**9. PETROLEUM GASES**

Petroleum gases are of three types:

**9.1 Natural gas**

Natural gas is a mixture of some hydrocarbon gases i.e. methane, ethane, propane, and butane. Over 70% of natural gas is formed by methane, the major component. In addition to hydrocarbon, other components, for instance, CO2, H2S, N2 and H2O vapor can also be found. Natural gas exists in nature under pressure in rock reservoirs in the Earth’s crust, either in conjunction with and dissolved in heavier hydrocarbons and water or by itself. It is produced from the reservoir similarly to or in conjunction with crude oil. Natural gas has been formed by the degradation of organic matter accumulated in the past millions of years. Two main mechanisms (biogenic and thermo genic) are responsible for this degradation.

Natural gas is colorless, odorless and it is lighter than air (specific gravity of about 0.6-0.8).It is inflamed during a range of 5-15% by volume of gas in air. The self-ignition temperature of natural gas is 537-540°C.Boiling point –162°C.

Raw natural gas comes from any one of three types of wells; Crude oil wells, Gas wells (natural gas wells average 6000 feet deep) and, Condensate wells (produce free natural gas along with a semi-liquid hydrocarbon condensate).

Natural gas is found in petroleum reservoirs as:

1. Dry gas: it is non-associated gas almost pure methane with few other gases such as ethane, H2O vapor, CO2, He, N2, and H2S.

2. Wet gas: it is associated gas mixture containing all of the hydrocarbons from methane to pentane and even hexane (C6H14) and heptane (C7H16) with few other gases such as H2O vapor, CO2, He, N2, H2S.

3. Natural gas that is associated gas (dissolved gas) in solution with petroleum in the reservoir.

Commercial forms of natural gas were supplied according to its application:

i. Pipe Natural Gas or natural gas that transport via pipeline, it is known in commercial term as Sale Gas. Sale Gas is mainly composed of methane. It is transmitted to customers to be used as fuel at the power generation and industrial plants.

ii. Natural Gas for Vehicles (NGV) is the form of natural gas used as fuel for vehicles. NGV is primarily composed of methane and transported through the pipeline to the gas stations. At the gas stations, low pressure gas will be compressed and stored at high pressure of 3000-3600 pound per square inch (psi) and can be then filled up the gas tanks.

iii. Liquefied Natural Gas (LNG) If the distance is over 2,000 kilometers, the gas is liquefied by lower temperature to (– 162°C) and becomes 600 times smaller in volume, then stored at atmospheric pressure in designed vessels and transport to users. The cost of waterway transport is less than transportation through pipeline.

**9.1.2 Uses**

There are many basic uses of natural gas:

(A). Fuel can directly use natural gas as fuel for power generation and in factories.

(B). Production of various chemical products through gas separation process such as methane, ethane, propane and butane, natural gasoline (NGL), and CO2 (dry ice).

(C). Primary gas in; H2 production, vehicles, domestic use, fertilizer, aviation.

(D). Manufacture of fabrics, glass, steel, plastics, paint, and other products.

**9.1.3Composition**

Natural gas is a fossil fuel with high efficiency and cleaning burning. It reduces greenhouse gases (CO and CO2 emissions) which is a main cause of global warming. Natural gas is cheaper than other types of fuel (e.g., fuel oil and LPG). It has high safety as it is lighter than air and disperses upward when leaked.

The composition of natural gas varies depending on the field, formation, or reservoir from which it is extracted. Typical make-up of natural gas before it is refined.

|  |  |  |
| --- | --- | --- |
| Name | Formula | Volume (%) |
| Methane | CH4 | >85 |
| Ethane | C2H6 | 3-8 |
| Propane | C3H8 | 1-2 |
| Butane | C4H10 | <1 |
| Pentane | C5H12 | <1 |
| Carbone dioxide | CO2 | 1-2 |
| Hydrogen sulfide | H2S | 1-5 |
| Helium | He | <0.5 |

Typical Composition of Natural Gas

**9.2 Refinery Gas**

All gaseous products and by-products from a variety of refinery processes and it is called refinery gas. It is the non-condensable gas that is obtained during distillation or treatment (desulfurization, thermal cracking, and catalytic cracking) of petroleum. It consists mainly of hydrogen (H2), methane (CH4), ethane (C2H6), propane (C3H8), butane (C4H10), and olefins (RCH=CHR1), where R and R1 can be hydrogen or a methyl group, and may also contain off-gases.

