, Kansas, which became a low-productivity well, even though it had been acidized. In 1949, Halliburton performed the **first** commercial **fracturing** treatment, and the development of specialized fracturing fluid systems became a constant research and development focus. Since then, hydraulic fracturing is a common treatment for stimulating the productivity of oil and gas wells. In general, hydraulic fracture treatments are mainly used to increase the productivity index of a producing well.

Fracturing Fluids: For most reservoirs, water-based fluids with appropriate additives are best suited for low temperature fracturing. In some cases, foam generated with **N2** or **CO2** is applied in low-pressure carbonate formations. Thus, an oil with a gelling agent is used in simple fractures with water-sensitive formations. "*Guar or HPG*" acids are also used in fractures with carbonate formation. A common practice in hydraulic fracturing is the use of non-viscous fluids pumped at high rates (>600 gpm) to generate narrow fractures with low concentrations of proppant, a granular material used in hydraulic fracturing operations, in order to obtain a permanent channel.



To create a hydraulic fracture, fluid is injected at a high rate pressure into a wellbore. The viscous fluid flow within the fracture and create a net pressure required to generate a wide profile. However, without pumping, the created fracture may close once the pumping operation ceases. The first fluid pumped into a well during a fracture treatment is called the "*prepad*", used to fill the casing and tubing, test the system for pressure, and break down the formation. The fluid containing a propping agent is called "*slurry*". The slurry particles move up, out, and down the fracture, to settle as a result of gravitational forces. Thus, the main purpose of the propping agent is to keep apart the fracture surfaces, since that once the pumping operation ceases, the pressure decreases bellow the compressive stress, closing the fracture. In deep reservoirs, ***ceramic beads*** are used as propellants, but in shallow reservoirs, **sand** is normally used as the propping agent.



Additives for Fracturing Fluids: Cross-linked borate gels use borate ions to cross-link hydrated polymers and provide greater viscosity. Therefore, polymers are used to increase the viscosity of the fluid, and biocides are used to kill bacteria in the mixing water. Buffers (sodium bicarbonate) are used to control the **pH** of the fracture fluid. Surfactants (fluoro carbides, nonionic) are used to lower surface tension and fluid loss additives (particles, fine sand) are also used to minimize fluid leakage from the formation. Stabilizers (KCI, NHCI) are used to keep the fluid viscous at high temperature. Acid oxidizers are also used to break the polymers and crosslink sites at low temperature. Liquid Gel Concentrates (LGC™) are concentrated liquid slurries prepared with the polymers.

The LGC technology also provides an efficient, precise method of varying the viscosity of the fracturing fluid during the fracturing treatment. Since the concentrated polymers are in liquid form, the handling and mixing of dry, powdered material at the well site is eliminated. Guar and its derivatives are the most extensively used polymers in fractured fluids, specifically in the area of hydraulic fracturing. Guar is used to thicken the fracturing fluid so that it can carry gra-ded sand into the fractured rock. The sand serves as a *proppant* to keep the fracture open, creating a route for oil or gas to flow into the well bore. The first commercial sale of HPG (hydroxypropyl-guar) for use in a fracturing fluid was in the late 1960s. Its success to economically stimulate oil and gas production led to extensive research in guar derivatives.

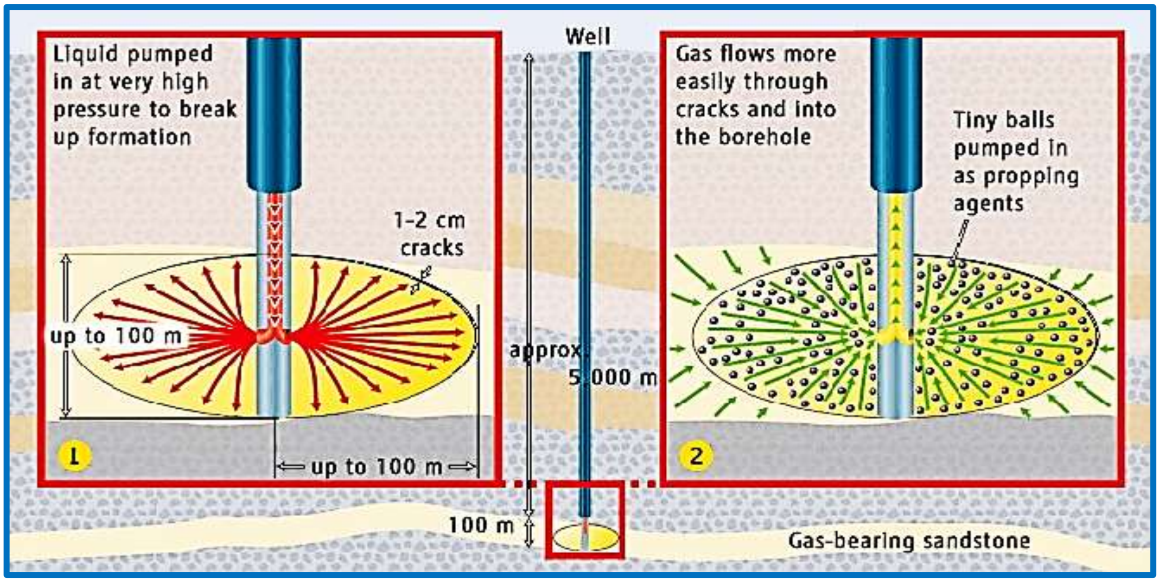
Proppants: Are solid materials, such as ceramic materials or commonly treated common sand, made to keep a hydraulic fracture open. Silica sand must be treated or coated with resin to form CRCS (Curable Resin Coated Sand) or PRCS (Pre-Cured Resin Coated Sand). In certain special situations, a different proppant material may be used, such as ceramic or sintered bauxite. Proppants come in a variety of different sizes and spherical shapes for a variety of different situations. These materials keep a rock fracture open before the fracture begins to close as the pumps shut off after pumping performance. The products that best suits are the silica sand, Resin-Coated Sand (RCS), and ceramic proppants. The "*Ceremite*" proppants possess advanced features, such as temperature-resistance, erosion-resistance, high-strength, low-density, low broken rate, quartz sand proppant, low acid solubility, and working temperature below 232 ºC, applicable to fracturing and acidification. According to specification, can be divided into 12-20 mesh, 16-20 mesh, 16-30 mesh, 20-40 mesh, 30-50 mesh, 40-60 mesh, 40-70 mesh, 70-100 mesh, and three serials: 52 Mpa (7500 psi), 69 Mpa (10000 psi) and 86 Mpa (12500 psi).These ceramic proppants are used to stimulate deep wells (> 8,000 ft).

On the other hand, Resin-Coated Sand (RCS) is stronger than sand, used where more compressive strength is required to minimize proppant crushing. Some resins can be used to form a consolidated pack in the fracture, which will help to eliminate proppant flow back into the wellbore. RCS is more expensive than sand, but it has an effective density that is less than sand. Ceramic proppants consist of:

- Sintered bauxite
- Intermediate-strength proppant (ISP)
- Lightweight proppant (LWP)

Raystone proppants, feature high strength alloy pellets, sintered with several kinds of metal materials, mainly used as proppants of fracturing of oil fields. Product can be divided into **three kinds**: High density (more than 1.90), intermediate density (1.75-1.90) and low density (less than 1.6), divided into four resistances; 7,500 psi, 10,000 psi, and 12,500 psi. The specifications may be 20/40 mesh, 30/50 mesh, 40/70 mesh, 16/30 mesh, and 12/18 mesh, produced in conformance with the users demands. The proppant agent is extracted once the fracturing process has been completed, and is disposed off by a certified waste disposal company. Solids and fluids are filtered (separated) and analyzed by the waste disposal company. Fluids are transported to a treatment plant, and solids are disposed off at a suitable landfill site. The remainder of the proppant agent is retained in the immediate vicinity of the fracture in order to keep the crack open.

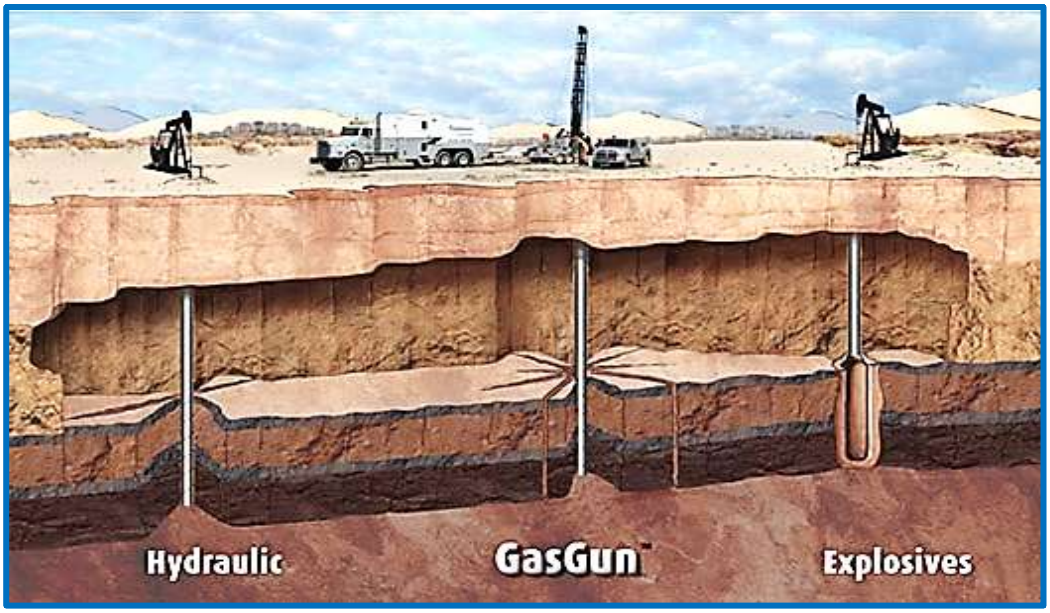
Propellant: Are low-explosive materials that generate large amounts of **gas** very rapidly, but is a very economical way to clean up a wellbore damage. Many methods are used to stimulate oil and gas wells, utilizing liquid, solid or gas rocket propellants. Most single base propellants traditionally contain a significant amount of **dinitrotoluene** (DNT) which acts as a plasticizer for the nitrocellulose. Common propellants consist of fuel like gasoline, jet fuel, rocket fuel, and oxidizers. Typical propellants consist of a mixture of propane, isobutane and n-butane, also used in most aerosols, (Liquefied Petroleum Gas, LPG). Di Methyl Ether is a **liquefied** propellant. Gunpowder and **fine coal** are examples of solid propellants. A propellant unit may include a detonating cord, and a detonating fuse, disposed in a steel tube.



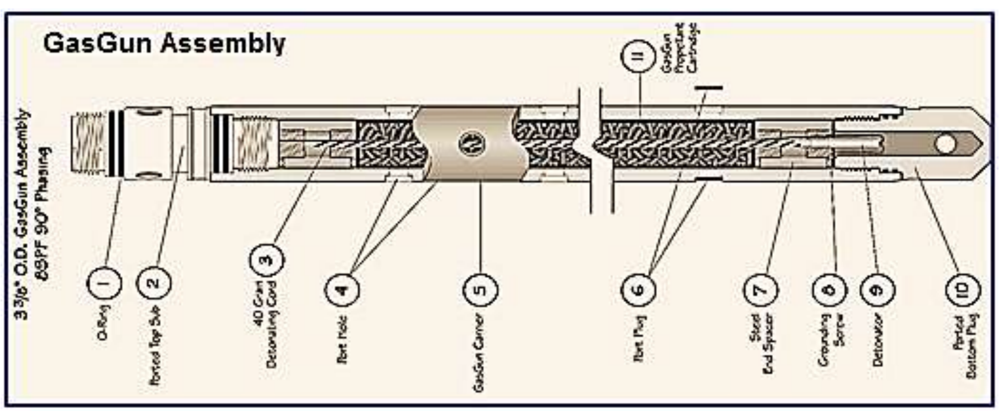
High Energy Gas Fracturing (HEGF): Is a generic name used by the oil and gas industry for stimulating wells with propellant gases. Other names used for this technology include Tailored Gas Pulse Loading, Tailored Gas Pulse Fracturing, Controlled Pulse Pressurization, and Controlled Pulse Fracturing. Propellant stimulation devices were developed about 40 years ago, and since that time, dozens of patents have been issued for different systems of gun propellant/rocket fuel/low explosive well stimulation schemes. The proponents of propellants, such as **nitroglycerine,** state that high explosives detonate and create high pressures that last only **few microseconds**, which is crucial to success. This explains why some high explosive fails, or even hurt production. The first successful well shot was 1865, using eight pounds of black powder (two years before the first use of nitroglycerine).

Some companies that offer propellant stimulation devices claim to be able to fine tune their product to fit specific well or rock conditions. Thousands of **HEGF** well stimulations have been conducted on the course of the last few years (thanks to the efforts of Dr. Schmidt at GasGun, LLC) taking on a commodity service, much like Liquid Nitroglycerine (LNG). Experts say that hydraulic fracturing is ineffective in very shallow wells, where stress factors favor the formation of undesirable horizontal fractures. However, these shallow wells may be especially good candidates for HEGF stimulation now that LNG is no longer available.

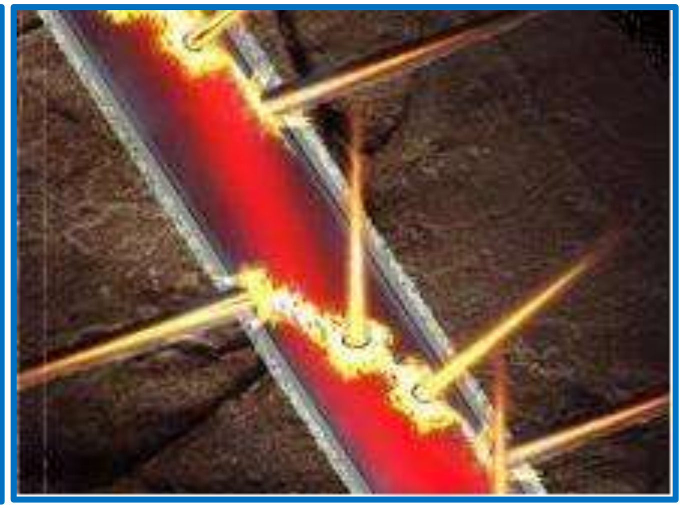
The propellants deflagrate at subsonic velocities. Propellants have energy densities approximating those of high explosives, and are more compact than any other energy source, such as nuclear. The propellant devices produce a high pressure in **few milliseconds** or **few hundred milliseconds**, producing multiple fractures and avoiding stress damage on oil wells. This explains why propellant stimulations require little or no cleanout, even after many high explosive shots.



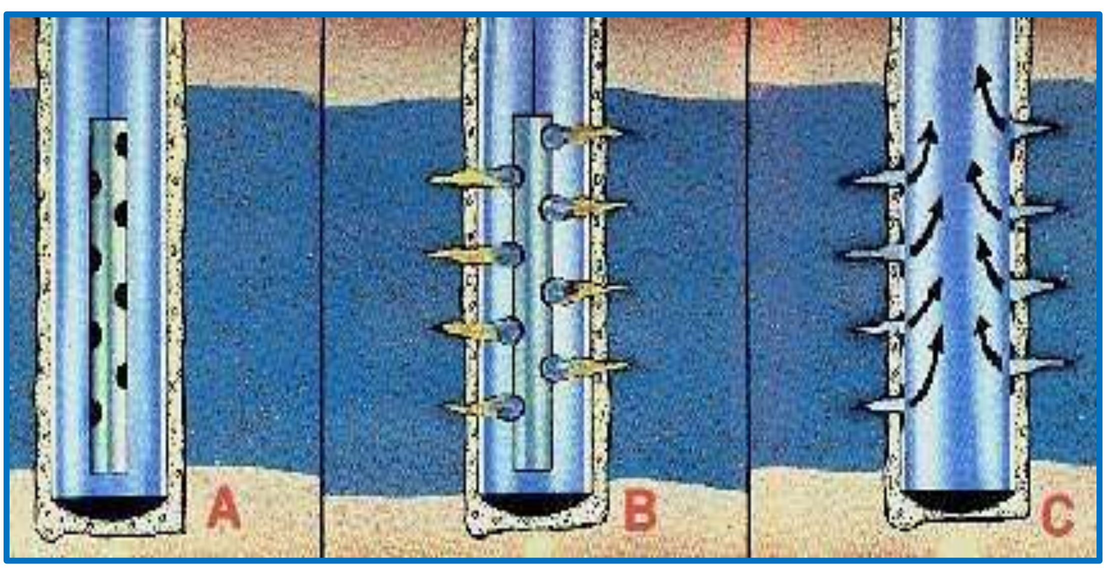
Another version, where a high-pressure gas may fracture an oil well is designated as *Liquid Fuel-Oxidizer* (FOS), which is an aqueous solution of an organic fuel and a mineral oxidizer. Since it does not react at atmospheric pressure, makes the fire/explosion safe. The combustion is initiated by a self-igniting enclosed container, which is lowered down the hole with the FOS, on a logging cable. The combustion begins when the container is broken by means of a detonating cord. The fractures created by this kind remain open. The high efficiency of this version (increase production by 100%) has been demonstrated for wells with high formation pressures.



The **Weatherford propellants** use high-pressure gas dynamic pulses to maximize well productivity, which also present a cost-effective option for well cleaning and an interval evaluation. The propellant designated as Stim-Tube™ and StimGun™ sets rely on a computational modeling service, the PulsFrac™ software, to evaluate the effects of dynamic fracturing. The StimGun®, which combines drilling and propellant stimulation technology, consist of a CO2-filled sleeve that slides over a hollow steel gun carrier system. For detonation, the sleeve is lit, producing an explosion of the high-pressure CO2 gas. This gas creates micro fractures in the reservoir's drilled tunnel.



Perforating Guns: These are weapons with hardened steel bullets, fired from a "*barrel*" to penetrate the oil well formation. The drilling "*gun*" is lowered into the hole at the depth where the oil or gas formation is located, which can vary from hundreds of meters to tens of thousands of meters. Once it is correctly aligned, powerful explosive charges are fired (B) from the control panel of a truck at ground level. Then, the oil and gas fluids flow into the "*pipe*" holes and rise through the well to the surface (C), as shown in the figure below: The explosives from the drilling gun open a hole in the rock, up to several meters deep. The drill gun is then removed back in preparation for the next stage of the hydraulic fracturing. The horizontal well is drilled in the same way as the vertical well, which allows the bit to enter the formation horizontally.



Well Acidizing: Is another type of well stimulation, to increase or restore production, performed below the reservoir fracture pressure as an effort 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. The most common type of acid employed on wells to stimulate production is the hydrochloric acids (HCI), which are useful in removing carbonate reservoirs, limestones and dolomites, from the rock. There are two types of acid treatment: *matrix acidizing and fracture acidizing*.

- Matrix Acidizing: A matrix acid job is performed when acid is pumped into the well and into the pores of the reservoir rocks. 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.

- Fracture Acidizing: Involves pumping highly pressurized acid into the well, physically fracturing the reservoir rock and dissolving the permeability inhibitive sediments. This type of acid job forms channels through which the hydrocarbons can flow.

The **hydrochloric acid** HCI can also be combined with **hydrofluoric acid** (HF), to dissolve quartz, sand and clay from the reservoir rocks. In order to protect the integrity of the completed well, inhibitor additives are introduced, to prohibit the acid from erode the steel casing. Then, a sequestering agent can also be added, to block the formation of gels or iron precipitation, which can clog the reservoir pores during the well acidizing. After an acidizing job is performed, used sediments are removed from the reservoir, and washed out in a process called backflush.

Pumping out acids

VI. OIL WELL EXPLORATION AND DRILLING:

Oil Well Exploration: Seismic data and advanced visualization 3D models are used to explore and plan the extraction. The best reservoirs with advanced Enhanced Oil Recovery (EOR) allow up to 70% of average recovery. Modern wells are drilled with large horizontal offsets to reach different parts of the structure and with multiple completions so that one well can produce from several locations. Exploration risk is a difficult concept and is usually defined by assigning confidence with the presence of imperative geological factors, based on data and/or models, usually mapped on Common Risk Segment Maps (CRS Maps).

Hydrocarbon exploration is the search by petroleum geologists and geophysicists for hydrocarbon deposits beneath the Earth's surface, such as oil and natural gas. Oil and gas exploration are grouped under the science of petroleum geology. Visible surface features such as oil seeps, natural gas seeps, underwater craters caused by escaping gas, provide basic evidence of hydrocarbon generation, shallow or deep. Sensitive instruments, such as the gravimeter, the magnetometer, and the seismograph, may be used to find subsurface rock formations that can hold crude oil.

Since there are several different types of exploration licenses, oil companies often operate in joint ventures to spread the risk, and one of the companies in the partnership is designated by the operator to supervise the work. Commonly, the companies bid on a percentage of the production that the host government receives (this may be variable with the oil price). Reserves are separated into three categories; *proved, probable and possible*, thus, technical issues separate proved from unproved categories. All reserve estimates involve some degree of uncertainty.

Many years ago, geologists interpreted surface features, surface rock and soil types, and perhaps some small core samples obtained by shallow drilling. Modern oil geologists also examine surface rocks and terrain, with the additional help of satellite images. However, they also use a variety of other methods to find oil. They can use sensitive gravity meters to measure tiny changes in the Earth's gravitational field that could indicate flowing oil, as well as sensitive magnetometers to measure tiny changes in the Earth's magnetic field caused by flowing oil. They can detect the smell of hydrocarbons using sensitive electronic noses called sniffers or, most commonly, they use seismology, creating shock waves that pass through rock layers and the interpreting waves are reflected back to the surface. In seismic surveys, a shock wave is created by the following:

- **Compressed-air Gun:** Shoots pulses of air into the water (for exploration over water);
- **Thumper Truck:** Slams heavy plates into the ground (for exploration over land);
- **Explosives:** Drilled into the ground (for exploration over land) or thrown overboard (for exploration over water), and detonated.

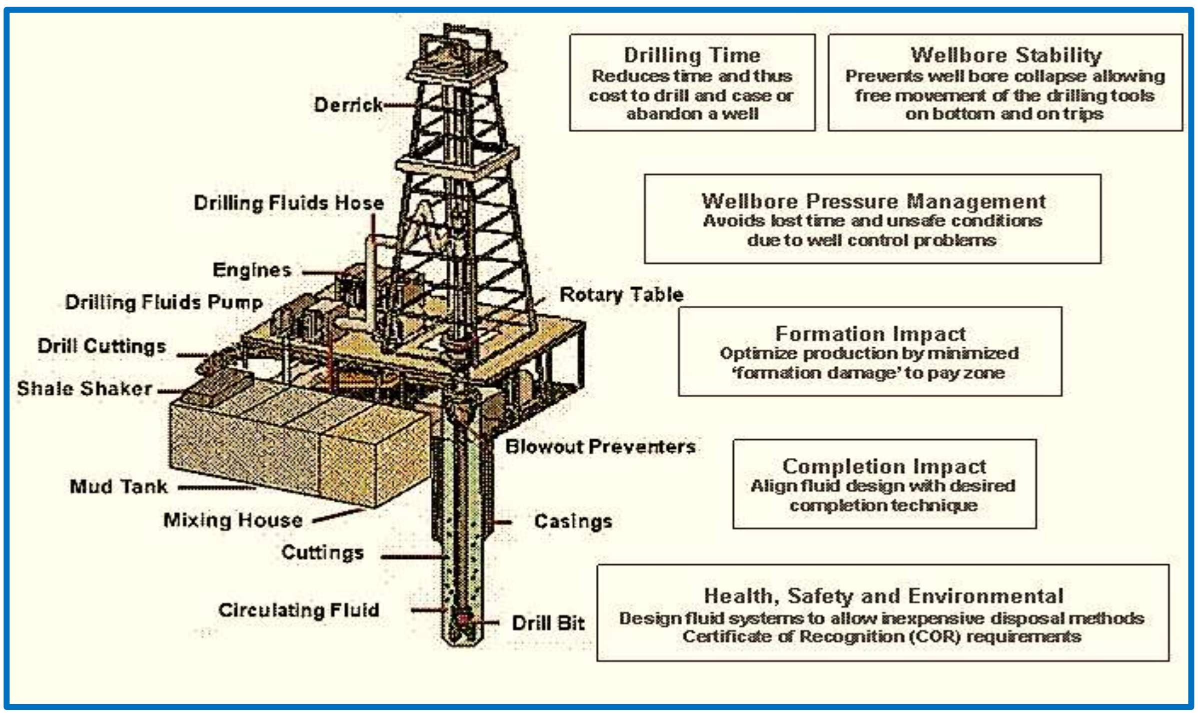
Shock Waves: Can travel beneath the surface of the Earth and reflected back by the rock layers, as the reflections travel at different speeds depending upon the type or density of the surface. Sensitive microphones, vibration detectors, and hydrophones are used over water, and seismometers over land detect the reflections of the shock waves. Seismologists use the signs of oil and gas traps to interpret the readings. Although modern oil-exploration methods are better than previous ones, they still may have only a 10-percent success rate for finding new oil fields. Once a prospective oil strike is found, the location is marked by **GPS** coordinates on land or **by marker buoys** on water. An example of onshore and offshore exploration is shown in the **picture above**. The **Houston Energy** was able to assemble over **5,100 blocks** of **3D seismic data** in the Gulf of Mexico, employing a seismic modeling, AVO, to qualify and quantify prospects.

With this device of seismic control, Houston was able to map large portions of the Gulf in detail and categorize prospects within regional geologic frameworks, with thirty-four 3D workstations for generating 3D prospects. Then, when a petroleum prospect is identified, evaluated and approved, an exploration well is **drilled** as an attempt to determine the presence or absence of oil or gas. Drilling is a fairly complex and often **risky** process. Some wells must be dug several miles deep before petroleum deposits are reached. Many are now drilled offshore with platforms standing in the ocean bed. Then, the crude oil must be pumped out or forced to the surface by injecting water, air, natural gas, steam, carbon dioxide, or another substance into the deposits. Enhanced recovery techniques have increased the percentage of oil that can be extracted from a field.

Drilling: Is the process of making a hole in the ground for the extraction of a natural resource such as ground water, brine, natural gas, or petroleum, also used for the injection of a fluid from surface to a subsurface reservoir or for evaluation of subsurface formations. There are **three types** of formations; *soft, medium and hard*. Soft formations include unconsolidated sands, clays, soft limestones, red beds and soft shale. Medium formations include calcites, dolomites, limestones, and hard shale. Hard formations include hard shale, calcites, mudstones, cherty lime stones and hard and abrasive formations. The equipment used for oil and gas drilling is the known **drilling rig**.

Drilling rigs are generally massive structures, housing equipment used to drill oil wells, water wells or natural gas extraction wells, or they can be small enough to be moved manually by one person, called augers. 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. Preparing to drill, the site must be surveyed to determine its boundaries, and environmental impact studies are done. After every legal document is approved and drilling project is ready, the land is prepared and several holes are dug to make way for the rig and the main hole.

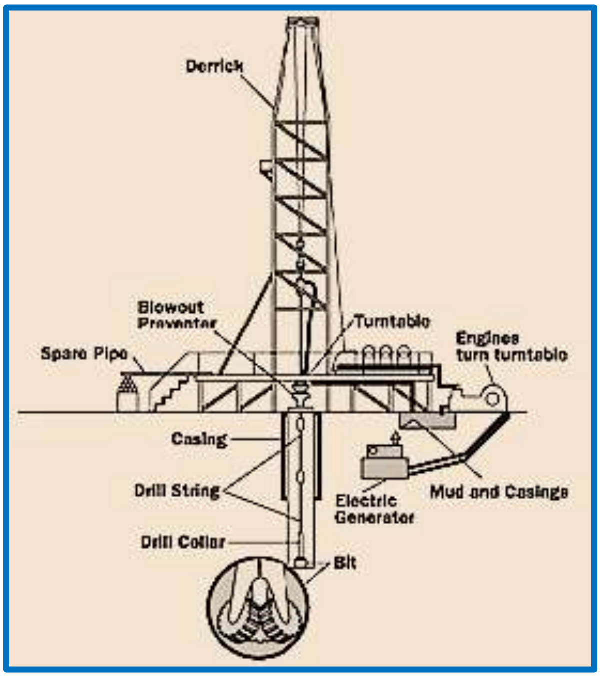
A rectangular pit, called a cellar, is dug around the location of the actual drilling hole to provide a work space, for the **workers and drilling** accessories. The first part of the hole is larger, but shallower than the main portion, lined with a large-diameter conductor pipe. When these holes preparations are finished, the rig equipment can be brought in and set up. Depending upon the remoteness of the drill site and its access, equipment may be transported to the site 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 common rig (as in oceans or lakes). Once the equipment is at the site, the rig is set up. Here are the major systems of a land oil rig:



Drilling rigs can be mobile equipment mounted on trucks, tracks or trailers or more permanent in land, or marine-based structures (such as oil platforms, commonly called "*offshore oil rigs*"). The term "*rig*" therefore generally refers to the complex of equipment that is used to penetrate the surface of the Earth's crust. In summary, the **main components** of drilling rigs are the Derrick, Drill Floor, Drawworks, Top Drive, Drill String, Casing, Rotary Drill Bits, Mud Handling, Wellhead, Christmas Tree, Blowout Preventer (BOP), Tubing Spool. The rig control and power can be hydraulic or electric, as described below:

Derrick: Is a lifting device composed of a metallic tower, which is hinged freely at the bottom. The basic type of derrick is controlled by lines (usually four of them) connected to the top of the mast, powered by some means, such as man-hauling or motors, so that the pole can move in all four directions. The term "*derrick*" is used to call the tall structure or framework that holds the drilling apparatus of an oil rig system, and got this name from **Thomas Derrick**, an English executioner from the Elizabethan era.

Drilling Floor: Also called **Rig Floor** is the heart of the drilling rig. The rig floor is the most dangerous location on the rig, because heavy equipment is moved around there, and where the drill string begins its trip into the earth. It is commonly where joints of pipes are assembled, as well as, the Bottom Hole Assembly (BHA), drilling bits, and several other tools. The drill floor is located directly under the derrick.



Derrick and drilling rig components


Drilling or rig floor

Drawworks: Is the hoisting machinery, which is an important component of the drilling rig, and its main function is to provide means of raising and lowering the **traveling blocks**. A modern drawworks consists of five main parts; the drum, the motor, the reduction gear, the brake and the auxiliary brake. Direct motordrive can be AC or DC-motors, or diesel engines using chain belts. The main brake, usually operated manually by a long handle, may be friction band brake, a disc brake or a modified clutch, which serves as a parking brake, when no motion is desired.

Top Drive: Is a mechanical device on a drilling rig that provides clockwise torque to the **drill string** to facilitate the process of drilling a borehole. Commonly used to rotate the drill string during the drilling process, the top drive is simply a **motor** that is suspended from the derrick of the rig. This power boasts at least **1,000 HP**, replacing the traditional Kelly or rotary table. It is located at the swivel place and below the traveling block suspended from a hook, comprised of one or more electric or hydraulic motors, connected to the drill string via a short section of pipe, known as **the quill**, which allows a vertical movement up and down the derrick.

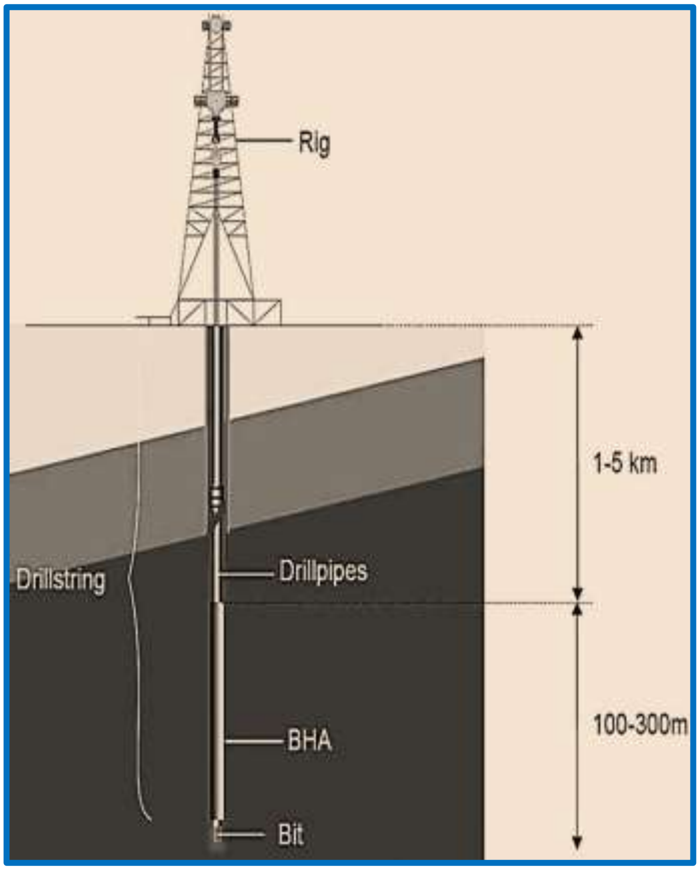

Drawworks


Top drive

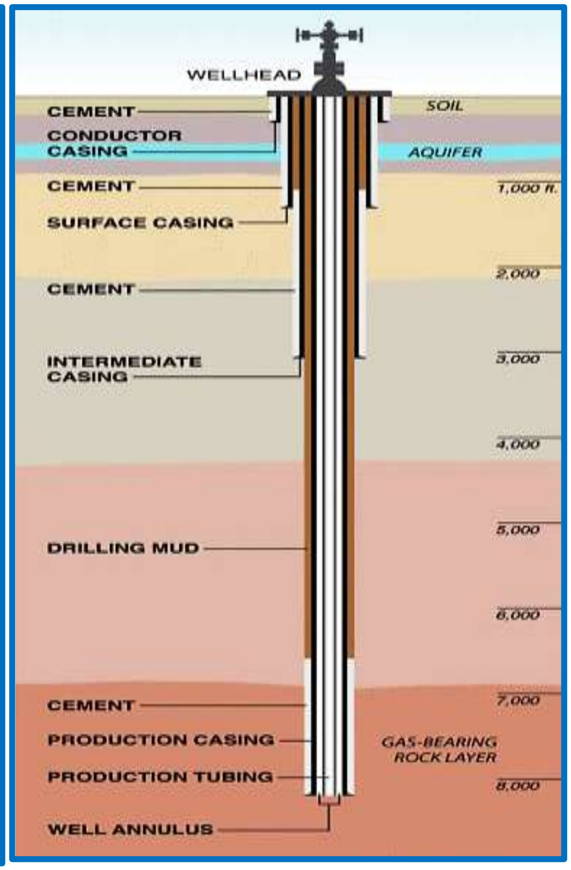
Drill String: Is the main column of the rig, which transmits the **drilling fluid** (via the mud pumps) and torque (via the Kelly drive or top drive) to the rotary drill bit, known also as an assembly of pipe segments, about 30 meters (100 feet) long normally connected with conical inside threads at one end and outside at the other. As each 30 meter segment is drilled, the drive is quickly disconnected and a new pipe segment is inserted in the string. The drill string is tubular, so that the drilling fluid can be pumped down and circulated back up, between the drill string and the open hole, with casing. The drill string is typically made up of three sections:

- ✓ **Bottom Hole Assembly (BHA):** Is a rotary drill bit, with heavy, thick-walled tubes used to break up the rock formations, with drilling stabilizers to keep the assembly hole-centered.
- ✓ **Transition Pipe:** The Heavy-weight Drill Pipe (HWDP) is used to make the transition between the drill collars and drill pipe, providing a flexible transition between the drill collars and the drill pipe. HWDP is most often used, as weight on rotary bit can deviate the well.
- ✓ **Drill Pipe:** It comprises a long tubular section with a specified outside diameter (e.g. 3 1/2 inch, 4 inch, 5 inch). The joint connections are threaded, which allows each drill pipe part be easier mounted to the next segment.

