

Oil and Gas Process

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The Natural Gas Production Industry

Natural gas systems encompass wells, gas gathering and processing facilities, storage, and transmission and distribution pipelines.

● Production & Processing

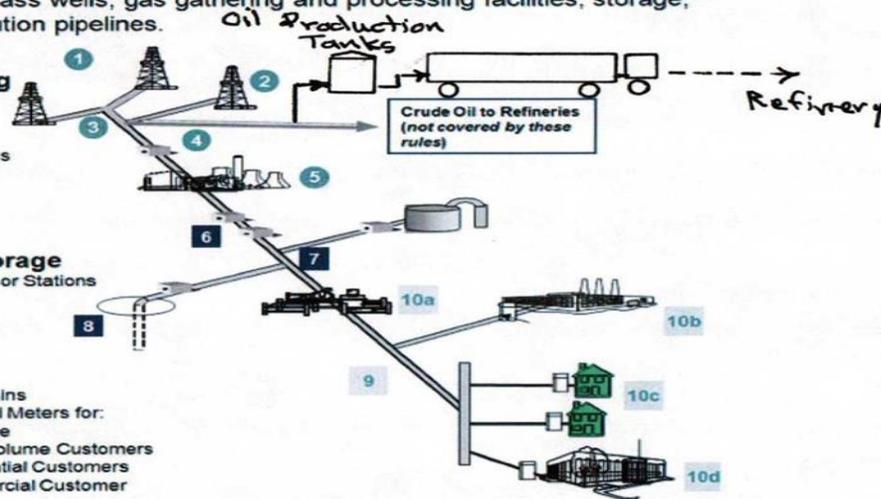
1. Drilling and Well Completion
2. Producing Wells
3. Gathering Lines
4. Gathering and Boosting Stations
5. Gas Processing Plant

■ Natural Gas Transmission & Storage

6. Transmission Compressor Stations
7. Transmission Pipeline
8. Underground Storage

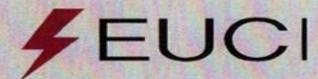
■ Distribution

9. Distribution Mains
10. Regulators and Meters for:
 - a. City Gate
 - b. Large Volume Customers
 - c. Residential Customers
 - d. Commercial Customer



Source: Adapted from American Gas Association and EPA Natural Gas STAR Program

Source: <http://www.epa.gov/airquality/oilandgas/basic.html>



The Oil and Gas Extraction Industry

The oil and gas extraction industry can be classified into four major processes: (1) exploration, (2) well development, (3) production, and (4) site abandonment.

Exploration involves the search for rock formations associated with oil or natural gas deposits, and involves geophysical prospecting and/or exploratory drilling.

Well development occurs after exploration has located an economically recoverable field, and involves the construction of one or more wells from the beginning (called *spudding*) to either abandonment if no hydrocarbons are found, or to well completion if hydrocarbons are found in sufficient quantities.

Production is the process of extracting the hydrocarbons and separating the mixture of liquid hydrocarbons, gas, water, and solids, removing the constituents that are non-saleable, and selling the liquid hydrocarbons and gas.

Production sites often handle crude oil from more than one well. Oil is nearly always processed at a refinery; natural gas may be processed to remove impurities either in the field or at a natural gas processing plant.

Site abandonment involves plugging the well(s) and restoring the site when a recently-drilled well lacks the potential to produce economic quantities of oil or gas, or when a production well is no longer economically viable.

Two ancillary processes are maintenance of the well and reservoir is important in sustaining the safety and productivity of the operation and in ensuring protection of the environment.

Exploration

Exploration

Oil and natural gas deposits are located almost exclusively in sedimentary rock and are often associated with certain geological structures.

- Geophysical exploration is the process of locating these structures in the subsurface via methods that fall under the category of remote sensing.
- In particular, common hydrocarbon-containing structures are those where a relatively porous rock has an overlying low-permeability rock that would trap the hydrocarbons.
- Two common structural traps are anticlines are upward folds in the rock layers, while faults are fractures in the Earth's surface where layers are shifted.

Geophysicists search for these structures by taking advantage of the fact that seismic waves will travel through, bend, absorb, and reflect differently off of various layers of rock.

