ME 423: FLUIDS ENGINEERING

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Gas Properties

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PSEUDO-CRITICAL PROPERTIES FROM GAS GRAVITY, G

If the percentages of the various components in the natural gas mixture are not available, we can calculate approximate values of the pseudo-critical properties of the gas mixture if we know the gas gravity, G. The pseudo-critical properties are calculated, approximately, from the following equations:

$$T_{pc} = 170.491 + 307.344\, G \qquad (1.24)$$

$$P_{pc} = 709.604 - 58.718\, G \qquad (1.25)$$

where

G = gas gravity (air = 1.00)

T_{pc} = pseudo-critical temperature, °R

P_{pc} = pseudo-critical pressure, psia

Example 8

Calculate the gravity of a natural gas mixture consisting of 83% methane, 12% ethane, and 5% propane. From the gas gravity, calculate the pseudo-critical temperature and pseudo-critical pressure for this natural gas mixture.

IMPACT OF SOUR GAS AND NON-HYDROCARBON COMPONENTS

The ***Standing-Katz chart*** used for determining the compressibility factor (Fig. 1.2) of a gas mixture is accurate only if the amount of non-hydrocarbon components is small.

Since **sour gases contain carbon dioxide (CO_2) and hydrogen sulfide (H_2S)**, adjustments must be made to take into account these components in calculations of the pseudo-critical temperature and pseudo-critical pressure.

Depending on the amounts of carbon dioxide and hydrogen sulfide present in the sour gas, we calculate an adjustment factor ε from

$$\varepsilon = 120(A^{0.9} - A^{1.6}) + 15(B^{0.5} - B^{4.0}) \qquad (1.26)$$

where

ε = adjustment factor, °R

A = sum of the mole fractions of CO_2 and H_2S

B = mole fraction of H_2S

The pseudo-critical temperature is modified to get the adjusted pseudo-critical temperature ***T'_{pc}*** from the following equation:

$$T'_{pc} = T_{pc} - \varepsilon \qquad (1.27)$$

where

T'_{pc} = adjusted pseudo-critical temperature, °R

Similarly, the pseudo-critical pressure is adjusted as follows:

$$P'_{pc} = \frac{P_{pc} \times T'_{pc}}{T_{pc} + B(1-B)\varepsilon} \qquad (1.28)$$

where

P'_{pc} = adjusted pseudo-critical pressure, psia.

IMPACT OF SOUR GAS AND NON-HYDROCARBON COMPONENTS

Example 9

The pseudo-critical temperature and the pseudo-critical pressure of a natural gas mixture were calculated as 370°R and 670 psia, respectively. If the CO_2 content is 10% and H_2S is 20%, calculate the adjustment factor ε and the adjusted values of the pseudo-critical temperature and pressure.

$$\varepsilon = 120(A^{0.9} - A^{1.6}) + 15(B^{0.5} - B^{4.0}) \tag{1.26}$$

where

ε = adjustment factor, °R
A = sum of the mole fractions of CO_2 and H_2S
B = mole fraction of H_2S

$$T'_{pc} = T_{pc} - \varepsilon \tag{1.27}$$

$$P'_{pc} = \frac{P_{pc} \times T'_{pc}}{T_{pc} + B(1-B)\varepsilon} \tag{1.28}$$

Compressibility Factor

The **compressibility factor**, or **gas deviation factor, *Z*** is a measure of how close a real gas is to an ideal gas. The compressibility factor is defined as the ratio of the gas volume at a given temperature and pressure to the volume the gas would occupy if it were an ideal gas at the same temperature and pressure.

The compressibility factor is a dimensionless number close to 1.00 and is a function of the gas gravity, gas temperature, gas pressure, and the critical properties of the gas. As an example, a particular natural gas mixture can have a compressibility factor equal to 0.87 at 1000 psia and 80°F. Charts have been constructed that depict the variation of *Z* with the reduced temperature and reduced pressure.