Casings: Are large diameter pipes, assembled and **inserted into the drilled section of a borehole** and typically held into place with cement. The inside diameter of the first casing string must be large enough to fit the drill bits. Then, each casing string will have a subsequently smaller diameter according to the applied drill bit. The inside diameter of the final casing string (or penultimate) must accommodate the associated hardware such as packers, gas lift mandrels and subsurface safety valves. The casing strings are supported by hangers set in the wellhead, which later will be mounted with the Christmas tree. The wellhead is usually installed on top of the first casing string after it has been concreted in place.



Drill String



Casing

Rotary Drill Bits: Are used to drill vertical or horizontal holes into the rocks. The first roller cone patent was for the rotary rock bit and was issued by **Howard Hughes Sr**., in **1909**. It consisted of two interlocking cones and the success of this bit led to the founding of the **Sharp-Hughes Tool Company**. In 1933 two Hughes engineers, one of whom was Ralph Neuhaus, invented the ***tricone bit***, with three cones that lasted until 1951, when other companies made similar bits. Different cones are used according to types of rocks and at different stages of the well. Rotary drilling uses two types of drill bits; **Roller-Cone bits** and **Fixed-Cutter bits**:

1. ***Roller-Cone* Bits:** Are generally classified in *Tungsten Carbide Insert (TCI) bits* or *Milled-Tooth bits*. The *Tungsten Carbide Inserts bits* (or button bits) are used in a wider range of formations, including the hardest and most abrasive drilling applications. The *Milled-Tooth* (or steel-tooth) bits are typically used for drilling relatively soft formations.

2. ***Fixed-Cutter* Bits:** Can drill an extensive array of formations at various depths. Drilling occurs due to percussion or rotation of the drill string, and includes **four types**; *Polycrystalline Diamond Compact (PDC), Impregnated, Diamond, and Dual-Diameter bits*.

a. *Polycrystalline Diamond Compact (PDC) Bits*: Are one of the most important material for oil drilling tools in recent years. These bits rotate as one piece and do not contain separately moving parts. Since their first production in 1976, the popularity of PDC cutter bits has grown steadily. PDC aggregates tiny, synthetic diamonds extremely wear resistant, identical to natural diamond.

***b. Impregnated Bits*:** Are also a PDC bit type in which the cutting elements are fully imbedded with a matrix impregnated with diamonds. However, these impregnated bits do not have good performance in rotary drilling, because of relatively low rotary speeds, and frequently run in conjunction with turbo drills for rotary drilling (500 to 1500 rpm).

***c. Diamond Bits*:** Are surface-set natural diamond cutters, commonly used in very abrasive formations, in a high-speed plowing action that breaks the rock grains. Natural-diamond bits use an industrial-grade natural gem-quality, where crushed and processed produce specific sizes and rounded shapes. In about 1910, Geologists used natural diamonds for drilling in hollow coring bits that cut doughnut-shaped holes and retrieved columns of rock for analysis. The diamonds were first introduced to full-hole bits for oil wells in the early 1920s, widely used today.

d. Dual-Diameter Bits: Have a unique geometry that allows them to drill and under-ream. To achieve this, the bits must be capable of passing internally through a well casing and then drilling an oversized (larger than casing diameter) hole. Dual-Diameter bits are similar to conventional PDC bits in the manufactured way. They typically incorporate a steel body construction and a variety of diamond-enhanced cutters.

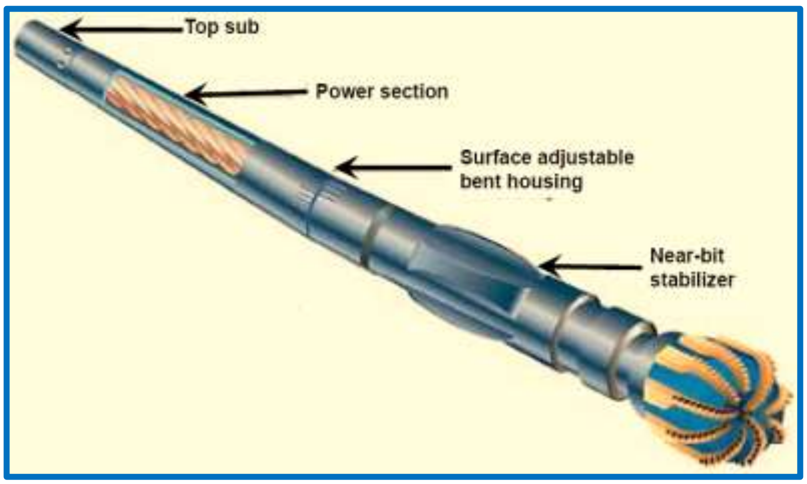
Rotary Drill Bits

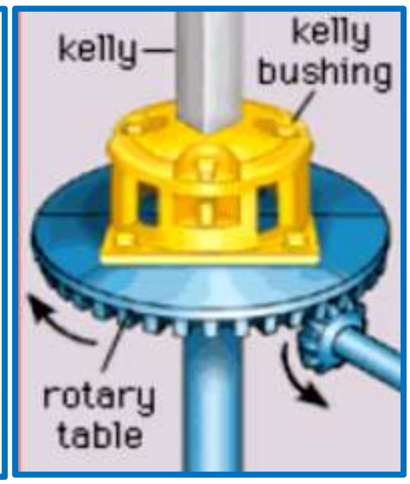
Drilling Fluid and Mud Handling: Drilling fluid, also known as "*drilling mud*", includes most fluids used in drilling oil and natural gas wells. The term includes fluids based on water, hydrocarbons or gases, and various additives intended to adjust the properties of drilling fluid systems, which encompass the functions of hole cleaning, stabilization of drilled strata, control of underground pressures, sealing of fluid losses, improving drilling rates and protecting potential production zones, while preserving the surrounding surface and sub-surface environment.

Drilling Mud: It is a mixture of water, clay, solids and chemicals, used to facilitate pumping of rock fragments from the drill bit to the surface, through the Kelly, rotary table, drill pipes and drilling controls. The mud pump is an essential technology for vertical and horizontal drilling, developed in the

1970s, and driven by a hydraulic pressure stabilizer of the fluid, which circulates through the drill string. This allows the bit to rotate more easily while the drill pipe remains stationary. Drill steering is also accomplished by aligning the mud pump angle in the desired direction. The **three main types of drilling fluids** are: water-based muds (dispersed and non-dispersed), non-aqueous muds (oil-based muds), and gaseous drilling fluid. The water-based drilling mud generally consists of clay, bentonite, and additives, such as barium sulfate (barite, calcium, carbonate or hematite. Various thickeners are used to influence the viscosity of the fluid, such as guar gum, glycol, polyanionic cellulose, etc. In turn, deflocculants are used to reduce the viscosity of clay-based muds such as anionic polyelectrolytes (acrylates, polyphosphates, etc.

Kelly Drive: Refers to a well drilling device that employs a **polygonal** section of pipe, the bushing and the rotary table. The drill bit is attached at the end of the drill string and the Kelly drive makes the bit to rotate, and as the Kelly rotates also turns the drill stem, which includes the drill bit and the entire hollow pipe above it.

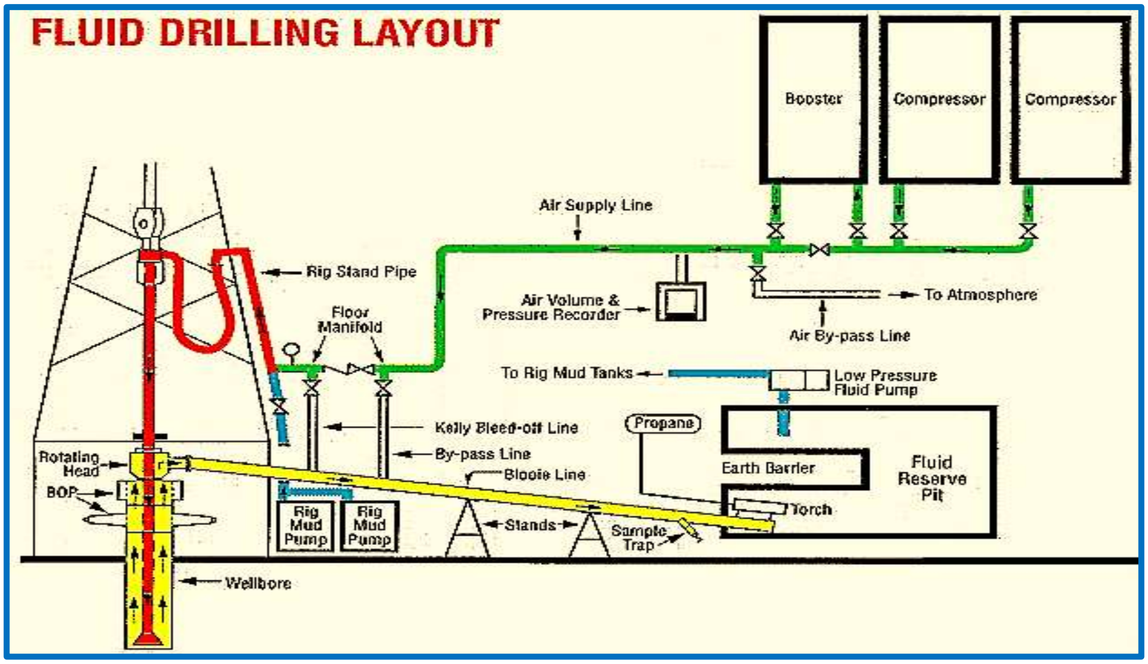




The following common equipment for mud handling is:

- ✓ **Pump:** Sucks mud from the mud pits and pumps it to the drilling apparatus;
- ✓ **Mud pump:** a reciprocal type of pump used to circulate drilling fluid through the system.
- ✓ **Mud tanks:** often called mud pits, provides a reserve store of drilling fluid until it is required down the wellbore.
- ✓ **Pipes and hoses:** Connects pump to drilling apparatus;
- ✓ **Mud-return line:** Returns mud from hole;
- ✓ **Shale shaker:** Shaker/sieve that separates rock cuttings from the mud;
- ✓ **Shale slide:** Conveys cuttings to the reserve pit;
- ✓ **Reserve pit:** Collects rock cuttings separated from the mud;
- ✓ **Mud pits:** Where drilling mud is mixed and recycled;
- ✓ **Mud-mixing hopper:** Where new mud is mixed and then sent to the mud pits.

Mud Engineer: Is the name given to an oil field engineer who is charged of solid controls and with maintaining the completion fluid system on an oil and/or gas drilling rig. The role of the mud engineer or more properly *Drilling Fluids Engineer* is very critical to the entire drilling operation because even small problems with mud can stop the whole operations on rig. The "*Compliance Engineer*" is another name for a relatively new position in the oil field, emerging around 2002, due to new environmental regulations on synthetic oil mud in the United States, which was formerly disposed of in offshore waters, but new regulations now restrict this operation.



Wellhead: It is a safety component at the top of oil or gas wells for structural and pressure interface for drilling and production equipment. The main purpose of the wellhead is to provide a support and sealing point for the drill strings, which run from the bottom of the well to the surface pressure control equipment. Wellheads are typically welded to the first string of borehole casing pipe, and then concreted, to form an integral wellbore structure. Once the well is drilled, the wellhead provides an interface with the reservoir. The pressure control is monitored by a Christmas tree, installed at the top of the wellhead, with isolation and throttling valves to control the flow of fluids during production. When a wellhead is located on an **offshore** platform, it is called as **surface wellhead**, and if located **below water**, it is called a **subsea wellhead** or mudline wellhead.

Subsea wellheads within a protection structure

In subsea wells, the wellhead lies on the ocean floor at depths of about 30 meters to more than 2,500 feet (~750 m). The heads of these wells are independent units with controls that are manipulated remotely by a **ROT** (Remotely Operated Tool), by professional underwater divers or by an **ROV** (Remotely Operated Vehicle). The subsea wellhead can also lock the blowout prevention valve (BOP) and the drilling riser (tubing and hoses) back to the floating oil platform. The subsea wellhead located on the ocean floor is installed together with the drill pipe, with a protective structure, called a "template", which covers the subsea equipment, as shown above. The model serves as a locator for almost all tools used to drill, complete and work the well.

Christmas Tree: It is a set of valves and accessories used in oil or gas wells, for water injection, fluid disposal, gas injection, condensate and other types of processes, installed at the top of the wellhead. It got its name from its resemblance to a decorated Christmas tree. The main function of this system is to control the flow, generally of oil or gas, and also to control the injection of gas or water into an unproductive well, in order to increase production rates. When the well and facilities are ready to produce and receive oil or gas, the Christmas tree valves are opened and fluids pass through a flow line.Christmas trees are commonly used in offshore and subsea wells whose flow lines lead to a fixed or floating production platform or storage vessel, known as a Floating Storage Offloading Vessel (FSO), Floating Processing Unit (FPU) or Floating Production, Storage and Offloading Vessel (FPSO).

Christmas trees also provide numerous additional functions including chemical injection points, intervention means, pressure relief conditions, monitoring points (such as pressure, temperature, corrosion, erosion, sand detection, flow rate, flow composition, valve and choke position feedback), and connection points for devices such as Down Hole Pressure and Temperature transducers (DHPT). Functionality may be extended further by using the control system on a subsea tree to monitor, measure, and react to sensor outputs on the tree or even down the well bore. Christmas trees can be conventional, double hole, single hole, horizontal, mud line, side valve, TFL (direct flow line) and TBT (through hole tree) Christmas trees. The deepest installed Christmas tree is in the Gulf of Mexico, at approximately 3,000 m (10,000 ft).

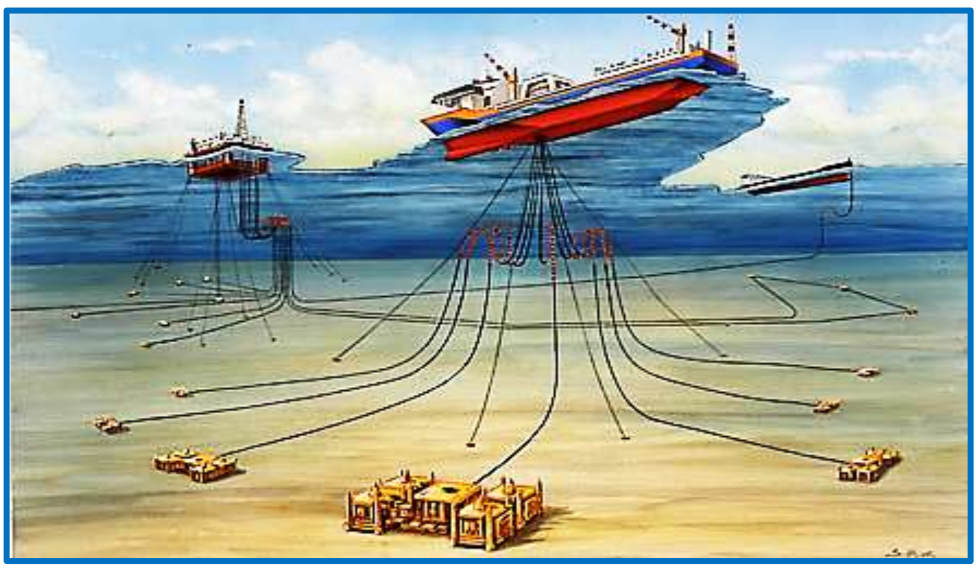
Wellhead Surface

Christmas Tree

The piping system attached to a Christmas tree also controls the downhole safety valves, and acts as an attachment to the pipeline. On producing wells, chemicals or alcohols or oil distillates are also injected to preclude production problems (such as blockages). The master valve is a full opening valve, which is the main control point for access to the pipeline. On hazardous wells or very high pressure (P > 5000 psi), there may be two master valves and a backup for insurance against leaks. The purpose of these multiple valves is to allow the flow line repair, without interrupting the well flow. Subsea Christmas trees are used in field developments worldwide, from shallow to ultra-deepwaters. The deepest subsea trees are rated for waters measuring up to 10,000 feet deep. There are various kinds of subsea trees, rated for a certain water depth, temperatures, pressure and expected flow, as described below:

- ✓ **Dual Bore Subsea Tree**: Was the first tree to include an annulus bore for troubleshooting, well servicing and well conversion operations.
- ✓ **Standard Configurable Trees (SCTs):** Specifically tailored according to the client, normally used in shallower waters measuring up to 1,000 meters deep.
- ✓ **High Pressure High Temperature Trees (HPHT):** For rough environments, such as the North Sea, for pressures up to 16,500 psi and temperatures ranging from -33º C to 175º C.

Obs.: Other subsea trees include horizontal trees, mud-line suspension trees, mono-bore trees and large bore trees. The companies that manufacture subsea trees are Aker Solutions, Cameron, FMC Technologies and Schlumberger.

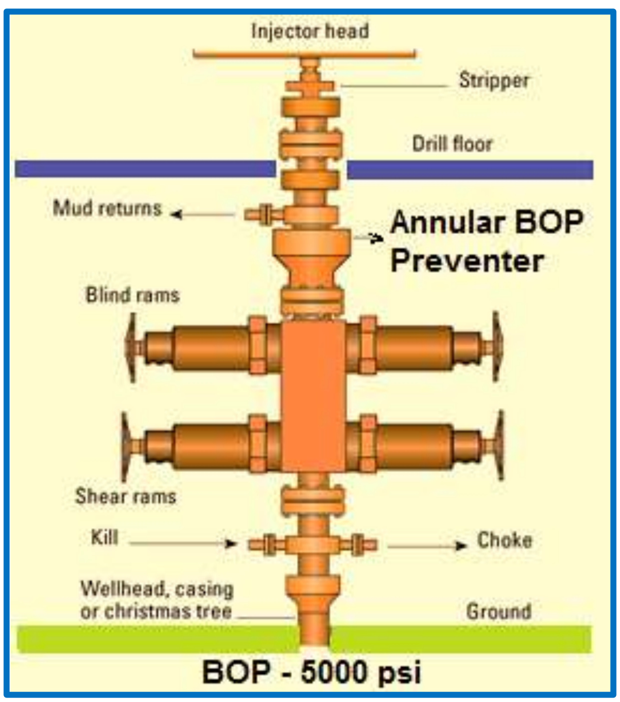


Subsea Wellheads and Christmas trees

Blowout Preventer (BOP): is a large valve used to shut off, control and monitor oil and gas wells. The BOPs were developed to deal with extreme pressure differences and uncontrolled flow emanating from the reservoir of an oil or gas well during drilling, which could lead to a potentially catastrophic event, the **blowout**. In most wells, oil flow must be initiated by acidifying or fracturing the well. They also aim to prevent drilling fluid from being expelled out of the reservoir. The BOP valve was invented by James Smither Abercrombie and Harry S. Cameron in 1922 and marketed in 1924 by Cameron Iron Works. A plunger-type BOP is similar in operation to a gate valve, but has a pair of opposing high-alloy steel plungers, called pistons, that can open or close the valve, to control the flow of fluids from an oil well or gas. The Blowout Preventer is generally operated remotely by hydraulic actuators. In production operations, procedures are possible to increase the density of the drilling mud, opening the BOP and maintaining formation pressure. BOPs come in a variety of styles, sizes and pressure ratings. Some can effectively close an open well, but the most of them are applied to seal tubular components in the well (drilling pipe, casing, or tubing).

Annular Blowout Preventer: Installed with the Blowout Preventer, its main function is to close the drill string, casing or a non-cylindrical equipment, known as the Kelly. The annular BOP is also effective at maintaining a seal around the drill-pipe, even when it rotates during the drilling. This equipment was invented by Granville Sloan Knox in 1946 and patented in 1952, also called the "*Hydril*". There are three types of blowout preventers; annular preventers, shear rams, and pipe rams. Annular preventers and pipe rams make a tight seal around the outside of a drill pipe. Shear rams (blind rams) cut through the drill pipe and seal everything, including whatever might be coming up inside the drill pipe.

Tubing Spool: Also called "tubing head" or "casing head" is usually a spool with both flanged ends, which is set on the top flange of a casing head to hang tubing hanger and seal the annular space between the tubing string and oil-layer casing and which consists of tubing head spool and tubing hanger, what is an assembly to support tubing string and seal the annular space between tubing and casing, which is connected with tubing and seated into tubing spool. During drilling operation, the casing head is important for controlling the wellhead pressure. Drilling rigs typically include at least, some of the following items:



Blowout Preventer (BOP)

Tubing (Casing) Spool

Blind Rams: Or sealing rams, close off the well when the well does not contain a drill string.
Blind Shear Rams: Or shear seal rams, seal the wellbore, by cutting through the drill string.
Centrifuge: Device that separates fine silt and sand from the drilling fluid.
Chain Tongs: Wrench with a section of chain that wraps piping. Similar to a pipe wrench.
Core Samples: Taking samples of rock to look for characteristics of reservoir rock.
Degasser: Device that separates air and/or gas from the drilling fluid.
Desander / desilter: A set of hydrocyclones that separate sand and silt from the drilling fluid.
Diesel Engines: Burn diesel-fuel oil to provide the main source of power.
Drill String: Consists of drill pipe (connected sections of about 30 ft / 10 m) and drill collars (larger diameter, heavier pipe that fits around the drill pipe and places weight on the drill bit).
Drill Bit: End of the drill that actually cuts up the rock, comes in many shapes and materials (tungsten carbide steel, diamond) for various drilling tasks and rock formations.
Drill-stem Testing: Lower a device into the hole to measure the pressures, to reveal whether reservoir rock has been reached.
Electrical Generators: Powered by the diesel engines to provide electrical power.
Elevators: Gripping device used to latch to the drill pipe to facilitate lowering or lifting out borehole.
Hoisting System (drawworks): For lifting heavy loads, is a mechanical winch with a large steel cable spool, a block-and-tackle pulley and a receiving storage reel for the cable.
Kelly: Four or six-sided pipe shaft that transfers rotary motion to the turntable and drill string.
Pipe Rams: Restricts flow in the annulus, between the outside of the drill pipe and the wellbore.
Shear Rams: Cut through the drill string or casing with hardened steel shears.
Rotary Table: Rotates the drill string along with the attached tools and bit.
Shale Shaker: Separates cuttings from the drilling fluid before pumped back down the borehole.
Swivel: Large handle that holds the weight of the drill string and allows the drill string to rotate making a pressure-tight seal on the hole.
Turntable or **Rotary Table**: Drives the rotating motion using power from electric motors.
Well Logging: Lower electrical and gas sensors into the hole to take measurements of formations.

Subsea Wells: They are essentially the same as onshore wells, but installed in a subsea structure, which allows the wells to be drilled and controlled remotely from the surface. Wellheads and Christmas trees are also placed to couple the outlet piping, as well as hydraulic and electrical control signals. Subsea oil fields are generally defined as “Shallow Water and Deep Water” categories, to distinguish between the different facilities and approaches required, described below:

• Shallow water is a term used for very shallow water depths where drilling platform installations and fixed offshore structures are used where diving is viable.

• Deepwater is a term used to refer to offshore installations located in waters deeper than 600 feet, where drilling ships and floating platforms can be used, and remotely operated underwater vehicles are required as manned diving is required.

Hydraulic Power Unit (HPU): Provides a clean supply of hydraulic fluid to remotely operated subsea valves, which drives motors, cylinders, and hydraulic power to the subsea installation via “*umbilicals”*. *Umbilicals* are composite cables containing tension wires, hydraulic pipes, electrical power and control and communication signals. HPU also has a panel that contains control valves and electronics, which operates most subsea equipment via hydraulic switches, with inert gas and/or oil protection. More complex solutions may contain subsea separation/stabilization and electrical multiphase pumping. This can be necessary if reservoir pressure is low; so that the gas and liquids cannot stably flow to the surface, then, product is piped back through pipelines and risers to the surface. The main choke valves are located topside.

Well Completion: Once the drill string has reached the final depth, completion of the well is necessary, to allow oil to flow into the casing in a controlled manner. Then, a perforating gun is lowered into the depth of the well, with explosive charges that create holes in the drill casing and the well rocks, the way oil can flow. After blowing up, the drill casing is perforated, and a small-diameter pipe (tubing) is also lowered into the hole, as a conduit for oil and gas to flow up the well. A device called "*packe*r" is run down the outside of the tubing. When the packer is set at the production level, it is expanded to form a seal around the outside of the tubing. Finally, the Christmas tree is connected at the top of the casing, and concreted.

Then, a second hole is drilled into the reservoir and steam is injected 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 "*Enhanced Oil Recovery (EOR)*". When the reservoir rock is from limestone formation, acid is pumped down the well and out the perforations. The acid dissolves the channels in limestone facilitating oil to flow into the well. When the reservoir rock is sandstone, a specially blended fluid containing "*proppants*" (sand, aluminum pellets, walnut shells, etc.) is pumped down the well. The pressure of this fluid makes small fractures in the sandstone, facilitating oil to flow, while the *proppants* hold all 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.

Subsea Wells

Jet Edge and Chukar Waterjet companies developed the first known subsea ultra-high pressure waterjet system, capable of operating below **5,000 ft** in 2010. Subsea production systems vary in complexity, from a single well with a flowline connected to a fixed platform (FPSO), or a complex onshore installation. Deep water conditions can also have varied production systems, from traditional surface installations to installations with steel pile jackets. Subsea completions have been traced from 1943 to the completion of Lake Erie with 35 feet water depth. The well had a Christmas tree that required professional divers for installation, maintenance and flowline connections.

Well Drilling Monitoring: Technicians monitoring from a distance or in the same location as the well are able to guide the drill bit through the subsurface to the intended destination. When something out of the ordinary is observed, such as higher underground pressures than expected, they typically advise the rig to adjust the drilling plan and take extra precautions to reinforce the well before proceeding. Deepwater exploration wells use sensors that transmit real-time information, such as pressure and temperature, to operation centers. The basic systems are:

- **MWD (Measurement While Drilling):** It is a system that performs downhole drilling with related measurements that transmit data to the surface without disturbing drilling operations. MWD, also known as Logging While Drilling (LWD), is a measurement taken to see the inclination of the well, like a compass. Using basic trigonometry, and a three-dimensional graph of the well trajectory, the information is used to drill in the pre-planned direction, into the formation containing oil, gas, water and condensed. The MWD tools are part of the drill string just above the rotating bit.

- **Mud Pulse Telemetry:** Sends messages as a sequence of pressure pulses. The mud pulse systems use valves to modulate the flow of drilling fluid in the bore of the drill string, generating pressure pulses that propagate up the column of fluid inside the drill string and then are detected by pressure transducers at the surface. The positive pulse system momentarily restricts mud flow through the downhole tool, resulting in a pressure increase, or positive pressure pulse, that propagates to the surface.

- **Electromagnetic (EM) Telemetry:** Uses electrical currents passing through the rocks. The EMT system allows data transmission without a continuous fluid column, providing an alternative to negative and positive pulse systems. The EMT system also establishes a two-way communications link between the surface and the tool downhole. Using low-frequency electromagnetic wave propagation, the EMT system facilitates high-speed data transmission to and from the surface through any formation.

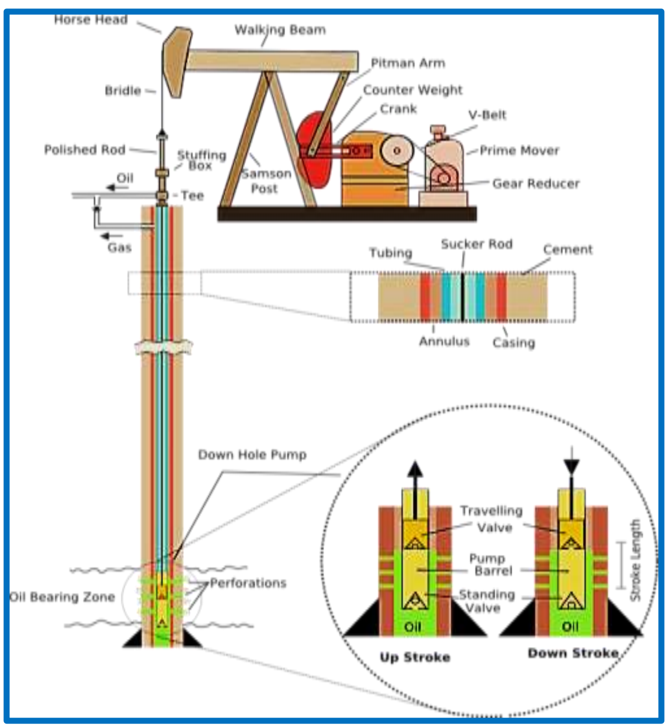
- **Acoustic Telemetry (AT):** Uses the drillstring as the transmission medium and acoustic extensional waves as the data carrier. Multiple quartz sensors provide accurate pressure and temperature monitoring downhole. Data acquired is transmitted to the surface in real-time. The system applies to exploratory or developmental wells where real-time subsurface data during well testing operations is desired.

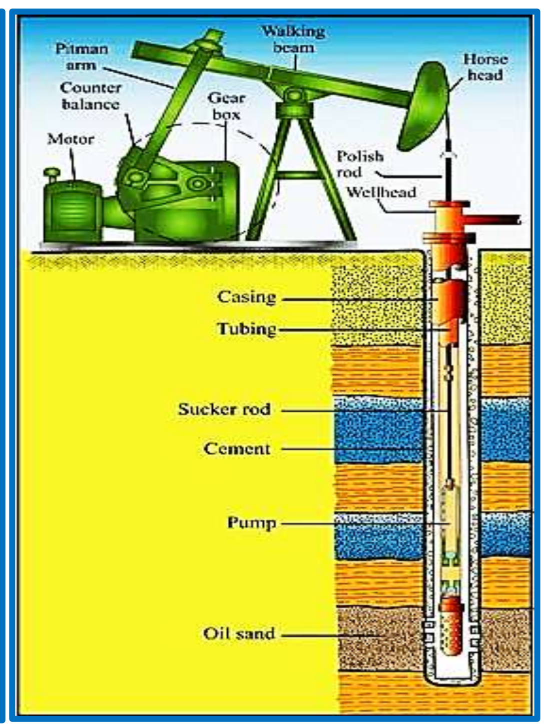
- **Inclinometers:** Monitor subsurface movement and provide information on developing instabilities. This allows engineers to make informed decisions on possible remedial actions.

VII. ARTIFICIAL LIFTS:

Artificial lifts use lifting equipment to **increase the flow** of gas or liquids, such as crude oil or water from a production well. Artificial elevations are necessary in wells when there is not enough pressure in the reservoir to raise the produced fluids to the surface, but they are often used in wells to increase the flow rate above what could flow naturally. Generally, artificial elevations are obtained with the use of **mechanical devices** inside the well (hydraulic pumps) or by reducing the weight of the hydrostatic column by injecting gas at some distance from the well. For example, if the formation pressure is very low and the water or gas injection cannot maintain the pressure, then the well must have artificial elevation. For smaller wells, a wellhead pressure of **0.7 MPa** (100 PSI) with a permanent column of liquid in the tubing allow the well to flow normally. Larger wells are generally equipped with artificial lift to increase production, even at much higher pressures. The most common artificial elevation methods are:

Oil Horse (Rod Pump): The most common onshore artificial lift pumping system is a sucker rod, or an oil horse pumping, which drives equipment below the surface to increase pressure and push oil upward. It consists of a column with a rod and a suction pump. Oil horses have jack pumps, quite familiar from onshore oil wells. After removing the platform, an oil horse is installed at the wellhead. Then, a pump system and electric motor drive a gearbox that moves a lever, which pushes and pulls a suction rod up and down. The suction rod pumps elevates the oil from the reservoir through the borehole and up. Controlled power reduces the speed of the main engine to a suitable pumping speed, typically pumping about **20 times per minute**, driven electronically or via a generator. A speed reducer is employed to ensure that the pump unit moves steadily.





Sucker Rod (Rod Pump)

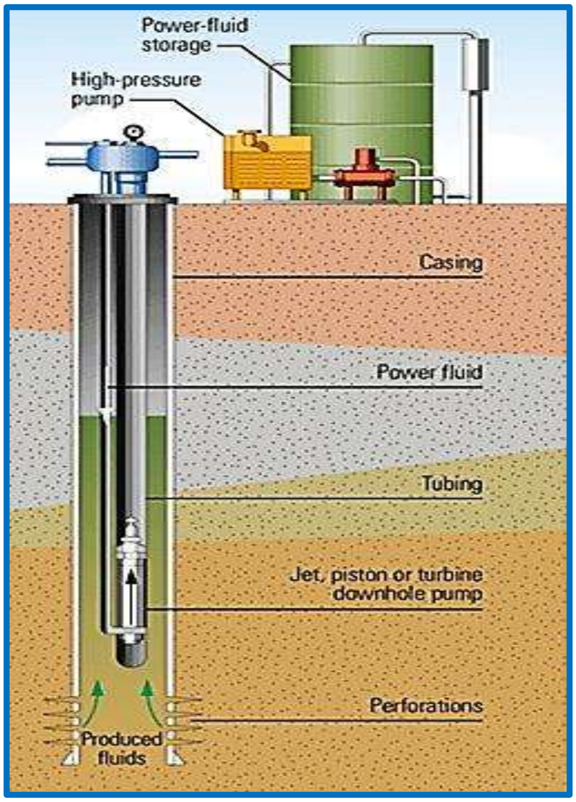
Hydraulic Pumping Systems: Transmit energy to the bottom of the well by means of pressurized power fluid that flows down in the wellbore tubular to a subsurface pump. There are at least three types of hydraulic subsurface pump:

- ✓ **Reciprocating Piston Pump:** One side is powered by the (injected) drive fluid while the other side pumps the produced fluids to surface
- ✓ **Jet pump:** The drive fluid passes through a nozzle-throat venturi combination, mixes with produced fluids and creates a high pressure at the discharge side of the pump.
- ✓ **Downhole Turbine:** The turbine is mechanically connected to an impeller-pump section, which pumps the fluid.

