

Lecture (1)

DEFINITIONS

Natural gas (or fossil gas) is the gas obtained from natural underground reservoirs either as free gas or gas associated with crude oil. It generally contains large amounts of methane (CH_4) along with decreasing amounts of other hydrocarbons. Impurities such as H_2S , N_2 , and CO_2 are often found with the gas. It also generally comes saturated with water vapor.

Natural gas engineering is the application of petroleum engineering know-how to the development of natural gas resources. Natural gas engineering research includes topics such as how to extract gas and natural gas liquids efficiently from reservoirs taking into account geology, well locations, well type, well performance, injection and production strategies, production history, reservoir characteristics, fluid characteristics, economics and many other factors.

Pipeline Gas is the gas which has the quality to be used as a domestic or industrial fuel. It meets the specifications set by a pipeline transmission company, and/or distributing company.

Sour Gas: Gas that contains more than 1 grain of H_2S /100 SCF

Sweet Gas: Gas in which the H_2S content is less than 1 grain /100 SCF.

Wet Gas: Gas that contains more than 0.1 US gallons of condensates per 1000 CF of gas.

Dry Gas: Gas that contains less than 0.1 US gallons of condensates per 1000 CF of gas.

Rich Gas: Gas containing more than 5 to 7 US gallons of compounds heavier than ethane (C_3^+) per 1000 CF of the gas.

Lean Gas: Gas containing 1 US gallons or less of compounds heavier than ethane (C_3^+) per 1000 CF of the gas.

Pentanes+ : The pentane and heavier fraction of hydrocarbon liquid.

Condensates: The hydrocarbon liquid fraction obtained from a gas stream containing essentially pentanes.

Liquefied natural gas (LNG):

- When natural gas is cooled to a temperature of approximately $-260\text{ }^{\circ}\text{F}$ ($-160\text{ }^{\circ}\text{C}$) at atmospheric pressure it condenses to a liquid called liquefied natural gas (LNG).
- One volume of this liquid takes up about 1/600th the volume of natural gas at a stove burner tip.
- LNG is only about 45% the density of water.
- LNG is odorless, colorless, non-corrosive, and non-toxic.
- When vaporized it burns only in concentrations of 5% to 15% when mixed with air.
- Neither LNG, nor its vapor, can explode in an unconfined environment.

Compressed natural gas (CNG):

- Is natural gas pressurized and stored in welding bottle-like tanks at pressures up to 3,600 psig (25 MPa).
- Typically, it is same composition of the local "pipeline" gas, with some of the water removed.

Liquid petroleum gas (LPG):

- Sometimes called propane is often confused with LNG and vice versa. They are not the same and the differences are significant.
- Varieties of LPG bought and sold include mixes that are primarily propane, mixes that are primarily butane, and mixes including propane, propylene, n-butane, butylene and iso-butane.
- Depending on the season—in winter more propane, in summer more butane. Vapor pressures, at 30°C, are for commercial propane in the range 10-12 barg (1 to 1.2 MPa), for commercial butane, 2-4 barg (0.2 to 0.4 MPa). In some countries LPG is composed primarily of propane (upwards to 95%) and smaller quantities of butane.

LPG compared to natural gas

1. LPG has a higher energy content at 93.2MJ/m³ vs natural gas at 38.7MJ/m³
2. LPG ratio for air-to-gas mixture (propane: 24:1, butane: 30:1) for good combustion vs LNG (10:1).
3. LPG can be stored as a liquid in tanks by applying pressure alone. While the distribution of LNG requires heavy infrastructure investments (pipelines, etc.), LPG is portable. This fact makes LPG very interesting for developing countries and rural areas.
4. LPG is distributed in gas bottles and tanks vs natural gas being conveyed via pipeline.
5. LPG appliances operate at 2.75 kPa vs 1.1 kPa for natural gas appliances.
6. LPG is heavier than air vs natural gas which is lighter than air.

LPG (sometimes called autogas) has also been used as fuel in light duty vehicles for many years. An increasing number of petrol stations around the world offer LPG pumps as well. A final example that should not be forgotten is that the "bottled gas" can often be found under barbecue grills.

Lecture (2)

GASEOUS FUELS

Type of Gaseous Fuels

The following is a list of the types of gaseous fuel:

(A) Fuels naturally found in nature:

- Natural gas
- Methane from coal mines

(B) Fuel gases made from solid fuel

- Gases derived from Coal
- Gases derived from waste and Biomass
- From other industrial processes (Blast furnace gas)

(C) Gases made from petroleum

- Liquefied Petroleum gas (LPG)
- Refinery gases
- Gases from oil gasification

(D) Gases from some fermentation processes.