Another term, the "supercompressibility factor," *Fpv*, which is related to the compressibility factor *Z*, is defined as follows:

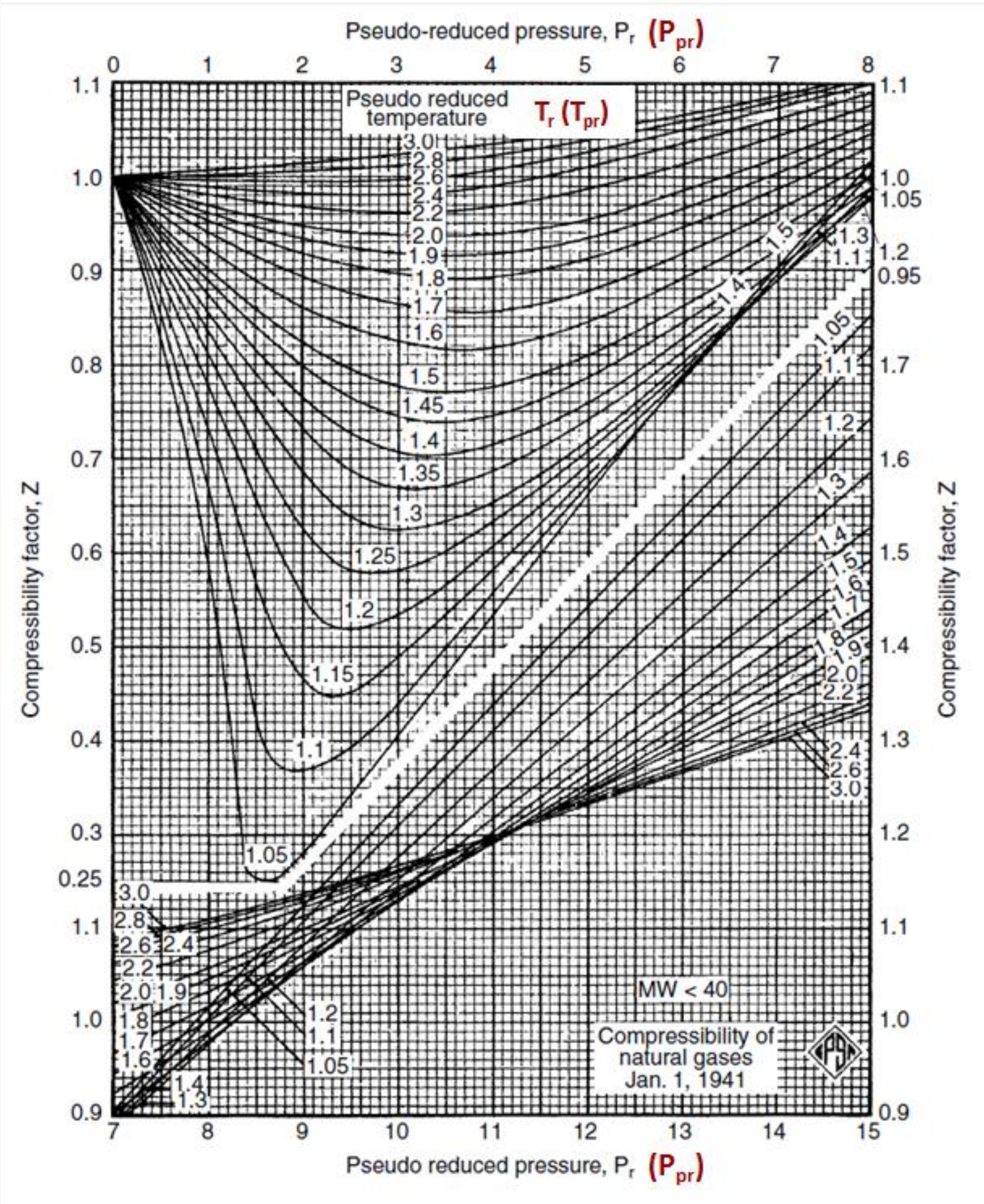
$$F_{pv} = \frac{1}{\sqrt{Z}} \qquad (1.29)$$

Compressibility Factor

The following methods are available to calculate the compressibility factor:

a. Standing-Katz method
b. Dranchuk, Purvis, and Robinson method
c. Americal Gas Association (AGA) method
d. California Natural Gas Association (CNGA) method

Standing-Katz method is the most popular.



