Tikrit University

College of Petroleum Processes Engineering

Department of Petroleum and Gas Refining Engineering

Gas Technology

Forth Class

Lectures 6

By

Jasim I. Humadi

NATURAL GAS PROPERTIES

Natural gas is colorless, odorless, tasteless, shapeless, and lighter than air. The natural gas after appropriate treatment for acid gas reduction, odorization, and hydrocarbon and moisture dew point adjustment would then be sold within prescribed limits of pressure, calorific value, and possibly Wobbe index (often referred to as the Wobbe number).

Table 4: Properties of Natural Gas

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
Autoignition 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 CO_2 formation, g/MJ	38–50

Ideal gas

Ideal gas: is defined as one for which both the volume of molecules and forces between the molecules are so small that they have no effect on the behavior of the gas.

PV = nRT

where:

P=absolute pressure, psia . **V**=volume, ft^3 **T**=absolute temperature, ^oR

n=number of moles of gas, lb-mol R=the universal gas constant, which, for the above units, has the value 10.730 psia ft^3/lbmol ^oR.

Real Gases

Gases whose properties cannot be represented by the ideal gas law are called nonideal gases or real gases.

PV = ZnRT

Z: Gas Deviation Factor

$$P_r = \frac{P}{P_c} \text{ and } T_r = \frac{T}{T_c}$$

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$$P_c = \sum_i^n P_{Ci} y_i \text{ and } T_c = \sum_i^n T_{ci} y_i$$

at the standard conditions of psc = 14.7 psi and Tsc = 60°F = 520 R, the gas deviation factor, Zsc, can be taken as equal to 1

The Z factor chart of Standing and Katz (1942) , Shown in figure (3) is only valid for mixtures of hydrocarbon gases.

Wichert and Aziz (1972) developed a correlation to account for inaccuracies in the Standing and Katz chart when the gas contains significant fractions of acid gases, specifically carbon dioxide (CO2) and hydrocarbon sulfide (H2S). The Wichert and Aziz (1972) correlation modifies the values of the pseudocritical temperature and pressure of the gas. Once the modified pseudocritical properties are obtained, they are used to calculate pseudo-reduced properties and the Z factor.

The Wichert and Aziz (1972) correlation first calculates a deviation parameter ε:

$$\varepsilon = 120(A^{0.9} - A^{1.6}) + 15(B^{0.5} - B^{4})$$

where A is the sum of the mole fractions of CO_2 and H_2S in the gas mixture and B is the mole fraction of H_2S in the gas mixture. Then, ε is used to determine the modified pseudocritical properties as follows:

$$T'_{pc} = T_{pc} - \varepsilon$$

$$P'_{pc} = \frac{P_{pc}T'_{pc}}{[T_{pc} - B(1 - B)\varepsilon]}$$

The correlation is applicable to concentrations of $CO_2 < 54.4$ mol% and $H_2S < 73.8$ mol%.