- Geophysicists generate these seismic waves at the earth's surface, and measure the reflected seismic waves with a series of sensors known as geophones.
- Seismic waves can be generated by a variety of sources ranging from explosives that are detonated in holes drilled below the surface, to land vibroseis and marine airguns.
- Land vibroseis is typically used near populated areas and near sensitive environmental areas where detonations are not desirable.
- In the vibroseis process, trucks are used to drop a heavy weight on hard surfaces such as paved roads in order to create seismic waves.

Exploration

Exploration

In marine locations, explosives are less effective and have deleterious environmental impacts.

- In addition, vibroseis is impractical in water that is hundreds of feet deep.
- Seismic energy is therefore created by an airgun, a large device that can be emptied of air and water to create a vacuum.
- Seismic waves are created when water is allowed into the device at a very fast rate.
- Remote sensing cannot identify oil or gas accumulations directly.
- It can only indicate the potential for reserves via the presence or absence of certain rock characteristics that may be worthy of exploration.

Drilling

Drilling

During the drilling process, wellsite geologists will augment the remote geophysical data with wireline logs, which are taken by means of devices lowered into the wellbore with wires.

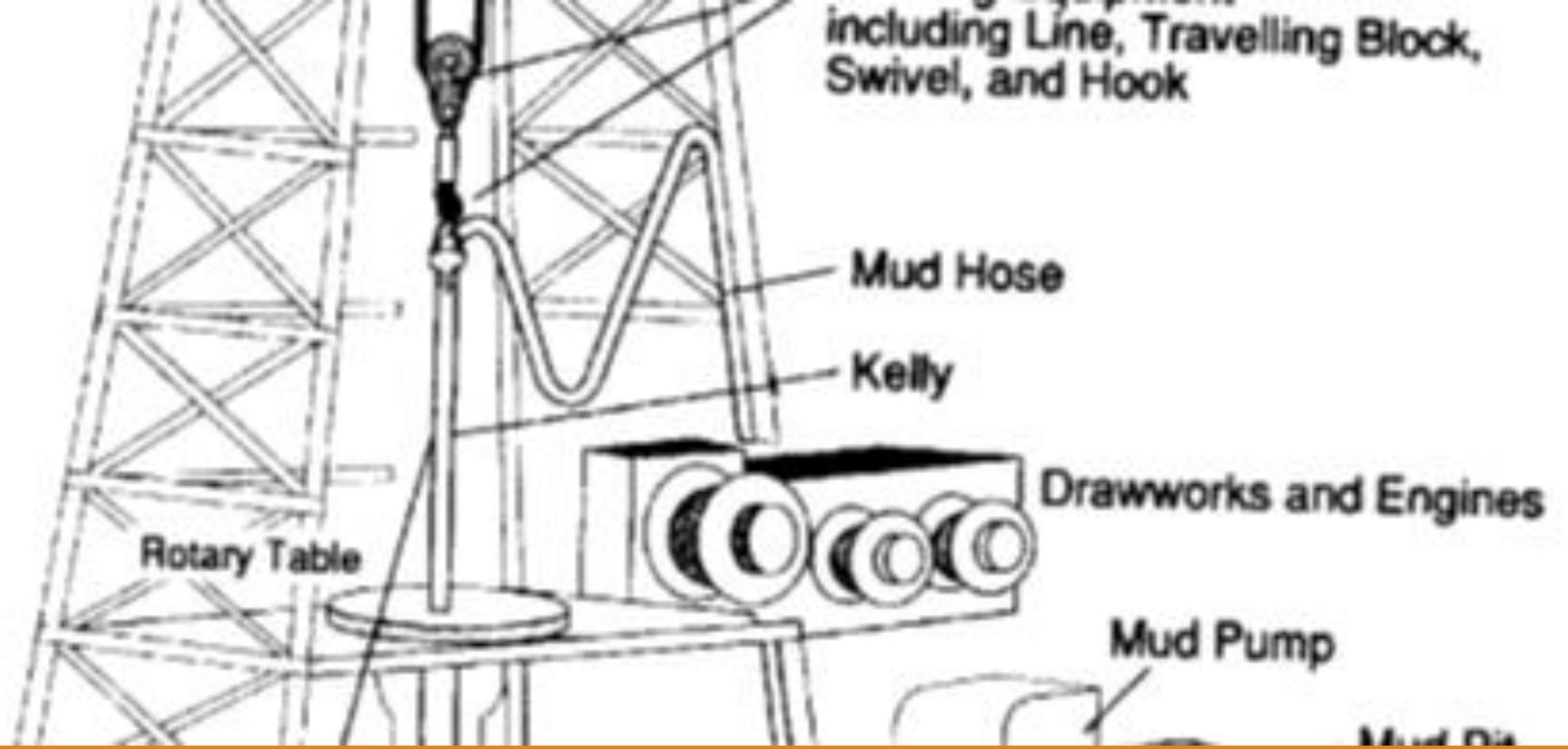
- Wireline logs include several types of measurements that help to characterize the depths and thickness of subsurface formations and the type of fluids that they may contain.
- As an example, one type of log analyzes the resistance of the formation to electrical current, which helps to indicate the type of fluid and the porosity of the formation.
- For exploratory wells, mud logs may also be developed, which document the drill rate, types of rocks encountered, and any hydrocarbons encountered.