The Importance of Gaseous Fuels

- Generally, very clean burning. Little soot. Operate with low XSA.
- Easy to burn - No grinding or atomization. Excellent mixing
- No problems with erosion or corrosion
- No ash
- The gas is easy to clean. E.g. if sulfur is present, it may be easily removed prior to combustion.
- Simplest combustion plant of all {Burners, Control system, No ash problems, Heat exchangers, can be started up and shut down very easily and quickly}.

Disadvantages of gaseous fuels

- Problems with distribution and storage
- Explosion risk - very volatile.
- Relatively costly. Offset by cheaper and more efficient plant.

Classification of Natural Gas

There are two different classifications of natural gas:

First classification: This classification divides natural gas into two types:

1) Hydrocarbon gases (methane (CH₄), ethane (C₂H₆), propane (C₃H₈), butane (C₄H₁₀), pentane (C₅H₁₂) and hexane (C₆H₁₄)).

2) Non-hydrocarbon gases (hydrogen (H₂), nitrogen (N₂), carbon dioxide (CO₂), hydrogen sulfide (H₂S) and inert gases (helium (He), argon (Ar), krypton (Kr) and radon (Rn)).

Table 1: Hydrocarbon gases

Name	Symbol	Molecular formula
Methane	C ₁	CH ₄
Ethane	C ₂	C ₂ H ₆
Propane	C ₃	C ₃ H ₈
Butane	C ₄	C ₄ H ₁₀
Pentane	C ₅	C ₅ H ₁₂
Hexane	C ₆	C ₆ H ₁₄

Second classification: This classification depends on the origin and therefore the natural gases are divided into three types:

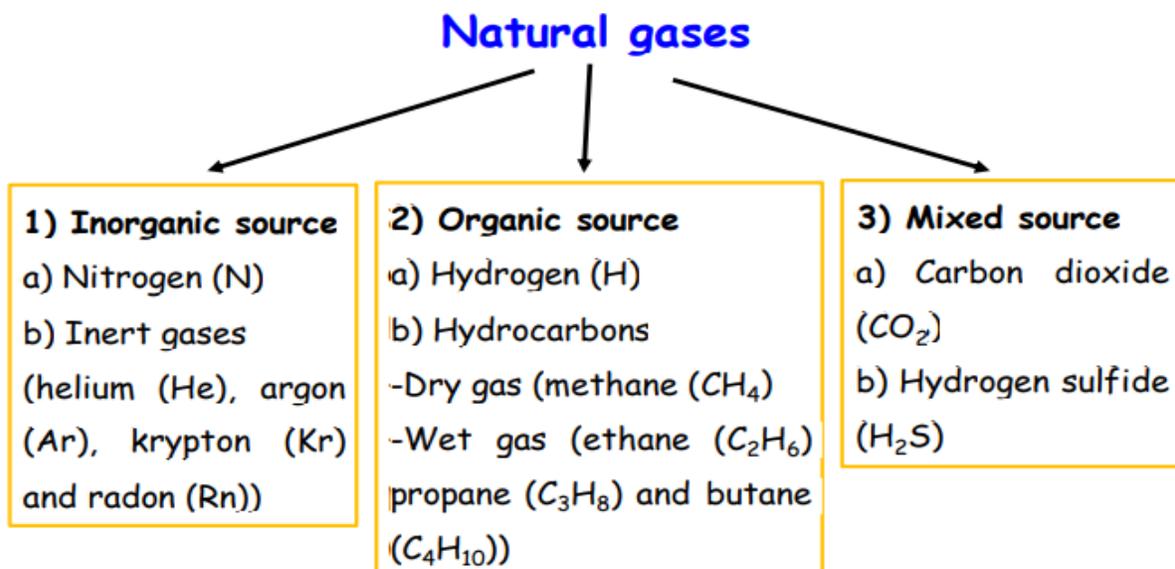


Figure 1: Classification of natural gas.

Natural Gas Fundamentals

Origin & Composition

Natural gas is a fossil fuel source of energy, which represents more than one fifth of total energy consumption in the world. It has been the fastest growing fossil fuel since the seventies.

Natural gas is used primarily as *a fuel and as a raw material in manufacturing*.

- It is used in home furnaces, water heaters, and cooking stoves. As an industrial fuel, it is used in brick, cement, and ceramic-tile kilns; in glass making; for generating steam in water boilers; and as a clean heat source for sterilizing instruments and processing foods.
- As a raw material in petrochemical manufacturing. Ethylene, an important petrochemical, is produced from natural gas.
- Natural gas is used to produce hydrogen, sulfur, carbon black, and ammonia. The ammonia is used in a range of fertilizers and as a secondary feedstock for manufacturing other chemicals, including nitric acid and urea.

Natural gas is considered *as an environmentally friendly clean fuel*, offering important environmental benefits when compared to other fossil fuels.

