

## CHAPTER-4

### RESERVOIR FLUID PROPERTIES

#### **4.1 Crude Oil**

Conversion of down hole volumes (or volumetric rate) of oil, gas and water to equivalent volumes at surface conditions is made so frequently that it is convenient to use conversion factors, which account for the overall changes due to solubility and compressibility. The most important units used to measure the hydrocarbon volumes are as follows:

##### **4.1.1 Crude Oil °API Gravity**

To define °API (American Petroleum Institute) gravity, one should first define the specific gravity of a liquid. Liquid specific gravity,  $\gamma_o$ , is defined as the ratio of the density of the liquid to the density of water, both taken at the same temperature and pressure.

$$\gamma_o = \rho_o / \rho_w$$

The most widely used indicator of a crude oil's worth to the producer is °API gravity. This value is actually a measure of an oil density, and is related to specific gravity by the following equation:

$$^{\circ}\text{API Gravity} = (141.5 / \gamma_o) - 131.5$$

°API gravity of 10 is equivalent to the specific gravity of 1. Normally the price, which a producer receives for his/her oil, depends on its gravity, the less dense (higher °API) being the most valuable.

##### **4.1.2 Oil Formation Volume Factor**

The letter **B** designates formation volume factor with a suffix denoting the fluid phase concerned. Formation volume factor is a function of fluid composition and pressure/temperature difference between the downhole and reference state.

Form. Volume Fact. (B) = volume at downhole cond. / volume at surface cond.

Gas formation volume factor, which is known as  $B_g$ , is equal to:

$$B_g = \text{volume at downhole T\&P} / \text{volume at 60F and 14.7 psia}$$

Oil formation volume factor, which is known as  $B_o$ , is equal to:

$$B_o = \text{volume at downhole T\&P} / \text{volume at 60F and 14.7 psia}$$

Oil formation volume factor being dependent essentially on the amount of dissolved gas increases with pressure up to the bubble point, where all of the available gas is dissolved and then decreases at a rate determined by the liquid compressibility.

#### **4.1.3 Oil Viscosity**

Viscosity is the property of a fluid which causes it to offer resistance to the movement of one adjacent particle. The friction forces arising between two immiscible layers of fluid in its motion are proportional to the change of velocities per unit length. The viscosity of crude oil decreases with an increase in temperature and with an increase of dissolved gas. Heavier oils are generally more viscous than lighter oils of the same hydrocarbon base. In SI units the unit of viscosity is *Pascal-sec.*, and in field units, *centipoise* (cp) is used as an oil viscosity.

#### **4.2 Natural Gas**

Natural gas is produced from three classes of wells. These are:

- From wells where the dominant product is oil (oil wells)
- From wells where the gas itself is the principal product (gas wells)
- As gas from condensate wells. Condensate wells produce from reservoirs in which the hydrocarbons (gas and liquid) originally existed as a single fluid, the reservoir temperature and pressure being above the critical point of the hydrocarbon mixture.

Each natural gas, like each crude oil, is a unique mixture of hydrocarbons. All are, however, composed primarily of the light members of the paraffin series and are predominantly methane.

#### **4.2.1 Wet Gas**

A natural gas is said to be wet if it contains an appreciable natural gasoline content as determined by standard tests.

#### **4.2.2 Sour Gas**

Natural gas containing hydrogen sulfide is known as sour gas.

#### **4.2.3 Sweet Gas**

Natural gas containing no hydrogen sulfide is known as sweet gas.

#### **4.2.4 Gas Oil Ratio**

Gas oil ratio -R- (sometimes abbreviated GOR) is the ratio of gas production to oil production to oil production, both measured at standard conditions (60 F and 14.7 psia). Unit is standard cubic feet / stock tank oil. There are 5.615 cubic feet in one barrel.