Drilling

Drilling

For both onshore and offshore sites, the subterranean aspects of the drilling procedure are very similar.

- The drill bit is the component in direct contact with the rock at the bottom of the hole, and increases the depth of the hole by chipping off pieces of rock.
- The bit may be anywhere from three and three-fourths inches to two feet in diameter, and is usually studded with hardened steel or diamond.
- The selection of the drill bit can vary, depending on the type of rock and desired drilling speed.
- For example, a large-toothed steel bit may be used if the formation is soft and speed is important, while a diamond-studded bit may be used for hard formations or when a long drill life is desired.
- The drill bit is connected to the surface by several segments of hollow pipe, which together are called the *drill string*.
- The drill string is usually about 4 inches in diameter; drilling fluid is pumped down through its center and returns to the surface through the space, called the *annulus*, between the drill string and the rock formations or casing.



Source: Energy Information Administration, Department of Energy, 1991.

Drilling

Drilling fluid is an important component in the drilling process.

A fluid is required in the wellbore to:

- (1) to cool and lubricate the drill bit;
- (2) remove the rock fragments, or *drill cuttings*, from the drilling area and transport them to the surface;
- (3) counterbalance formation pressure to prevent formation fluids (i.e. oil, gas, and water) from entering the well prematurely, and
- (4) prevent the open (uncased) wellbore from caving in.

Drilling

Casing

- As the hole is drilled, casing is placed in the well to stabilize the hole and prevent caving. The casing also isolates water bearing and hydrocarbon bearing zones.
- Three or four separate casing “strings” (lengths of tubing of a given diameter) may be used in intermediate-depth wells.
- In locations where surface soils may cave in during drilling, a “conductor” casing may be placed at the surface, extending only twenty to one hundred feet from the surface.
- This string is often placed prior to the commencement of drilling with a pile driver.

Drilling

Casing

- The next string, or “surface” casing, begins at the surface and may penetrate two thousand to three thousand feet.
 - Its primary purpose is to protect the surrounding fresh-water aquifer(s) from the incursion of oil or brine from greater depths.
 - The “intermediate” string begins at the surface and ends within a couple thousand feet of the bottom of the wellbore.
 - This section prevents the hole from caving in and facilitates the movement of equipment used in the hole, e.g., drill strings and logging tools.
- The final “production” string extends the full length of the wellbore and encases the downhole production equipment.
- Shallow wells may have only two casing strings, and deeper wells may have multiple intermediate casings.
- After each casing string has been installed, cement is forced out through the bottom of the casing up the annulus to hold it in place and surface casing is cemented to the surface.
- Casing is cemented to prevent migration of fluids behind the casing and to prevent communication of higher pressure productive formations with lower pressure non-productive formations.
- Additional features and equipment will be installed during the completion process for production: perforations will allow reservoir fluid to enter the wellbore; tubing strings will carry the fluid to the surface; and packers (removable plugs) may be installed to isolate producing zones.