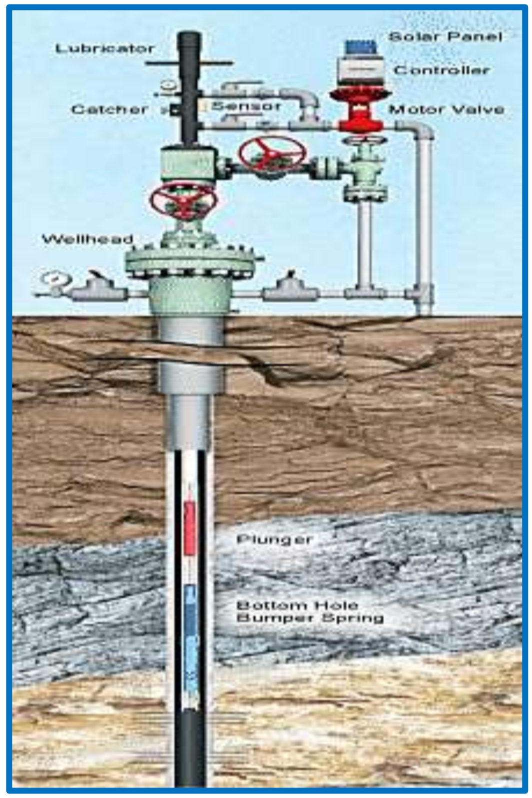
These systems have been used in shallow depths (**1,000 ft ~ 300 m)** to deeper wells (**18,000 ft ~ 6000 m**), for small productions of dozens of barrels per day, up to wells producing more than 20,000 bbl (3,200 m3) per day. In most cases, the driving (injected) fluid can be water or combined fluids (oil/water mixture). Certain chemicals can be mixed with the injected fluid to help control corrosion, paraffin and emulsion problems. Hydraulic pumps are generally composed of two pistons connected by a rod that moves up and down. Both, surface hydraulic pumps and underground hydraulic pumps are powered by filtered oil, previously removed from the well. The surface hydraulic pump sends the oil through the piping string to the underground hydraulic pump installed at the bottom of the drilling string, as can be seen in the figures below:

Plunger Lift: It is another artificial lifting method that uses the energy of the well itself (gas and/or pressure) to lift accumulated fluids from the pipe. It is typically used in low pressure gas wells with condensate, oil, water or gas. The system operates through a series of flow periods, interrupting the well, but is very inefficient due to fluid return during the flow cycle. Well flow conditions can be improved as liquid begins to accumulate at the bottom, eventually locking up the gas. The general rule for closure is that approximately **10%** of the fluid jet is lost for every **1,000 feet** of lift. A plunger pump utilizes an interface seal between a fluid in the tubing and the gas stored in the annulus. In this case, an opening/closing valve can also be inserted into the piping. The plunger pump at the top opens the valve and can hold the fluid, while another mechanism at the bottom of the well closes the valve. A gas is blown creating a differential pressure bringing the fluid to the surface.

By remotely monitoring critical data points such as pressure, time, production volume and line pressure, an operator can achieve better results with minimal cost and minimal risk. A Remote Terminal Unit (RTU), and Programmable Logic Controller (PLC) or EFM can automatically tune itself and determine when to open or close the production valve to optimize the process. Wireless automation is a system in which analog and digital signals (1–5 V or 4–20 mA) are used for temperature and pressure sensors, as well as discrete inputs are used for valve control, tank level alarms, pulse counting and other signals, which can be transmitted via radio to or from a central processing device (EFM, RTU, PLC) and from one to other sensor. With a plunger pump, this transmitted data would include level, flow, pressure, temperature, fluid input, alarms, and signals generated to control devices, such as valves.



Hydraulic Pumping Systems



Plunger Lift

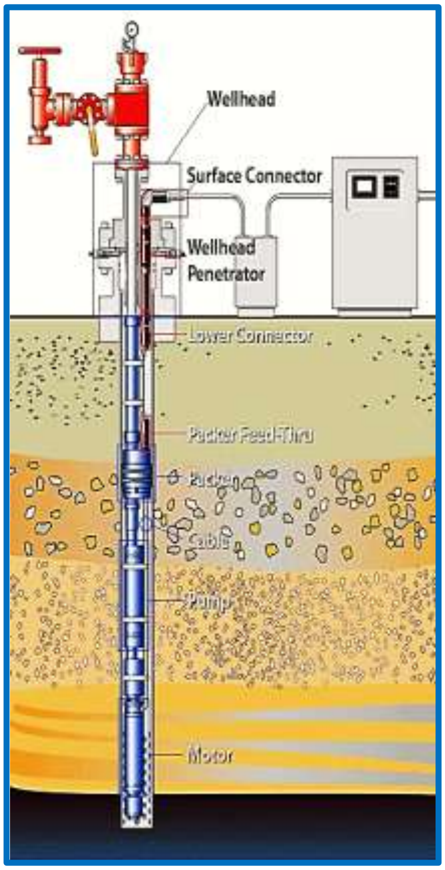
Electric Submersible Pumps: These are downhole pumps (centrifugal pumps), which use a protection to prevent the fluids from entering the electric motor, which have an electrical power cable that connects the motor to a control panel on the surface. These submersible pumps can handle a wide range of flow rates up to **14,000 m^3** per day, with lift requirements from zero to **10,000 feet** (3,000 m), and can be modified to handle contaminants commonly found in aggressive corrosive fluids, such as H2S and CO2.

Progressive Cavity Pumps: These types of pumps are widely applied in the petroleum industry. They have a stator and a rotor, and are used with an upper side motor or a lower motor. The rotation creates sequential cavities and produces fluids that are pushed to the surface. These pumps have rates up to **790 m^3/d** and applied up to **6,000 feet** (2000 m) depth. Progressive cavity pumps offer good resistance to abrasives and solids, but are restricted in some depths and temperatures. Some chemical components, such as aromatics, may deteriorate the stator elastomer.

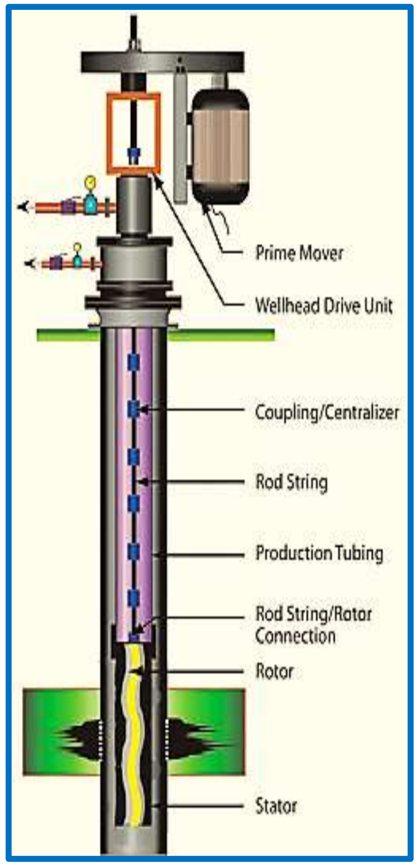
Gas Injection: As the name suggests, the gas is injected into the well when the reservoir pressure decreases, due to the counterpressure of the weight of the oil column in the pipe. The injected gas reduces the weight of the hydrostatic column, allowing the reservoir pressure to push the mixture of fluids and gases to the surface, up to **4,800 m^3** and **15,000 feet** (4,600 m). Injecting gas into the fluid stream also reduces fluid density and lowers bottomhole pressure.The bubbles help push the oil to the surface of the well. The gas is injected below the fluid, using a gas meter to control the injection time. Fluid valves must withstand an increase in pressure in the piping to open and close. A pressure throttling valve opens when casing pressure increases and closes when pressure drops. There are two main types of gas injection:

Continuous Gas Injection: Gas is injected at a constant flow to reduce the overall density of the fluid column and reduce the flowing hydrostatic pressure at the bottom of the well. However, this method is only generally applied in wells with high productivity levels.

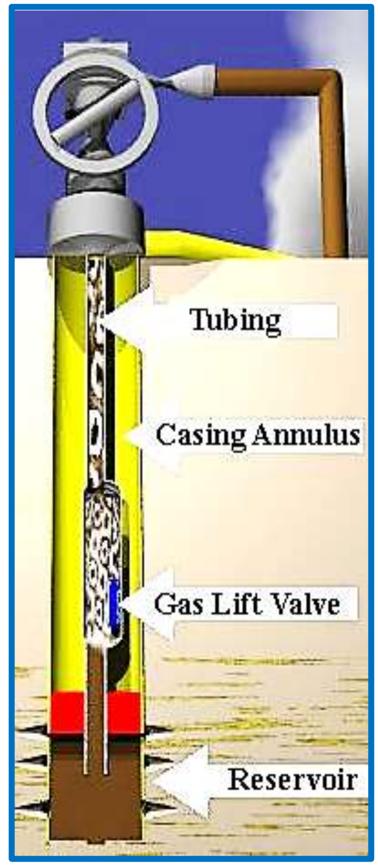
Intermittent Gas Injection: In this system, fluids accumulate inside the production piping. An injection of high-pressure gas below the liquid displaces the fluids to the surface. Subsequently, gas injection is stopped and the liquid accumulation-gas injection-liquid production cycle is repeated. This system is implemented in low production wells.



Electric Submersible Pumps



Progressing Cavity Pumps



Gas Injection

VIII. OIL AND GAS PROCESSES:

The oil and gas industry is generally divided into **three main sector**s: **upstream, midstream and downstream**. The upstream sector is known as **exploration and production** (E&P). The **midstream** sector involves the **transportation** (pipeline, train, barge, ship or truck), storage and marketing of crude or refined petroleum products. The downstream sector refers to the **refining** of crude oil and the processing of natural gas, as well as the marketing and distribution of products derived from oil and natural gas.The **upstream** sector includes the search for potential underground or underwater fields of crude oil and natural gas, the drilling of exploratory wells and, subsequently, the drilling and operation of wells that recover and bring back the crude oil and natural gas to the surface. The **downstream** sector produces petroleum derivatives, such as gasoline, kerosene, aviation fuel, diesel oil, heating oils, fuel oils, lubricants, waxes, asphalt, natural gas and liquefied petroleum gas (LPG) and hundreds of other **petrochemical** products.

Oil Fields: Geologists use seismic surveys to look for geological structures that could form oil reservoirs. The "*classic*" method consists of making an underground explosion nearby and observing the seismic response that provides information about the geological structures below ground. Other instruments, such as **gravimeters** and **magnetometers**, are also used. When a reservoir is explored, a geologist (known as a "*mudlogger*") notices the presence of oil. The oil and gas industry can be classified into **four main types**; exploration, development, production and site closure.

- ✓ **Exploration:** Involves the search for rock formations associated with oil or natural gas deposits, geo-physical prospecting and exploratory drilling.
- ✓ **Development:** After exploration has located an economically productive field, there may be the construction of one or more wells, or abandonment if no oil or gas is found, or continuation of research if hydrocarbons are found in sufficient quantities.
- ✓ **Production:** It is the process of extracting oil & gas and separating the mixture of liquid, gaseous hydrocarbons, water and solids. Oil is processed in a refinery and natural gas is produced in a natural gas processing plant.
- ✓ **Abandonment:** Involves closing the well(s) and restoring the site, when a well does not have the potential to produce economic quantities of oil or gas, or when production is not economically viable.

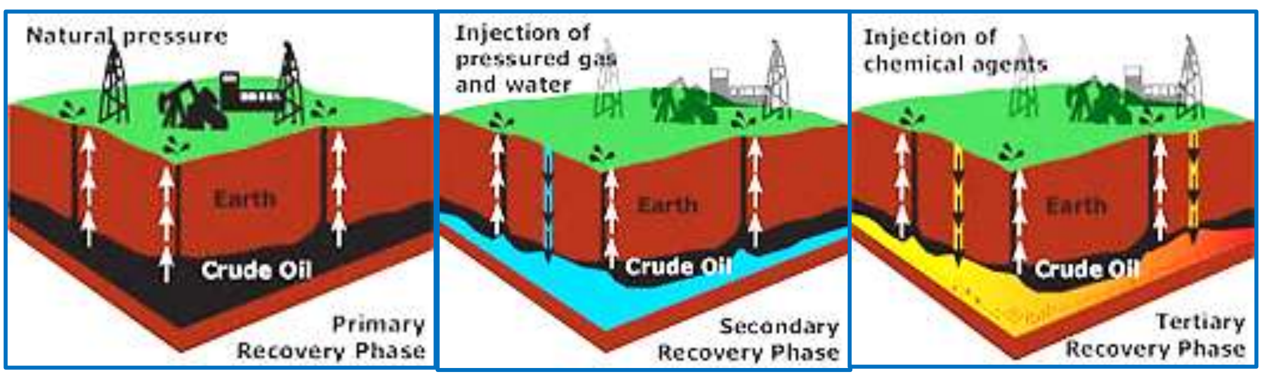
Oil Recovery: Is extensively used to reduce oil viscosity and refers to some of the processes by which crude oil is extracted. Occasionally, **surfactants** (detergents) are injected to alter the surface tension between the water and oil in the reservoir and improve the oil flow, which remain in the reservoir as residual oil. Oil recovery and can be categorized into **three** phases:

a) Primary Recovery: It uses the natural pressure of the reservoir to push the crude oil to the surface, including natural water to displace the oil, expansion of the natural gas at the top of the reservoir, expansion of the gas dissolved in the crude oil and gravity drainage, due to the movement of oil in the reservoir, from the top to the bottom. The primary recovery factor during the primary recovery stage is typically **5 to 15%.**

b) Secondary Recovery: Over the life of the well, the pressure drops and, at some point, there will be insufficient underground pressure to force the oil to the surface. Secondary recovery techniques increase reservoir pressure by injecting water and pressurized gas, which injects air, carbon dioxide, or some other gas into the bottom of the well to help reduce fluid density and improve flow rate. The typical secondary recovery factor is about **30%**, depending on the oil properties and rock characteristics.

c) Tertiary Recovery: This method consists of injecting **chemical agents** into the well. The TEOR (a thermal recovery method) heats the oil, reducing its viscosity and facilitating its extraction. Steam injection is the most common form of TEOR, and is often done with a cogeneration plant, and the steam produced (in addition to generating electricity through a turbo-generator) is injected into the well, to increase extraction of the heaviest oil. Oil burning is another form of TEOR, but instead of steam, some of the **oil is burned** to heat the surrounding oil.

d) Carbon Dioxide Recovery: Is another well recovery method to reduce viscosity through carbon dioxide. Carbon dioxide recovery is particularly effective in reservoirs deeper than 2,500 feet (750 m), with oil API gravity greater than **22-25°** and remaining oil saturations greater than **20%**. Normally, CO2 injection is alternated with water injection, to make the oil rise towards the production zone. This process is a very common recovery technique used in facilities around the world.



1. OIL PLATFORMS OR DRILLING RIGS: These are large facilities for drilling wells, extracting oil and natural gas with a storage structure until they can be brought for refining and commercialization. In many cases, platforms also contain facilities to house workers, but these may be just a basic structure on land or floating. Depending on the circumstances in which an oil field is physically prospected, platforms are installed in oceanic waters, fixed to the seabed by a reinforced metal structure. Thus, subsea wellheads are connected to an offshore platform by **flow lines and umbilical connections**. Subsea drilling may consist of one or more subsea wells, with one or more collecting centers set up for multiple wells.

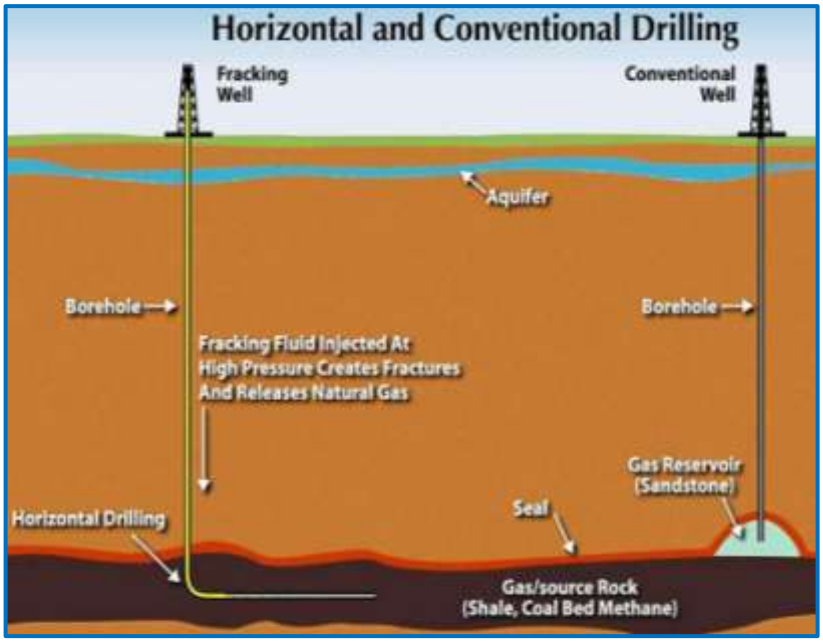
Oilfield Drilling: When a drilling process begins, periodic surveys are performed with instruments to provide the survey data (inclination and azimuth) of the wellbore. They may range from **10–150 meters** (30–500 feet), with **30 meters** (90 feet) during active changes of angle or direction, and distances of **60–100 meters** (200–300 feet), with typical."*drilling ahead*" (without making active changes in angle and direction). During critical angle and direction changes, a Measurement While Drilling (MWD) tool is added to the drill string to provide continuously updated measurements, and for real-time or approximate adjustments.The **MWD** indicates whether the drilling is following the planned path, and corrections are regularly made by simple techniques, such as adjusting the rotational speed or weight of the drill string, as well as more **complicated** and time-consuming methods, such as introduction of a hydraulic pump at the bottom of the well.

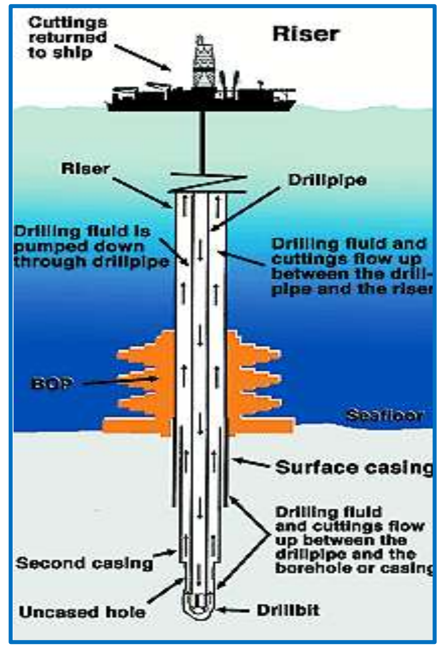
The well can be fully surveyed at regular depth intervals, typically approximately every **30 meters** (90 feet), or with a typical length of **2 or 3** drill pipe joints, as most drillings "*move away*" from the pipe. Drilling distant targets lateral to the surface requires careful planning and design. Current drilling records record wells more than **10 km** (6.2 mi) away from the surface location, but with an actual vertical depth of approximately **1,600–2,600 m** (5,200–8,500 ft). Such surveys are maintained as an engineering record, which describes the path of the well. Survey images taken during drilling are typically confirmed using a “*multi-shot camera*” device.

Directional Drilling: Also called horizontal or inclined drilling is the practice of drilling non-vertical wells. Oil or water wells may not be effectively vertical, and horizontal wells typically have a larger reservoir footprint and offer significant production improvements over vertical wells. The inclination of a well needs to be measured with an **azimuth** (direction in relation to the geographic grid) or a **gyroscope**, similar to aeronautical navigation. Horizontal drilling is performed by using data configurations and instruments to measure the path of the well in three-dimensional space, with data for communication, measurements taken from the bottom of the well to the surface, mud pumps and special components, including rotary systems, steerables and drills, which can be divided into **three main** groups: *vertical drilling, horizontal drilling and surface drilling*, which can also horizontally cross a vertical well to extract methane from a coal bed. Control rotary tools enable steering during rotation, with higher penetration rates and smoother holes. Horizontal drilling is common in shale reservoirs, as it is the most productive reservoir rock.

Deepwater Drilling: Also called offshore drilling is the exploration and extraction of oil and natural gas in the ocean. Offshore oil drilling began commercially in the **1890s**, and in the early **1970s** the first wells were drilled more than 300 meters deep. Then, drilling began to reach various depths, and a new term for drilling in ultra-deep waters emerged, which means 5,000 feet (1,500 meters) or more, and today it has become a very common reality. The Mobile Offshore Drilling Unit (MODU) is a platform that uses sonic equipment to drill oil wells in offshore locations, with a greater probability of production. Some units are converted into **production platforms**, and continue drilling once a productive site is found. The line of piping, hoses and fittings that extend below the oil platform, beneath the seawater is called as **riser**, which allows oil on the ocean floor to be pumped to the platform. Large companies work in this sector, including Halliburton, Diamond Offshore, TransOcean, Geoservices and Schlumberger.

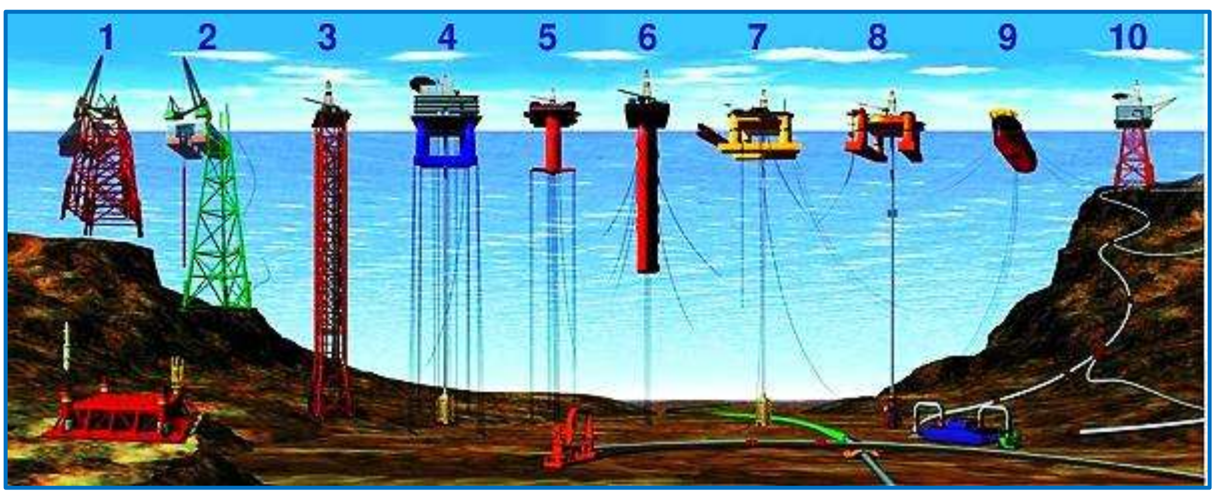
Remote subsea wells are typically connected to a platform by **flowlines** and **umbilical** connections. Depending on the circumstances, the platform is fixed with a strong metal structure on the ocean floor called as fixed or floating platform. Current technologies, such as stringer configurations, duct end collectors, concentric risers and up-to-date data are necessary to overcome many operational difficulties. It is believed that **90%** of the world's undiscovered hydrocarbon reserves are in waters deeper than 3,000 feet. As water depth increases, even under ideal maritime conditions, new technologies associated with new drilling and production systems emerge.





Conventional, horizontal and deepwater drilling

Offshore Drilling: Is is a complex process where a well is drilled into the ocean floor to explore and extract oil or gas found in rock formations on the seabed. Drilling in water depths greater than **520 m** (320 ft) requires operations to be carried out from a floating vessel. There are different types of offshore drilling units, such as the drill ships that have what is called a "*moon pool*", which is nothing more than an **opening** at the base of the hull, where drilling equipment, underwater divers and small submersible vessels can pass through the "*moon pool*" opening. The **basic types** of deepwater drilling rigs or drilling rigs are:



1, 2) conventional fixed platforms; 3) compliant tower; 4, 5) vertically moored tension leg and mini-tension leg platform; 6) spar; 7,8) semi-submersibles; 9) floating production, storage, and offloading facility; 10) sub-sea completion and tie-back to host facility.

1. Semi-Submersible Drilling Rig: It is a maritime platform used in various offshore functions, such as a drilling and production platform, or a heavy load crane, adapted to extreme safety conditions. These platforms are designed to be floating with structural and ballasted pontoons below the ocean surface, adaptable to wave action. The operations deck is located above the sea level, where equipment and operational personnel are located, away from the waves. This type of semi-submersible platform can be transformed from deep to shallow draft, removing ballast water from the hull, to become a surface vessel. Semi-submersible platforms can be used at depths of **60 to 3,000 meters** (200 to 10,000 feet).

2. Drillship: Is a merchant vessel designed for use in exploratory offshore drilling of new oil and gas wells or for scientific drilling purposes. The drillship can be used as a platform to carry out well maintenance or completion work, such as, casing and tubing installation, subsea tree installations and well capping. Currently, the vessels are used in deepwater and ultra-deepwater applications, equipped with the latest and most advanced Dynamic Positioning System (DPS). Drillships have the functional ability of semi-submersible drilling rigs and have great mobility, and can move quickly under its own propulsion.

When the drillship has a drilling operation, a marine riser is lowered to the seabed with a Blowout Preventer (BOP) at the bottom that connects to the wellhead. The BOP is used to quickly disconnect the riser from the wellhead in times of emergency or in any needed situation. Underneath the derrick is a "moon pool", an opening through the platform covered by the rig floor. Some of the modern drillships have larger derricks that allow dual activity operations, for example simultaneous drilling and casing handling. Several drillships are outfitted with a *Dynamic Positioning System (DPS)* to maintain position over the well. They can drill in water depths up to 3,700 m (12,100 ft).


Semi-Submersible Drilling Rig Drillship

3. Floating Spar Platform: It is a type of floating platform, which consists of a large diameter vertical structural tube, which supports the operational topdeck above. The structural tube is fixed to the ocean floor by a chamber filled with a material denser than water, to lower the platform's center of gravity and provide stability. The stringers are used as buoys and anchored to the seabed using a mooring system with a chain-chain or chain-polyester composition. There are three main types of stringers; *the classic spar, truss spar and cellular spar*.

a) The **classic spar** consists of a cylindrical hull, with a heavy ballast in the lower part of the cylinder. The **truss spar** consists of a shorter tube with a frame connected to the bottom. At the bottom of the structure, there is a relatively small, square-shaped "*tank*" that houses the ballast material.

c) The **cellular spar** consists of a large central cylinder with smaller tubes of alternating lengths. At the bottom of the tubes there is a tank that houses the ballast material.

4. Fixed Platforms: These platforms are built on concrete or steel supports, or both, anchored directly to the seabed, and support the operations deck with space for drilling rigs, production facilities and crew accommodation. Such platforms are, due to their immobility, designed for a long term, designed with various types of construction structures, steel jackets, floating systems, pipelines and umbilical connections. Steel jackets are vertical sections made of tubular steel pieces and generally protected by a cover on the seabed.

Floating Spar Platform

Fixed Platforms

5. Jack-up Rigs, Mobile Drilling Units or MODUs: Are drilling rigs that can be jacked up, above the sea using legs, or mobile platforms used for non-permanent oil storage. Depending on the circumstances, these platforms may be fixed on the ocean floor or may float. They are generally also called MODUs (Mobile Offshore Drilling Units), typically used in water depths from **120 meters** (390 ft), and can go to **170 m** (560 ft) depth. These platforms can be moved around, towed into position by a tugboat and anchored, or kept in position by their own, with dynamic positioning.

6. Compliant-Tower Rigs: They are similar to fixed platforms, built with flexible towers and a pile foundation that supports a conventional deck for drilling and production operations. These platforms are designed to withstand lateral deflections and forces, typically used in deep waters ranging from **370 to 910 meters** (1,210 to 2,990 feet) deep. Both fixed and tower platforms are anchored to the seabed and both have decks well above the sea surface. However, the compatible tower platform can operate up to **1 km** (3,000 feet) below the surface.

Jack-up Rigs

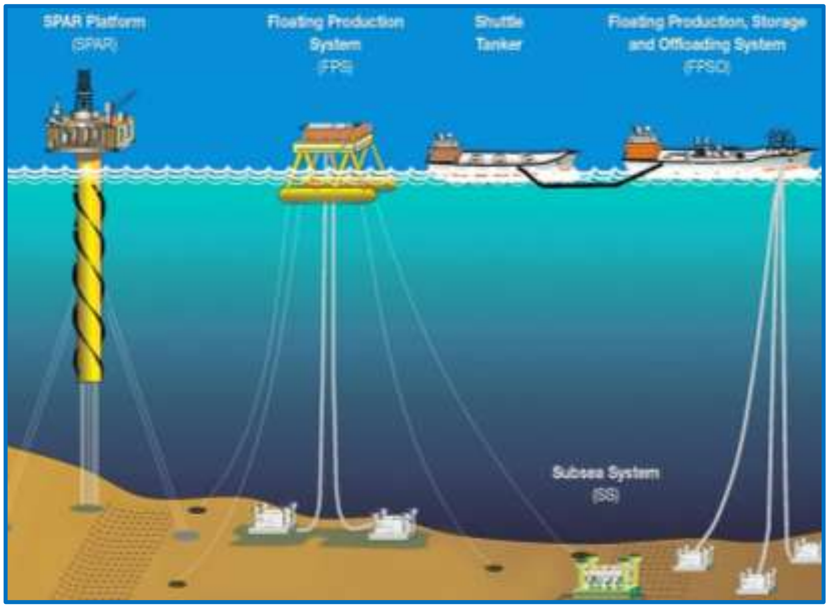
Compliant-Tower Rigs

7. Floating Production System (FPS): The main type of Floating Production Systems is the FPSO (Floating Production, Storage and Offloading system), which consists of large mono-hull structures, generally equipped with many processing facilities. The basic design of the FPSOs is a ship-shaped vessel, with processing equipment (topside), aboard the vessel's deck and crude oil storage below in the double hull. After extraction, the hydrocarbons are transmitted through flowlines and umbilical connections to risers, which transport the oil and gas to the vessel's turret and then to the FPSO on the water's surface.

The FPSO stores oil or gas in the hull itself, and then discharges to tankers or transmits the crude oil or gas through pipelines. The FPSOs are anchored on the ocean floor and are very effective in deepwater fields. A central mooring system allows the vessel to rotate freely to better respond to weather conditions and advancing sea waves, with a reinforced anchoring connection to the sea-bed. In environments where cyclones or hurricanes occur, disconnectable mooring systems are used, so that the vessel can be removed from the path of the storm and returned when it passes.

Other variant is called **FSO** (Floating Storage and Offloading), which is a vessel used only **to store oil or gas**, without processing. The vessel is kept by an extra turret mooring system that allows the vessel to take in any direction of wind, wave and sea current, commonly designed to remain on site during 15 years with accommodation for 60 professionals. Other type, the **FSU** (Floating Storage Unit) is used exclusively for storage purposes, but host very little process equipment.

8. Tension-Leg Platforms (TLPs): These are floating platforms also fixed to the seabed. The basic design includes four huge air-filled metal columns **forming a square**. These columns are supported and connected by pontoons, similar to a semi-submersible production platform. The upper part is common of the typical production system, consisting of a deck that houses the drilling and production equipment, as well as the power modules and accommodation. These platforms can extract crude oil from **200 to 1,200 meters** (660 to 3,940 feet) below the sea.



Floating Production Systems Tension-Leg Platform (TLP)

9. Condeep Platforms (Concrete Deep Water Structure): Refers to a huge gravity-based structure for oil platforms, developed by Norwegian engineer Olav Mo, consists of a base of concrete oil **storage tanks** from which one, three or four concrete shafts rise, built from reinforced concrete instead of steel, as a standard design. This platform type was designed for the most heavy weather conditions and great water depths, often found in the North Sea. The Condeep has the advantage to allow oil and gas storage in its own construction, and equipment installation in its hollow legs. However, it only allows a limited weight on the deck for production equipment.

10. Concrete Caisson: It is a watertight containment structure used in the construction of a concrete dam or for ship repair. This type of structure has **oil storage tanks** embedded below the sea surface, often with floating capacity, allowing them to be built close to the coast and then moved to their final position, where they remain. These fixed platforms are economically viable for installation in water depths of up to approximately **520 m** (1,710 ft).

Condeep Platforms Concrete Caisson

11. Gravity-Based Structure (GBS): can either be steel or concrete and is usually anchored directly onto the seabed, usually without hydrocarbon storage capability. During installation, it is usually connected to a transportation barge, and positioned by pulling it off the yard, to the sea. The jacks are released gradually, while the GBS is ballasted, to ensure that the platform does not sway too much from the target location. Generally, larger platforms are permanently assisted by ESVs (Emergency Support Vessels), when a search and rescue operation is necessary. During normal operation, the PSVs (Platform Supply Vessels) also keep the platforms supplied. Anchor Handling Tug Supply (AHTS) vessels are built primarily to handle the oil platform anchors, tow them to the site, anchor them and serve as Emergency Rescue and Recovery Vessels (ERRV), or also used to transport supplies.

12. Normally Unmanned Installations (NUI): These installations (sometimes called toadstools) are small platforms, consisting of little more than a well bay, helipad and emergency shelter. They are designed to be operated remotely under normal conditions, only to be **visited occasionally** for routine maintenance or well work. The Savonette offshore southeast Trinidad has been developed as a series of normally unmanned "clone concept" platform.

13. Satellite Platforms: These installations, also known as conductor support systems, are small unmanned platforms consisting of little more than a well bay or a small process plant. They are designed to operate in conjunction with a static production platform, which is connected to the platform by flow lines or by umbilical cable, or both.

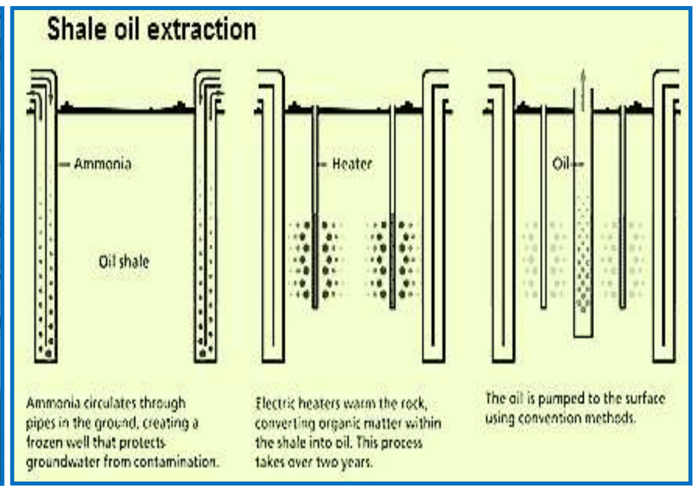
Gravity-Based Structure– GBS - Normally Unmanned Installations (NUI) - Satellite Platforms

2. UNCONVENTIONAL OIL: Is petroleum produced or extracted using techniques other **than the conventional** oil well methods. Terms included as "*unconventional oil*" are **shale oil, oil sands, synthetic fuel, and derivative products** as heavy oil, coal-based liquid supplies, biomass-based, liquid gas, Gas to Liquid (GTL) and even liquids arising from chemical processing of gas.

a) Shale Oil: Was transformed when algae and sediment were deposited in lakes, lagoons and swamps in anaerobic environment, allowing the oil to accumulate in thick layers. Shale oils can be produced by pumping out the rock reservoir source, or extracted by further pressuring, when fracturing and heating are not approved. Companies are utilyzing ammonia and direct electrical heating, rather than steam injection. One of the largest known locations is the oil shale locked in Green River Formation in Colorado, Utah, and Wyoming.