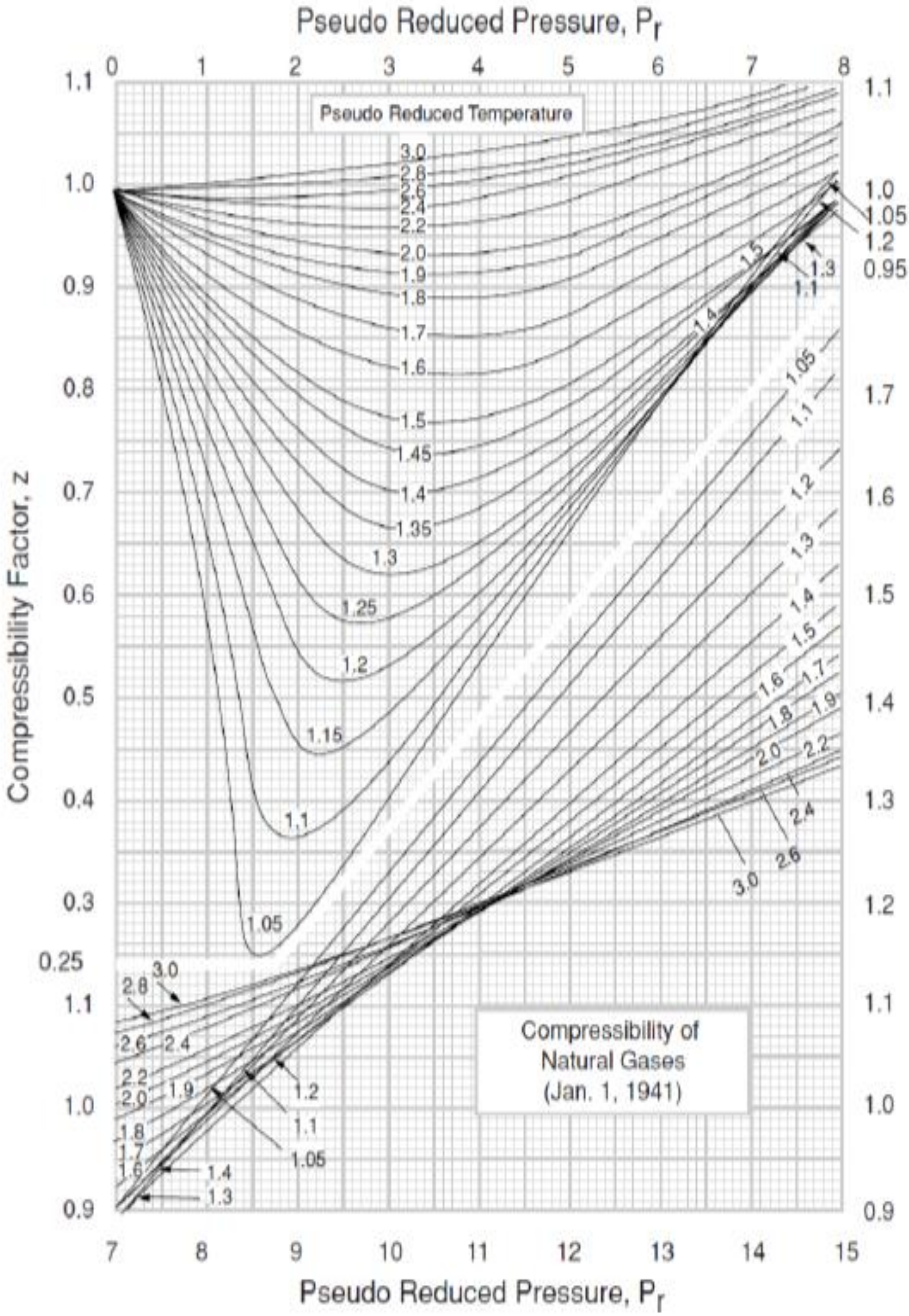

Figure1: Gas Deviation Factor

Gas-Specific Gravity

$$\gamma_g = \frac{M}{M_{air}}$$

Where Mair is the molecular weight of air, which is equal to 28.97. Once we can calculate the value of the molecular weight of the mixture, we can calculate the specific gravity of the mixture. For a gas mixture, we can calculate the molecular weight as

$$M = \sum_{i=1}^{n} y_i M_i$$

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.

So,

$$\gamma_g = \frac{MW_m}{MW_{air}} = \frac{\sum_{i=1}^{n} y_i MW_i}{28.97}$$

Example 2: A natural gas consists of the following (molar) composition: C1 = 0.871, C2 = 0.084, C3 = 0.023, CO_2 = 0.016 and H_2S = 0.006. Calculate the gas gravity to air.

Compound	y_i	MW_i
C_1	0.871	16.04
C_2	0.084	30.07
C_3	0.023	44.09
CO_2	0.016	44.01
H_2S	0.006	34.08
	1	

Solution:

Compound	y_i	MW_i	y_iMW_i
C_1	0.871	16.04	13.971
C_2	0.084	30.07	2.526
C_3	0.023	44.09	1.014
CO_2	0.016	44.01	0.704
H_2S	0.006	34.08	0.204
	1		18.419

the gas gravity is 18.419/28.97 = 0.64.

Gas Density

Gas density is defined as mass per unit volume and so can also be derived and calculated from the real gas law:

$$\rho_g = \frac{m}{V} = \frac{PM}{ZRT}$$

Knowing that the molecular weight of gas is the product of specific gravity and molecular weight of air and that the value of R is 10.73 in field units [8.314 in SI units], we can write the equation for density as

$$\rho_g = 2.7\frac{P\gamma_g}{ZT}$$

where ρ_g is in lbm/ft^3, P is in psia, and T is in °R. Alternately,

$$\rho_g = 3.49\frac{P\gamma_g}{ZT}$$

Example 3: Calculations with real gas law Given the natural gas gravity to air gg = 0.75, the pseudocritical pressure, ppc and temperature, Tpc are 667 psi and 405 R, respectively. If the pressure and temperature are 1,500 psi and 20°F, respectively, calculate how many lb of gas can fit in 1,000 ft^3 of space?

Solution:

For T = 20°F = 480 R

Tpr = 480/405 = 1.19 (which will remain constant).