Well Completion

Well Completion

- When drilling has been completed, several steps may be needed before production begins.
- First, testing is performed to verify whether the hydrocarbon-bearing formations are capable of producing enough hydrocarbons to warrant well completion and production.
 - As many as three types of tests may be performed before the final (production) string of casing is installed.
 - These tests are coring, wireline logging, and drill stem testing.

Well Completion

Well Completion

- Coring is typically performed only in exploratory wells, and not in fields where several wells have already been drilled.
 - A special drill removes an intact sample, or *core*, of rock at the depth where oil or gas is most likely to be.
 - The core can be as short as 15 feet or as long as 90 feet.
 - Special side-wall coring techniques may be employed in some wells.
 - Unlike the more indirect testing methods described below, a core allows a geologist to observe the rock type directly, and measure its *porosity*, or the volume of fluid-occupying space relative to the volume of rock, and *permeability*, the ease with which fluids can flow through a porous rock.
- Wireline logging refers to the recording of acoustical, electrical resistivity, and other geophysical measurements within a wellbore.
 - These measurements provide detailed information on the geologic formations encountered by the well, and augment the seismic data recorded prior to the well drilling and the mud log for that well.
 - These data often help to determine more precisely the depth at which oil and gas could be produced.

Well Completion

Perforation

- When the production casing is cemented in the wellbore, the casing is sealed between the casing and the walls of the well.
 - For formation fluid (oil, gas, and water) to enter the well, the casing must be perforated.
 - The depth of the producing zone is determined by analyzing the logging data; small, directed explosive charges are detonated at this depth, thereby perforating the casing, cement, and formation.
 - The result is that formation fluid enters the well, yet the rest of the well's casing remains intact.

Stimulation

- Some formations may have a large amount of oil as indicated by coring and logging, but may have a poor flow rate.
 - This may be because the production zone is not have sufficient permeability, or because the formation was damaged or clogged during drilling operations.
 - In these cases, pores are opened in the formation to allow fluid to flow more easily into the well.
 - The hydraulic fracturing method involves introducing liquid at high pressure into the formation, thereby causing the formation to crack.
 - Sand or a similar porous substance is then emplaced into the cracks to prop the fractures open.
 - Another method, acidizing, involves pumping acid, most frequently hydrochloric acid, to the formation, which dissolves soluble material so that pores open and fluid flows more quickly into the well.

Well Completion

Production equipment installation

- When drilling, casing, and testing operations are completed, the drilling rig is removed and the production rig is installed.
 - In most cases, tubing is installed in the well which carries the liquids and gas to the surface.
 - At the surface, a series of valves, collectively called the Christmas tree because of its appearance, is installed to control the flow of fluid from the well.
 - Pumps are added if the formation pressure is not sufficient to force the formation fluid to the surface.
 - Different types of pumps are available; the most common is the rod pump.
 - The rod pump is suspended on a string of rods from a pumping unit, and the prime mover for pumping units can be an electric motor, or a gas engine.
- Equipment is usually installed onsite to separate natural gas and liquid phases of the production and remove impurities.
- A pipeline connection or storage container (tank) is connected to the well to facilitate transport or store the product.
- In the case of natural gas, which cannot be stored easily, a pipeline connection is necessary before the well can be placed on production.

Petroleum Production

Primary Production

- Primary recovery is the first stage of hydrocarbon production, and natural reservoir pressure is often used to recover oil.
 - When natural pressure is not sufficiently capable of forcing oil to the surface, artificial lift equipment is then employed.
 - This includes various types of pumps, gas lift valves, and may occasionally include oil stimulation.

Secondary Recovery

- Secondary recovery enhances the recovery of liquid hydrocarbons by repressurizing the reservoir and reestablishing or supporting the natural water drive.
 - Usually water which is produced with the oil is reinjected, but other sources of water may also be used.
 - This type of secondary recovery is generally called a “waterflood”.

Petroleum Production

Tertiary Recovery - A final method for removing the last extractable oil and gas is tertiary recovery.