Geologists classify the shale oil on the basis of its source as carbonate-rich shales, siliceous, or cannel shales. Shale oil deposits are found in all world oil provinces, although most of them are too deep to be exploited economically. The term "*resources*" refers to all oil shale deposits, while "*reserves*", represent those deposits, from which producers can actually extract the shale oil economically using existing technology. Although resources of oil shales occur in many countries, only 33 countries possess known deposits of possible economic value.

Most oil shales are sedimentary rocks containing relatively large amounts of organic matter, where significant amounts of shale oil and combustible gas can be extracted by process distillation, which is about 70% of this resources on land owned or managed by the US federal government. Significant amounts of *kerogen* (solid mixture of organic chemical compounds) are extracted from sedimentary rocks, as well, liquid hydrocarbons and combustible shale gas. The kerogen can be converted to oil through a chemical process of pyrolysis, hydrogenation, or thermal dissolution.



b) Oil Sands: Tar sands or bituminous sands**,** are all types of *unconventional petroleum* deposits. Tar sands are often strip mined and ***two tons of tar sands*** may produce ***one barrel of oil***. Typical tar sands contain sand grains with a water envelope, covered by a bitumen film that may contain **70% oil**. Tar sands are processed with water extraction and various fine particles are suspended in the water. Then, **hot water** is added to the sand, and the resulting **slurry** is piped to the extraction plant where it is agitated and the **oil skimmed** from the top. The bitumen froth floats to the top of separation vessels, and is further treated to remove residual water and fine solids.

Oil sands are either loose sands or partially consolidated sandstones containing a naturally occurring mixture of sand, clay, and water, saturated with a dense and extremely viscous form of petroleum, commonly known as bitumen (or colloquially tar due to its similar appearance, odor and colour). Natural bitumen deposits are reported in many countries, but in particular are found in extremely large quantities in Canada (Alberta) and Venezuela, estimated in 250 billion barrels. Other large reserves are located in Kazakhstan and Russia.

The oil that Canada extracts and exports, much of it comes from the Athabasca oil sands in Alberta that are rich in bitumen (a form of extremely heavy crude oil). Using open-pit mining technology the bitumen-rich earth is dug up and transported to separation facilities, where bitumen is extracted from other clays, water and sand. After a series of cleaning and processing procedures, the bituminous **heavy oil** is transported to refining facilities, where it can be turned into gasoline, diesel and other petroleum products. Depending on the exact method employed, extraction of oil sands crude can also involve significant quantities of natural gas.

c) Synthetic Fuel or Synfuel: Is a liquid fuel, or sometimes gaseous, obtained from coal or natural gas, or a mixture of carbon monoxide and hydrogen, in which the syngas was derived from gasification of solid feedstocks, such as coal, biomass and natural gas. Synthetic fuels are produced by the chemical process of conversion. The main conversion types are:

- ✓ **Direct Conversion:** Refers to processes in which coal or biomass feedstocks are converted directly into intermediate or final products, without going through the intermediate step of conversion to syngas via gasification. Direct conversion processes can be broadly broken up into two different methods; pyrolysis or carbonization and hydrogenation.

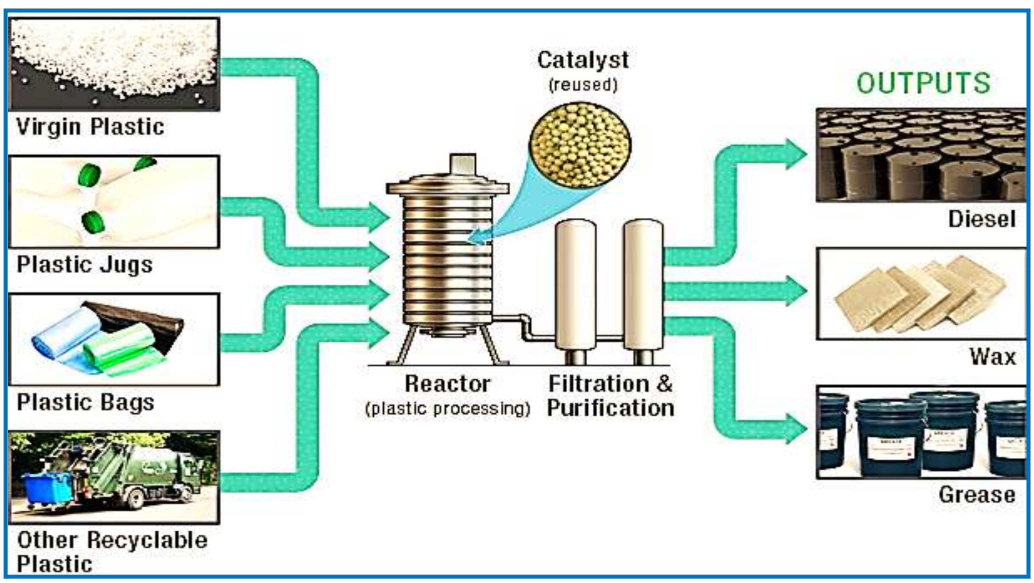
- ✓ **Indirect Conversion:** Is a process where the biomass, coal, or natural gas is converted to **hydrogen** and **carbon monoxide**, known as **syngas**, through a gasification system or steam methane reforming. The liquid processed syngas uses one of these various different conversion techniques, depending on the desired end product.

- ✓ **Synthetic Liquid Fuels Program:** Was performed when the United States Bureau Mines experienced a technology to produce synthetic fuel from **coal and oil shale**, which initiated in 1944 during World War II. Between 1928 and 1944, the Bureau made other experimentations, with coal liquefaction by hydrogenation using the **Bergius** process. A small-scale test unit, constructed in 1937, produced 100-pound per day of continuous coal feed.

d) Synthetic Crude Oil: May also be created by upgrading bitumen, or synthesizing liquid hydrocarbons from oil shales. There are several of other extracting shale oil processes, including synthetic crude oil produced through **pyrolysis**, hydrogenation, or thermal dissolution. Recent advances by oil companies have produced synthetic profitable fuels. The Shell Company built a GTL (Gas-to-Liquid) large scale plant in Qatar, inaugurated in 2011, where gas is relatively inexpensive without CCS (Carbon Capture and Storage or Carbon Capture and Sequestration).

e) Thermal Depolymerization (TDP): Is a process called "*hydrous pyrolysis*", which is the reduction of complex organic materials (usually waste products known as biomass) into light crude oil. This process, which imitates natural geological processes, has been involved in the production of fossil fuels, using heat and pressure to break down organic and inorganic compounds. According to Changing World Technologies, this process has also the ability to break down several types of materials, many of them, poisonous to humans and the environment.

Under **pressure and heat**, long chain polymers of hydrogen, oxygen, and carbon decompose into short-chain **petroleum hydrocarbons** with a maximum length of 18 carbons. Thermal depolymerization is similar to other processes that use **superheated water** in their processing to produce fuels, such as direct Hydrothermal Liquefaction. Thermochemical conversion (TCC) means conversion of biomass to oils using superheated water, although it more usually is applied to fuel production via pyrolysis. Thermal conversion process is another name for thermal depolymerization.

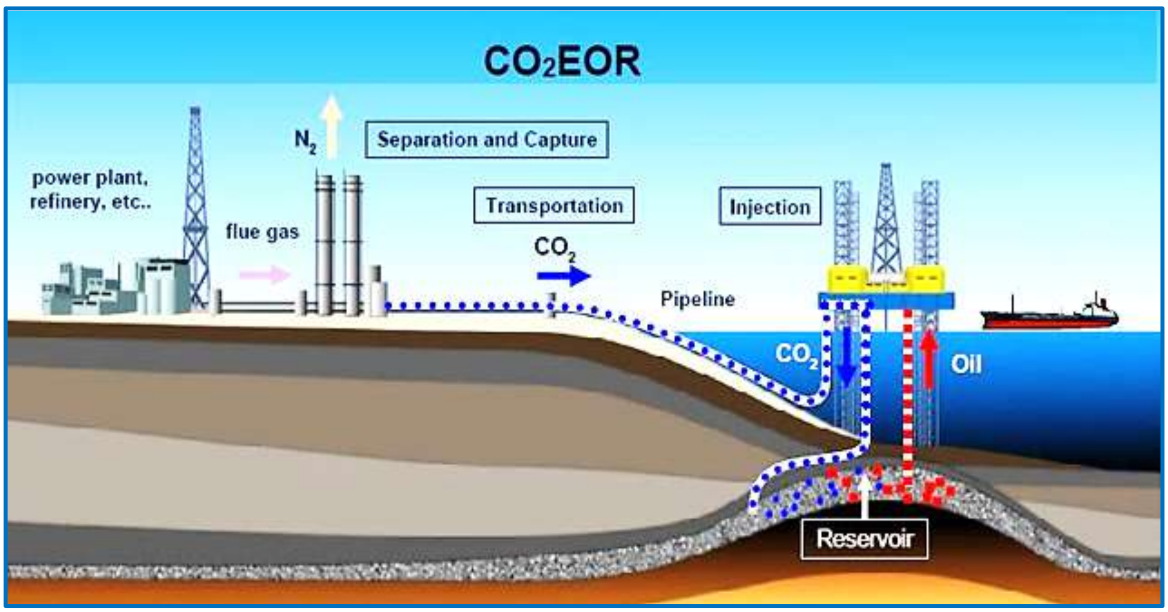


Thermal Depolymerization

3. CARBON CAPTURE AND STORAGE (CCS): Or Carbon Capture and Sequestration is the technique of **capturing waste carbon dioxide** (CO2) from large point sources, such as fossil fuel power plants, transporting to a storage site and deposits, to not enter the atmosphere, normally extracted from underground geological formation. The aim is **to prevent** the release of large quantities of **CO2 into the atmosphere** (power generation and uses from other industries) as potential means of mitigating fossil fuel emissions, causing global warming and ocean acidification.

When CO2 is heated up to **2400 °C**, it **splits** into **carbon monoxide** (CO) and **oxygen**, achieved by using temperature in a chamber containing a mirror to focus sunlight on the CO2. According to National Laboratories, these chambers can **provide enough fuel to power 100%** of vehicles. Unlike other **biofuels**, the CO2 capture could be done in a warehouse or in an unused industrial facility. An example of carbon sequestration is the existing US pilot version at Big Brown Steam Electric Station, in Fairfield, Texas, which converts carbon from smokestacks into baking soda.

Leakage through injection pipe system can become a greater risk. A major concern is whether **leakage** of stored CO2 can compromise CCS, as a climate change mitigation option. In 1986 a large leakage of naturally sequestered CO2 through pipe system, rose from Lake Nyos in Cameroon, and asphyxiated **1,700 people** indicating a real point of evidence for the potentially **catastrophic effects** of sequestering carbon artificially, without improving the monitoring performance.



4. DRILLING RIGS: Is a defined geographically area for the purpose of prospecting, exploration, mining or extraction of natural resources, with licenses to prospect, explore or extract issued for a specific period, as each block is identified by a unique name or number. Oil blocks are not always technologically and economically feasible, but, with **rising oil prices**, several companies invest in this area. The **common terms** used in Drilling Rigs are:

a) Roughneck & Roustabout: Roughneck is a **slang term** for a person whose occupation is the hard-manual labor working on oil rigs. The Roughneck workers specifically mean all those who work on the **drill floor** of a drilling rig, handling specialized drilling equipment and pressure controls. In many oil fields the **roughneck's duties** include work involved with connecting pipe down the wellbore, as well as, general activities around a rig. Originally this term was used in the 19th century, almost interchangeably with "***roustabout***", which refers to a maintenance worker, but generally, it is also an **official professional classification** of oil rig personnel with hard labor. He or **she** sets up the oil "*wellheads*" or oil lead lines connected to stock tanks. The **roustabouts** also help maintain the saltwater disposal pumps, release roads, release mowing and create dykes around tank batteries, etc. The other **professional designations** of the crew in drilling rigs are:

- **Toolpusher:** Is the **highest position** at the drilling rig, **responsible** for every crew, and may stay on location for a few days or weeks during operations, where individual drilling crews work only **8** or **12 hour shifts** or "tours" (pronounced as "towers").
- **Driller:** Is the **head** of the drilling crew, and responsible for controlling a rig's machinery during drilling, as well as most other rig operations.
- **Derrickhand (Derrickman):** Is **responsible** for the drilling mud, the mud pits and the mud pumps, where drilling fluids are circulated, as well as, being the hand up to the derrick manipulating situations during tripping operations. The Derrickman acts as a **leader** for the driller, mostly restricted to the rig floor, and in many cases, he is also exclusively responsible for the whole work in the "*tripping*" pipe in and out of the hole.
- **Pit Watcher:** Is also **responsible** for the drilling mud, mud pits, and associated pumping and circulating of various fluids through the pits, downhole and returning through the pits.
- **Motorman (Motorhand):** Is **responsible** for maintenance of engines, water pumps, water lines, steam lines, boilers and other diversified machinery, incorporated into the rig on a daily basis. He is also responsible for movement of equipment on site. On a four-man drilling crew, the motorman is also the chainhand.
- **Boilerman:** Is **responsible for boilers**, though this position is currently obsolete. The Boilerman also functioned as the laundryman, which is a steam-cleaning clothes work type in the "*blow barrel*", then hanging them up to dry in the warm air near the boilers.
- **Leadhand, Floorhand (Worm):** Is a type of "*doing everything*" member of the drilling crew, often nicknamed "***worm***", because his **hand is always dirty** and most difficult position. These types of professionals work on the rig floor, to operate the tongs, iron roughnecks, pumps, tugger, catwalk, etc., and also doing any other job that is asked to them.
- **Chainhand (Floorhand):** Is **responsible** to throw chains and ropes, but actually he is a type of floorhand, which watches out for the "*worm*", but does not get so filthy.
- **Ginsel:** Is a "*worm helper*", also called the fifthhand.

Roughneck Monument, Texas

b) Iron Roughneck: Is a complex equipment that **connects and disconnects** the drill pipe as an integral part of the drilling process, and also uses a rotary table and torque wrenches to make up or break down pipe. Iron roughnecks clamp the bottom pipe, providing torque, while a spinning or rotary wrench turns the top pipe. Each **30-foot section** of drill pipe has a female joint end, with internal threads, for attaching the male joint. The tube is mounted in the hole drilled by the main drill, with Iron Roughnecks tools.The connector (Iron Roughneck) can also be operated and controlled remotely, through integrated control stations, which automatically perform complete opening/closing cycles, with greater levels of automation on several drilling rigs. The Iron Roughnecks drill pipe connectors are highly adaptable to a wide variety of installations When the rotary bit needs to be replaced, or the well is completed, the pipe is simply turned to another direction.

Iron Roughnecks

c) Inflatable Packers: Provide a permanent, reliable, high-pressure **seals** to isolation in several applications, including water/gas shutoff, open hole testing, acidizing, and plug. Packers are custom engineered fit-purpose applications, which provide sealing, reducing well construction costs and risks. More recently packer products can now operate to **150ºC** and **15,000 psi**.

d) Solid Expandable Systems: Are **expandable steel liners** that are expanded downhole to isolate sections of an existing wellbore. This type of solution gives outflow conclusions (access in and out of the reservoir) without compromising the inflow conditions. Standard expandable systems include high-performance technology, which enhances the liner's burst and collapse ratings. This is especially important, as operators push deeper into higher pressure and temperature regimes.

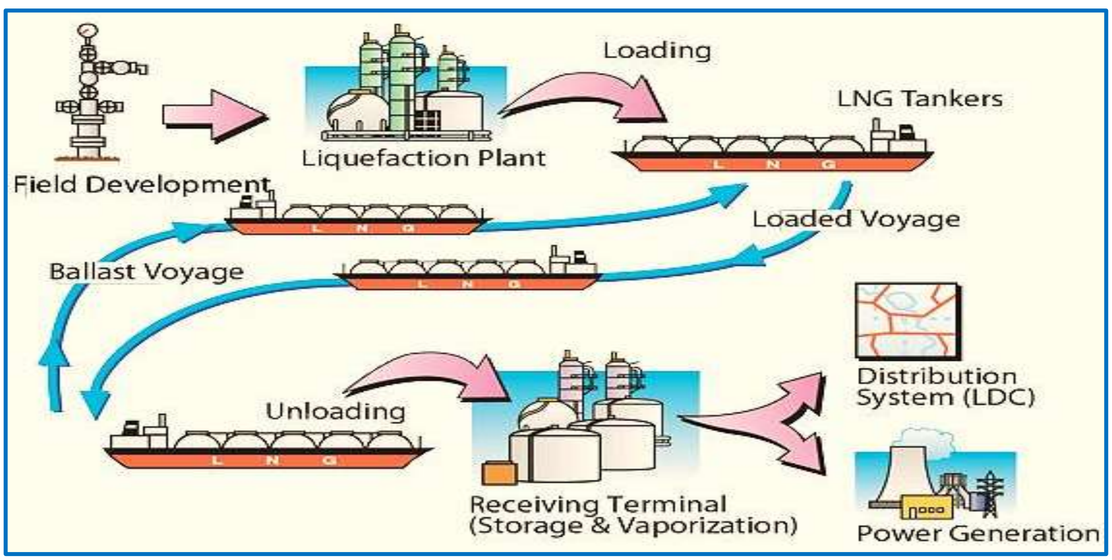
e) Swellable Well Products: Swellable **elastomers are polymers** that swell proportionally when immersed in well fluids (water, oil or a mixture of both). The introduction of swellable elastomer packers to the market in the early 2000s, have provided a wider set of technology options for zonal isolation and in multizone fracture stimulations. Swellable packers offer a less expensive and often more effective alternative to traditional cementing and mechanical and open-hole packer methods.

f) Blowout: Is an **uncontrolled explosion** of oil and natural gas from an oil well, after pressure control systems failures. Prior to the advent of pressure control equipment in the 1920s, the uncontrolled release of oil and gas from a well, while drilling was common, and was known as oil gusher or wild well. An accidental spark during a **blowout**, always lead to a catastrophic oil or gas fire.

5. GAS PRODUCTION: Natural gas is a fossil fuel formed when layers of buried plants, gases, and animals exposed to intense heat and pressure over thousands of years. Natural gas is a hydrocarbon gas mixture consisting primarily of **methane**, but also includes **alkanes** and a lesser percentage of carbon dioxide (CO2), nitrogen, and hydrogen sulfide. Natural gas is an energy source often used for **heating**, cooking, electricity generation, fuel for vehicles, chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.

Natural gas is found in deep underground rock formations or associated with other hydrocarbon reservoirs, in coal beds and as methane sources. Most natural gas was produced over time by two mechanisms; ***biogenic and thermogenic***. Methanogenic organisms in marshes, bogs, landfills, and shallow sediments create ***biogenic*** gas. The ***thermogenic* gas** is produced from buried organic material, deeper in the earth, at greater temperature and pressure.

a) Liquefied Natural Gas (LNG): Is natural gas, predominantly methane (CH4), processed and converted to a **liquid form** for ease of storage or transport. The liquefaction process involves removal of certain components, such as acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty in processes. The natural gas is **condensed** into a liquid, close to atmospheric pressure, by cooling it to approximately **−162 °C** (−260 °F), and the maximum transport pressure is set at around **25 kPa** (4 psi). It takes up about **1/600th** the volume of natural gas in the gaseous state, odorless, colorless, non-toxic and non-corrosive. Hazards include flammability after vaporization into a gaseous state, freezing and asphyxia.



The natural gas has much more volume than oil, generally transported by pipelines, designated as "***gas ducts***". The most famous are the **natural gas pipeline networks in Russia**, crossing Europe. Other important pipelines are in North America and South America. Natural gas is less dense, even at higher pressures, and travels much faster than oil through a high-pressure pipeline, but can transmit only about a fifth of the amount of energy per day due to its lower density. Natural gas is usually liquefied to LNG at the end of the pipeline, prior to shipping, and can be transported using tanker trucks, railway tankers, and ships known as LNG carriers. Natural gas could be considered the most environmentally friendly fossil fuel, because it has the **lowest CO_2** emissions per unit of energy. In its liquid state, **LNG** is not explosive and cannot burn. For LNG to burn, it must first **vaporize**, (the flammable range is 5 percent to 15 percent). In case of a leak, LNG vaporizes rapidly, turning into a gas (methane), and mixing with air. If this mixture is within the flammable range, there is risk of ignition, which would create fire and thermal radiation hazards.

b) Compressed Natural Gas (CNG): Is the natural gas under pressure which remains clear, odorless, and non-corrosive, compressed to pressures above **3,100 psi**, to be used in vehicles that can use natural gas as either a liquid or a gas; however, most vehicles use the gaseous form. Variations include storage at high pressure (over 250 bar or **~3625 psi**) at atmospheric temperature, moderate pressure or reduced temperature (~**-30º** C or **-86º F**), in horizontal or vertical large diameter tanks, or steel pressure vessels, also transported in FPSOs. Natural gas comes from three types of wells; natural gas-and-condensate wells, oil wells, and coal bed methane wells.

c) Liquefied Petroleum Gas (LPG): Or LP gas, is a flammable mixture of hydrocarbon gases, referred to as simply propane or butane, used as **fuel in heating appliances**, (cooking equipment, and vehicles), aerosol propellant, and as a refrigerant (R-290) or isobutane (R-600a), replacing chlorofluorocarbons to **reduce** damage to the ozone layer. Varieties of LPG include mixes; in **winter** the mixes can contain more **propane**, while in **summer** contain more **butane**. The LPG is produced during the refining of petroleum (crude oil) or "*wet*" natural gas, and is almost entirely derived from fossil fuel sources, or also extracted from petroleum or natural gas streams, as they emerge from the ground. Compared with **LNG**, the **LPG** is composed of **propane** and **butane,** widely used for **cooking** in many countries for economic reasons, while **natural gas** is composed of the lighter **methane** and **ethane**.

d) Heavy Liquefied Gas (HLG): Is natural gas that is condensed at a pressure of **10-20 bar**, corresponding to a temperature of **100 to 120°C**. This technology combines the **LNG** technology with the **CNG** (Compressed Natural Gas) and involves condensing the gas at a temperature significantly above the LNG liquefaction temperature. This lessens the cost of liquefaction, and reduces the need to remove feed gas components, such as **CO2** and LPGs.

e) Gas to Liquids (GTL): Is a refinery process to **convert** natural gas or other gaseous hydrocarbons to **other products**, such as, gasoline or diesel fuel. Methane-rich gases are **converted** into liquid **synthetic fuels** either via direct conversion (non-catalytic processes that convert methane to methanol in one step), or via **syngas** as an intermediate, such as GTL Fischer-Tropsch synthesis process or the Mobil and syngas to gasoline plus processes.

f) Natural Gas Hydrate (NGH): Is a solid **clathrate** compound (also called methane hydrate, hydromethane, natural gas hydrate, or gas hydrate), trapped within a crystal structure of water, forming a solid similar to ice. This gas is **mixed with water** at a pressure of **80-100 bar** (1160~1450 psi) at normal temperatures for the gas hydrates to appear. Each cubic meter of hydrate contains **160-180 m³** (5650 ~ 7062 ft³) of gas. There ar alternative methods for storing and transporting hydrates, for example, as **solid crystals** or as a **mixture** of solid hydrates and oil (slurry). The oil/hydrate slurry is produced by mixing the hydrates with oil, and then cooling the mixture to a temperature **below** the freezing point of water. The oil/hydrate mixture consist of up to 50% gas hydrate, the rest is crude oil. Then, the mixture (slurry) is pumped to storage tanks onboard of a floating production unit for subsequent transportation by tankers, to a receiving terminal. At the terminal the mixture is heated in order to **melt** the hydrates.

5.1) STORAGE GAS SYSTEMS AND TERMINALS: Are the final destination of **LNG carriers**, where the liquefied gas returns to the gaseous state and fed into transmission and distribution grids. Liquefied natural gas is received and offloaded from the LNG carrier, into **cryogenic** storage tanks ranging in capacity from **100,000 to 160,000 m³**, usually in the liquid state at **-162 °C** (-260 °F). The **regasification** involves gradually re-warming the liquefied gas, until its temperature rises **above 0°C**. The process takes place at high pressure (60 to 100 bar), through a series of **seawater heat exchangers**, with cooling water quality available, and the most energy-efficient techniques. In other cases, some of the gas is burned to provide the necessary heat.

The **storage terminals**, nowadays, are an essential part of many organizations operating across different corners of the world. Terminal **automation** in oil and gas market offers a wide array of services like monitoring and evaluating systems, present at remote locations. Monitoring sensors at terminals **analyze** the execution of operations and transfers the data to the terminal system. Then, the gas is processed as necessary, to conform the regulatory end-user specifications. For example, the heating value can be set by **adjusting** the concentrations of nitrogen, butane or propane or by **blending** with other gases according to the client´s needs.

Modern **LNG storage tanks** are typically **full containment** type. Large tanks are cylindrical in design with a **domed** steel or concrete roof, but can be also a **pre-stressed concrete** with an **outer-wall and a high-nickel steel inner tank**, with extremely efficient **insulation** between the walls. Sometimes more expensive underground tanks are used for storage. Smaller quantities, say **700 m³** (190,000 US gallons) and less, are designed to store gas in horizontal or vertical, vacuum-jacketed, pressure vessels. Spherical shaped **according to ASME** Pressure Vessels, are also used in gas and liquid storage, including **midstream, downstream**, petrochemical, chemical, waste water, and aerospace.

Spheres can **store** many products, such as anhydrous ammonia, LPG, NGL, gasoline, naphtha, butadiene, ethylene, hydrogen, oxygen, nitrogen, argon, LNG, biogas, sewage gas and waste water. Most of these spheres feature double walls with an evacuated, perlite-filled annular space. The common characteristic of LNG Storage tanks is the ability to store LNG at the very low temperature of **-162 °C** (-260 °F). The LNG storage tanks generally have double containers, and the outer containers contain **insulation** materials. Storage **pressure** in these tanks is very **low**, less than **10 kPa** (1.45 psig). These tanks may be at pressures anywhere from less than **50 kPa** to over **1,700 kPa** (7 psig to 250 psig). The **boil-off** gas is typically compressed and exported as natural gas, or is re-liquefied and returned to storage.

a) LNG FPSO: Or **LNG Floating Production, Storage and Offloading**, is a floating offshore installation which processes hydrocarbons and refrigerates gas to produce LNG (Liquefied Natural Gas). The installation may feed gas directly from a gas well or a gas network in conjunction with crude oil production. Current designs for medium size units have LNG storage capacity between **180,000 to 190,000 m³** and LPG storage capacities of approximately **25,000 m³.** A very large scale **FPSO** unit may have the LNG storage capacity of **220,000 m³** and proposed **LPG** and condensate storage in the range of **100,000 m³.**

A typical **LNG FPSO** design, bases the installation on an LNG carrier hull. The various parts of the **process equipment** are located **topside** and distributed as **modules**, installed on the deck. The storage capacity of a FPSO is defined according to the need to store **LNG** and **LPG** (Liquefied Petroleum Gas), dependent on the feed gas composition. The FPSOs are preferred in offshore, as they are easy to install and do not require a local pipeline infrastructure to carry oil and gas. FPSOs can be a **conversion** of an **oil tanker** or a **vessel built** specially for the LNG application.

b) FSRU (Floating Storage and Regasification Unit): Is an offshore unit, which receives and **regasifies LNG** to provide gas to onshore consumers. Regasification units may also be located quayside or at any sheltered place. Floating storage units (FSRUs) provide a flexible and economic alternative to land-based LNG receiving terminals. The floating installations may either be located near-shore (e.g. alongside a pier) or offshore (permanently moored to the seafloor).Depending on their mode of operation (dry-docking vs. wet-docking) and local regulation. The FSRUs are considered either as **ships** or as **offshore installations**, which may also be converted from existing vessels, typically LNG carriers.

c) SRV (Shuttle Regasification Vessels): Is an **LNG vessel** with onboard LNG vaporizers, or a vessel that transports LNG. The regasified LNG is discharged from de SRV via a **turret** and swivel through a mooring and **unloading** buoy connected to a **riser** and subsea pipeline, or connected to an offloading buoy to discharge. Then may be disconnected and leave to collect a new cargo. A large version of a SRV can also operate as a Floating, Storage and Regasification Unit (FSRU).

The SRV is classified as a **ship**, since it implies that the equipment systems are built at regular shipyards. The SRV vessel is capable of staying **moored** to the transfer system at a location off-shore, in severe weather conditions. The onboard regasification capacity can reach **600.000.000 ft^3** per day. The vaporization capacity is designed to empty a **140,000 m^3** vessel in **less** than 6 days, but the capacity can be doubled by additional units.

5.2). GAS COMPRESSION AND METERING SYSTEMS: The air compressor is a specific type of **gas compressor**, which increases the pressure of gas by **reducing its volume**, similar to pumps, as both increase the pressure of a fluid to be transported through a pipeline. Since gases are compressible, the compressor reduces the volume of a gas. Turbine compressors serve to operate a centrifugal compressor, which contains a type of **fan** that compresses and pumps the natural gas through the pipeline. The compression includes a large section of associated equipment, such as **scrubbers** (removing liquid droplets), heat exchangers, lube oil treatment etc.

Compressors are generally **driven** by gas turbines or electrical motors. The basic operation of the **gas turbine** is similar to a **steam turbine**, commonly used in power plants, except that **air** is used instead of **water**. Fresh **atmospheric air** flows through a compressor that brings it to higher pressure. Gas from separators loses pressure, and then must be re-compressed to be transported. For gas gathering systems, it is common to meter individual lines into a manifold pipeline, which allow operators to monitor and manage the natural gas and oil exported from the production installation.

Typically, the **metering installation** consists of **several record meters**, since only one meter has not a full capacity range and associated loops, as accuracy of all meters have to be tested and calibrated at regular intervals. These metering stations employ specialized **instrumentation** to measure the natural **gas** or **oil** as it flows through the pipeline, without impeding its flow movement. This metered volume represents a transfer of owner ship from a producer to a customer.

6. OIL & GAS PROCESSES AND INSPECTION: Oil and gas pipelines dimensions are commonly from **6 to 48 inches in diameter**. In order to ensure the efficient and safe operation of the pipelines, **operators routinely inspect their pipelines** to avoid corrosion and defects, through the use of sophisticated equipment known as ***pigs***. Pigs are **intelligent robotic devices** propelled down **pipelines** to evaluate the **interior** of a pipe, suited to **test pipe thickness**, roundness, check for signs of **corrosion** and detect **leaks**. Defects along inside of the pipeline may either impede the flow of gas, or pose a **potential safety risk** for operation of the gas pipeline. Sending a **pig down** a duct is known as "*pigging*" to wholly inspection of the pipeline.

The **gas pipeline** is fed with **high pressure compressors**, contrary to **oil pipelines** that are driven by **powerful booster pumps**. For longer pipelines, intermediate compressor stations or pump stations are required due to distance or crossing of mountain and hills. Pipeline terminals include termination systems and at least a **pig launcher** and a **receiver system**, to allow the insertion of a

pipeline pigging, used to clean or inspect the pipeline, essentially at the start and final, with large pressurized chambers to insert and remove the pig, without depressurizing the pipeline.

Pipeline inspection with "pigs"

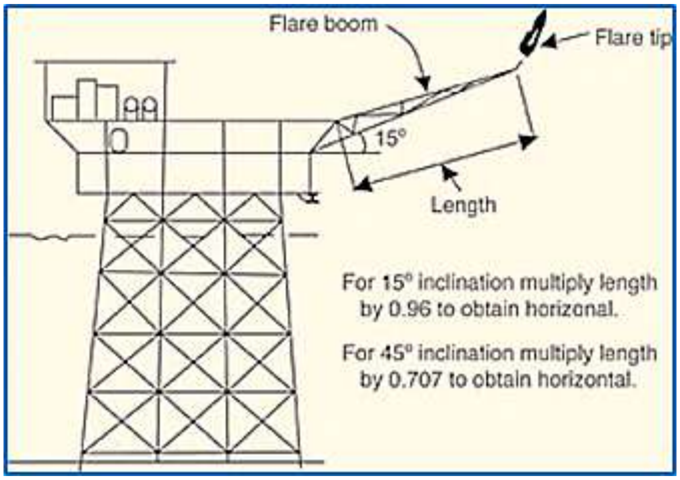
a) Flaring Systems: Flaring is the controlled **burning of natural gas** in the course of routine oil and gas production operations. A complete **flare system** consists of a **flare stack or boom** and a **piping system** that collect the gases to be flared. The flare tip at the end of the stack or boom is designed to avoid entrainment of air into the flare and improve burn efficiency. Seals installed in the stack prevent flashback of the flame, and a vessel at the base of the stack removes and conserves any liquids from the gas passing to the flare. Depending on the design, one or more flares may be required at a production location.

Flare systems generally have a ignition device that ignites the gas exiting the system because the discharge may be either continuous or intermittent. Gas disposal systems for tanks operating near atmospheric pressure are often called **atmospheric vents or flares**, and gas disposal systems for pressure vessels are called **pressure vents or flares**. A flare or vent system from a pressurized source may include a control valve, collection piping, flashback protection, and a gas outlet. A scrubbing vessel is commonly used to remove liquid hydrocarbons.

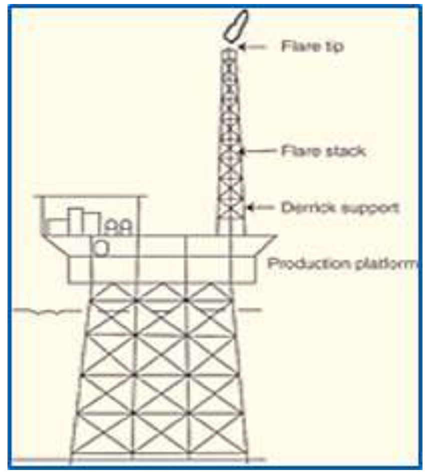
Due day/night offshore processes, platforms produces very large quantities of high-pressure gas, and, therefore, the flare systems, must be designed **to handle** extremely large quantities of gas quickly. By nature, flares normally have to be located very close to production equipment and platform personnel or located on remote platforms. Maximum emergency-flare design is based on emergency shut in of the production manifold and quick depressurization of the system. The typical offshore flare-support structures are described below:

b) Flare Booms: Are usually **100 to 200 ft long**, and extend from the edge of the platform at an angle of **15 to 45**°. Sometimes two booms, oriented **180°** from each other, are used to take advantage of prevailing winds.

c) Derrick Flares: Are the most **common** flare towers used offshore, since these types provide a safe **four-legged design** and dead load that are critical parameters for offshore flares, and normally are used when space is limited and moderate relief quantities. Disadvantages of the derrick-supported flares are **possible** crude-oil spill onto the platform, **interference** with helicopter landing, and higher **radiation** intensities.