#### **4.2.5 Gas Formation Volume Factor**

Gas formation volume factor, which is known as  $B_g$ , is equal to:

$$B_g = \text{volume at downhole T\&P} / \text{volume at 60F and 14.7 psia}$$

#### **4.2.6 Gas Specific Gravity**

Gas specific gravity,  $\gamma_g$ , is widely used in the oil industry to characterize natural gases. It is defined as the ratio of the density of gas to the density of air, both measured at standard conditions.

$$\gamma_g = (\rho_g)_{sc} / (\rho_{air})_{sc}$$

The weight of any volume of gas can be determined by multiplying the volume of gas and  $\rho_{air}$ . The density of air at standard conditions is 0.001223 gr/cc or 0.0762 lb/ft<sup>3</sup>. The density of gas at any temperature and pressure can be found from the gas formation volume factor,  $B_g$ .

$$1/ B_g = \rho_{gwf} / \rho_{asc}$$

#### **4.2.7 Gas Density**

To calculate the natural gas density one should start with the real gas law. The gas law as applied to the behavior of natural gas is most commonly stated as:

$$PV = znRT$$

where: **P** = pressure, **V** = volume, **n** = number of mols, **R** = gas constant, **T** = absolute temperature and **z** = deviation factor (compressibility factor).

The above equation can also be written as:

$$PV = z (W/M)RT$$

where: *W* = total weight and *M* = molecular weight of the gas.

$$P(V/W) = zRT/M$$

$$V/W = zRT/PM$$

where: *V/W* is the specific volume of gas (*v*) and equals to;

$$1/v = \rho$$

where:  $\rho$  is the gas density and the equation takes the following final form.

$$\rho = PM / zRT$$

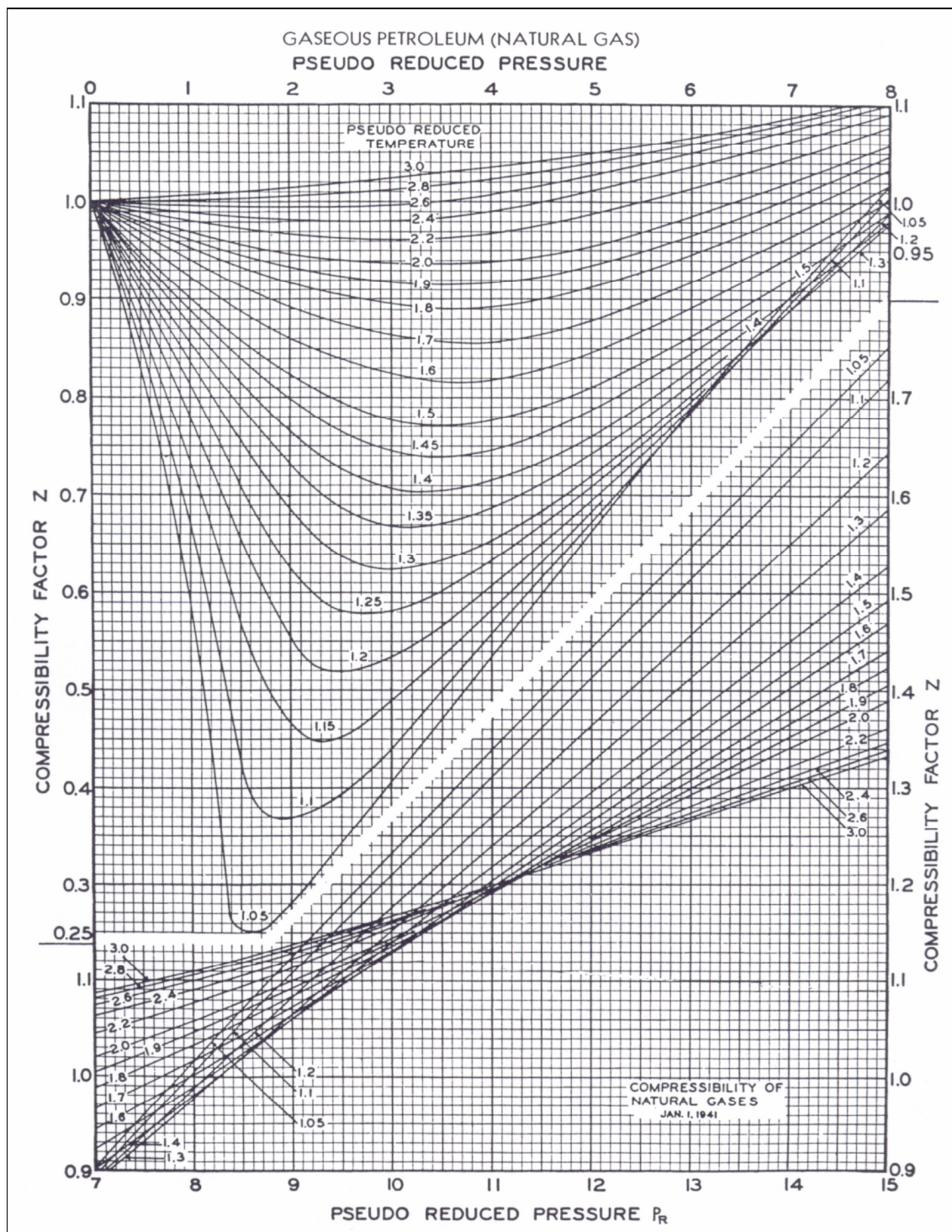
The value of gas constant, *R*, is dependent on the system of units used as follows.