- In contrast to primary and secondary recovery techniques, tertiary recovery involves the addition of materials not normally found in the reservoir.
- These methods are often expensive and energy-intensive.
- In most cases, a substance is injected into the reservoir, mobilizes the oil or gas, and is removed with the product. Examples include:
 - Thermal recovery, in which the reservoir fluid is heated either with the injection of steam or by controlled burning in the reservoir, which makes the fluid less viscous and more conducive to flow;
 - Miscible injection, in which an oil-miscible fluid, such as carbon dioxide or an alcohol, is injected to reduce the oil density and cause it to rise to the surface more easily;
 - Surfactants, which essentially wash the oil from the reservoir; and
 - Microbial enhanced recovery, in which special organic-digesting
 - microbes are injected along with oxygen into the formation to digest
 - heavy oil and asphalt, thereby allowing lighter oil to flow

Crude Oil Separation

When the formation fluid is brought to the surface, it may contain a spectrum of substances including natural gas, water, sand, silt, and any additives used to enhance extraction.

The general order of separation with respect to oil is the following: the separation of gaseous components, the removal of solids and water, and the breaking up of oil-water emulsions. (The conditioning of the natural gas that is removed in the first step will be discussed in the next subsection.)

- The removal of gaseous components primarily is intended to remove natural gas from the liquid; however, gaseous contaminants such as hydrogen sulfide (H₂S) also may be produced in some fields during this process.
 - The gases are removed by passing the pressurized fluid through one or two decreasing pressure chambers; less and less gas will remain dissolved in the solution as the pressure is lowered.
- The liquids and solids that remain are usually a complex mix of water, oil, and sand.
 - Water and oil are generally immiscible; however, the extraction process is usually very turbulent and may cause the water and oil to form an emulsion, in which the oil forms tiny droplets in the water (or vice versa).
 - Fluid separation often produces a layer of sand, a layer of relatively oil-free water, a layer of emulsion, and a (small) layer of relatively pure oil.
 - The free water and sand, or basic sediment and water (BS&W) are generally removed by a process called free water knockout, in which the BS&W are removed primarily by gravity.
 - Finally, emulsions are broken by heating the fluid in a heater-treater to a temperature of 100-160 degrees fahrenheit, or by treating it with emulsion-breaking chemicals.
 - Following the emulsion breaking, the oil is about 98 percent pure, which is sufficient for storage or transportation to the refinery.

Natural Gas Conditioning

Natural gas conditioning is the process of removing impurities from the gas stream so that it is of high enough quality to pass through transportation systems.

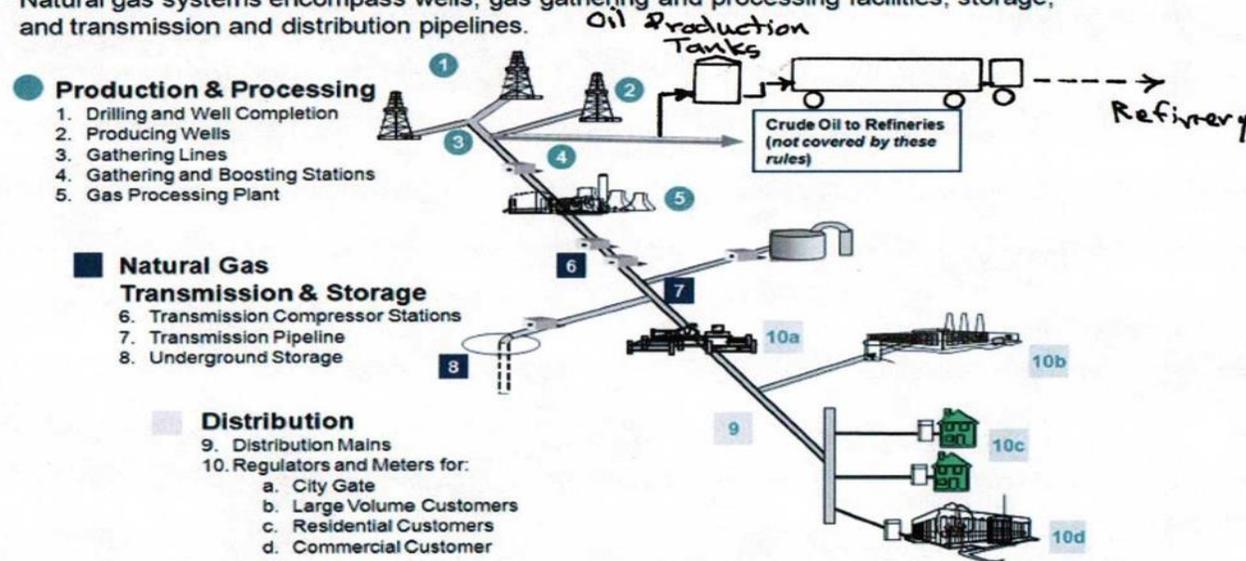
- It should be noted that conditioning is not always required; natural gas from some formations emerges from the well sufficiently pure that it can pass directly to the pipeline.
- As the natural gas is separated from the liquid components, it may contain impurities that pose potential hazards or problems.
- The most significant is hydrogen sulfide (H₂S), which may or may not be contained in natural gas.
- Hydrogen sulfide is toxic (and potentially fatal at certain concentrations) and is desirable to remove it as soon as possible in the conditioning process.
- Another concern is that posed by water vapor.
- At high pressures, water can react with components in the gas to form gas hydrates, which are solids that can clog pipes, valves, and gauges.
- Nitrogen and other gases may also be mixed with the natural gas (methane) in the subsurface.
- These other gases must be separated from the methane prior to sale. At cold temperatures the water can freeze, also clogging pipes, valves, and gauges.
- High vapor pressure hydrocarbons that are found to be liquids at surface temperature and pressure (benzene, toluene, ethylbenzene, and xylene, or BTEX) are removed and processed separately.