The Standing-Katz method of calculating compressibility factor is based on the use of a graph that has been constructed for binary mixtures and saturated hydrocarbon vapor. This method is used generally for **sweet natural gas mixtures** containing various hydrocarbon components.

When the natural gas mixture contains appreciable amounts of non-hydrocarbons such as nitrogen, hydrogen sulfide, and carbon dioxide, certain corrections must be applied for these components.

Compressibility Factor

California Natural Gas Association (CNGA) Method

This is a fairly simple equation for quickly calculating the compressibility factor when the gas gravity, temperature, and pressure are known. The following equation is used for calculating the compressibility factor *Z*:

$$Z = \frac{1}{\left[1 + \left(\frac{P_{avg}\, 344{,}400(10)^{1.785G}}{T_f^{3.825}}\right)\right]} \qquad (1.34)$$

where

P_{avg} = average gas pressure, psig

T_f = average gas temperature, °R

G = gas gravity (air = 1.00)

This formula for the compressibility factor is valid when the average gas pressure, P_{avg}, is more than 100 psig. For pressures less than 100 psig, *Z* is approximately equal to 1.00

Note that the pressure used in Equation (1.34) is the gauge pressure.

Compressibility Factor, CNGA Method

In a gas pipeline, the pressure varies along the length of the pipeline. The compressibility factor Z also varies and must therefore be calculated for an average pressure at any location on the pipeline. If two points along the pipeline are at pressures P_1 and P_2, we could use an average pressure of $\frac{P_1+P_2}{2}$. However, the following formula is used for a more accurate value of the average pressure:

$$P_{avg} = \frac{2}{3}\left(P_1 + P_2 - \frac{P_1 \times P_2}{P_1 + P_2}\right) \quad (1.35)$$

Another form of the average pressure in a pipe segment is

$$P_{avg} = \frac{2}{3}\left(\frac{P_1^3 - P_2^3}{P_1^2 - P_2^2}\right) \quad (1.36)$$

Problem

Example 11

A natural gas mixture consists of the following components:

Component	Mole Fraction *y*
C_1	0.780
C_2	0.005
C_3	0.002
N_2	0.013
CO_2	0.016
H_2S	0.184

(a) Calculate the apparent molecular weight of the gas, gas gravity, and the pseudo-critical temperature and pseudo-critical pressure.

(b) Calculate the compressibility factor of the gas at 90°F and 1200 psia.

Heating Value

The heating value of a gas is defined as the thermal energy per unit volume of the gas. It is expressed in Btu/ft^3. For natural gas, it is approximately in the range of 900 to 1200 Btu/ft^3. There are two heating values used in the industry. These are the lower heating value (LHV) and higher heating value (HHV). For a gas mixture, the term *gross heating value* is used. It is calculated based upon the heating values of the component gases and their mole fractions using the following equation:

$$H_m = \Sigma(y_i H_i) \tag{1.37}$$

where

H_m = gross heating value of mixture, Btu/ft^3
y_i = mole fraction or percent of gas component i
H_i = heating value of gas component, Btu/ft^3

For example, a natural gas mixture consisting of 80% of gas A (heating value = 900 Btu/ft^3) and 20% of gas B (heating value = 1000 Btu/ft^3) will have a gross heating value of $H_m = (0.8 \times 900) + (0.2 \times 1000) = 920$ Btu/ft^3.