**Table 4-1** Values of Gas Constants

Pressure (P)	Volume (V)	Temp. (T)	Gas Const. -R-
atm	cc	K	82.14
Atm	lt	K	0.082
mm Hg	cc	K	62369
gr/cm <sup>2</sup>	cc	K	8.314
psi	cu ft	R	10.72

The values of *z* (compressibility factor) for natural gas mixtures have been experimentally correlated as a function of pressure, temperature and composition. In preparing a correlation for hydrocarbon mixtures, the ratios of actual pressure and temperature to the molar average of critical or pseudo-critical pressure and temperature have been used.

These ratios are called reduced pressures and reduced temperatures. The following figure is a correlation of  $z$  as a function of these quantities.



**Figure 4-1** Compressibility of natural gases as a function of reduced pressure and temperature. After Standing.

### **4.3 Example Problems :**

1) Calculate the specific gravity of methane (CH<sub>4</sub>) at standard conditions.

Molecular weight of methane is  $12 + 4 = 16$

Molecular weight of air = 29

The volume of one mol of any gas occupies 379 ft<sup>3</sup> at standard conditions

$$\rho_{\text{gsc}} = 16 / 379 \text{ and } (\rho_{\text{air}})_{\text{sc}} = 29 / 379 \text{ so;}$$

$$\gamma_{\text{CH}_4} = (16 / 379) / (29 / 379) = \mathbf{0.55}$$

2) Calculate the density of methane at 3000 psig and 170 °F.

M = 16; T = 170 + 460 = 630 °R ; P = 3000 + 14.7 = 3014.7; R = 10.7 and z = 0.935

$$\rho_{\text{CH}_4} = PM / zRT$$

$$\rho_{\text{CH}_4} = [(3014.7) (16)] / [(0.935) (10.7) (630)] = \mathbf{7.65 \text{ lb/cu ft}}$$

3) What is the density of methane at standard conditions ?

$$\rho = PM / RT = [(14.7) (16)] / [(10.7) (520)] = \mathbf{0.0422 \text{ lb/ft}^3}$$

4) What is the density of air at standard conditions ?

$$\rho = PM / RT = [(14.7) (29)] / [(10.7) (520)] = \mathbf{0.0766 \text{ lb/ft}^3}$$