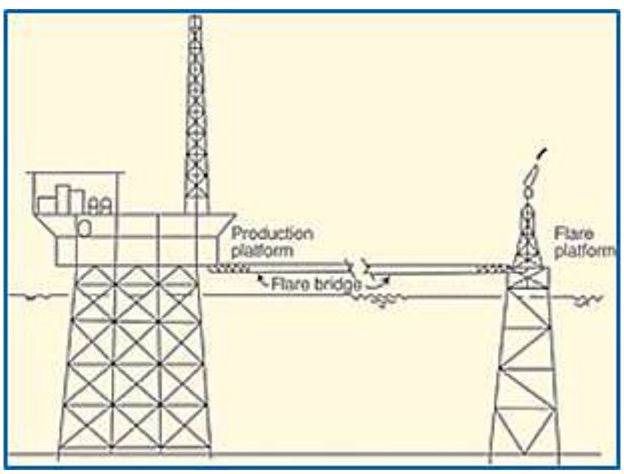
Flare Boom



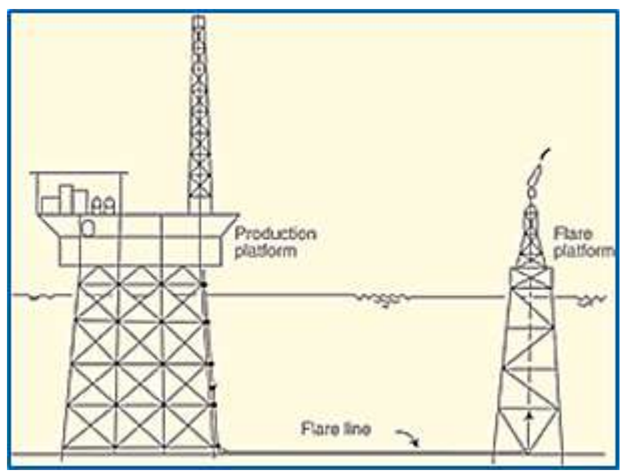
Derrick Flare

d) Bridge Flares: Are flaring systems, where the production platform is connected to the flare platform, through a **steel bridge structure**. The bridges can be approximately **600 ft long**, with all supports usually spaced approximately every **350 ft**.

e) Remote Flares: Similar to bridge flares. The difference is that the flare platform is connected to the main platform by a **subsea relief line**. The disadvantage of remote flares is that high density carryover liquid or subsea condensation may be **trapped** in pockets in the connecting line.



Bridge Flares



Remote Flares

Note: Gases being flared may come from a variety of sources. It may be excess to that which can be supplied commercially to customers. It may be unburned process gas from the processing facilities. It may be vapors collected from the tops of tanks as they are being filled. Sometimes, the gas may be from process upsets, equipment changeover or maintenance. Occasionally, a production shutdown may require the temporary flaring of all the gas stored on, or arriving at a facility, to release high pressure and avoid a catastrophic situation.

f) Venting Systems: Are controlled **release** of **gases** into the atmosphere in the course of oil and gas production operations. These gases might be natural gas or other hydrocarbon vapors, such as carbon dioxide. In venting, the natural gases are released directly to the atmosphere and not burned. Safe venting is assured when the gas is released at high pressure, but is lighter than air. Discharged gases mix with air in safe concentrations, the way there is no risk of explosion. Where gas cannot be stored or used commercially, it is essential that the risk of fire and explosion be reduced by either flaring or venting.

The availability of a flare or a vent is absolutely **necessary** in oil and gas production operations, as any system can ensure safe disposal of the hydrocarbon gas in the process installation, in emergency and shut down situations. In some cases, venting is the best option for disposal of the associated gas. For example, if a high concentration of inert gas is present in the associated gas, without sufficient high hydrocarbon content, the gas will not burn, and flaring is not a viable option. Sometimes the source of inert gas may come from the process systems. The purging of process systems with inert gas may justify the venting system as the safest means of disposal.

g) Purge Gas: Offshore flare and atmospheric venting systems are **required** to be purged in order to **prevent** oxygen ingress to the flare and atmospheric vent systems, and to avoid the formation of **explosive** mixtures in the headers, which could lead to explosions if ignited. Fuel gas or nitrogen can be used as purge gas. The purge gas is injected at different locations in the systems in order to maintain a positive pressure in the flare headers thus preventing the air ingress. Cold vents (atmospheric vent headers) are used to vent hydrocarbon gas, when there is no available pressure to allow the gas to be flared. Under normal operating conditions the volume of gas vented via the cold vent is minimal.

Purge gas is injected into the relief header at the upstream end and at the major branches to maintain a hydrocarbon-rich atmosphere in each branch, into the flare stack. The **API RP 521** states that the oxygen concentration must not be greater than **6% at 25 ft** inside the tip. When there is enough PSV leakage or process venting to maintain the desired backpressure, no purge gas is injected. The **API Standard 521** is applicable to pressure-relieving and vapor de-pressuring systems, applicable to petrochemical facilities, gas plants, liquefied natural gas (LNG) facilities, and oil and gas production facilities.

Nitrogen has being used on facilities for **purging** the flare system, in order to clean the flare stack, with Fast Opening Valves, normally installed in the main headers as part of flare recovery projects. When the Flare Gas Recovery is installed it is not necessary to replace the use of fuel gas with **nitrogen** for purging purposes, as the purge fuel gas is recovered and sent back to the process.

h) Burn Pit: Is an area devoted to **open-air combustion** used to handle volatile liquids. The burn pit must be **large** enough to contain the maximum emergency flame length, with drain valves and pumps (if required) to dispose the trapped wastes. However, burning **solid wastes** in an open pit generates numerous pollutants, including dioxins, particulate matter, polycyclic aromatic hydrocarbons, volatile organic compounds, etc., and highly toxic dioxins, in small amounts in all burning processes, can be produced in elevated levels.

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7. ENVIRONMENT EMISSIONS: The use of **fuel gas** in flare and vent headers for **purging** purposes also results in environmental **emissions**. These can be in the form of CO2 or NOx when the fuel gas used in the flare headers is burnt in form of CH4 (methane) and other gases present in the atmospheric. NOx is a generic term for the mono-nitrogen oxides NO and NO2 (nitric oxide and nitrogen dioxide), produced from **reaction** of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. The greenhouse effect associated with the CH4 is around 23 times worse than that for the CO2 emissions.

a) Environment Impact: Use of **seawater** in offshore applications typically involves large volumes of water and also use of **biocides**. This factor brings a potential to impact to the marine environment in short and also in the long term. Licenses to address these issues include controlling water intake velocity and intake mesh size, to reduce ingestion of marine organisms, limitations on biocides, and limitations on seawater temperature drop. Use of direct-fired vaporizers offshore has been questioned due to the production of CO2 and air pollutants in the fuel burning process and also due to the amount of energy required in terms of fuel consumption.

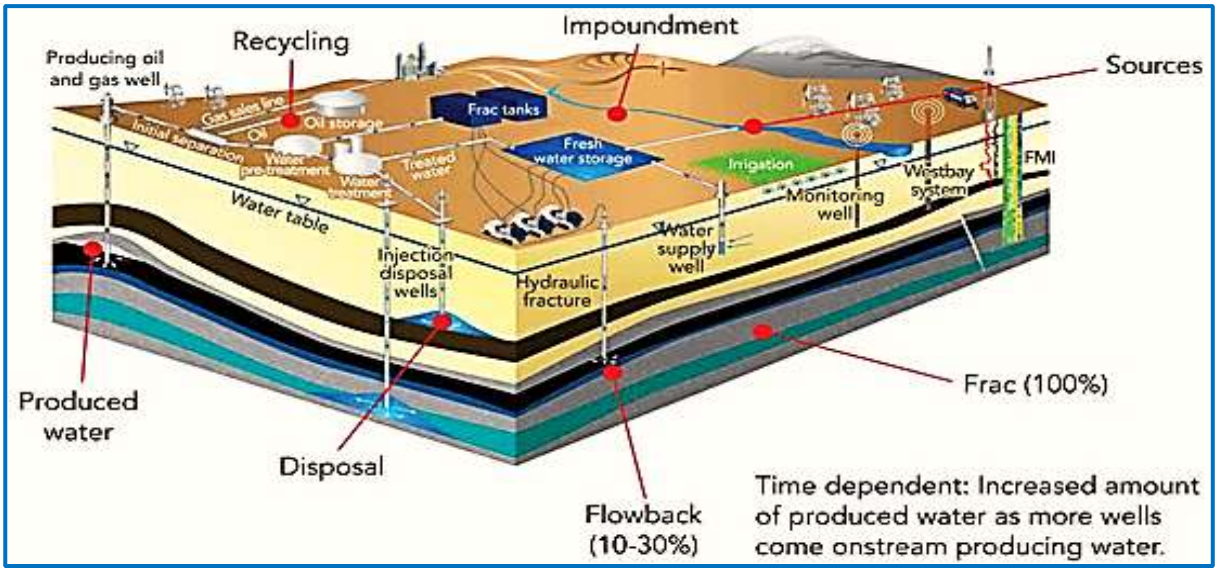
b) Onshore, Offshore Environment: There are several factors that may influence the choice of a process, however, for the most NGL extraction the **amine** absorption process is the preferred one. The amine process is well known to the industry and involves a contactor (absorber column) and a stripping cycle where the absorber (amine) is freed from the "*recovered*" gases, H2S and CO2. Target levels of CO2 would be below **50 ppmv**. (Membrane technology is currently considered as not proven and would be subject to technology qualification program for any offshore application).

7. ONSHORE & OFFSHORE WATER MANAGEMENT: Historically, water treatment has been critically important in the oil and gas sector, related to the produced water brought to the surface along with the oil or natural gas. Since that produced **water** has to be **separated** from the oil, and the oil often has to be further cleaned before it can be offloaded, or transferred into a pipeline, the produced water also undergoes several treatment steps before it is discharged to the sea or re-injected in a well. However, growing environmental restrictions in some production areas is driving to recycling treatment and reinjection of produced water.

Hydraulic **fracturing** process use more than **5 million gallons of water** per well. Water for unconventional **shale oil and gas** comes from a variety of conventional sources, including fresh or brackish waters from surface or groundwater withdrawal, treated wastewaters, or recycled water. The flowback water often contains very high **dissolved solids** (TDS), characterized by the presence of sand, clays, polymers and chemistry associated with **drilling** and completion of the well. Regardless of the origin of the water source, it is important that the correct water treatment, used during hydraulic fracturing operations, can minimize the impact of unwanted salts and other compounds that may interfere with the performance of the fracturing fluid.

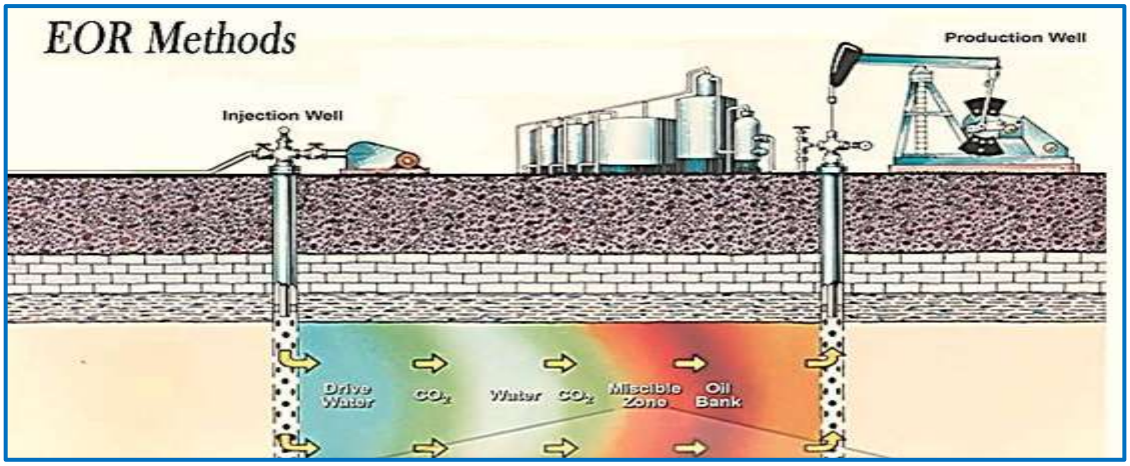
Produced water can be described as any water from a hydrocarbon **reservoir** with oil and gas, which needs to be treated, as it contains substances, such as suspended and dissolved solids, gases and metals to be removed, the way produced water can be re-used or **disposed of** into the sea, injected into a disposal well, re-injected to maintain pressure, reused for irrigation or used as industrial process water. All of these are subject to local **environmental** regulations. Then, water for injection, must be of a very high **quality** to avoid plugging and **scaling** of the injection equipment. Souring can occur when water containing oxygen and bacteria is mixed, reducing the produced hydrocarbons process. Until very recently, was considered that a separator design could reach an excellence in performance, using the Computational Fluid Dynamics (CFD) technology, to meet the necessary requirements of separating gas/liquid hydrocarbon/water and solids.

Note: The offshore water treatment commonly utilizes either **Reverse Osmosis** (RO) or **Nanofiltration** (NF) to reduce the salinity of the seawater to the necessary level. The Membrane technology is also used because it is more energy efficient and less intensive than Thermal Distillation Desalination. Many FPSO vessels are installed with flexible risers to provide a means of obtaining low oxygenated water for the FPSO utility cooling, process, and water injection systems.



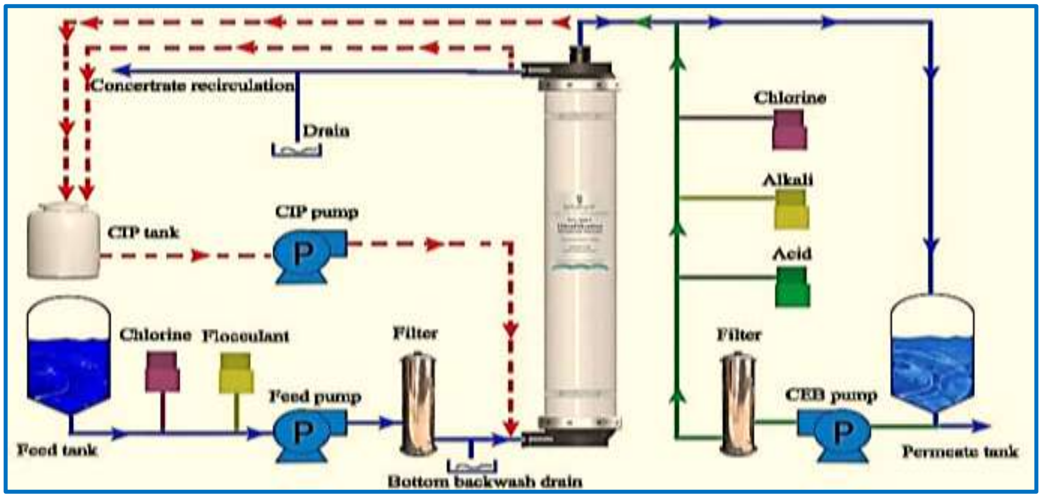
Improved Oil Recovery (IOR): Is used to describe waterflood management and some more sophisticated methods, aimed to improving **reservoir recovery**. An Improved Oil Recovery with a pilot data for low salinity water injection may vary from **2% to 40%** increases in waterflood efficiency, depending upon the reservoir and composition of water injection. Salinity of the injection water greatly impacts the viscosity, or thickness, of polymer floods used in CEOR (Chemically Enhanced Oil Recovery) applications. In reservoirs with high salinity formation, injection of low salinity water can generally **shift** the properties of the reservoirs, increasing the microscopic sweep efficiency, and also increasing the potential oil recovery.

Enhanced Oil Recovery (EOR): Is a **subset** of IOR, and also includes methods to increase recovery of oil, ranging from thermal methods based-chemical, microbial addition and gas injection. The majority of this water is related to *waterflooding* into reservoir formations, to maintain pressure and to force oil out of the production wells. EOR may also increase the **amount of oil** that can be extracted from a well, by reducing viscosity. The purpose of EOR is not only to restore formation pressure, but also to improve oil displacement or fluid flow in the reservoir. The main water treatment commonly used onshore and offshore are described below:

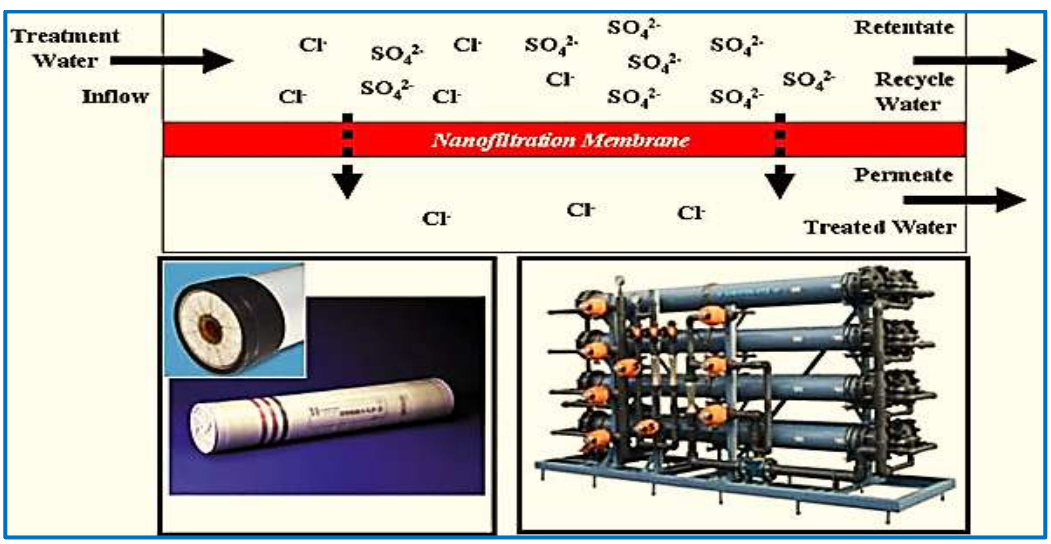


1. Sulphate Removal Plant (SRP): Is the installation of a **small plant** to extract **sulphates** from the seawater prior to injection. The SRP uses **nano-filtration** membranes to remove the sulphates while leaving the other salts (sodium, chloride etc.) substantially unaffected, thus maintaining the stability and permeability of the formation clays. Barium and strontium sulphate **scales** are also notoriously difficult to remove since they cannot be easily dissolved. These scales have the effect of reducing reservoir permeability and can stay deposited in production pipe internals. When pipe-line scaling happens, it has to be removed by mechanical means. Inhibition treatments are utilized to improve the well permeability, but are extremely difficult to control, and cannot be applied to complex sub-sea networks from Floating Production Storage and Offloading vessels (FPSOs).

2. Ultrafiltration: Utilize a modified **poly-acrylonitrile** chemistry developed to be extremely **oil-phobic** and thus resistant to free-oil fouling. The "*clarified' water*" is physically polished by **ultrafil-tration** membranes that reduces oil concentration to less than **0.3 mg/**l, and suspended solids to below the limits of detection. The various sludge and aqueous waste streams are combined before undergoing precipitation, flocculation and filtration, to produce a "*cake*" for landfill, and a mix that can be recycled through the process. Reject is recycled at the front end of the process and the concentrated oil is reclaimed on site. The degree of treatment may be designed to meet specified limits, such as the treated water is suitable for re-use on site or disposed of.



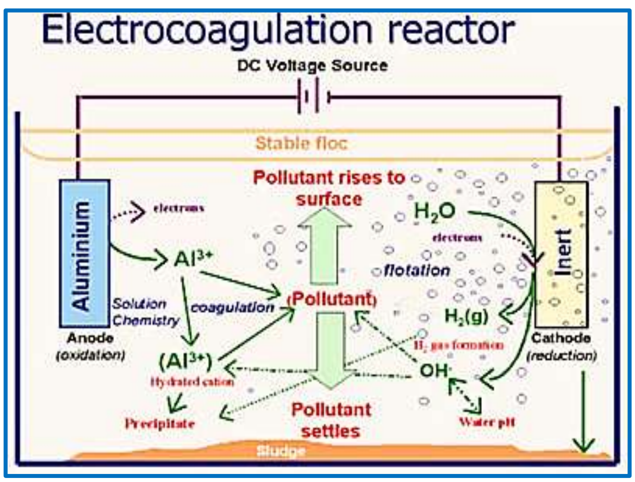
3. Nanofiltration Membranes: The oil and suspended solids are generally treated using **nanofiltration** membranes to remove the bulk of heavy metals and organic compounds. Organic compounds and heavy metals, in the nanofiltration permeate are removed by Activated Carbon absorbers and selective Ion-Exchange resin. Nanofiltration provides **negligible** resistance to the passage of monovalent **ions**, such as chlorides, but it is able to operate on high salinity waters, where **inefficient** productivity of Reverse Osmosis is uneconomical. Nanofiltration selectively removes ions, such as calcium, magnesium and sulfate, which may interfere with both fluid and formation chemistries, while allowing sodium chloride salts to pass through the membranes. Configurations of nanofiltration and reverse osmosis systems have also been used to clean and concentrate the brines, essentially splitting the waste streams into reusable brines and fresh water.



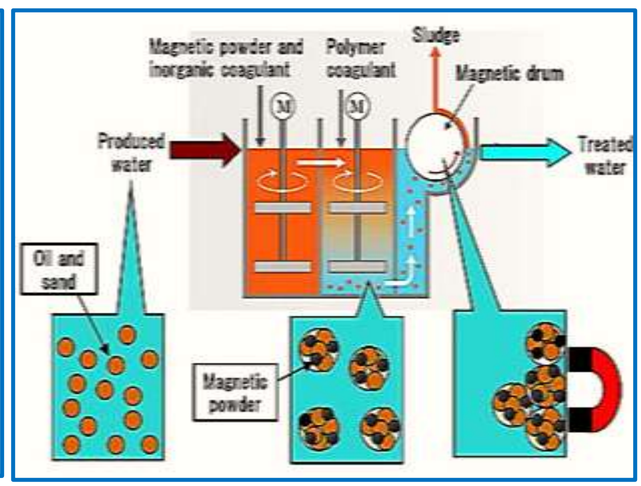
4. Electrocoagulation: Involves the **dissolution** of metal cations into the passing water, typically **iron and aluminum**. The process consists of an **anode, a cathode**, and water as the electrolyte. The metal cations react with the negatively charged suspended particles and colloids in the water, and **neutralize** the surface charges. After, the particles collide, combine and form large particles that are readily removed from the water by the flotation cell. Electrocoagulation destabilizes the particulate and break oil/water emulsions, typically achieving **99%** reduction in contaminants. The stackable components can process up to **500 m³** of water per day. Water containing solids and hydrocarbons pass through the electrocoagulation cells (EC) and then to an integral flotation process, reliably producing discharge quality water for most offshore applications.

5. Flocculation Magnetic Separation: Is a system that performs an advanced treatment on the water, produced during the extraction of crude oil and gas from onshore and offshore, and quickly **removes** the oil content. High-quality treated water can be delivered with just five minutes retention time. The treated water can either be utilized as injection water, contributing to improved oil productivity or can be **disposed of** directly into the sea. The whole equipment has a compact design, which allows to be installed on offshore platforms with limited space.

6. Desanding Hydrocyclones: Operate by introducing produced water through the tangential inlets into the widest part of the internal hydrocyclone cavity, to create a **vortex** inside the liner. As the water passes through the vortex, the suspended solids are forced by centrifugal forces. The vortex flow **transports** the separated solids to the outlet port, to a beneath catchment chamber. The water flows in a reverse direction, up to the centre of the liner and out through the axial port, at the top. Then, **sand** in the catchment chamber is intermittently discharged to a cleaning system.



Electrocoagulator



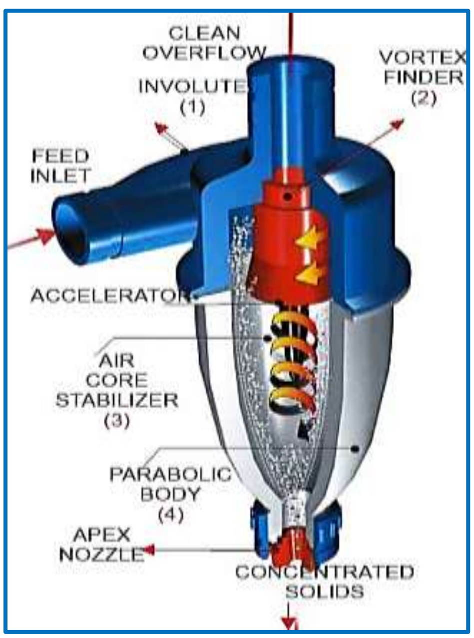
Flocculation Magnetic Separation

7. De-oiling Hydrocyclones: Are similar to Desanding Hydrocyclones, to separate **free oil** from produced water, prior to discharge or injection. Produced water is injected under pressure, into a large **conical end** of the hydrocyclone liner. The inlets are generally tangential to the wall of the liner, so that the entering fluid has to rotate. The conical shape of the hydrocyclone liner causes an increase in rotation speed, as the diameter narrows, resulting in the development of high centrifugal forces, and therefore the **separation** of the **lighter oil** from the heavier water and solids. De-oiling hydrocyclones are commonly situated after the primary separators, as the first stage of the treatment process. Energy to drive the process comes from the pressure in the separators.

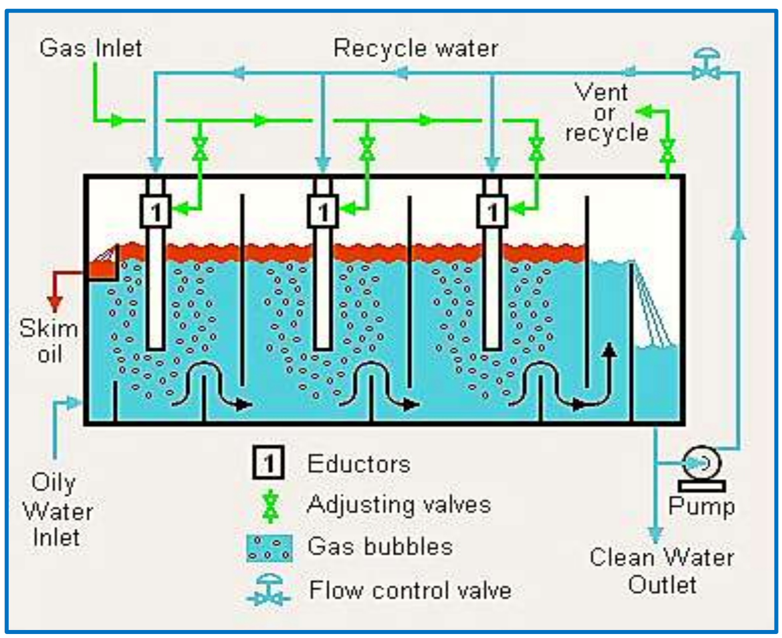
8. Dissolved Gas Flotation System: Use an external **reactor** to dissolve the gas (usually air) into a **recycled stream** of water, prior dropping pressure, thus allowing the gas to be released from solution. The traditional produced water treatment is usually comprised of **hydrocyclones**, followed by **degassing** or **flotation** processes. The single step gas flotation, oil droplet coalescence and centrifugal separation type, also generates a **vortex** within the separation volume. Then, the water passes through the separation volume, in what is termed "*rotating plug flow*", which leads to a higher oil removal efficiency, than any other achieved in the older designs. The majority of these methods use special pumps to either recycle blanket gas from the separation/flotation vessel or introduce a separate low pressure feed of fuel gas into a stream of recycled water.

9. Corrugated Plate Separation (CPS's): Is a economical and effective **removal** of oil and solids from **wastewater** by gravity, in a smooth, efficient automatic flow. This design ensures that the oil droplets **coalesce** on the undersides of the corrugated plates, facilitating the free oil removal process. The configuration and number of **plates of the CPS** units provide enough effective area for free oil removal down to **15 ppm**, with greater than **60 micron** removals. The plate pack design minimizes the distance of oil droplet, before coming into contact with other oil droplets. Since the plates are arranged parallel to each other, the separator is able to tolerate up to **100 ppm** total suspended solids without affecting the effluent quality.

10. Induced Static Gas Flotation (ISF): Is a process that uses a hydraulic **flotation** process, designed for **removing** fine oil droplets and suspended solids from waste water streams. The contaminated water enters the inlet chamber and passes successively through each of the four flotation chambers. In each chamber, the stream is subjected to a contact of **fine bubbles of gas**, which attach to the dispersed oil droplets. This is achieved by an eductor located underneath each chamber which **recycles** the gas from the vessel head space into the flotation chamber. Part of the outlet water flow is recirculated, with use of a pump, through the eductor assembly.



Desanding & De-oiling Hydrocyclones



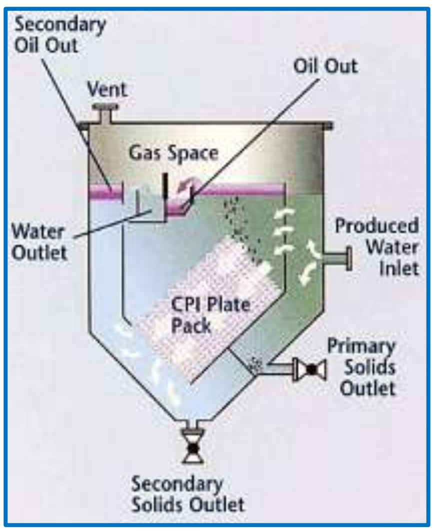
Induced Gas Flotation

11. Thermal Distillation Desalination: As the name implies, involve the **heating** of saline water and collecting the condensed vapor (distillate) to **produce pure water**, used for seawater desalination and can be sub-divided into three groups: Multi-Stage Flash Distillation (MSF), Multi-Effect Distillation (MED), and Vapor Compression Distillation (VCD).

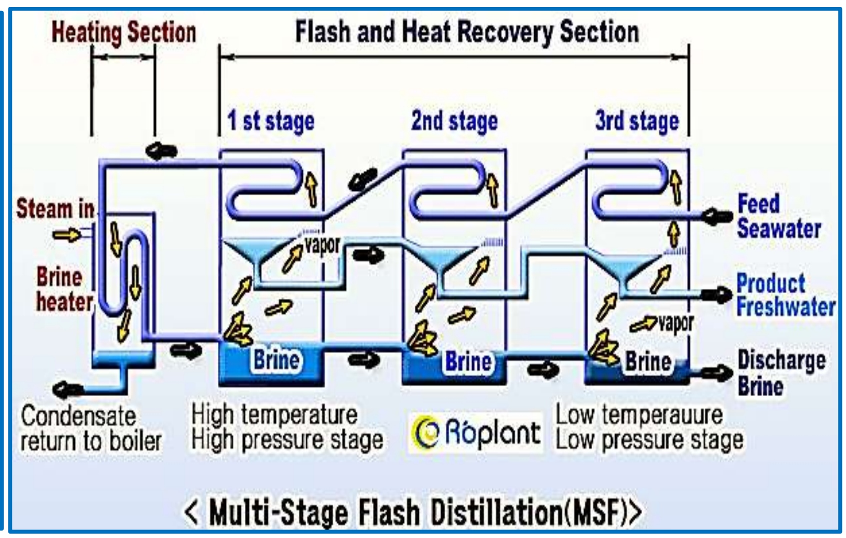
- **Multi-Stage Flash Distillation (MSF):** Is a Multi-stage flash **distillation** plant, and each successive stage operates at progressively lower pressures. The feed water is first **heated** under high pressure, and then is led into the first "*flash chamber*", where the pressure is released, causing the water to boil rapidly resulting in sudden evaporation or "*flashing*".

- **Multi-Effect Distillation (MED):** Utilize evaporator effects that **produce water** at progressively lower pressures. Water **boils** at lower temperatures, as pressure decreases, so the water vapor of the first vessel, serves as a **heating medium** for the second, and so on. The more vessels or effects there are, the higher is the performance ratio. Depending upon the arrangement of the **heat exchanger** tubing, the MED units could be classified as horizontal tube, vertical tube or vertically stacked tube bundles.

- **Vapor Compression Distillation (VCD):** Is used in combination with other processes, such as the MED. The **heat** for evaporating the water comes from the compression of the vapor from steam produced in a **boiler**. VCD units have a variety of configurations, usually with a compressor used to generate the heat for evaporation. The VCD units are generally small in capacity, often used at hotels, resorts and in industrial applications.



Induced Static Gas Flotation

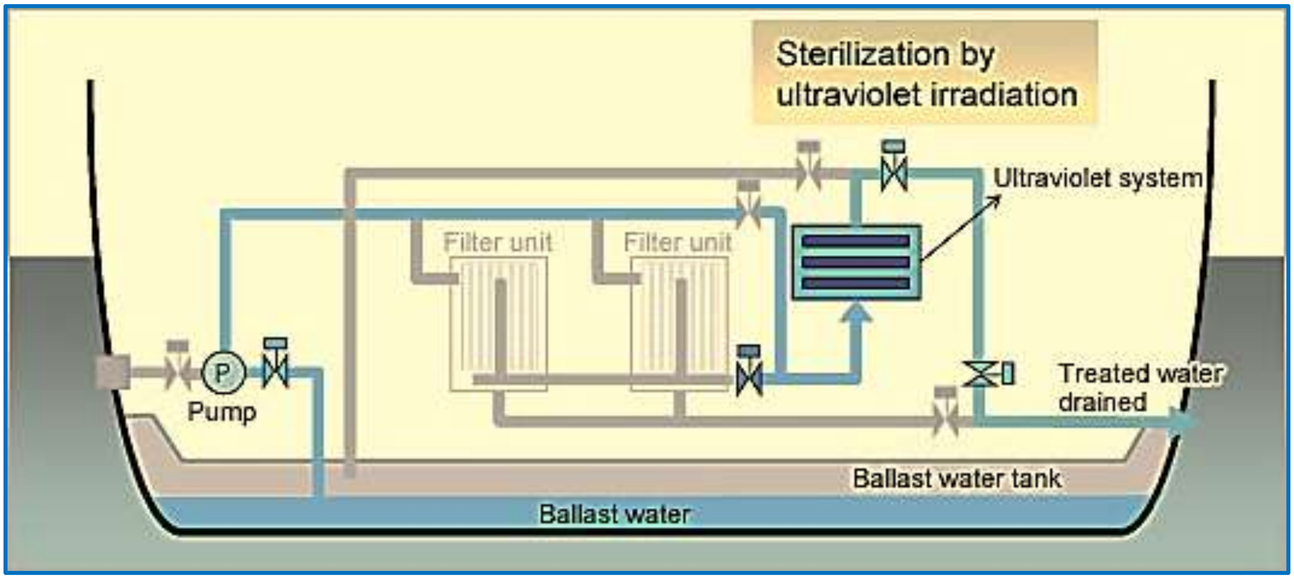


Multi-Stage Flash Distillation

12. Low-Temperature Thermal Desalination (LTTD): This system uses **vacuum pumps** to create a **low-pressure**, low-temperature environment, in which the **water boils** at a temperature gradient of **8-10°C** (46-50°F). Cooling seawater is supplied from depths of up to **600 m** (2,000 ft), and this cold water is **pumped** through coils to **condense** the water vapor. The resulting condensate is **purified water**. The LTTD may also take advantage of temperature gradient available at power plants, where large quantities of warm wastewater are discharged from the plant.