Two significant natural gas conditioning processes are dehydration and sweetening.

- Dehydration is performed to remove water from the gas stream.
- Three main approaches toward dehydration are the use of a liquid or solid desiccant, and refrigeration.
- When using a liquid desiccant, the gas is exposed to a glycol that absorbs the water.
- Sweetening is the procedure in which H₂S and sometimes CO₂ are removed from the gas stream. The most common method is amine treatment.

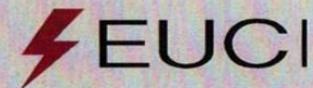
The Natural Gas Production Industry

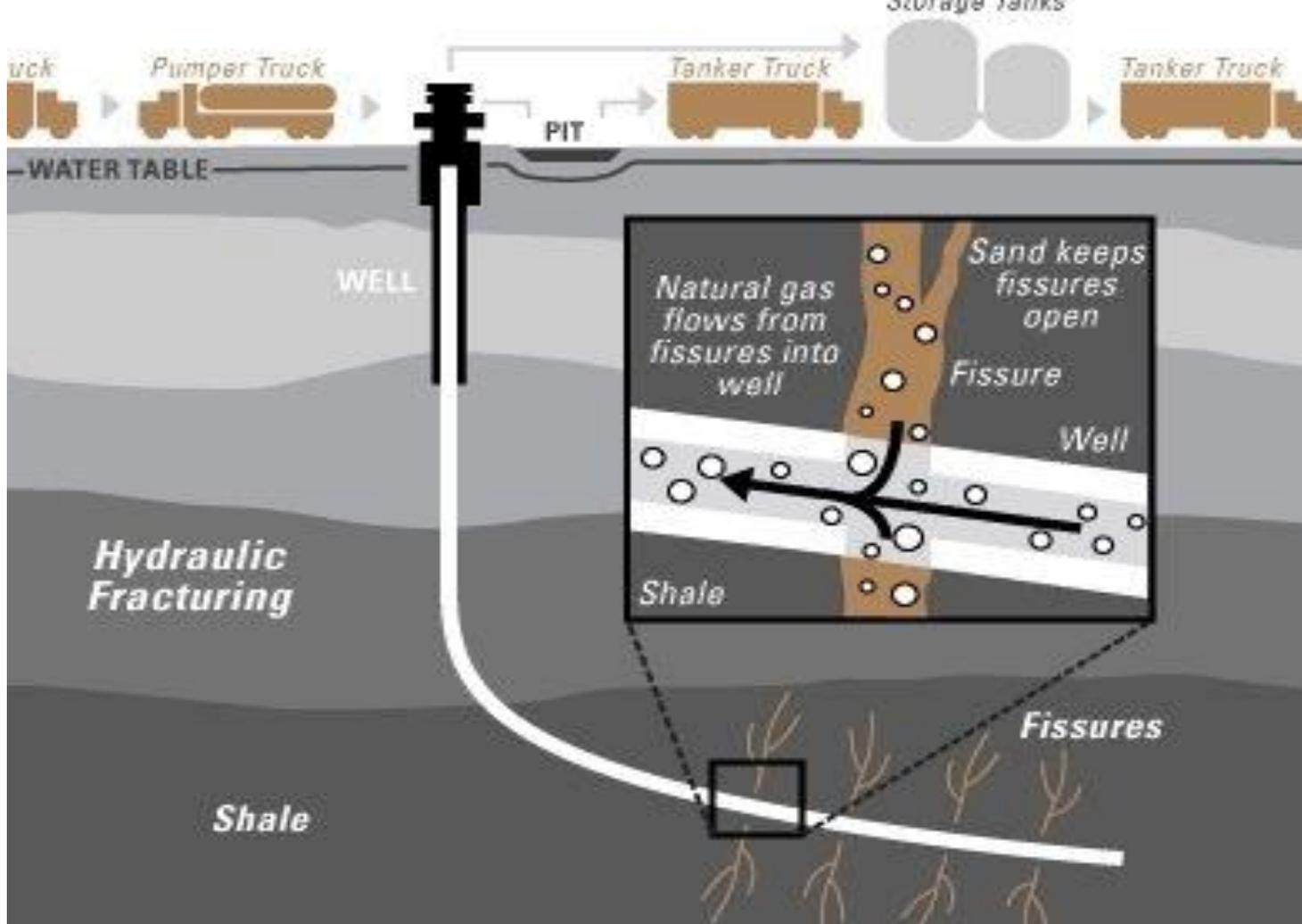
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Source: Adapted from American Gas Association and EPA Natural Gas STAR Program

Source: <http://www.epa.gov/airquality/oilandgas/basic.html>





Non copyrighted diagram from:
<http://vtdigger.org/2012/05/04/vermont-first-state-in-nation-to-ban-fracking-for-oil-and-gas/>

The Process of Hydraulic Fracturing

A hydraulic fracture is formed by pumping [fracturing fluid](#) into a wellbore at a rate sufficient to increase pressure at the target depth (determined by the location of the well casing perforations), to exceed that of the fracture *gradient* (pressure gradient) of the rock.

The fracture gradient is defined as pressure increase per unit of depth relative to density, and is usually measured in pounds per square inch.

The rock cracks, and the fracture fluid permeates the rock extending the crack further and further.