The composition and volume of refinery gas, depending on crude origin and on any additions to the crude made at the loading point. In addition to the refinery gases obtained by distillation of petroleum, more highly volatile products result from the subsequent processing of naphtha and middle distillate to produce gasoline, such as desulfurization process, thermal cracking process, catalytic cracking process, etc…

**9.3 Liquefied Petroleum Gas (LPG)**

LPG is a product from the oil refineries or the gas separation plants. LPG is a mixture of two hydrocarbon gases: propane (B.P. –42°C) and butane (B.P. –1°C) that are produced during natural gas refining, petroleum stabilization, and petroleum refining. It can be in any ratio or purely propane or butane. Most LPG comes from the gas separation plants which have a ratio of propane and butane of 70:30. Like natural gas, LPG can be used as fuel for domestic, industry and transportation. As the gas provides high heating value, the user can thus save the time and energy cost.

**9.4Chemical and Physical Properties**

Natural gas is colorless, odorless, tasteless, and lighter than air .The natural gas after appropriate treatment for acid gas reduction, deodorization, and hydrocarbon and moisture dew point adjustment would then be sold within prescribed limits of pressure, calorific value, and Wobbe index Iw (is an indicator of the interchangeability of fuel gases such as natural gas, liquefied petroleum gas (LPG), and town gas, where Iw = heating value/ √ Sp.Gr.).

**9.4.1 Gas-Specific Gravity**

Specific gravity of gas is defined as:

Where Mair is the molecular weight of air, which is equal to 28.96.

The sp. gr. of a gas is proportional to its molecular weight (M) when gas is ideal.

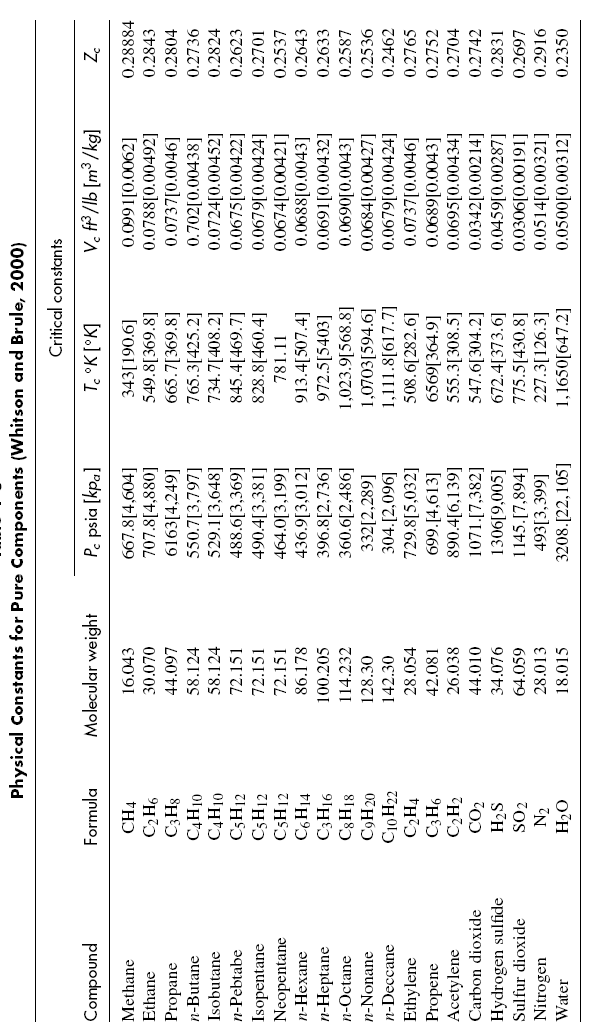
|  |  |  |  |
| --- | --- | --- | --- |
| Properties | value | Properties | Value |
| Relative molar mass | 17-20 | Carbon content weight% | 73.3 |
| Hydrogen content weight% | 23.9 | Oxygen content weight% | 0.4 |
| Hydrogen/carbon atomic ratio | 3.0-4.0 | Relative density , 15 C | 0.72-0.81 |
| Boiling point, C | -162 | Auto ignition temperature , C | 540-560 |
| Octane number | 120-130 | Methane number | 69-99 |
| Stoichiometric air/fuel ratio , weight | 17.2 | Vapour flammability limits , volume % | 5-15 |
| Flammability limits | 0.7-2.1 | Lower heating/calorific value ,MJ/kg | 38-50 |
| Stoichiometric lower heating value ,MJ/Kg | 2.75 | Methane concentration , volume% | 80-99 |
| Ethane concentration , volume% | 2.7-4.6 | Nitrogen concentration , volume% | 0.1-15 |
| Carbon dioxide concentration , volume% | 1-5 | Sulfur concentration , weight % ppm | <5 |
| Specific CO2 formation g/MJ | 38-50 |  |  |

Properties of natural gas

The molecular weight of the mixture can be calculated; the specific gravity of the mixture can also be calculated. For a gas mixture, the molecular weight as:

Where Mi is the molecular weight of component i, yi is the mole fraction of component i, and n is the total number of components.