Hydrocarbon gases are common in marine sediments. Such gases originate from decomposition of organic matter by biochemical and chemical processes. There are three main stages of natural gas formation. The earliest stage is biological C1 formation, which occurs at low temperatures (<50oC) under certain environmental conditions. The next stage is early thermogenic (nonbiological) gas formation, in which the whole series of gaseous and liquid hydrocarbons are

formed at rates that become geologically significant when burial temperatures are in the range of 80-120°C. Late thermogenic C1-rich gas is produced during the last stage of gas formation, at temperatures higher than about 150°C at which previously formed heavier hydrocarbons are converted to C1. Natural gas formed during each of these stages has a characteristic chemical and isotopic composition.

Based on the methane content, there are two general types of hydrocarbon gases:

- **Biogenic gas** ($\geq 95\%$ methane) is formed at shallow depths and low temperatures by the anaerobic bacterial decomposition of sedimentary organic matter. Biogenic gas consists almost entirely of methane.

Methanogens are microscopic organisms which live in environments devoid of oxygen and chemically decompose organic matter, creating methane as a byproduct.

- **Thermogenic gas** ($< 95\%$ methane) is formed at deeper depths by:

- (1) Thermal cracking of sedimentary organic matter into hydrocarbon liquids and gas

- (2) Thermal cracking of oil at high temperatures into gas.

Thermogenic gas can also contain significant concentrations of ethane, propane, butanes, and heavier hydrocarbons.

Natural Gas Resources

The presence of gas in a mixture of hydrocarbons depends on their phase behavior, which in turn, depends greatly on:

- The pressure and temperature of the mixture which both increase with depth
- The history of the reservoir.

It is generally true that the same organic matter could have evolved into :

- Coal,
- Heavy oil with virtually no gas, usually found at depth ≤ 3000 ft
- Light oil with lots of dissolved gas, at depths > 3000 ft Oil becomes lighter which means that gas coexist with oil. Gas can be in the form of :
 - A gas-cap on top of the oil zone, or
 - It can be dissolved in the oil.

As depth increases, more gas is present. Around 10,000 to 12,000 ft depth are some of the most prolific oil reservoirs in the world and almost all of them contain oil of API gravity between 28 and 32. They also coexist with substantial quantities of gas, which, when separated from oil at the surface, will evolve into 500 to 1,000 scf/stb (standard cubic feet per stock tank barrel).

- Just gas. At depth of 17,000 ft and certainly over 20,000 ft, reservoirs contain almost exclusively natural gas.

* In general, if the reservoir temperature is above the critical temperature (T_c) the reservoir is classified a natural gas reservoir. **There are three types of gas reservoirs:**

- 1) **Dry gas reservoir:** All mixture stays in vapor state.
- 2) **Wet gas reservoir:** All mixture stays in vapor state with a small amount of liquid.
- 3) **Gas condensate reservoir:** It is also called natural gas liquids. It is a low-density mixture of hydrocarbon liquids that are present as gaseous components in the raw natural gas

[Terms used in the petroleum industry to describe natural gas reservoirs]

Associated gas is produced with the oil and separated at the casinghead or wellhead. Gas produced in this fashion is also referred to as casinghead gas, oil well gas, or dissolved gas, (They are gases produced as a byproduct of the production of crude oil).

Nonassociated gas is sometimes referred to as gas-well gas or dry gas. However, this dry gas can still contain significant amounts of NGL components, (They are gases produced as a primary production of natural gas).

Figure (2) shows a simplified flow of material from reservoir to finished product and provides an overall perspective of the steps involved in taking natural gas from the wellhead to the customer. Some gas plants receive feeds from refineries. These streams differ from natural gases in that they can contain propylene and butylene. They may also contain trace amounts of undesirable nitrogen compounds and fluorides.