Fractures are localized as pressure drops off with the rate of frictional loss, which is relevant to the distance from the well. Operators typically try to maintain "fracture width", or slow its decline following treatment, by introducing a [proppant](#) into the injected fluid – a material such as grains of sand, ceramic, or other particulate, thus preventing the fractures from closing when injection is stopped and pressure removed.

The propped fracture is permeable enough to allow the flow of gas, oil, salt water and hydraulic fracturing fluids to the well.

The location of one or more fractures along the length of the borehole is strictly controlled by various methods that create or seal holes in the side of the wellbore.

Hydraulic fracturing is performed in [cased](#) wellbores, and the zones to be fractured are accessed by [perforating](#) the casing at those locations.

Once the injection process is completed, the internal pressure of the rock formation causes fluid to return to the surface through the wellbore.

This fluid is known as both "flowback" and "produced water" and may contain the injected chemicals plus naturally occurring materials such as brines, metals, radionuclides, and hydrocarbons.

The flowback and produced water is typically stored on site in tanks or pits before treatment, disposal or recycling. It is [injected underground for disposal](#) or it may be treated and reused.

Hydraulic-fracturing equipment used in oil and natural gas fields usually consists of a slurry blender, one or more high-pressure, high-volume fracturing pumps (typically powerful triplex or quintuplex pumps) and a monitoring unit.