Example: calculate for gas mixture contains methane 85%, ethane 10% propane 5%.



**9.4.2. Real Gas Relations**

The ratio of the real volume to the ideal volume, which is a measure of the amount the gas deviates from perfect behavior, is called the compressibility factor. It is also called the gas deviation factor and is given the symbol Z. The volume of a real gas is usually less than what the volume of an ideal gas would be, and hence a real gas is said to be super compressible.

As know the ideal gas equation of state is

While the real gas equation of state is then written as:

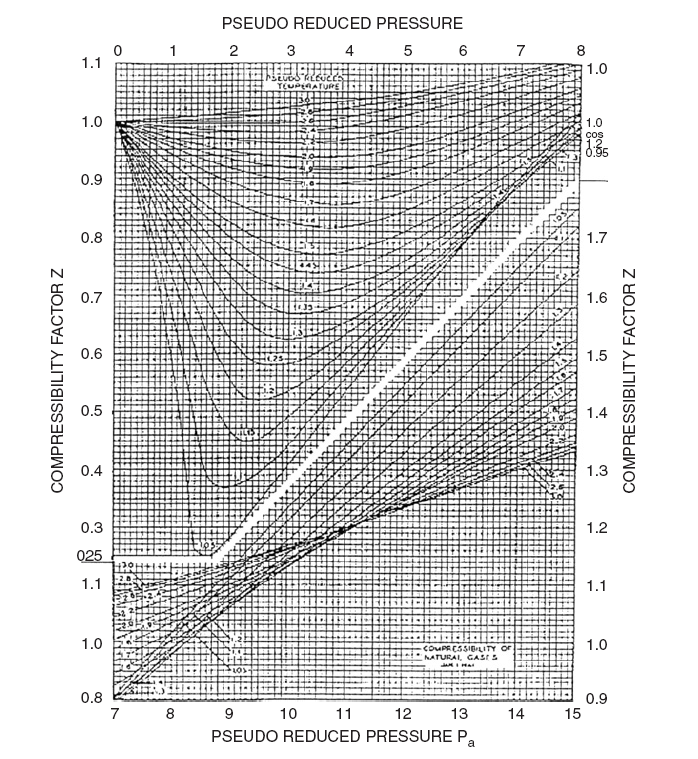
Where P is the pressure, V is the volume, T is the absolute temperature, Z is the compressibility, n is the number of kilomoles of the gas, and R is the gas constant.

The Z factor can be defined as a function of reduced pressure and reduced temperature. The reduced pressure and reduced temperature are defined as:

Where Pr and Tr are reduced pressure and reduced temperature, respectively, and Pc and Tc are critical pressure and critical temperature of the gas, respectively. The values of critical pressure and critical temperature can be estimated from the following equations if the composition of the gas and the critical properties of the individual components are known:

Where Pci and Tci are the critical pressure and critical temperature of component ***i***, respectively; and yi is the mole fraction of component i. The values of critical pressure and critical temperature can be estimated from its specific gravity if the composition of the gas and the critical properties of the individual components are not known. Sutton (1985) used regression analysis on raw data to obtain the following second-order regressions for the pseudo critical properties:

These equations are valid over the range of specific gas gravities with which Sutton (1985) worked 0.57 < **γg** < 1.68. The most commonly used method to estimate the Z factor is the chart provided by Standing and Katz (1942). The Z factor chart is shown in below.



Compressibility of natural gases as a function of reduced pressure and temperature (Standing and Katz, 1942)

**9.4.3. Formation Volume Factor (FVF)**

Formation Volume Factor (FVF) is defined as the ratio of volume of gas at the reservoir temperature and pressure (VR) to the volume of gas at standard conditions (Psc and Tsc) (Vsc). FVF (Bg) of a gas is defined as Using the real gas law and assuming that the Z factor at standard conditions is 1, the equation for formation volume factor (Bg) can be written as:

**9.4.4 Natural Gas Density**

The density of a reservoir gas is defined as the mass of the gas divided by its reservoir volume and can also be derived and calculated from the real gas law:

**9.4.5. Isothermal Gas Compressibility**

The isothermal gas compressibility (cg) is a useful concept used extensively in determining the compressible properties of the reservoir. Gas usually is the most compressible medium in the reservoir. However, care should be taken so that it is not confused with the gas compressibility factor, Z, where general (cg):

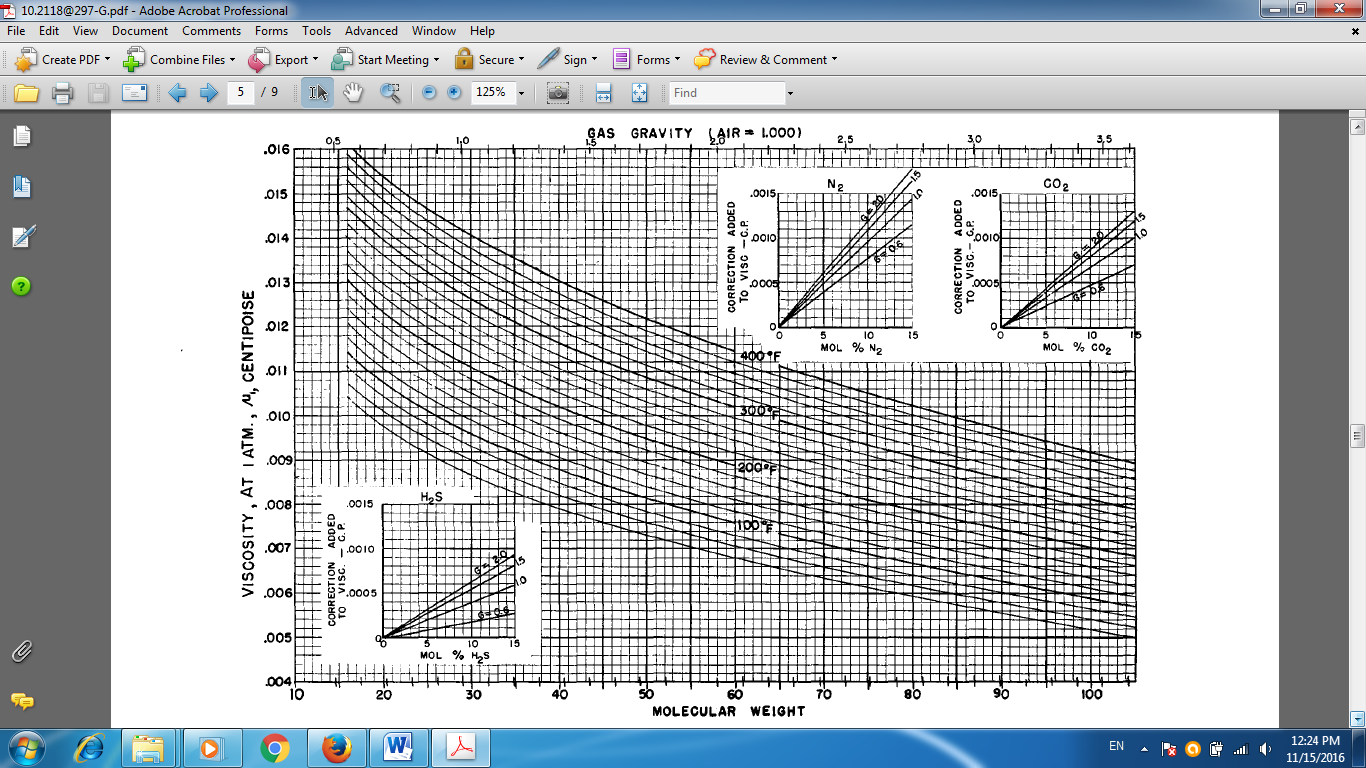
Where Vg and P are volume and pressure and T is the absolute temperature.

For ideal gas, we can define the isothermal gas compressibility as:

Whereas, for real gas, the isothermal gas compressibility is defined as:

**9.4.6. Gas Viscosity**

The viscosity of natural gas is usually lower than oil or water. This makes gas much more flow able in the reservoir than either oil or water. Reliable correlation charts are available to estimate gas viscosity as shown below:



Viscosity of natural gas as a function of molecular weight and temperature

The viscosity of gas mixtures at one atmosphere and reservoir temperature can be determined from the gas mixture composition:

Where ***μga*** is the viscosity of the gas mixture at the desired temperature and atmospheric pressure, yi is the mole fraction of the ith component, μi is the viscosity of the ith component of the gas mixture at the desired temperature and atmospheric pressure, Mgi is the molecular weight of the ith component of the gas mixture, and N is the number of components in the gas mixture.