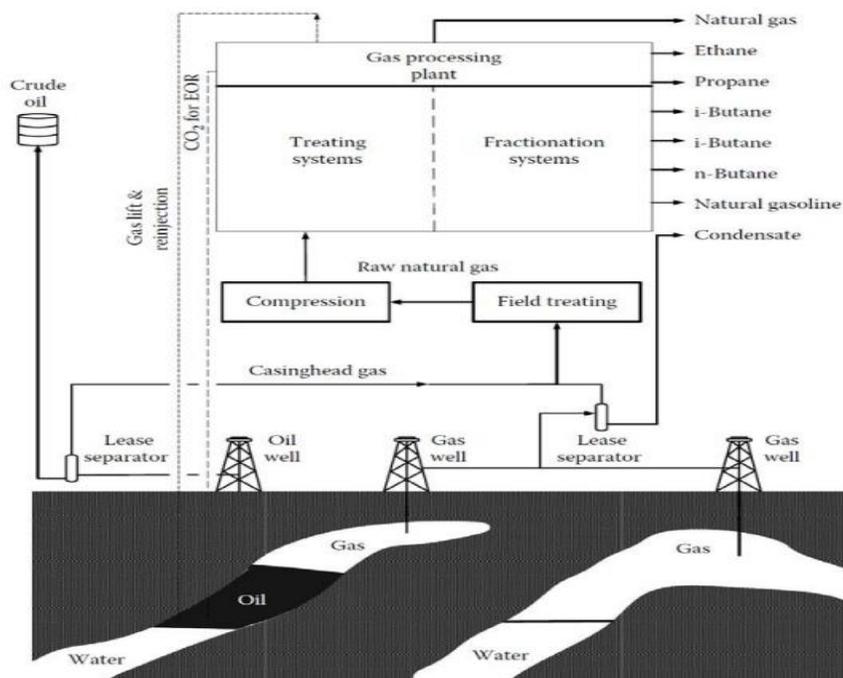


Figure 2: Schematic Overview of Natural Gas Industry

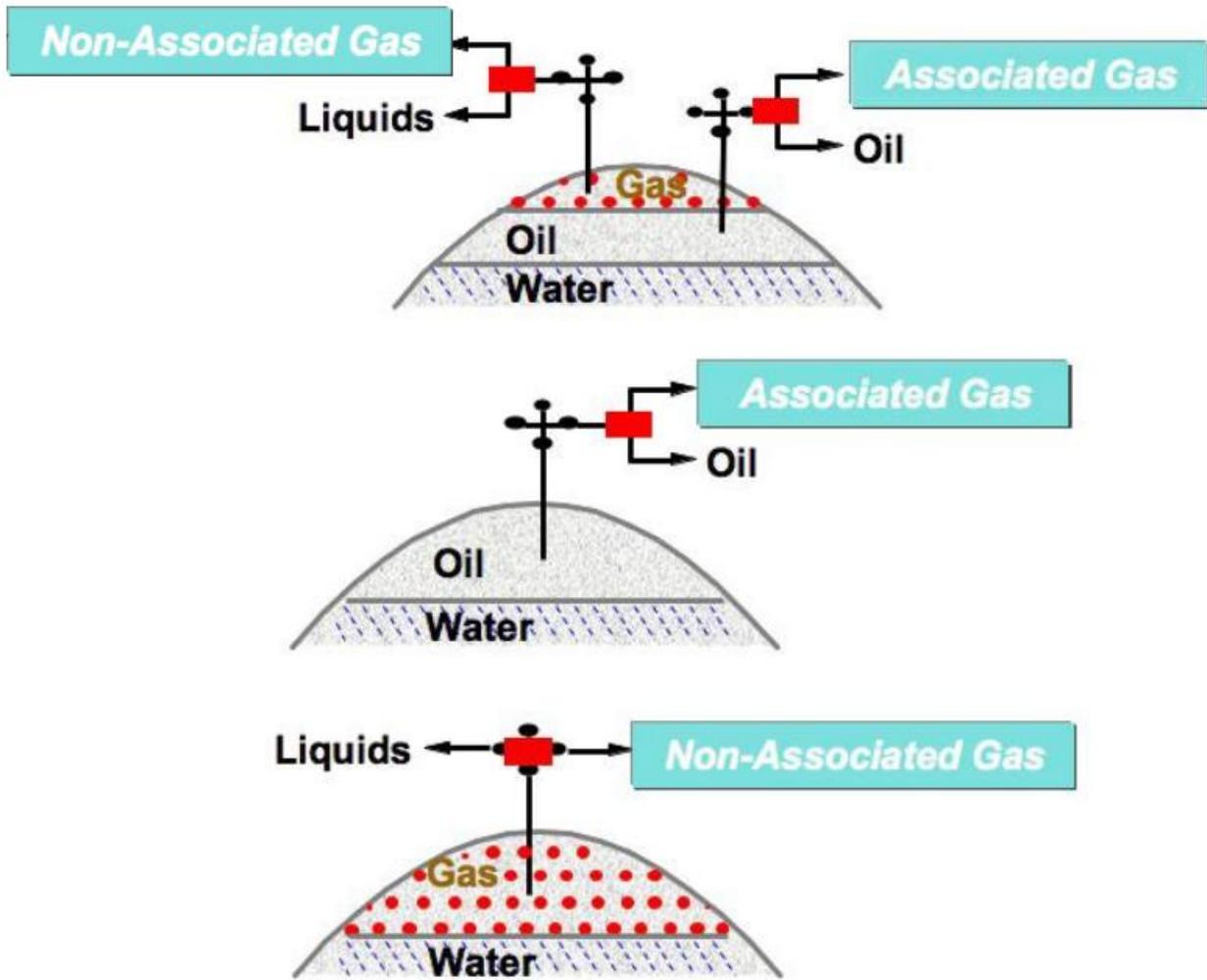


Figure 3: Associated and non-associated gases.