Associated equipment includes fracturing tanks, one or more units for storage and handling of proppant, high-pressure treating iron, a chemical additive unit (used to accurately monitor chemical addition), low-pressure flexible hoses, and many gauges and meters for flow rate, fluid density, and treating pressure.

Chemical additives are typically 0.5% percent of the total fluid volume. Fracturing equipment operates over a range of pressures and injection rates, and can reach up to 15,000 psi and 100 barrels per minute.

Shell, Anacortes, Washington



Common Process Units In A Refinery

[Desalter](#) unit washes out salt from the crude oil before it enters the atmospheric distillation unit.

Atmospheric distillation unit distills crude oil into fractions. See [continuous distillation](#).

[Vacuum distillation](#) unit further distills residual bottoms after atmospheric distillation.

Naphtha [hydrotreater](#) unit uses [hydrogen](#) to desulfurize naphtha from atmospheric distillation. Must hydrotreat the naphtha before sending to a catalytic reformer unit.

[Catalytic reformer](#) unit is used to convert the naphtha-boiling range molecules into higher octane [reformate](#) (reformer product). The reformate has higher content of aromatics and cyclic hydrocarbons). An important byproduct of a reformer is hydrogen released during the catalyst reaction. The hydrogen is used either in the hydrotreaters or the hydrocracker.

[Distillate hydrotreater](#) desulfurizes distillates (such as diesel) after atmospheric distillation.

[Fluid Catalytic Cracker](#) (FCC) unit upgrades heavier fractions into lighter, more valuable products.

[Hydrocracker](#) unit uses hydrogen to upgrade heavier fractions into lighter, more valuable products.

[Visbreaking](#) unit upgrades heavy residual oils by thermally cracking them into lighter, more valuable reduced viscosity products.

[Merox](#) unit treats LPG, kerosene or jet fuel by oxidizing [mercaptans](#) to organic [disulfides](#).

Common Process Units In A Refinery

Alternative processes for removing mercaptans are known, e.g. [doctor sweetening process](#) and caustic washing.

[Coking units](#) ([delayed coking](#), fluid coker, and flexicoker) process very heavy residual oils into gasoline and diesel fuel, leaving petroleum coke as a residual product.

[Alkylation](#) unit uses [sulfuric acid](#) or [hydrofluoric acid](#) to produce high-octane components for gasoline blending.

[Dimerization](#) unit converts [olefins](#) into higher-octane gasoline blending components. For example, [butenes](#) can be dimerized into isooctene which may subsequently be hydrogenated to form [isooctane](#). There are also other uses for dimerization. Gasoline produced through dimerization is highly unsaturated and very reactive. It tends spontaneously to form gums. For this reason the effluent from the dimerization need to be blended into the finished gasoline pool immediately or hydrogenated.

[Isomerization](#) unit converts linear molecules to higher-octane branched molecules for blending into gasoline or feed to alkylation units.

[Steam reforming](#) unit produces hydrogen for the hydrotreaters or hydrocracker.

Liquefied gas storage vessels store propane and similar gaseous fuels at pressure sufficient to maintain them in liquid form. These are usually spherical vessels or "bullets" (i.e., horizontal vessels with rounded ends).

Storage tanks store crude oil and finished products, usually cylindrical, with some sort of vapor emission control and surrounded by an earthen [berm](#) to contain spills.

[Amine gas treater](#), [Claus unit](#), and tail gas treatment convert [hydrogen sulfide](#) from [hydrodesulfurization](#) into elemental sulfur.

Utility units such as [cooling towers](#) circulate cooling water, [boiler plants](#) generates [steam](#), and instrument air systems include pneumatically operated [control valves](#) and an [electrical substation](#).

[Wastewater](#) collection and treating systems consist of [API separators](#), [dissolved air flotation \(DAF\) units](#) and further treatment units such as an [activated sludge](#) biotreater to make water suitable for reuse or for disposal.^[3]

Solvent refining units use solvent such as [cresol](#) or [furfural](#) to remove unwanted, mainly aromatics from lubricating oil stock or diesel stock.

Solvent dewaxing units remove the heavy waxy constituents [petrolatum](#) from vacuum distillation products.

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