For p = 1,500 psi

ppr = 1,500/667 = 2.25.

From Figure, Z is obtained as 0.51.

By using the real gas law and gas gravity definition, the mass of gas that can fit in 1,000 ft^3 of space is:

$$m = \frac{pV\gamma_g MW_{air}}{ZRT} = \frac{1,500 \times 1,000 \times 0.75 \times 28.97}{0.51 \times 10.73 \times 480} = 12,408 \text{ lb.}$$

Gas Viscosity

Just as the compressibility of natural gas is much higher than that of oil, water, or rock, the viscosity of natural gas is usually several orders of magnitude lower than oil or water. This makes gas much more mobile in the reservoir than either oil or water. Reliable correlation charts are available to estimate gas viscosity, and the viscosity of gas mixtures at one atmosphere and reservoir temperature can be determined from the gas mixture composition:

$$\mu_{ga} = \frac{\sum_{i=1}^{N} y_i \mu_i \sqrt{M_{gi}}}{\sum_{i=1}^{N} y_i \sqrt{M_{gi}}}$$

where μga is the viscosity of the gas mixture at the desired temperature and atmospheric pressure, *y*i is the mole fraction of the *i*th component, μga is the viscosity of the *i*th component of the gas mixture at the desired temperature and atmospheric pressure, *M*gi is the molecular weight of the *i*th component of the gas mixture, and *N* is the number of components in the gas mixture. This viscosity is then multiplied by the viscosity ratio to obtain the viscosity at reservoir temperature and pressure.

Presence of Nonhydrocarbon Gases

In the presence of large amounts of nonhydrocarbon gases, the gas deviation factor must be adjusted. The pseudocritical properties, Tpc and ppc, can be corrected by:

$$T'_{pc} = T_{pc} - \varepsilon_3,$$

$$p'_{pc} = \frac{p_{pc} T'_{pc}}{T_{pc} + y_{H_2S}(1 - y_{H_2S})\varepsilon_3}$$

where :

y_{H2S} :is the mole fraction of hydrogen sulfide

ε_3: is a function of the H2S and CO2 concentrations, which can be obtained from :

$$\varepsilon = 120\,[A^{0.9} - A^{1.6}] + 15\,(B^{0.5} - B^{4.0})$$

$$A = y_{H_2S} + y_{CO_2}$$

Example 4: Calculation of the Z-factor for a sour gas Calculate the gas deviation factor, Z, of a sour gas at 190°F and 4,000 psi. Gas composition is given below:

C_1	C_2	C_3	i-C_4	n-C_4	i-C_5	n-C_5	C_6+	N_2	CO_2	H_2S
0.784	0.028	0.007	0.0008	0.0005	0.0008	0.0003	0.0006	0.005	0.021	0.152

Solution:

From Figure and using the compositions of CO_2 and H_2S, the adjustment factor e3 = 23.5 R. The pseudocritical properties are calculated.

Compound	y_i	MW_i	y_iMW_i	p_{ci}	y_ip_{ci}	T_{ci}	y_iT_{ci}
C_1	0.784	16.04	12.575	673	527.63	344	269.70
C_2	0.028	30.07	0.842	709	19.85	550	15.40
C_3	0.007	44.09	0.309	618	4.33	666	4.66
i-C_4	0.0008	58.12	0.046	530	0.42	733	0.59
n-C_4	0.0005	58.12	0.029	551	0.28	766	0.38
i-C_5	0.0008	72.15	0.058	482	0.39	830	0.66
n-C_5	0.0003	72.15	0.022	485	0.15	847	0.25
C_6+	0.0006	100.2	0.060	397	0.24	973	0.58
N_2	0.005	28.02	0.140	492	2.46	227	1.14
CO_2	0.021	44.01	0.924	1072	22.51	548	11.51
H_2S	0.152	34.08	5.180	1306	198.51	673	102.30
	1.000		20.19		p_{pc}= 777		T_{pc}= 407

$$T'_{pc} = 407 - 23.5 = 383.5\,\mathrm{R},$$

$$p'_{pc} = \frac{777 \times 383.5}{407 + [0.152 \times (1 - 0.152) \times 23.5]} = 726.7\,\mathrm{psi}.$$

The pseudoreduced properties are then, Tpr= (190 + 460)/383.5=1.70 and ppr = 4,000/726.7=5.5, respectively. From Figure , Z = 0.9

Quality

The amount of energy that is obtained from the burning of a volume of natural gas is measured in British thermal units (Btu). The value of natural gas is calculated by its Btu content.