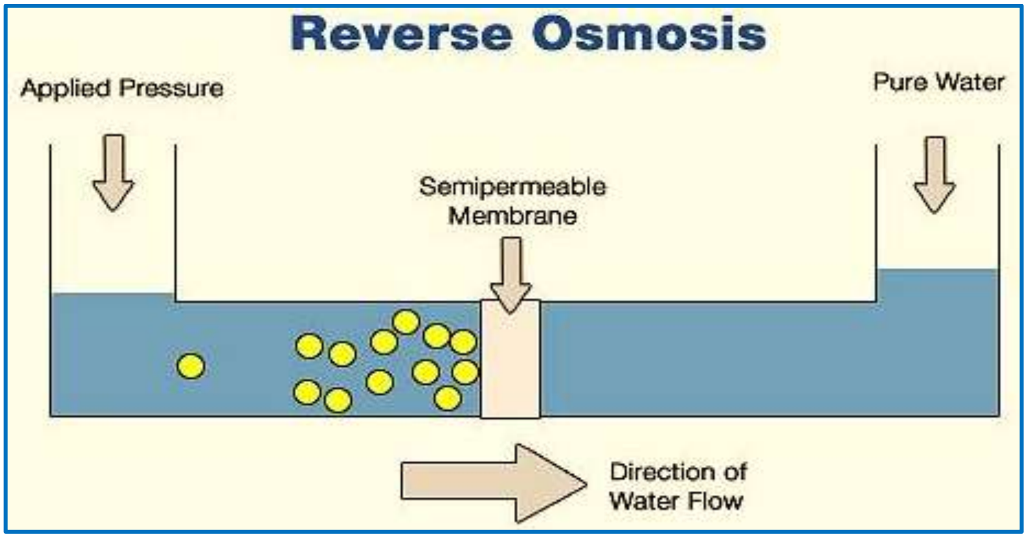
13. H2S Stripping: Is a liquid feed stream that enters the **top** of a column, via a distribution manifold, while the stripping gas is introduced at the **bottom** of the tower. Valves force the liquid to **flow back** and forth horizontally while the **vapor bubbles** up through the holes in **trays**. Then, H2S is transferred from the **liquid phase to the gas phase**, exiting through the bottom of the column.

14. Ultraviolet (UV) Treatment: It is a compact, high-power system used to **prevent** the transit of a wide variety of **organisms** across the globe, in **ballast water** carried by ships. Ballast water is taken on board in ports of supplies, to maintain the carrier stability when the vessel is not laden, and discharged when the vessel takes on cargo. The discharge, often thousands of miles from the port of embarkation, can relocate microscopic plants, mussels, crabs, and, recently, the fish pathogen VHS (Viral Hemorrhagic Septicemia). The ballast water is prepared for **UV disinfection** using a variety of **filters** or cyclonic separators, usually skid-mounted and automated. However, a growing number of organisms are demonstrating advanced resistance to chlorine, but can be effectively disinfected using UV. The sizing of the UV system is determined by flowrate, transmittance of the fluid to ultraviolet light, and the dose requirement. The method is nonintrusive and does not alter the chemistry, color or physical property of the ballast water.

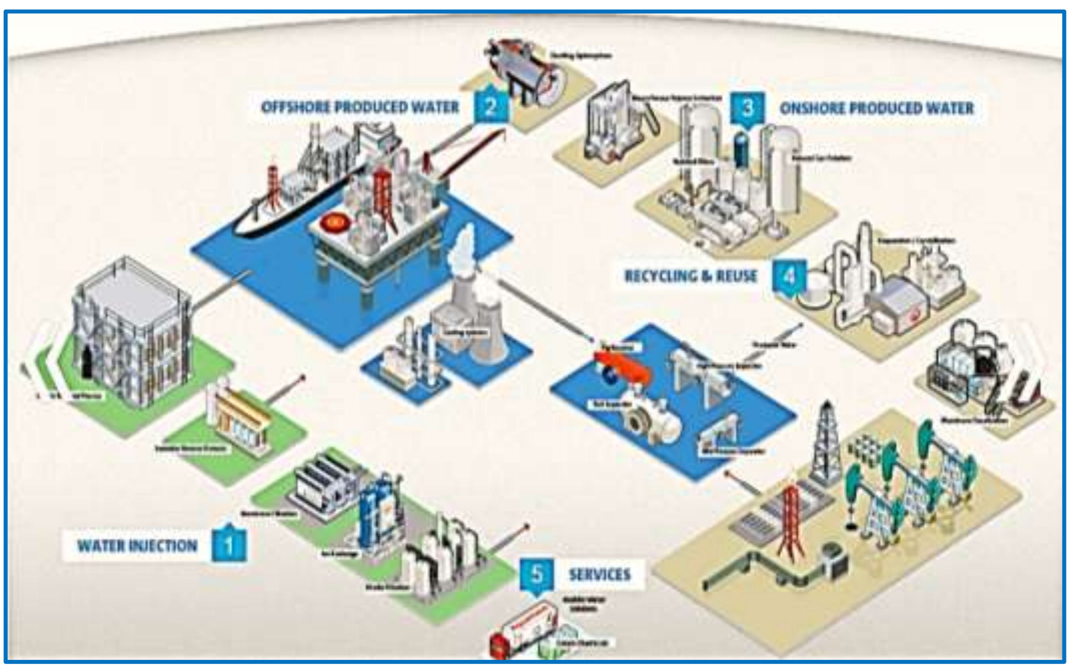


15. Reverse Osmosis: Is an important process used to **desalinate water** or to convert brackish or seawater to **drinking water**, in which dissolved inorganic solids (such as salts) are **removed** using a **membrane** (which is about as thick as cellophane), removing the impurities or contaminates. The phenomenon of **osmosis** occurs when pure water flows from a dilute saline solution through a membrane. The semi-permeable membrane is placed between two compartments. Then, a salt solution is retained in one compartment and **pure water** gets through in other compartment. The direction of water flow through the membrane can then be reversed. This is the basis of the term **Reverse Osmosis**, as the reversed flow produces **pure water**, since the membrane is not permeable to salt. This process requires that a high pressure be exerted on the high concentration side of the membrane, usually **2-17 bar** (30-250 psi) for fresh and brackish water, and **40-70 bar** (600-1000 psi) for seawater, that must be overcome in order to achieve the Reverse Osmosis.

The best known applications for **RO process** is in desalination, where fresh water is generated from seawater by removing the salt. However, there are **numerous other applications** in the chemical, pharmaceutical and food industry, as well as, in **effluent and waste treatment** applications. In practice, with a high-pressure pump, the pressurized saline feed water is continuously pumped to the module system. Within the module, consisting of a pressure vessel (housing) and a membrane element, the feed water is **split** in a low saline product called permeate and a high saline brine called concentrate or reject. A flow regulating valve controls the percentage of feed water, which is going to the concentrate stream, and the permeation obtained from the feed.

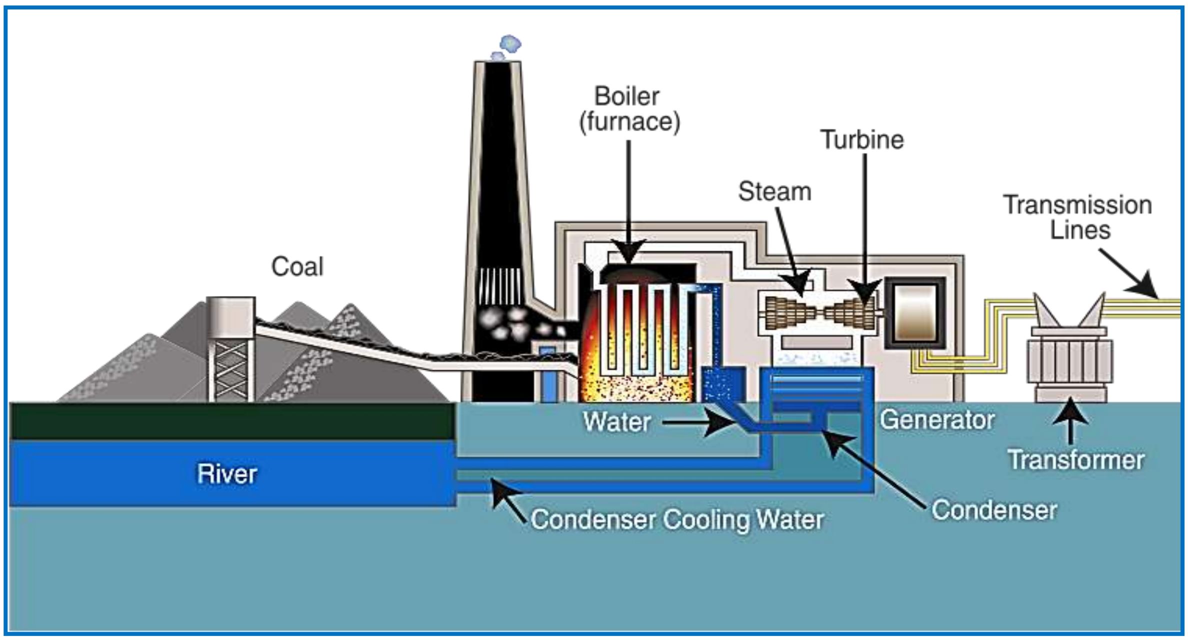


16. Water Recycling: The oil and gas industry also faces increasing pressure to **manage its environmental footprint**, including offshore. This is even more critical in deeper waters, where water treatment can be extremely expensive due to platform weight requirements and difficult in logistics, with limited options and flexibility. Water recycling is widely seen as a potential means of reducing the **impact** on local water resources, particularly in areas where hydraulic fracturing is new or water is relatively scarce. Recycling reduces the need for makeup water to the well and subsequent wastewaters to remote disposal facilities, providing an environmental gain.



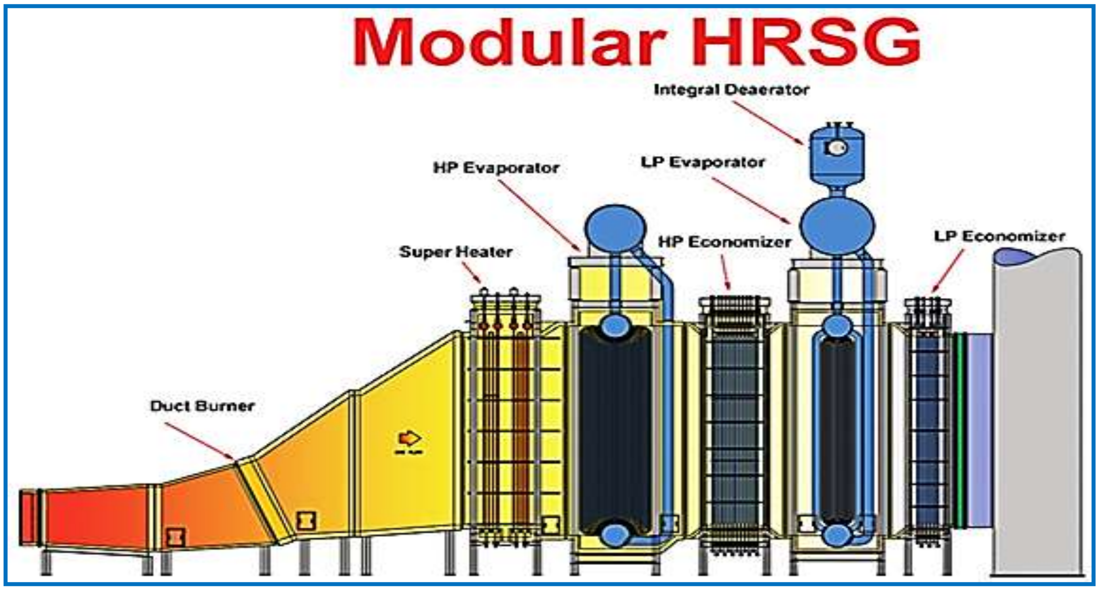
8. POWER GENERATION AND DISTRIBUITION: The main purpose of a fossil fuel power station is to burn fossil fuels, such as, natural gas, coal, or petroleum to **produce electricity**. All oil plants can use the energy extracted from expanding gas, steam or combustion gases to generate power. Oilfield operations often unlock plentiful natural gas supplies, and power generation solutions can put low cost fuel, with oil and gas production sites across the globe. Gas engines are commonly used to deliver reliable performance for a variety of mobile and stationary applications, either in liquid natural gas (LNG) or compressed natural gas (CNG).

Alternatives to fossil fuel **power plants** include nuclear power, solar power, geothermal power, wind power, tidal power, hydroelectric power (hydroelectricity) and other renewable energies. Some of these are proven technologies in industrial scale (i.e. nuclear, wind, tidal and hydroelectric power) others are still in prototype form. Today natural gas accounts for **23%** of the world's energy consumption. However, raw natural gas as it comes from the ground must be processed, to remove impurities, including water, and to separate out valuable components including natural gas liquids such as ethane, butane and propane. Compressors driven by aeroderivative gas turbines and gas engines are commonly used throughout gas processing facilities.



Biogas: Is produced during anaerobic fermentation, and serves as high-energy, renewable fuel that can be used as a substitute for fossil fuels. The process of biogas generation is divided into **three steps**; *preparation of* the *bio-input, fermentation, and post-treatment* of the residual material. The biogas produced in the digester is collected in a storage tank to ensure a continuous supply of gas, independent of fluctuations in the production. Finally, the **biogas** is fed into a gas engine, but for safety reasons, the installation of a *gas flare* is recommended, so that excess can be burned off in the event of excessive production.

Heat Recovery Steam Generator (HRSG): Is an **energy recovery system**, used through **heat exchangers** that recovers heat from a hot gas stream, and consists of **four components**; *the economizer, evaporator, superheater, and water preheater*. It produces **steam** to be used in a **co-generation** process or used to **drive a steam turbine** (combined cycle). Based on the flow of exhaust gases, HRSGs are categorized into ***vertical and horizontal types***. In horizontal type, the exhaust gas flows horizontally over **vertical tubes**, whereas in vertical types, the exhaust gas flow vertically over **horizontal tubes**. Based on pressure levels, HRSGs is categorized into *single pressure and multi pressure*. *Single pressure* has only **one steam drum** and the steam is generated at single pressure level, and *multi pressure* models, employ **two** (double pressure) or three (triple pressure) **steam drums**.



Once-Through Steam Generator (OTSG): Is a **specialized type** of HRSG **without** boiler drums. In this design, the **inlet feedwater** follows a continuous path without segmented sections for economizers, evaporators, and superheaters, providing a high degree of flexibility, based on the heat load being received from **gas turbines**. The absence of drums allows for quick changes in **steam production** and fewer variables to control, and is ideal for cycling and base load operation. The OTSG can be run dry, meaning the **hot exhaust gases** pass over the tubes with no water flowing inside the tubes. This eliminates the need for a **bypass** stack and exhaust gas diverter system which is required to operate a combustion turbine with a drum-type HRSG out of service.

Thermal Power Station: Is a **power plant** in which the prime mover is **steam driven**. Water is heated, **turns into steam** and spins a **steam turbine**, which drives an **electrical generator**. Some places or countries prefer to use **thermal energy** centers because such facilities convert heat into **electrical power**, specifically designed to produce heat energy for industrial purposes and residential electrical power. Natural gas is frequently combusted in gas turbines, as well as, gas boilers. The waste heat from a gas turbine is also used to raise steam, in a combined cycle plant that improves overall efficiency.

Power stations are usually **very large** and designed for continuous operation. Electric power plants typically use *three-phase electrical generators* to produce **alternating current** (AC) electric power at a frequency of **50 Hz or 60** Hz. Steam driven power plants are generally used in large naval ships. These power plants installed in **ships** also provide steam to smaller turbines driving **electric generators**, and to supply electricity. An important class of thermal power stations is associated with **desalination** facilities, typically found in desert countries with large supplies of natural gas, to produce **freshwate**r.

Cogeneration Systems: Are also called **Combined Heat and Power** (CHP) systems, used to generate both **heat and power**. CHP systems use the waste heat created during an engine's operation to generate overall plant efficiencies of more than 90%. This is an efficient and economical method of energy conversion, and achieves primary energy savings of roughly 40% by using a gas engine cogeneration system, instead of separate power and heat generation equipment. Transportation and distribution losses also are reduced or eliminated, as the decentralized energy supply is aligned where it is necessary to be used.

Cogeneration systems are supplemented with a **boiler system** for bridging peak heat demand periods. The connection of a heat storage medium makes it possible to increase system operating time and efficiency. The thermal energy can be used to generate **heating water** and steam production, as well as, for various types of process heat. Power plant electrical switch and control systems distribute electricity and manage the engine, while hydraulic equipment ensures heat distribution. Generated power is used by industrial plant facilities or disposed to the public power grid.

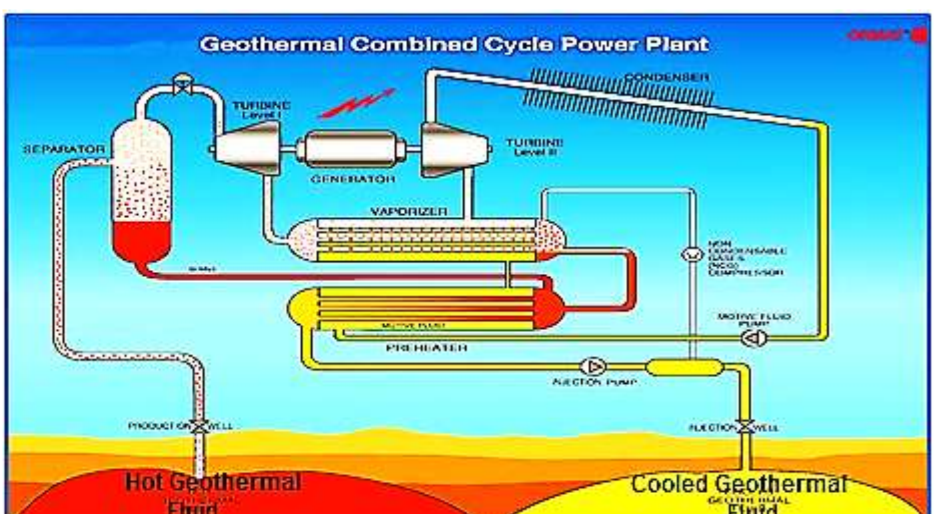
Trigeneration Systems: Are the **combination** of cogeneration plants and **chillers**, designated as **Combined Cooling, Heat, and Power** (CCHP) systems. Gas engines, aeroderivative gas turbines, and absorption chillers provide an economic and environmental alternative, offering an excellent solution for generating air conditioning and/or refrigeration. These combined equipment can also enable elimination of HCFC/CFC refrigerants, and reduced overall air emissions.

The cogeneration plant with an absorption refrigeration system, enables the use of combined equipment for heat and cooling. Hot water from the cooling circuit of the cogeneration plant serves as drive energy for the absorption chiller to **produce chilled water**, by heating two substances (water and lithium bromide salt, used as absorbent). The generation of **chilled water** is commonly used in the **temperatur**e range from **6 to 12°C** (43 to 53º F). Ammonia (refrigerant) and water are also used for a **very low temperature**, chilling down to **-60°C** (-140º F).

Biomass: Is a **biological material** derived from **living organisms**, which refers to plant-based materials, specifically called **lignocelluloses biomass**. Wood remains the **largest biomass** energy source, (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to **biofuel** is achieved by different methods, such as thermal, chemical, and biochemical methods. Biomass is converted to other usable forms of energy like **methane** or transportation fuels like **ethanol** and **biodiesel** produced from products, like **vegetable oils** and animal fats. Biofuels are classified broadly into **two** categories. The first generation biofuels are derived from sources, such as **sugarcane**. The compound sugar presented in this biomass is fermented to produce the ***bioethanol*,** or serve as an additive to gasoline.

Flue-Gas Stack: Is a type of **chimney**, vertical pipe, channel or similar structure, where flue gases are exhausted to the outside air. Flue gases are produced when *coal, oil, natural gas, wood or any other fuel* is combusted in an industrial furnace, a power plant's steam-generating boiler, or any other large combustion device. Flue gas is usually composed of **carbon dioxide** (CO2) water vapor, nitrogen, carbon monoxide, nitrogen oxides and sulfur oxides. Many power plants are equipped with removal of sulfur dioxide (flue-gas desulfurization, selective catalytic reduction, exhaust gas recirculation, thermal **NOx**, or low NOx burners and particulate matters (using electrostatic precipitators), and is also possible to use cooling towers, as flue-gas stacks.

Geothermal Electricity: The development of binary cycle power plants and improvements in drilling and **extraction** technology may enable enhanced **geothermal systems** over a much greater geographical range. The thermal efficiency of **geothermal electric** stations is around **7-10%,** because geothermal fluids are at a **low temperature**, compared with **steam** from boilers. Exhaust heat is wasted, unless it can be used locally, for example, in greenhouses, timber mills, and district heating. Technologies in use include dry steam power stations, flash steam power stations and binary cycle power stations. The **electricity generating** potential of geothermal energy is estimated from **35 to 2,000 GW**, considered to be sustainable, because the heat extraction is small compared with the Earth's heat content.



9. AIR & WATER COOLING SYSTEMS: HVAC stands for "***Heating, Ventilation and Air Conditioning***" often combined into one system, with common use in the heating and cooling applications. Warmed, cooled or dehumidified air flows through a series of tubes, *called ducts*, to be distributed to all the rooms of a residence or a building. The central **HVAC** system is the most convenient way to be used in heating and cooling, and this system may use heat pumps that combine both the heating and cooling functions. Central air conditioners are also called "*split systems*", due the combined application of an outdoor unit (condenser) and an indoor unit (evaporator coil).

Tons of Refrigeration: For commercial and industrial refrigeration systems most of the world uses the kilowatt (kW) as the basic unit refrigeration or rated in **Tons of Refrigeration** (TR). One Ton of Refrigeration was defined as the energy removal rate to freeze **1 ton of water at 0°C** (32 °F) or, the amount of heat required to **melt 1 ton of ice in 24 hours**. The TR unit's value is approximately **11,958 Btu/h** (**3.505 kW**), redefined to be approximately:

1 Ton of Refrigeration = 12,000 Btu/h (3.517 kW) = 3024 Kcal/h.

Metabolic Rate: Metabolic rate is measured in Met units. A **Met** is the average amount of heat produced by a sedentary person (e.g. office work = 1 Met). Human beings are essentially constant-temperature creatures with a normal internal body temperature of **98.6°F** (37º C). Heat is produced in the body as result of metabolic activity. **1 Met unit** = **360 Btu/h** = **90.718 kcal/h**. The cooling capacity of room air conditioners is measured in *BTUs, or British Thermal Units*, per hour:

Thermal Comfort Zone: It is an area plotted with a **psychrometric ch**art. During summer the comfort range of temperature varies between **70 to 76°F dry bulb** temperatures and **45 - 65% RH**. During cold winters the comfort condition would be in the range of **65 to 68°F** dry bulb temperature and relative humidity of a minimum of 30%. Thermodynamic properties of moist air are affected by atmospheric pressure. The **standard** temperature is **59°F** and standard **atmospheric pressure** is **29.921 in.Hg** (14.697 psi) at sea level. In summer, the split system extracts heat from indoor air and transfers it outside, leaving the cooled indoor air to be re-circulated through ducts by a fan. Some types of gasses used as a "*refrigerant*" carries the heat from one area to another.

Sound Levels: In some units, the HVAC noise created by the outside condensing unit can interfere with indoor peace and quiet. The sound level of outdoor units is measured in *bels* (a term similar to decibels). The **rating scale** goes from **0**, the rating for a barely perceptible sound to **13**, the threshold of pain. Most air conditioners and heat pumps operate in the range of **8 to 9 bels**, although some are quiet enough to rate as **6.8 bels** (the noise output at **9 bels** is 10 times louder than 8 bels, as loud as 10 units rated at 8 bels).

Geothermal Heat Pumps: Are similar to **heat pumps**, but instead of outside air, use **heat of the earth** to provide heating, air conditioning and, in most cases, **hot water**. In winter it collects the Earth's natural **heat** through a series of pipes, called a loop, installed below the surface of the ground or submersed in a pond or lake. Fluid circulates through the loop and carries the heat to the building using a **compressor** and a heat exchanger to concentrate the energy and release it inside, at a higher temperature. In summer, the process is reversed. The system cools the building in the same way that a refrigerator, by drawing heat from the interior, not by blowing in cold air.

Cooling Towers: Cooling towers are very important parts of many commercial buildings and industrial plants. The **primary task** of a cooling tower is to **reject heat** to the atmosphere. These types of equipment represent an inexpensive and dependable means of removing low-grade heat from **cooling water**. An open circuit cooling tower is a specialized **heat exchanger** in which two fluids (air and water) are brought into direct contact with each other to affect the transfer of heat. Following the rules, someone can easily calculate a common process for a basic Mechanical Draft Cooling Tower. Cooling towers fall into **two** main categories; *Natural draft and Mechanical draft.*

- ✓ **Natural Draft Towers:** Use very large concrete chimneys to introduce air through the media. Due to the large size of these towers, they are generally used for water flow rates, above 45,000 m^3/h (~1,590,000 ft^3). Natural draft towers are used only by utility power stations and thermal energy centers.

- ✓ **Mechanical Draft Towers:** Utilize large fans to force or suck the air through circulated water. The water falls downward over fill surfaces, which help increase the contact time between the water and the air, this helps maximize heat transfer between the two. *Mechanical Draft Towers* are available in the following airflow arrangements:

  1. Counter flow induced or forced draft: In this design type, hot water enters at the top, while the air is introduced at the bottom and exits through the top, as warm water falls downward. Both forced and induced draft fans are used. Because of the need for extended intake and discharge plenums; the use of high pressure spray systems and the typically higher air pressure losses, some of the smaller counter flow towers are physically higher, and require more pump head and utilize more fan power than the cross flow counterparts.

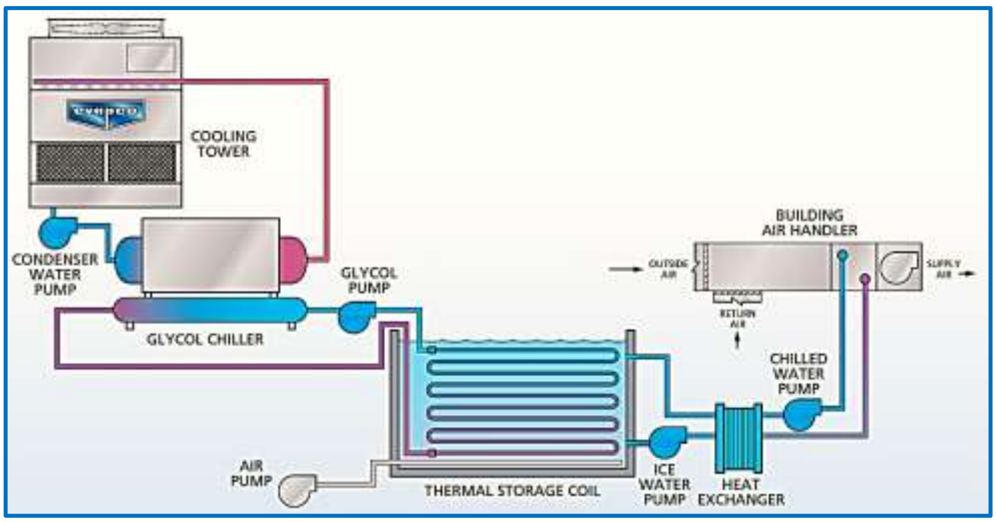
  2. Cross flow induced or forced draft. In this flow draft design, the air flows horizontally, across the downward fall of water. The air, however, is introduced at one side (single-flow tower) or opposite sides (double-flow tower). An induced or forced draft fan draws the air across the wetted fill and expels it through the top of the structure as the water cascades down through the tower.


Mechanical Draft Towers


Natural Draft Towers

Chillers and Air Handling Units: Chillers provide **cooling** for chilled water used in the **air cooling coils for air conditioning**, while **Air Handling Units** provide cooling by direct expansion of the **refrigerant**, in air cooling coils. In general, **AH Units** are used for relatively **small** capacity systems, not larger than **100 ton** capacity, and **chillers** are used for relatively **large** capacity systems, based on the type of compressors, packages or split designs. Typically chillers are package units mounted on one skid, with the water piping system being external to the unit. The package includes the compressor, condenser, evaporator and associated components. Chillers types are scroll compressors, reciprocating, centrifugal or screw compressors combined with split systems, (condenser, compressor, evaporator on the same skid as a condensing unit, and the evaporator located separately).

Note: The **R22 refrigerant** is commonly used in most reciprocating type of compressors, while the **R123** gas refrigerant is commonly used in centrifugal chillers. The Hydro Fluoro Carbon (HFC) refrigerant, such as R134a, which do not harm the ozone layer, is currently being used in the newer machines to replace the CFC (Chloro Fluoro Carbon) and HCFC (Hydro Chloro Fluoro Carbon). The liquid refrigerant expands, turning into a low temperature and low pressure gas.

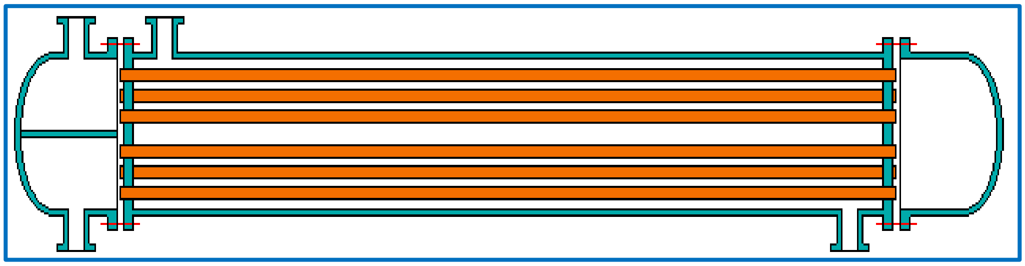


Heat Exchangers: Are devices that regulate efficient heat transfer from one fluid to another. In intercoolers, boilers, pre-heaters and condensers inside power plants, as well as, other engineering processes, heat exchangers are utilized for controlling heat energy. The term heat exchanger is used to describe all types of equipment, where heat transfer is promoted from one fluid to another. In a temperature control application, the inlet temperature of the secondary fluid to the heat exchanger may change with time. The main *types* of heat exchangers are described below:

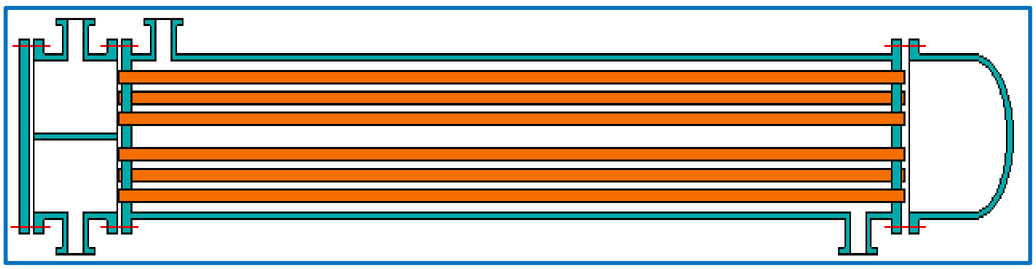
- **Recuperative Type:** Is the first type of a heat exchanger, in which heat are exchanged on either side of a dividing wall by fluids;

- **Regenerative Type:** Is the second type, in which hot and cold fluids are in the same space, and contains a matrix of materials that work alternately as a source for heat flow.

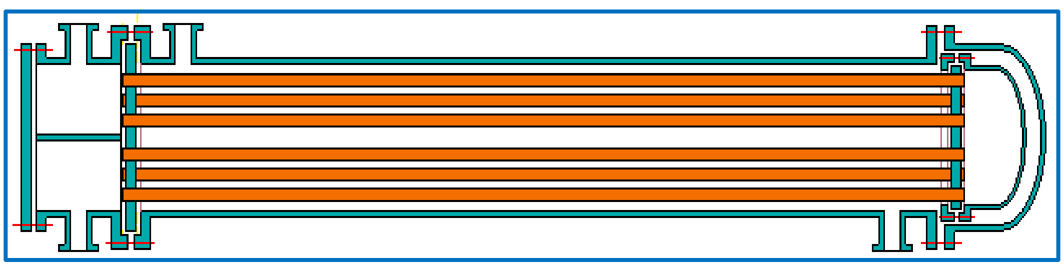
BEM - One Pass Shell, Fixed Tubesheet Bonnet: This is a very popular equipment version as the heads can be removed to clean the inside of the tubes. The front head piping must be unbolted to allow the removal of the front head. It is not possible to clean the outside surface of the tubes as these are inside the fixed part. Shown below is a version with one shell pass and two tube passes.



AEM - One Pass Shell, Fixed Tubesheet Bonnet: This is almost the same type of heat exchanger as the first BEM, the removable cover allows the inside of the tubes to be inspected and cleaned without unbolting the piping. If BEM is undesired this can be avoided by applying the type AEM front head.



AES - One Pass Shell, Floating Head with Floating Head: For applications where the difference in temperature between the hot and cold fluid causes unacceptable stresses in the axial direction of the shell and tubes. The floating head can provide the possibility to expand in the axial direction and the bundle cannot be pulled from the front end. For maintenance both the front and rear end head, including the backing head must be disassembled.



Air Compressors: Are **positive** displacement or dynamic pump machines that increase the **pressure of air by reducing its volume**. These types of equipment take successive volumes of air, which is confined within a closed space, and then elevating the air to a higher pressure. The most important compressor types are:

Reciprocating Air Compressor: Is a very useful machine, constructed either as *air-cooled or* water-cooled in lubricated and non-lubricated configurations in a wide range of pressure and capacity selections. The reciprocating compressor, accomplished by a piston within a cylinder, as the compressing and displacing of this compressor is specified as; *single or double stage and single or double acting*.

- **Single-stage:** Is when the entire compression has a single cylinder or a group of cylinders in parallel, generally used for pressures in the range of *70 psig to 100 psig.*
- **Double-stage:** Is when two or more steps of compression are grouped in series generally used for pressures in the range of *100 psig to 250 psig.*
- **Single acting:** When the compressing is accomplished using only one side of the piston.
- **Double acting:** Are those using both sides of the piston.

Diaphragm Compressor: Is a variant of the classic reciprocating compressor with backup and piston rings and rod seal. The compression of gas occurs by means of a flexible membrane, instead of an intake element. The back and forth moving membrane is driven by a rod and a crankshaft mechanism. Only the membrane and the compressor box come in touch with pumped gas. For this reason this construction is the best suited for pumping toxic and explosive gases, with adequate chemical properties and sufficient temperature resistance. A Diaphragm Compressor is the same as a Membrane Compressor.

Rotary Screw Compressors: Are also positive displacement compressors. The most common is the single stage helical or spiral lobe oil type. These compressors consist of two rotors within a casing where the rotors compress the air internally. These units are basically oil cooled (with air cooled or water cooled oil coolers) where the oil seals the internal clearances. The working parts never experience extreme operating temperatures. The rotary compressor, therefore, is a continuous duty, air cooled or water cooled compressor package.

Rotary Lobe Air Compressor: Is a two mating lobe-type rotors mounted in a case. The lobes are gear-driven at a close clearance, but without metal-to-metal contact. As the lobes rotate the cavity size is reduced causing compression of the gas within. The suction of the unit is located where the cavity made by the lobes has larger spaces. The compression continues until the discharge port is reached at which point the gas exits the compressor at a higher pressure.

Centrifugal Air Compressor: Centrifugal Compressors produce high-pressure discharge by converting angular momentum imparted by the rotating impeller (dynamic displacement), and the oil lubricated running gear is separated from the air by shaft seals and atmospheric vents. Centrifugal Air Compressors are usually oil-free compressors and designed for higher capacity, because the airflow through the compressor is continuous, available from 200 HP on up to several thousand HP, for specialized applications.