5) What is the density of a miscellaneous 0.90 gravity gas at 2000 psia and 150 °F. What is the specific volume at these conditions

$$\rho = PM / zRT = [(2000) (29) (0.90)] / [(0.67) (10.7) (610)] = 11.9 \text{ lb/ft}^3$$

$$V = 1/\rho = 1 / 11.9 = \mathbf{0.084 \text{ ft}^3/\text{lb}}$$

6) A cylindrical tank contains miscellaneous 0.80 gravity gas at 2500 psia and 100 °F. The volume of tank is 10 ft<sup>3</sup>. How many mols of gas are there in the tank.? What standard volume of gas is this?

$$n = PV / zRT = [(2500) (10)] / [(0.67) (10.7) (560)] = \mathbf{6.2 \text{ moles}}$$

$$V_s = 6.2 \times 379 = \mathbf{2350 \text{ SCF}}$$

7) If the sp.gr. of a crude oil is 0.86, what is the °API gravity and density in lb/cu ft?

$$^\circ\text{API} = (141.5 / \text{sp.gr.}) - 131.5 = 141.5 / 0.86 - 131.5 = \mathbf{33 \text{ }^\circ\text{API}}$$

$$0.86 \times 62.4 \text{ lb/cu ft} = \mathbf{53.86 \text{ lb/cu ft}}$$

8) Given the analysis in the table below of a natural gas produced from an oil well,

a-Compute the gas gravity

b-Compute the pseudo-critical temperature and pressure

<u>Comp.</u>	<u>Mol %</u>	<u>Mol %</u>	<u>Mol %</u>	<u>Mol %</u>	<u>T<sub>cs</sub> °R</u>	<u>1x4</u>	<u>1x5</u>
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<b>Methane</b>	79.05	16.04	12.7	673	344	531.0	272.0
<b>Ethane</b>	10.85	30.07	3.26	709	550	77.0	59.7
<b>Propane</b>	4.61	44.09	2.03	618	666	28.5	30.7
<b>Iso-butan</b>	1.28	58.12	0.74	530	733	6.8	9.4
<b>n-butane</b>	2.04	58.12	1.19	551	766	11.2	15.6
<b>Iso-penta</b>	0.21	72.15	0.15	482	830	1.0	1.7
<b>n-pentan</b>	0.34	72.15	0.25	485	847	1.6	2.9
<b>Hexane</b>	0.84	86.17	0.72	434	915	3.6	7.7
<b>Heptane</b>	0.78	140.0	1.09	405	1172	3.2	9.2
	<b>100.0</b>		<b>22.13</b>			<b>664</b>	<b>409</b>

$$\text{Gas Gravity} = G_g = (\text{Density of Gas at Stan. Cond}) / \text{Density of Air at Stan. Cond}$$

Since one mol of gas occupies the same volume at std. Conditions (379 ft<sup>3</sup>)

$$G_g = (22.13/379) / (29/379) = 22.13 / 29 = \mathbf{0.76}$$

where 29 = mol weight of air

$$\text{Pseudo critical temp.} = \mathbf{664 \text{ psia}}$$

$$\text{Pseudo critical temp.} = \mathbf{409 \text{ } ^\circ\text{R}}$$

9) What volume will 100 lb of above gas occupy at P = 3000 psig and T = 170 °R

$$V = (znRT) / P$$

$$N = 100 / 22.13 = \mathbf{4.52 \text{ moles}}$$

$$T = 460 + 170 = \mathbf{630 \text{ } ^\circ\text{R}}$$

$$P = 3000 + 14.7 = \mathbf{3015 \text{ psia}}$$

$$R = \mathbf{10.7}$$

Obtain **z** from the figure.

$$P_r = P / P_c = 3015 / 664 = \mathbf{4.54}$$

$$T_r = T / T_c = 630 / 409 = \mathbf{1.54}$$

So; **z = 0.81** (from Figure 4-1)

$$V = (znRT) / P$$

$$V = [(0.81) \times (4.52) \times (10.7) \times (630)] / 3015 = \mathbf{8.2 \text{ ft}^3}$$