Axial Compressors: Are rotating, airfoil-based compressors, in which the working fluid runs parallel to the axis of rotation and produce a continuous airflow with high efficiency and large mass capacity. Axial compressors are widely used in gas turbines, such as jet engines, high speed ship engines, and small scale power stations and in industrial applications, such as large volume air separation plants, blast furnace air, fluid catalytic cracking air, and propane dehydrogenation.

Nm³/h and SCFM: Whenever the capacity of a compressor is given in **Nm³/h or SCFM**, is necessary to know the weather conditions (atmospheric pressure, air temperature and relative humidity) and altitude conditions of the place where to install any process compressor.
Nm³/h (Normal Cubic Meter per Hour) - refers to:

- Atmospheric Pressure at Sea Level = **1.033 kg/cm² abs**.
- Temperature = 273°K (0ºC)
- Relative Humidity = 0% (dry)

SCFM (Standard Cubic Feet per Minute) – refers to:

- Atmospheric Pressure at Sea Level = **14.7 psi abs**
- Temperature = 60°F (15.6°C)
- Relative Humidity = 0% (dry)

Ventilation: According to Occupational Safety & Health Administration (OSHA), industrial ventilation is one of the most **important** engineering **control** for improving or maintaining the quality of **the air** in the occupational work environment. The quality of indoor air inside workplaces is important not only for workers' comfort, but also for their health and specific diseases like asthma, lungs cancer, headaches, fatigue, irritation of the eyes, noses, throat and several other symptoms. Fan selection is based on calculating the airflow and pressure requirements of a system, then finding a fan of the right design and materials to meet these requirements. There are two primary types of fans; centrifugal and axial:

- ✓ **Centrifugal Fans**: Centrifugal fans are the most used ventilation equipment, commonly applied in systems to control environment temperatures and in material handling applications to control room moisture or the air particulate content.

- ✓ **Axial Fans:** Axial fans move an airstream along the axis of the fan. The air is pressurized by aerodynamic fan blades, much like a propeller and an airplane wing frequently used in exhaust applications where air particulate sizes are small, such as dust streams, smoke and steam and applications that require reverse airflow.

NTP - Normal Temperature and Pressure: Is commonly used as a standard condition for testing and documentation of fans and blowers capacities. The standard conditions are:

- Air temperature at **68°F** (293.15 K, 20°C)
- Air pressure at **29.92 in Hg** (101.3 kPa, 14.7 psia, 0 psig, 1 atm, 760 torr)
- Air density at 0.075 lb/ft³ (1.204 kg/m³)

Boilers: Are close vessels used to **generate steam and hot water** for heat or power. Boilers are ruled by the **ASME** code. ***Section I*** provides requirements for all methods of construction of power, electric, and miniature boilers. ***Section IV***, requirements for design, fabrication, installation and inspection of steam generating boilers, intended for low pressure service directly fired by oil, gas, electricity, or coal. ***Section VI*** defines general descriptions, and guidelines applicable to steel and cast iron boilers. ***Section VII*** are guidelines to promote safety in the use of stationary, portable, and traction type heating boilers. Boilers come in many types and varieties, as following defined:

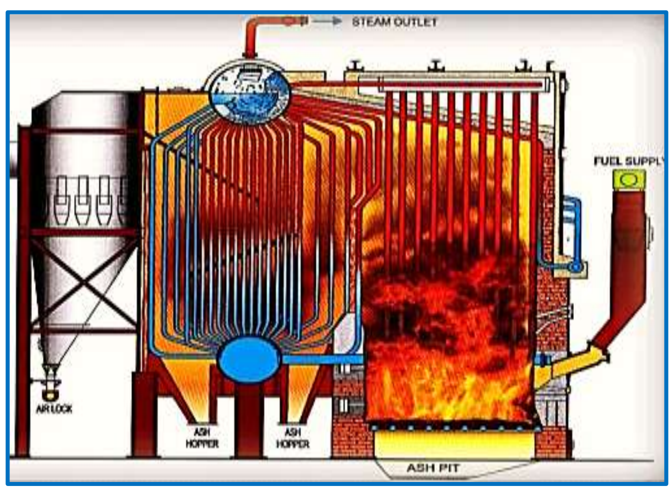
a. Hot Water Boilers: A high temperature (HTHW) boiler furnishes water at a temperature greater than **250º F** or at a pressure higher than **160 psig**. A Low-Temperature Hot Water (LTHW) boiler furnishes water at a temperature less than **250º F** and a pressure less than 160 psig. The most common types of industrial boilers are:

b. Firetube Boilers: Are medium-sized industrial boilers. The name comes from tubes through which the flue gas flow and heat is transferred to the water externally around the tubes. The most common Firetube boilers are the Wetback and Dryback types, variations of the Scotch boilers. Wetback refers to the water-lined design of the rear of the combustion chamber. Dryback is lined with a high-temperature insulating material.

Watertube Boilers: Are boilers applicable for a wide range of sizes and pressures. The name is because of the circulating water through the boiler tubes, generally connected to two cylindrical steam drums. Sizes may be from **20,000 to 1,000,000 lb/h** of steam and pressures range from **50 to 5,000 psig** and require grater spacing between the boiler tubes when using solid fuels than those using liquid and gaseous fuels. The most common types are:

- **Forced-Draft Boiler**: Consists of a burner and blower where the air is pushed through the burner wind box.
- **Natural-Draft Boiler:** Has this designation due the draft is caused by the difference in weight of the column of flue gases within the stack, with a corresponding column of equal dimensions outside, and the intensity of draft is negative, expressed in inches of water.
- **Induced-Draft Boiler:** Is when a fan is used to pull the air and combustion through the boiler, which allows to suck particles through the boiler, not permitting ash, etc., to settle and clog the air passage, to avoid the boiler becomes dirty an inefficient.


Firetube Boilers



Watertube Boilers

9. OIL & GAS CONTROL SYSTEMS: An Industrial Control System (ICS) is comprised of many components, including **hardware and software** technologies. In the oil and gas space, information produced by the ICS is typically required by a wide variety of applications, including HMI/SCADA for visualization and hardware components that can range from simple rod pump controllers, to advanced flow computers, **PLCs** and DCSs that vary depending the upstream, midstream or downstream operations. Due the remote nature of many oil and gas sites, the multiple networks present a communication challenge, considering the ability to communicate even over a single telemetry method (such as radio, cellular, or satellite modem).

Oil and gas control systems can control, monitor, and report upstream, midstream, and downstream processes, including **water** disposal systems, oil and gas processing, refining, flow, production, emergency, safety shutdown, fire and gas detection, utility, power generation, distribution, and several other general controlling systems. Automated systems for enhanced oil and gas recovery processes also include gas injection, chemical injection, microbial injection, thermal steam injection, fluid dehydration, produced fluids and gases, waste gas handling, waste water handling, oil/gas separation, measurement, storage, handling, refining, spill prevention, custody transfer, and control production reporting.

Differential **pressure flow meters** are commonly used for metering the gas flow rate for asset and revenue accounting. Today, Remote Terminal Units (RTUs) can communicate to a remote central host system via radio communication, also referred to as a Supervisory Control and Data Acquisition (**SCADA**) system. The remote RTU is a "*gas flow computer*", may be essentially a sophisticated subprogram or an algorithm. When gas sites are distant and electrical power is rarely available, the RTUs can be powered by solar panels plus batteries. The batteries enable RTUs to continue to function when the sun is below the horizon or is obscured by heavy cloud cover.

The system is operated from the Central Control Room (CCR) with a **combination** of graphical process displays, alarm lists, reports and historical data curves. Desk screens are often used in combination with large wall screens, where information is available to near and remote locations, such as an onshore corporate operations support centre. The main function of the Central Control Room is to make sure that the production, processing and utility systems, operate efficiently within design constraints, safety and alarm limits.

Programmable Logic Controllers (PLCs): Are essentially nothing more than special-purpose, industrial **computers**. As such, they are built far more **ruggedly** than an ordinary personal computer (PC), and designed to run extremely reliable operating system software. Typical devices that may be connected to **PLC's** inputs include hand switches, process switches, sensors, analog transmitters (4-20 mA), thermocouples, thermistors, and strain gauges. Typical devices connecting to a PLC's outputs include electric lamps, solenoids, relay coils, motor contactors, analog final control elements (e.g. throttling control valves, variable-speed motor drives), and audible buzzers.

Large PLC systems consist of a **rack** into which circuit "*cards*" are plugged. These cards include processors, input and output (I/O) points, communications ports, and other functions necessary to the operation of a PLC system. Such "*modular*" PLCs may be configured differently according to the specific needs of the application. Individual card failures are also easier to repair in a modular system, since only the **failed** card need be replaced, not all the cards or the whole card rack.

Ladder Logic Programming: Are **written** methods to document the construction of **relay** racks used in manufacturing and process control, where each device is represented by a symbol on the **ladder** diagram. The ladder **logic** is used for Programmable Logic Controllers (PLCs), widely used in industrial control applications. The name is based on the observation that the programming resembles ladders, with two vertical **rails** and a series of horizontal rungs between them.

Pressure, temperature, flow, weight and many different **processes** are commonly automated by the Ladder Logic Programming. Analog signals can use voltage or current with a magnitude proportional to the value of the process signal. For example, an analog **0-10 V** input or **4-20 mA** could be converted into an integer value of 0 **-32,767**.

Human-Machine Interfaces: Is the part of the machine that provides a **graphics-based** visualization of a control and monitoring system and handles with the human–machine interaction. A Human Machine Interface (HMI) is exactly what the name implies; a graphical interface that **allows** humans and machines to interact, which can vary widely, from control panels for nuclear power plants, to the basic screen on an iPhone.

The Human Machine Interface (HMI) includes the **electronics** required to signal and control the state of industrial **automation**, where multiple equipment are linked by a host control system that can be accessed and controlled. The term "*user interface*" is often used in the context of personal computer systems and electronic devices. An HMI is typically local to one machine or piece of equipment, and is the interface method between the human and the equipment/machine.

PLCs

HMI

Fieldbus & Distributed Control Systems (DCS): Are industrial network systems used in process control and **industrial automation**, as a way to connect instruments in a manufacturing plant. Fieldbus is the name of a family of industrial computer network **protocols** used for distributed control, standardized today, as **IEC 61158**. Fieldbus and Distributed Control Systems (DCS) are used to continuous or batch-oriented **control** processes, such as oil refining, petrochemicals, central sta-tion power generation, fertilizers, pharmaceuticals, food and beverage manufacturing, cement production, steelmaking, papermaking and many other consolidated processes.

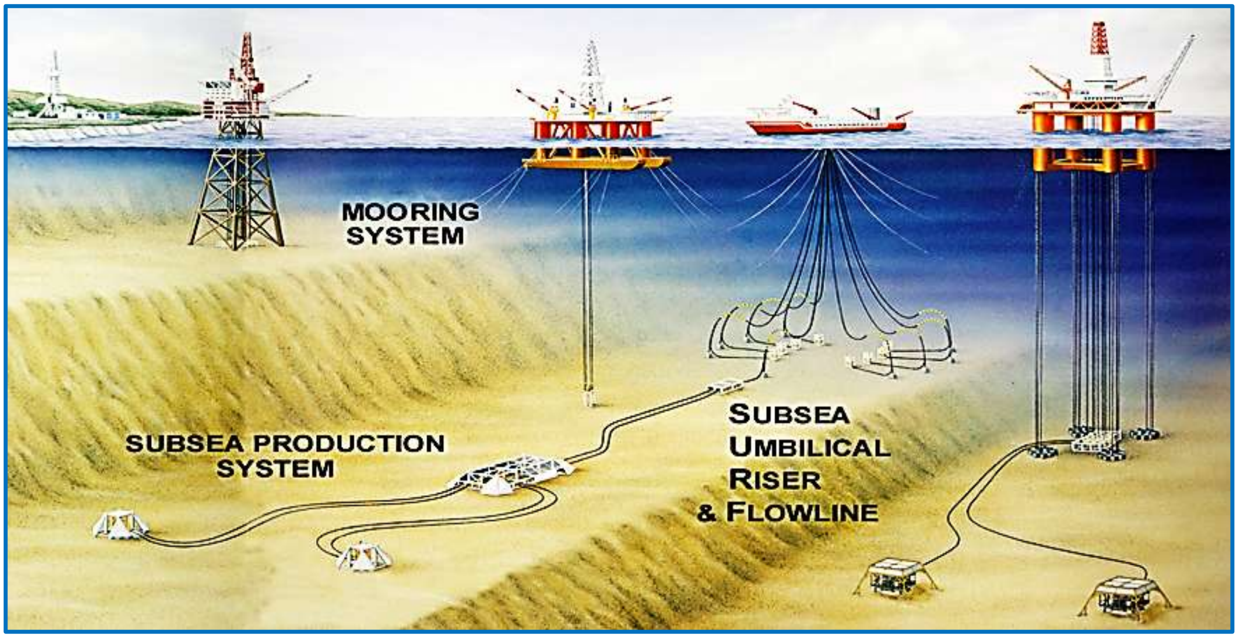
Foundation Fieldbus is a **communication protocol** while DCS is a control platform. Foundation Fieldbus is a digital signal that replaces the traditional **4-20 mA** signal and deals with communication between instruments, actuators, and controllers, whether distributed or centralized. DCS is a centralized control for inputs distributed geographically, and the operator station is normally intimately connected with its I/O (Fieldbus, local wiring, networks, etc.).

Types of Reservoir Fluid: Each kind requires a different method of control systems in processing (techniques of predicting oil and gas reserves, sampling, **plan** of extraction and recovery, and production) to correctly determine the necessary type of materials, equipment and monitoring of the fluid flow. The five types of reservoir fluids are:

- **Black Oil:** Consist of large, heavy, non-volatile molecules. The molecular weight of black oil is typically **70 to 150** in molecular weight with high points at 190 to 210, also called "*low-shrinkage crude oil*" or "*ordinary oil*", but isn't always black oil.
- **Volatile Oil:** Are composed of intermediates, such as ethane and hexane, ranging from 4**3 to 70**. If the petroleum fluid has a molecular weight less than 43, it is classified as any of the three gases, also called "*high-shrinkage crude oil*" and "*near-critical oil*".
- **Retrograde Gas:** Are also called "*gas condensates*" or "*condensates*" and range in molecular weight from **23 to 40**, and have white fluorescence, which is an aid in identifying them in reservoirs. This gas is often processed to obtain the intermediates (liquid propane, butane, pentane, and heavier hydrocarbon), often called "*plant liquids*".
- **Wet Gas:** The first step in processing these fluids is to split them up into individual components, using some types of separators. Wet gas is the type of natural gas containing more ethane, complex hydrocarbons, and less than **85% methane** and contains heavy hydrocarbons from which liquid hydrocarbons, such as **propane and butane** can be liquefied.
- **Dry Gas:** Is the last hydrocarbon to be generated in the petroleum-formation process and is the type of gas that does not produce condensate, reservoir liquids, or liquid hydrocarbons. Typically, it is composed of **methane** and some intermediates.

Subsea Distribution System (SDS): Consists of several **instrumentations** and products that provide **communication** between subsea controls and topside controls for all equipment via umbilicals risers, connections, mechanical, hydraulic, pneumatic and automation network system. It is like the nerve system that makes the subsea production possible, designed in such a way that safety, environment protection, and flow assurance and reliability are taken into consideration for all subsea oil and gas exploitation.

Subsea Field Architecture: Based on the location of the tree installation, a **subsea** system can be categorized as a **dry tree** production system or a **wet tree** production system, for subsea processes that are generally arranged to extend the reach for existing platforms. Below is a schematic example of a subsea control/distribution system, including topsides components, subsea templates, clusters, and tie-in distribution. The most common **subsea systems** are described below:



1. Umbilical Termination Assembly (UTA): Is a complex **electro-hydraulic** system that allows many **subsea control modules** to be connected to the same data, electrical and hydraulic supply lines. The result is that many wells can be controlled **via one umbilica**l. From the UTA, the connections to individual **wells** are also made with jumper assemblies. A subsea umbilical is an assembly of hydraulic hoses that also include electrical cables or optical fibers, used to control subsea structures from an offshore platform or a floating vessel. It is an essential part of subsea production system and without, sustained economical subsea oil production could not be possible.

2. Topside Umbilical Termination Assembly (TUTA): Provides the **interface** between the main umbilical and the topside control equipment. The unit is a free standing enclosure that can be bolted or welded in a location adjacent to the **umbilical** hang-off in a hazardous exposed environment onboard the topside facility. The TUTA usually **incorporates** electrical junction boxes for the electrical power and communication cables, as well as tube work, gauges, and block and bleed valves for the appropriate hydraulic and chemical supplies.

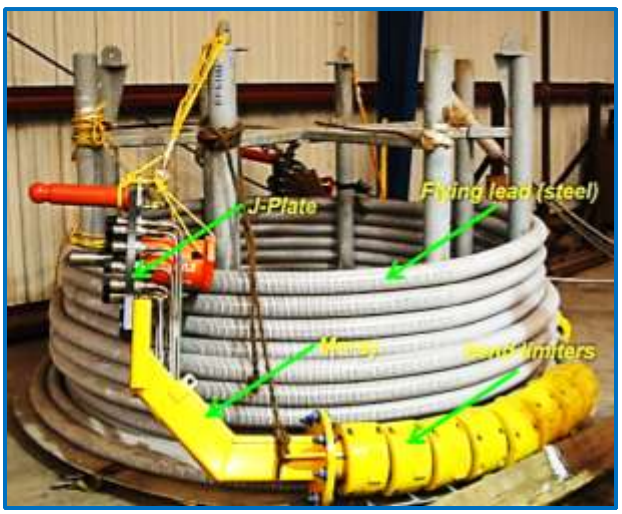
3. Subsea Distribution Units (SDUs): Are designed on the same **foundation** structure as the UTA or independent foundation, which is, typically designed to be **recovered**, reducing size and simplifying installation. SDUs **receive** electrical power, fiber optic communications, and hydraulic and chemical services from the UTA, and distributes to multiple users, such as trees, manifolds, pumping and boosting stations and infield **tie-ins**. SDUs are more easily recovered than UTAs reconfiguration and upgrades can be easier, without disturbing the umbilical system.

4. Umbilical Monitoring Devices (UMDs): Are subsea umbilicals tied to **floating systems**, specifically designed to **connect** to the closest point between the center tap of the subsea isolation transformer and the protective conductor. UMDs can **detect** a wide range of **leakage** conditions in umbilicals with a combination of sophisticated hardware and advanced software algorithms. The high sensitivity of these devices is achieved through intelligent signal amplification, precise online calibration service, and DC offset detection, which can be varied to maximize application flexibility, while connected to umbilicals, powered up to **1,000 V AC** at 50-60 Hz.

5. Flying Leads: Have the main function to **distribute** hydraulics, chemicals, electrical power and communication **signals** around the field, between the various parts of the network equipment (e.g. trees, manifolds, etc.), from the UTA to individual trees and control panels. Flying leads are part of the **subsea distribution system** that distributes umbilical functionalities to their intended service targets, typically installed after umbilical and connected by a ROV. Hybrid flying leads may contain both fiber and electrical conductors. Flying Leads between the UTA and SDU can perform the same function as **logic** plates, allowing simple system reconfiguration.

6. ModPod: Is a multiplexed, **electro-hydraulic** Subsea Control Module (SCM) ideal for tree-mounted and manifold-mounted applications, to effectively **simulate** subsea conditions and to verify the **reliability** of hydraulic and electrical components at depth, hyperbaric tested, and ROV-retrievable using an interface tool. These control modules support **flexible** instrumentation (4-20 mA, serial fieldbus, IWIS and SIIS interfaces), integral accumulation and hydraulic filtration, and include subsea electronics modules.

7. Semstar: Is a subsea **electronics module** that draws field-proven technologies, based on many years of subsea experience, according to **ISO 13628-6 2006** requirements, **optimize** reliability and its Ethernet data supports the TCP/IP with flexible subsea communications options.



Flying Leads

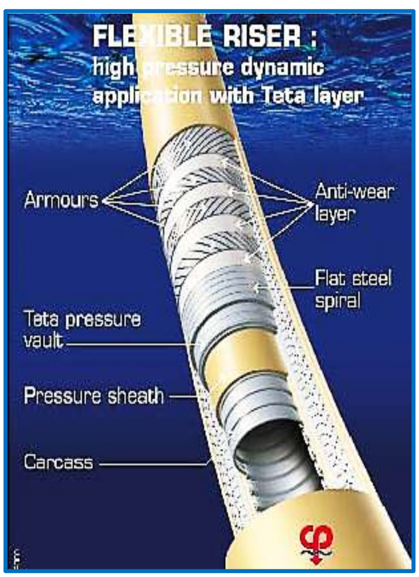
Semstar

8. Subsea Production Risers: Consist of **conductor pipes** connected to offshore production platforms or **FPSO** and the flowlines/manifolds/wellheads on the seabed and also the primary devices, to **convey fluids** to and from vessels. There are essentially **three types** of subsea risers; *rigid risers and flexible risers*. The ***hybrid riser*** is a combination of these two types. The main feature of hybrid risers is to accommodate the relative **movements** between a floating structure and a rigid metal riser, by connecting them with flexible jumpers.

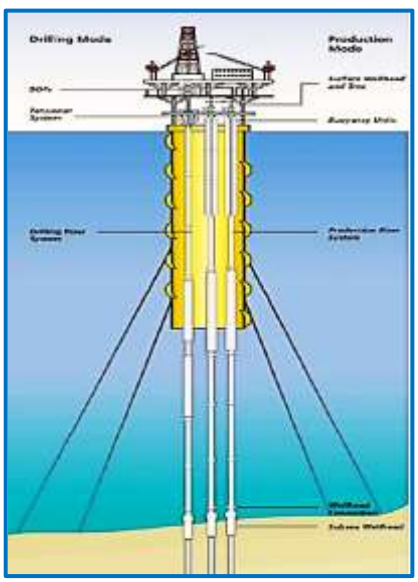
9. Steel Catenary Risers (SCRs): Are common methods of attaching an **offshore pipeline** to a **deep water** floating oil production platform. The flexible pipeline is extended up as a **catenary** on the **production platform**, a free-hanging riser with **no** intermediate buoys or floating devices. The relative rotational movements between risers and platform use flex joints, stress joints, and pull tubes to offset the movement. Use of Vortex-Induced Vibrations (VIVs) devices, such as helical stakes and fairing can help reduce the **vibration** to a reasonable level.

10. Top Tensioned Risers (TTRs): Connect the **sub-sea well bore** to the floating **production** vessel, enabling the installation of **Christmas trees** on the dry floating deck. The TTR pipes are normally in contact with high-pressure **production fluids** and are subjected to dynamic loads. The hydro-pneumatic tensioners allow the riser to **move axially** or stroke, commonly used on a **Tension Leg Platform** (TLP) or **spar dry tree** production platforms. Flexible risers are a successful solution for **deep and shallow** water connecting and flowline systems, based on flexible pipes, found out to be suitable for offshore application. Other multiplexed subsea control systems are:

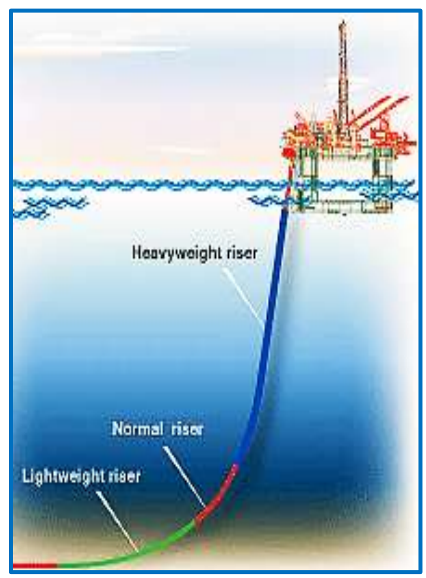
- ✓ **Multiple Quick Connectors (MQCs)**: The subsea umbilical termination assembly also consists of inboard connection plates, mounting steel structures, lifting devices, field assembled cable terminations, and electrical connectors.
- ✓ **Electric Distribution Manifold/Module (EDM):** The subsea distribution assembly also consists of electrical distribution modules (EDMs) that are bulkhead electrical connectors, cables and, in many cases, electrical transformer modules.
- ✓ **Hydraulic Distribution Modules (HDMs)**: Consists of inboard MQC plates, mounting steel structures, lifting pad eyes, mud mats, logic caps, and long-term covers.
- ✓ **Hydraulic Flying Leads (HFLs):** Consist of outboard MQC plates, holding structures, steel tubes, and Electric Flying Leads (EFLs), electrical connectors and a number of cables.



Subsea Riser



Top Tensioned Risers



Catenary Risers

Training Simulators: Are used to **provide realistic operator training** in a plant training environment, using the actual **control and safety** applications of the plant, running in operator stations. Plant models simulate the feedback from the plant in real time or fast/slow motion. The training simulator applications include functions for **backup** and reload including recreation of historical information and snapshots. Offsite training facilities are often connected to the live plant to give information from the real operating situation.

Maintenance Monitoring: Encompasses both **structural monitoring** and safety conditions for process equipment, such as turbines, compressors, generators and general pumps. Input devices are vibration meters, temperature, flowmeters, as well as, a number of start/stops, lubrication intervals and over-current trips. For other process equipment, such as instrumentation and valves the system can register closing times and functionality conditions. Generally, "*maintenances triggers*" are based on equipment **diagnostics** to predict when preventive maintenance is required. Fieldbus **mounted transmitters** and actuators are particularly used for process control and condition monitoring diagnostics.

For structural monitoring, the devices are corrosion meters, tension force meters and free swinging strings, that are logged to a central structure condition monitoring system to detect abnormal conditions, indicative for preventive maintenance. For this purpose the system maintains **sets** of limits for a **process value**, Low/Low (LL), Low (L), High (H) and High/High (HH). L and H are process warning limits which alert to process disturbances. LL and HH are alarm conditions and detects when the process is operating out of range and undesirable events and malfunction. Explosive **hazard equipment** is classified as safe by pressurization, safe by explosive proof encapsulation or intrinsically safe. All areas are mapped for explosive hazard zones from ***Zone 0*** (Inside vessels and pipes), ***Zone 1*** (Risk of hydrocarbons), ***Zone 2*** (Low risk of hydrocarbons) and *Safe Area*.

Hydraulic Power Units (HPUs): Provide stable supply of **hydraulic fluid** to remotely operated subsea valves, via **umbilicals** and hydraulic distribution system. HPUs are normally **installed** on the **FPSO**, fixed platforms or located onshore for subsea-to-beach tiebacks. Hydraulic valves properly direct the oil flow through a hydraulic system, and the direction is determined by the position of a spool. High pressure terminations supplies from **7.5 to 10 kpsi** working pressures, to operate downhole safety valves and completions, controlled by onboard **PLCs** with remote monitoring from Master Control Station.

Hyperbaric Testing: Is the only way to effectively **simulate subsea conditions** and to verify the reliability of hydraulic, electrical components at depth, simulate ultra deepwater conditions, and effective subsea components, usually tested to **6,454 psi** (445 bar), equivalent to **14,440 ft** (4,400 m) for quality and safety conditions.

IX. ONSHORE & OFFSHORE TELECOM NETWORK:

In telecommunications, **network is a system** containing total combination of computers, printers, terminals, audio, visual display devices and telephones, **interconnected** by cables to transmit or receive information. A network can consist of two computers, or **millions** of computers connected with cables or optical fibers, that are spread over a large geographical area, such as telephone lines, active equipment, radio, television and all visual or communication devices. Internet is an example of a very large network. The **onshore & offshore** oil production requires high-performance specialty wires and cables for utmost safety, productivity and resistance to harsh environmental conditions. From land-based **drilling rigs**, jack-up rigs or mobile offshore drilling units to FPSO (Floating Production Storage and Offloading) platforms should be according to advanced IEEE, IEC and marine shipboard standard cables. Power cables (15 to 45 kV) for distribution must be according to **ANSI/ICEA S-94-649** for concentric neutral and flat-strap cables. Conductors come in solid or **class B** compressed, concentric-lay stranded aluminum or copper, meeting appropriate requirements of ICEA and ASTM.

Field Telecommunications (FTs): Are technologies used to **remotely monitor** and manage exploration, development and production activities in onshore and offshore, such as, the Digital Oil Field (remote field assessment and management), WiMax (more spectrally efficient 3G technology), WiFi speeds (matching fixed BB speeds) and newer technologies as 4G/LTE, new satellite constellations and High Throughput Ka-band solutions. Other **predominant** technologies used are satellite (VSAT), Microwave, WiFi or Portable Satellite terminals (like BGAN and Iridium) connectivity for drilling rigs. The most common applied technologies are:

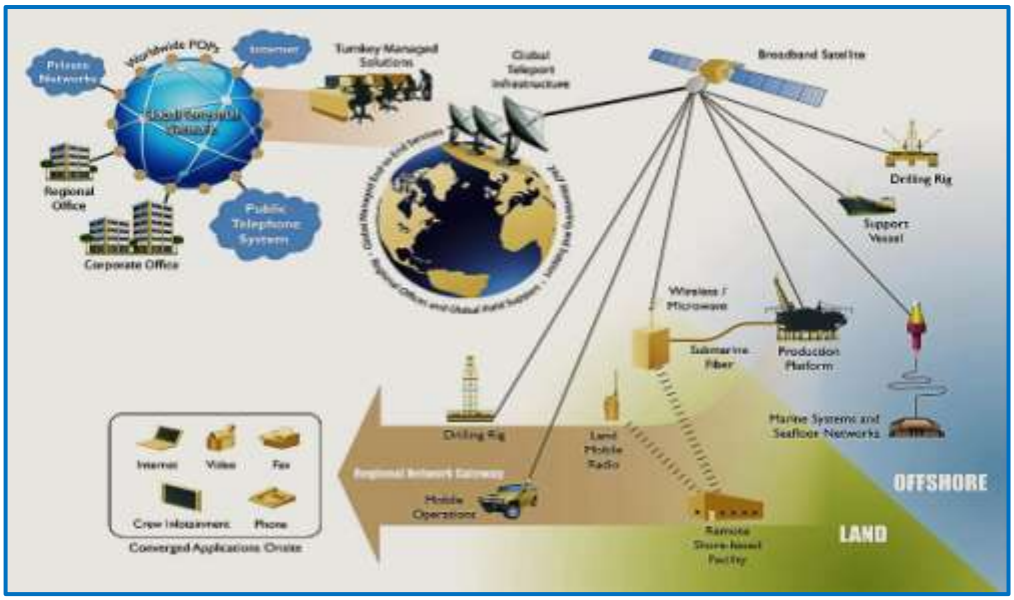
- **WiMax:** Provides high-capacity, short-range or mid-capacity, long-range services.
- **Microwave, 2-GHZ:** Provides medium-range coverage with fixed mast installation and operates in line, or near line, of sight, for offshore rigs.
- **VSat:** Provides flexibility for rapid deployments in the most remote and harsh locations, but constrained by high cost and limited bandwidth.
- **Cellular Radio 3G, 4G, 5G:** Provides mostly 4G and limited 5G, however, constrained due to contention ratio, signal unavailability, spectrum and ATEX compliant end devices.
- **Portable Satellites BGAN, Iridium, Thuraya:** Provide telephony and data solutions, however, with relatively expensive data rates.
- **Antennae, 2-GHZ:** Are placed close to communications equipment rooms, because of the low-gain antennae or the additional loss that long antenna leads would cause.

Very Small Aperture Terminal (VSAT): Is a two-way **satellite ground station** or a stabilized maritime antenna in a **dish form**, used to **transmit** narrowband data (Radio-Frequency Identification - RFID, SCADA, etc.), or **broadband data** (satellite Internet access, VoIP or video). VSATs are also used for transportable (phased array antennas) or mobile maritime communications. Data rates range up to **4 Mbit/s**, but upgraded modules can reach a maximum downlink up to **16 Mbit/s**. VSATs access satellites in geosynchronous orbit to establish data from small remote earth stations to other terminals (in mesh topology) or master earth station "*hubs*" (in star topology).

The VSATs range from **75 cm** (30 inches) to **1.2 m** (48 inches). Microwave companies offer a diverse product range of high-quality **microwave antennas** from **1.3 GHz to 86 GHz** for Point-to-Multipoint applications supporting all licensed and unlicensed band requirements. Applications include telecommunications backhaul WiMAX broadband wireless bands, ISM, LMDS and broadcast enterprise applications.

Broadband Global Area Network (BGAN): Is a **portable satellite terminal** for high-speed Internet and phone from **anywhere on the planet**, to deliver **broadband speeds** of up to 492 Kbps, small enough to be carried inside of a laptop case. BGAN terminals do not require an external **power source** for idle operation with an average of **36 hours** per charged battery. This system is an important communications tool to **thousands** of professionals and organizations, such as, industries, mobile offices, emergency, climate change, oil & gas, etc. The network is provided by **Inmarsat** and uses three geostationary satellites called I-4 to provide almost global coverage.

Iridium Satellite Phones: Is a **global** handheld **portable satellite** phone service, using a network of **66 low orbiting satellites**. With an Iridium satellite phone is **possible calls** from the middle of an ocean to the **nearest** station. A wide variety of Iridium phones are available including portable phones, such as the **Iridium 9555**. Iridium satellites pass overhead approximately every 7 minutes and the network automatically hands off to the next nearest satellite. However, the system cannot be used in a number of countries including Poland, North Korea, and Northern Sri-Lanka.



Thuraya: Is a **regional mobile satellite** phone provider. Thuraya comes from the **Arabic** name for the constellation of the **Pleiades**. The company is based in the **United Arab Emirates**, and provides mobile coverage to more than **110 countries** in Europe, the Middle East, North, Central and East Africa, Asia and Australia. Currently, operates **two** communications **satellites**. Thuraya 1 was for **testing** purposes, and now has been moved to junk orbit. Thuraya 2 is **located** in a geosynchronous orbit and serves most of Europe, Middle East, Africa and parts of Asia. Thuraya 3 is technically **the same** as Thuraya 2, but located in a close geosynchronous orbit.

Structured Cabling System: Is the wiring network that **carries data**, voice, multimedia, security, wireless connections, throughout a building or an industrial plant, including cabling, connecting hardwares, equipment and telecommunication rooms. Also include, VoIP, PoE, cable pathways, work areas, and even the jacks on **walls and racks**. The importance of structured cabling has increased right alongside the growth of LANs, MANs, and WANs.

LAN, WAN & MAN: *LAN or Local Area Network* is a computer network that **interconnect**s computers within a limited area, such as a home, school, computer labs or office buildings, using a network media. *WAN means Wide Area Network* and consists of **two** or more local-area networks (LANs). The largest WAN in existence is the **Internet**. *MAN or Metropolitan Area Network* is a network designed for a town or city.

VoIP & PoE: VoIP or Voice-over-Internet Protocol is a **methodology** and group of technologies for **voice communications** and multimedia Protocol (IP) networks. PoE means *Power over Ethernet* using industrial **Ethernet** switches to provide data and power over the same piece of cable. The terms commonly associated with VoIP are *IP telephony*, *Internet Telephony*, *Voice over Broadband* (VoBB), *Broadband Telephony*, *IP communications*, and *Broadband Phone Service*.

Unshielded Twisted Pair (UTP): An UTP cable consists of **four pairs of wires**, and each pair is **twisted** together with the purpose of **preventing** electromagnetic interference, or EMI. UTPs come in form of Cat 2, 3, 4, 5 and 6 grades; however, only Cat 5 e 6 are now recommended for any data applications. UTP cablings use RJ-45, RJ-11, RS-232, and RS-449 connectors. UTP applications are **telephone** networks using RJ-11 connectors, and 10BASE-T networks that use RJ-45 connectors. The maximum data transfer is 1000 Mbps for Gbit Ethernet.

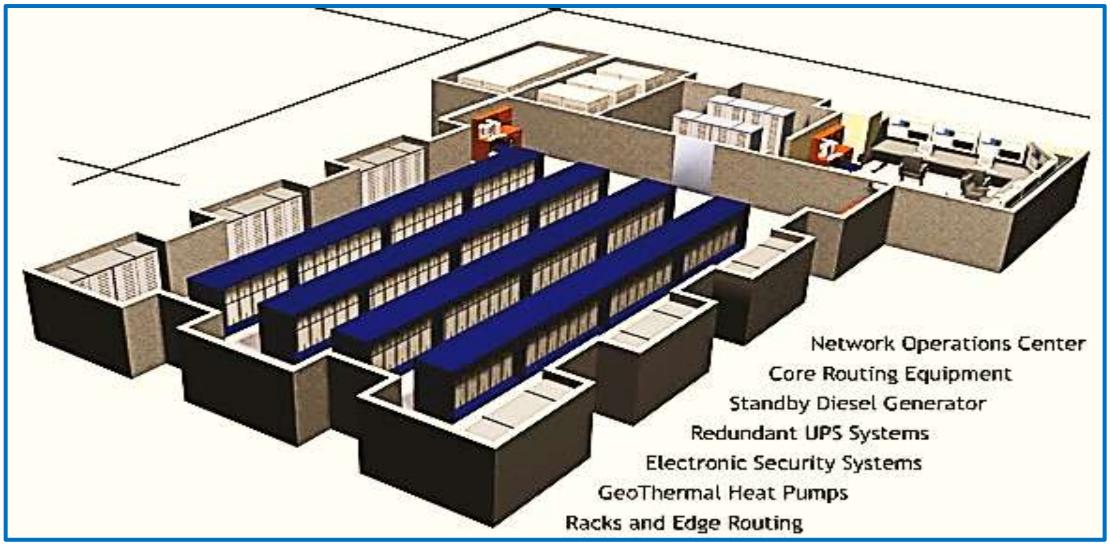
Shielded Twisted Pair (STP): Has also **four pairs of wires**, and each twisted pair wiring is **shielded** with an **insulating coating** that functions as a **ground** for wires and noise suppression. STPs cablings use RJ-45, RJ-11, RS-232, and RS-449 connectors for applications in electrically **noisy** environments. STPs also come in Cat 2, 3, 4, 5 or 6 grades, however, only Cat5 and 6 are recommended for any data applications. The maximum cable length with no signal regenerating device is **100 meters**, but the maximum data transfer rate is 500 Mbps.

Fieldbus Cabling: Fieldbus uses **twisted-pair wires**, commonly **shielded** twisted-pair cables for further noise suppression. The Fieldbus Foundation released the cable specification **FF-844** to provide the Fieldbus users **with guidance** in selecting cables, which includes the electrical requirements of **ISA 50.02** and **IEC 61158**, and additional requirements for use in fieldbus control networks. The **UL 2250 ITC** corresponds to **NEC** Article 727 Instrumentation Tray Cable, written to simplify the **guidelines** when the control circuits operate at **150 V** or less, and **5 A** or less.

Telephone Network: The most common telephone cables are *Category 5 and 6*, 4 pairs **22 AWG** solid copper. Along the installation road runs a thick cable packed **with 100** or more copper pairs. Many telephone lines are **bundled** together in a single cable using the **25-pair** color code. When it reaches the user area, acts as a digital concentrator and the customer end of that wire pair, is connected to a data access arrangement. RJ14 jacks are used when telephone wires are connected to two telephone lines. RJ11 jacks are used when only two of the telephone wires are connected in one telephone line.

Wireless Network: This system is used where **conventional** cabling infrastructure (copper or optical fiber) **cannot be used**, or in construction environments where passage of **cables** may be impractical. Telecom technologies evolve every day and there are **several types** of networks: LAN (Wireless Local Area Network), WLAN (Wireless Local Area Network), WMN (Wireless Metropolitan Networks), WMAN (Wireless Metropolitan Area Network), WWAN (Wireless Wide Area Network), WLL (Wireless Local Loop) and a new concept of wireless personal area networks or WPAN (Wireless Personal Area Network).

Data Centers: Are facilities used to **house computer systems** and associated components, such as **telecommunication** equipment, data and storage systems, **backup power** supplies (UPS´s and DRUPS´s), redundant data communications connections, environmental controls, HVAC (air conditioning), fire control suppressions, and many other safety devices. Design guidelines are ruled by the "***TIA/EIA-942****: Telecommunications Infrastructure Standards for Data Centers*", developed to ensure uniformity in design, performance, improvement and for data center designers who are beginners in the building development process.

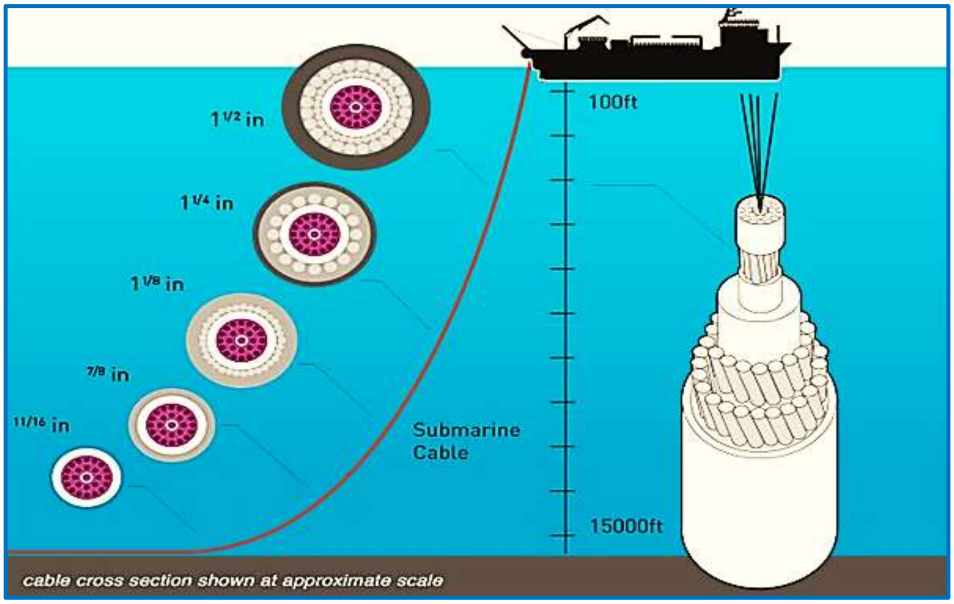


Bluetooth (IEEE 802.15.1): Is a **global standard** of wireless communication, allowing the transmission of data between **compatible devices**, that is, two or more devices can exchange information with simple **approximation** between them. Bluetooth is a standard for networks PAN (Personal Area Network). This **technology** allows a simple communication, quick, safe and cheap between computers, smartphones, cell phones, mouse, keyboards, headphones, printers, and other devices using radio waves instead of cables.

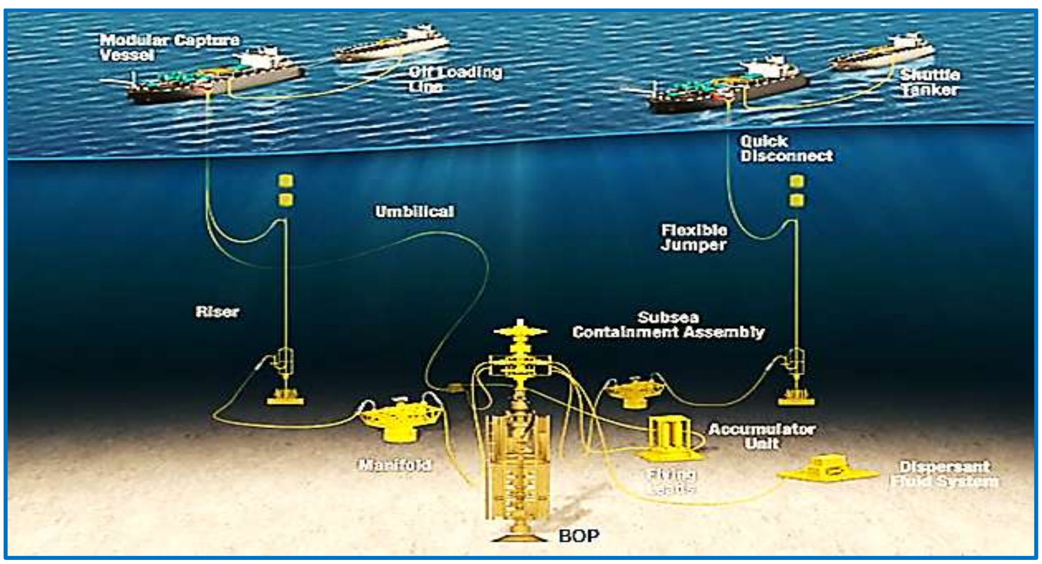
Optical Fiber Cables: Fiber optic technology ***uses light*** as its main information **carrier**. The cable consists of a core, a single continuous strand of **glass or plastic** that's measured in **microns (μ)** by the size of its outer diameter. Optical fiber cables are used to transmit voice, television and data signals through light waves. Fiber is the preferred cable for applications that require **high bandwidth**, long distances, and **immunity** to electrical interference. There are **two types** of optical fibers: *Singlemode and Multimode*. ***Singlemode fibers*** are used for applications of *wide area networks* (WAN). ***Multimode fibers*** are most frequently used in applications of *local network* (LAN).

Optical Telephone Cables: In the 1980s, **fiber optic cables** were developed. The first **transatlantic telephone cable** to use optical fiber was **TAT-8**, which went into operation in 1988. Modern optical fiber **repeaters** use solid-state optical amplifiers, usually an Erbium-doped **fiber amplifier**. Repeaters are powered by a **direct current** passed down the conductor near the center of the cable. A solid-state laser dispatches the **signal** into the next length of fiber and excites a short length of doped fiber that acts as a laser amplifier. As the light passes through the fiber, it is amplified, and also allows a wavelength-division multiplexing, which increases the capacity of the fiber.

Submarine Communications Cables: Are cables **laid on the sea bed** between land-based stations, to carry telecommunication signals across stretches of ocean. Modern cables use optical fiber technology to **carry digital data**, which includes telephone, Internet and international data traffic. The **first submarine communications cables** were laid in the **1850s**, to carry only telegraphy traffic. Subsequent generations carried telephone traffic, and data communications. Cables are typically **69 mm** (2.7 in) in diameter and weigh around **10 kg/m** (7 lb/ft), although thinner and lighter cables are used for deep-water sections.



Subsea Umbilicals: Are subsea cables that supplies **consumables** to offshore equipment, supply **air and power** to a hydraulic pressure assembly, electrical power and **fiber optics** to any subsea apparatus. Subsea umbilicals are deployed on the **seabed** (ocean floor), connected on platforms, to supply necessary control, energy (electric, hydraulic) and chemicals to oil & gas wells. Underwater umbilical cables, subsea risers, flowlines connectors and cable assemblies form important links for reliable operations.

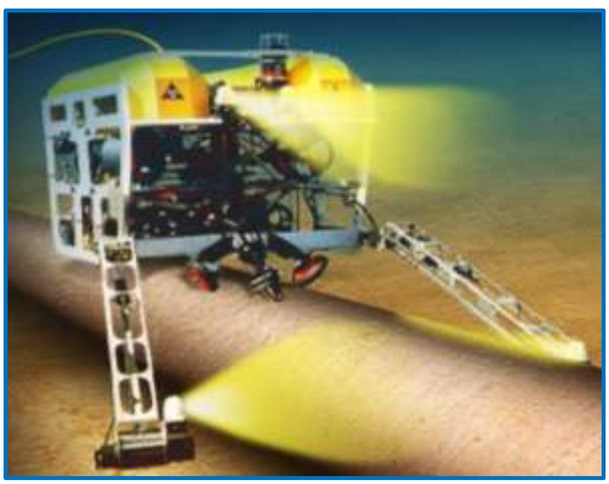


Instrumentation Cables: Are suitable for use with **digital or analogue** communication, telecoms, water treatment, oil & gas, petrochemical and to **carry data signals**. The signals can be for movement, time, measurement, alarm, pressure, temperature or voice, using a variety of transducers such as, pressure, proximity, analogic and digital instruments. The **BS5308** instrumentation cables standards are available with PVC or LSZH sheaths, designed to carry communication and control signals in a variety of installation types including the petrochemical industry.

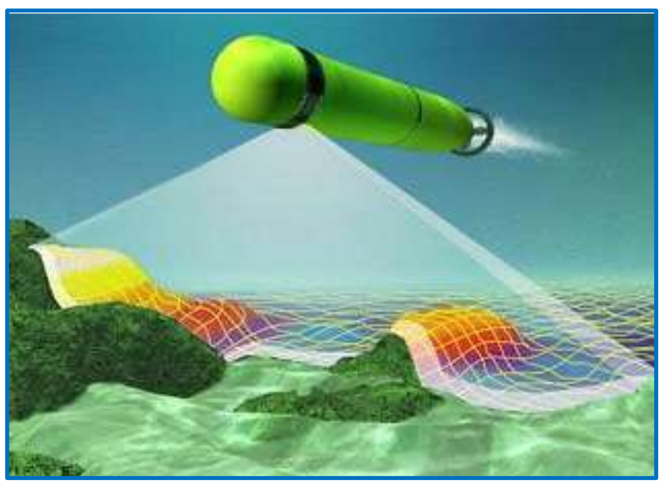
Bus Cables: Are applied in cabling **industrial field bus** systems, such as Profibus, Interbus, CAN, HART, etc., used in automation, machine tools, industrial plants and equipment, transport, conveying systems, Ethernet networks, actuator-sensor-interface components, and in an increasing number of industrial applications. In single words, **bus cables** technology can be applied in every branch of industry where process-control techniques are used.

Open System Interconnect (OSI): Foundation fieldbus is specified according to the simplified OSI model, consisting of **three layers**; Physical Layer (PHL), Data Link Layer (DLL) and Application Layer (APL). Application Layer of Foundation fieldbus consists of two sub-layers; Fieldbus Access sub-layer (FAS) and Fieldbus Message Specification (FMS). The **data unit** exchanged between the same layers is called "*Protocol Data Unit (PDU)*". A PDU may contain an optional data called "*Service Data Unit (SDU)*" which is a PDU of the next higher layer. A communication layer exchanges other PDUs without SDU to perform its functionality.

AUV's (Autonomous Underwater Vehicles): Or *ROV´s (Remote Operated Vehicles)* and *UUV (Unmanned Undersea Vehicles)* are used to make **general inspections**, maps, data transmissions, subsea maintenance evaluation, such as structures, umbilicals, pipelines and seafloor completions, in an effective manner with minimum disruption to the environment. Systems include communication module applications, high current, hydraulic power units (HPUs), optical fibers, UTPs, coaxial cables for video, phone, radio and computer communication or a combination of all.



ROV (Remote Operated Vehicle)



AUV (Autonomous Underwater Vehicle)

Virtual Communication Relationship (VCR): A Fieldbus device has **many VCRs** so that it can communicate with **various devices** or applications at the same time, because VCRs guarantee the messages go to the correct partner **without risks** of losing information. A VCR is identified by an application with device-local identifier called "*index*" specified in Application Layer. It is also identified from other devices with DL-address specified in Data Link Layers. A VCR has a **queue** (fast-in, fast-out memory) or a **buffer** (memory to store data) to save messages.

Riser Management System (RMS): Is commonly used on **drilling and completions**, to enhance **risers integrity** by tracking the historical performance and predicting behavior in the environmental conditions. Integrated with the **rig control** systems it provides a real-time information to optimize the riser handling during drilling, completion, and workover operations. This system has been installed on every type of MODU all over the world, to **support** operations and critical data.

OPGW (Optical Ground Wire): Is a special ***optical fiber cable*** installed at towers or poles of aerial power transmission lines, combining the functions of **grounding and communications**. OPGW cables typically contain **8 and 48 glass optical fibers** placed in a plastic tube for low transmission loss, allowing long distance transmission at high speeds. This optical fiber is also an insulator to protect against power transmission line and lightning induction, external noise and cross-talk.

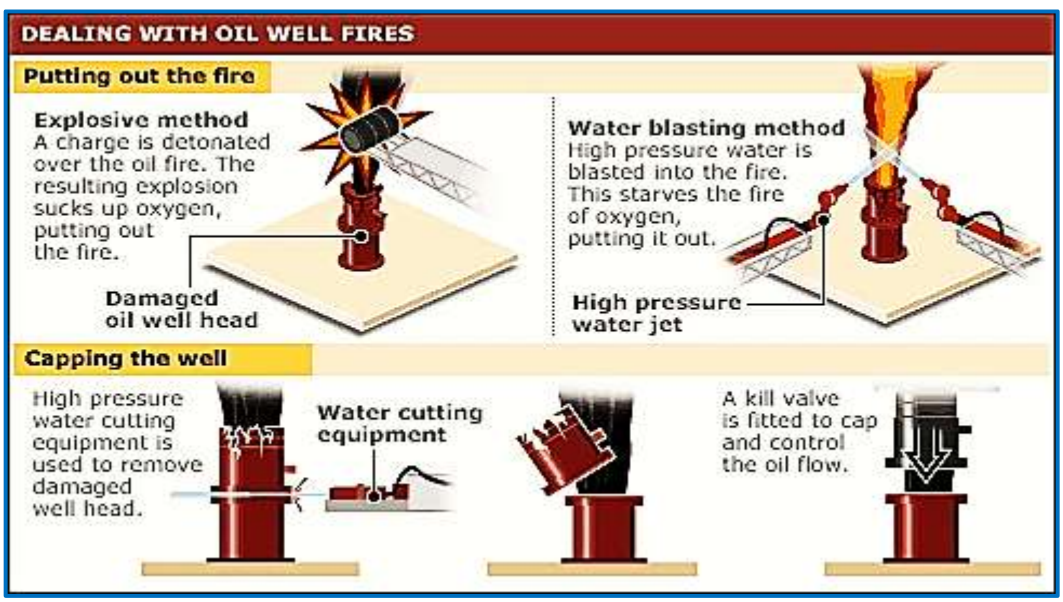
Fiber to the Premises (FTTP) or FTTH (Fiber to the Home): Is a form of fiber-optic communication delivery, where an **optical fiber** is installed in a **distribution** network, from the central office to the premises occupied by the subscriber. This system is the delivery of a communications signal over optical fiber from the operator's switching equipment to a home or business, thereby replacing existing copper infrastructure such as telephone wires and coaxial cable.

X. ONSHORE & OFFSHORE FIREFIGHTING SYSTEMS:

Oil well fires can be the result of human actions, such as accidents or natural events, such as lightning. A frequent cause of a well fire is a high-pressure blowout during drilling operations. In fighting a fire at a wellhead, it may be used high **explosives**, such as **dynamites**, to create a shockwave that pushes the **burning fuel** and local atmospheric oxygen away from the well. The flame is removed and the fuel can continue to spill out without catching on fire. After blowing out the fire, the wellhead must be capped to stop the flow of oil. However, the fuel and oxygen are present in copious amounts, and only one small spark (perhaps from a steel or iron tool striking a stone) or other heat source, might re-ignite the oil fire.

The NFPA is the first organization to **provide free public access** and develop codes and standards for **general firefighting**. For example, **NFPA 30** topics, include fire and explosion prevention and **risk control**, storage of liquids in containers, storage of liquids in tanks, piping systems, processing facilities, bulk loading and unloading, and wharves. As part of its commitment to enhancing public safety, NFPA makes its **codes and standards** available online to the public for free. NFPA is committed to serving the public's increasing interest in technical information, and online access to these key codes is a valuable resource. Techniques include:

- Using dynamite to 'blow out' the fire by forcing the burning fuel and oxygen away from the fuel source. This was one of the earliest effective methods and is still widely used. The first use was by Myron Kinley's father in California, in 1913.
- Dry Chemical (mainly Purple K) is commonly used on small well fires.
- Mechanical jaws were developed in the 1930s to clamp off the pipe below the fire, seldom used today. The design became the basis for a safety device used on offshore wells.
- Liquid nitrogen is also used to force the well bottom to reduce the oxygen supply and put out the fire.
- Raising the plume means placing a metal casing 30 to 40 feet high over the well head (thus raising the flame above the ground).
- Drill relief wells into the producing zone to redirect some of the oil and make the fire smaller. The first relief wells were drilled in Texas in the mid1930s.
- Nuclear Explosions was underground nuclear explosions employed in the former Soviet Union to stop well fires, the high heat of the detonation simultaneously displaces and melts the rock in its vicinity, and with that seals the previously drilled hole.



Note: The LeRoy Corporation constructed a **machine** with an arm that was positioned over an oil well pipe on fire. The machine lowers a **cap over the pip**e, extinguishing the flames, and later built 3 of these machines, and named them Shadrach, Meshach and Abednego, as the Biblical characters who survived death from a fiery furnace. Typically, large formation water flows lifted by the hydrocarbon flow, make ignition difficult if not impossible. Highly flammable blowouts may never ignite if no ignition source is present and flow is quickly dispersed. Thus, knowledgeable and experienced blowout specialists always restrict blowout access and carefully inspect the area around blowouts for ignition sources, particularly areas within an explosive vapor cloud.

Flashpoint is the lowest temperature at which a material gives off, as flammable vapors produce a momentary flash, when exposed to a small flame. The flash point of gasoline is **-43º C** (-45º F), which is the reason it is considered highly flammable. Methane has a relatively high spontaneous ignition temperature of **537ºC** (~1000ºF). This makes re-ignition of a methane fuel fire, after extinguishment, more difficult. In practice, low-flash-point, and low-spontaneous-ignition-temperature gas condensate present the **greatest blowout** ignition hazard, but explosive limit of differing blowouts, varies with chemical composition.

For gasoline vapor, the explosive range is from **1.3 to 6.0%** vapor to air. For methane, this range is **5 to 15%**. Crude oil is a highly volatile, explosive cocktail, which is lighter than water and burns twice as hot as coal. There is a minimum ratio of hydrocarbon vapor to air, below which ignition will not occur. Alternately, there is also a maximum ratio of hydrocarbon vapor to air, at which ignition will not occur. These limits are termed the lower and upper explosive limits. Vapor cloud explosion is possible, due the following sequence:

Most vapor cloud explosions are **deflagrations**, not detonations. The flame speed of a deflagration is *subsonic*, with flame speed increasing in restricted areas and decreasing in open areas. On the other hand, a detonation is *supersonic*, and proceeds through almost all of the available flammable vapor, at the detonation rate. Offshore rigs, production platforms and inland barges are at greatest risk. Hard-welded quarters and other enclosed areas are at particular risk, since it is also possible to get detonation in these confined areas.

The pressure-feed fires of a blowout, can totally destroy the surrounding steel structure in minutes. Firemen observed that derricks have fallen-in less than **30 minutes** after blowout ignition. The core temperature of a **28ºF** API crude oil blowout in Kuwait, was measured at **1,677ºC** (3,051ºF). Oil well firefighters commonly see surrounding sand and stones melted and fused on large fires. Steel loses most of its strength at **500ºC** (932ºF) and melts at **1,500ºC** (2,732º F).

Classification of Fires: Classification of fires is the systematic arrangement in classes of the various substances that as fuels produce heat by combustion, as follows:

- **Class A:** Ordinary combustible materials such as wood, cloth, paper, some types of rubbers and plastic materials.
- **Class B:** Flammable liquids, gases, greases, and some rubber and plastic materials. Flammable or inflammable liquids do not themselves burn or explode, but the gases or vapors heated and evaporated explode. The change of state from liquid to gas first occur.
- **Class C:** Live electrical equipment. When equipment is de-energized, extinguishers for **class A or B fire**s could be used safely; however, in fighting an electrical fire there are two important things to be taken into consideration, such as, damage to the equipment far beyond what the fire could do, and danger to the Individuals fighting the fire.
- **Class D:** Combustible metals such as magnesium, titanium, sodium, potassium, lithium, and zirconium.

Extinguishers Classification: Classification of fire extinguishers is another systematic arrangement in classes, where fuels produce fire by combustion, as follows:

- **Extinguishers for Class A Fires:** Multipurpose dry chemicals, foam extinguishers, loaded stream extinguishers;
- **Extinguishers for Class B Fires:** Multipurpose dry chemicals, foam, carbon dioxide (CO2), dry chemicals loaded stream extinguishers, Bromotrifluoromethane - Halon 1301;
- **Extinguishers for Class C Fires:** Multipurpose dry chemicals, Bromotrifluoromethane - Halon 1301, carbon dioxide (CO2);
- **Extinguishers for Class D Fires:** Extinguishers or extinguishing agents for class D fires shall be types approved for use on the specific combustible metal.

Water: The most important method to **limit fire damage** from a **blowout fire** is water and has been **the first** means of fighting fire. However, **water can damage** insulated conductors and windings, such as in motors and generators, and switchboard wirings. Damage to insulations due water soaking may require extensive drying out or rewiring operations and may be as much or more than the damage caused by the fire itself. For this reason, water should be used on a fire, only as a last resort. Water works to extinguish blowout fires by various means:

Main water use in **blowout firefighting is not to extinguish the fire**, but to **allow men and equipment to work** near the fire. Wells capped while burning may require more water than conventional extinguishing and capping efforts. Firefighters' efforts on burning blowouts, also involve removal of debris and working to get the fire burning vertically, not horizontally. Offshore marine vessels commonly have substantial firefighting capabilities, with firefighting equipment mounted high on the vessel, to allow water to reach even larger platforms.

Common use of **sprinkler heads**, and deluge nozzles in modern offshore production platforms, may greatly **reduce** the risk of a Piper Alpha type tragedy. Without modern fire water systems, blowout ignition is more likely the probable total loss of rigs or platforms. Water alone has extinguished some of the largest blowout fires, once flow was directed vertically by firefighters. Fire

pumps are commonly used on a typical large **firefighting barge rig**, and may provide a minimum of **4,000 gpm** with a **250 psi** head. Oil well firefighters use water piping systems, containing up to 4 inches high resistant material delivery piping, fire monitors and associated equipment. Modern derrick barges, pipeline barges, and large hydraulic dredge barges, are generally also used in off-shore, to support convenient firefighting efforts. On land, common mobile fire pumps, in use with civilian fire departments are commonly used on small fires. These truck-mounted pumps can provide from **1,500 to 3,000 gpm**.

Chemicals: Foam and **dry chemicals** are commonly used in oil well firefighting. Foam consists of water, foam concentrate and air, compounded on liquid hydrocarbon fires to **smothe**r the fuel surface, suppress vapor emissions (explosive vapor release), remove steam heat, displace oxygen, cool surfaces and reflect radiant heat. Foam can help contain fire near the source and allow work near the flow source. Dry **chemical extinguishers** work like water, but mainly act as a smothering agent. Common compounds used are **sodium bicarbonate**, Purple K (potassium bicarbonate base) and Monnex. Dry chemicals are generally used on **methane well fires**, where explosives cannot be used and water supply is inadequate. The main problem is that these systems are "*one shot*" devices, which cannot be topped up or refilled during application. The largest dry chemical extinguishers, commonly available, have **68 kg** of powder in storage.

Explosives: Are still **commonly used** in oil well firefighting, such as **80% nitroglycerin** grade dynamite. A slow-speed movie indicates that the explosion acts to temporarily drive fuel away from the point, where the flame develops, and deprive that immediate area of oxygen, to support instant re-ignition. Explosives are used today in **conjunction with water** to cool the shot and prevent re-ignition, when water supply or pump capability is insufficient to extinguish fire alone. Depending on fire size and prior experience up to **500 lb** of explosive may be used, however, as in any fire-fighting effort all ignition sources must be removed from the well area prior to making the shot. Typically, a smaller lube oil drum is used and packed with explosives. The drum is detonated using a detonating cord running through an athey wagon boom. The cord is electrically detonated at the front of the athey wagon, some 60 to 70 ft away from the explosive drum. Heat insulating, silicon based cloth and water spray are used to protect the explosives from the fire.

Well Fire Capping: The basic method involves using **conventional capping stacks**, equipping BOPs with heat shielding and water deluge, to limit a high temperature exposure. Once the BOPs are over the flow, and burning is underway above the riser tube, the flow within the capping stack helps to protect the BOPs. This technique was used on an **H2S** blowout in Canada after Boots & Coots replaced a company that lost two men, during conventional capping attempts.

Freeze Services: Are operations where a **fluid is pumped into the wellbore**, tree or valve, and then frozen, by **isolating** anything above or below the freeze area. During the freeze operation, a solution (often water based solutions) is pumped into the area to be frozen. The area is boxed in and packed with shavings of dry ice, or wrapped with copper pipe and insulated, then liquid nitrogen is pumped. Freezing is a delicate task, and takes many years to perfect time and temperature control for an effective operation. Once the operation is determined the wellbore is **sealed** by an ice plug, and a replacement section is taken off, such as, valves, tubing, etc., above the freeze plug. This process can save time and money verses a pump/kill operation to isolate surface equipment. It also prevents the possibility of damage to the formations from the kill fluids.

Pollution: This potential problem has not yet led to voluntarily ignite a blowout. However, after natural ignition, **major efforts** are taken to keep the fire burning lessens pollution. Operators have spent more money on **cleaning-up** than on blowout control, since ignition of an oil well blowout on an offshore platform, could complicate control efforts and likely total platform loss. Although scenarios predict long-lasting environmental impacts on a global atmospheric level due to the burning oil sources, ground level oil spill impacts, is much more detrimental to the environment regionally.

Fog Nozzles: Fog **spray** is also used to protect the **firefighter** in approaching a fire. Fires involving materials, other than liquids, require a balanced stream to break up or penetrate the burning material. Water use is determined by the type of fire to be extinguished as flammable liquid fires can be extinguished with water, only in the form of a fine spray or fog. The terms "*fog*" and "*spray*" are used interchangeably.

High-Expansion Foam: Is particularly suited as a flooding agent for use in difficult and **confined spaces**, transporting wet foam masses to inaccessible places, for volumetric displacement of vapor, heat, and smoke. Extinguisher foams are primarily used for control and extinguishment of fires involving flammable or combustible liquids, however, defined criteria and procedures must usually be met for the foam to be effective.

Carbon Dioxide (CO2) Extinguishers: Is based on the principle of using an inert gas to reduce and displace the oxygen content of the air. Since **CO2 is heavier** than air, has the ability to penetrate into loose material and confined spaces, has rapid expansion of the gas on discharging, and produces a refrigerating effect. This **refrigeration** turns into gas, and the process absorbs heat from the surrounding atmosphere. Most fires, where there are no flowing embers to maintain a high degree of heat for re-ignition, can be extinguished by a reduction of the oxygen content from the normal 21 percent to 15 percent.

Carbon Tetrachloride and Chloro-Bromo-Methane Extinguishers: Have toxic and **corrosive effects** and possible damage to some **electrical insulator**s, thus **they are not allowed** to use in any form installations. Inverting-type fire extinguishers, such as self-generating **soda acid**, self-generating foam, gas-cartridge water-type, or **portable fire extinguishers**, operate by inverting the unit to initiate an uncontrolled pressure and chemical reaction. These agents, are prohibited at facilities because their shells are subject to metal fatigue and creep at the welding seams, which can cause failure of the units, and harm operators.

Dry Chemical Extinguishers: Are extinguishers where the **powder** used consists principally of **bicarbonate of soda**, chemically processed to make it waterproof, noncorrosive, nonconducting, and free flowing. The **extinguishers** contain a **cartridge** of CO2 or nitrogen to expel the dry chemicals, suited mainly for electrical fires, rotating machinery and other equipment, since the powder is nonconductive and, in some types, nonabrasive. Expel a finely powdered dry chemical which, on striking flame, releases many times its volume in nontoxic fire-extinguishing gases, similar to CO2.

Fire Precautions: When fire starts and breaks out, the initial procedure is rapidly de-energize the circuit, and proceed the firefighting with CO2, dry chemical, or water (fog nozzle). Before implementing the Emergency Response Plan (ERP), every building, industry or process plants must designate and define training for a sufficient number of persons to assist in the safe and orderly emergency evacuation of employees. An alarm system which complies with OSHA (29 CFR 1910.165) must be established for alerting employees and/or fire-brigade members.

Safety: Recent deaths and near misses over the years, currently considerations are given to some blowouts for **safety**, mainly if **H2S** is present, and significant pollution potential, or close proximity to a civilian population. Automatic foam or CO2 systems should be checked, to see if are ready for operations all the time. All fire doors and shutters hardwares, including electrical apparatus and fusible links, should be in good conditions. Antifreeze **pump-tan**k extinguishers should be frequently inspected, kept full at all times, and refilled immediately after use, to prevent freezing or clogging of nozzles.

Automatic Sprinkler Systems: In the majority of buildings, industries and process plants, oil storage and oil purifier rooms must be provided with an **automatic water sprinkler** system, supplied with a valve blow-off line. These blow-off lines should be inspected monthly or with more frequently intervals, in order to **prevent** scale and rust from plugging up the sprinkler headers.Where power plants and switchyards have fog-nozzle-type, water-spray systems for transformer bank fire protection an initial test should be made for each system with the electrical transformers de-energized to see if the fog coverage is adequate. Subsequently, the waterlines should be flushed out annually to remove rust and scale and ensure proper functioning of the system.

Training: Foremen and other employees **should be instructe**d in the use of all fire equipment, so that they are able to bring it quickly into action in the event of fire, but also to realize the importance of this equipment are accessible and unobstructed at all times. Trained employees will not allow fire hoses or extinguishers to **become obstructed** by piles of construction or materials supplies, or allow fire doors to become blocked. In order to prepare employees with the necessary skills required in case of fire related emergencies, there are numerous colleges, universities and organizations that provide relevant fire safety training programmes dedicated especially to those working in the oil, gas and petrochemicals sector. Fire brigades are organized groups of employees who are knowledgeable, trained, and skilled in at least basic firefighting operations. Even employees engaged only in incipient-stage firefighting should be considered a fire brigade if they are organized in that manner.

All fire-brigade members should be **provided training and education**, commensurate with duties and functions. Fire brigade members will wear protective clothing, meeting the requirements of **OSHA** (29CFR 1910.156), which protects the head, body, and extremities, and consists of at least the following components: Foot and leg protection, hand protection, body protection, eye, face, and head protection. **NFPA 1001** standard identifies the minimum Job Performance Requirements (JPRs) for career and volunteer fire fighters whose duties are primarily structural in nature.

XI. REFERENCES AND LINKS:

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