Example1- 3 Calculation of gas reservoir volume Use the real gas law to calculate the volume of 5 lb-mol of a gas mixture at reservoir conditions of T = 180°F and p = 4,000 psi. Assume that this natural gas has the following molar composition: C1 = 0.874, C2 = 0.083, C3 = 0.022, i-C4 = 0.006, n-C4 = 0.002, i- C5 = 0.008, n-C5 = 0.003, n-C6 = 0.001 and C7+ = 0.001.

Solution

OPTION 1—Calculate the pseudocritical properties of the mixture. These properties are simply the summation of the individual contributions of the component gases, weighted by their molar fractions. This is based on the classical thermodynamics law for ideal mixtures and Dalton's law of partial pressures. the results of this calculation.

Mwt=18.94, *Ppc*=671 psi ,*Tpc*=378 R,

The pseudoreduced properties are, *Ppr* = 4,000/671 = ( )and *Tpr* = (180 + 460)/378 =( ). From Figure 1, *Z* =( ). Then, from Eq. (1.2) and rearrangement,

V=ZnRT/P=

Presence of Nonhydrocarbon Gases

It is worth noting that the well known graph in Figure 1 was constructed for only hydrocarbon gas mixtures. In the presence of large amounts of nonhydrocarbon gases, the gas deviation factor must be adjusted. In the absence of complete natural gas composition but knowing the gas gravity and the composition of nonhydrocarbon gases. the inserts in Figure 2 can be used to adjust the pseudocritical properties of a gas mixture to account for the presence of nonhydrocarbon gases. Wichert and Aziz (1972) have presented a correlation that allows the use of the Standing-Katz graph (Figure 1) in the presence of nonhydrocarbon gases. The pseudocritical properties, *Tpc* and *ppc*, can be corrected by

$$T'_{PC} = Tpc - \varepsilon_3 \quad \ldots\ldots\ldots\ldots \quad 7$$

$$P'_{PC} = (T'_{PC}\, Ppc)/\, Tpc + y_{H2S}(1 - y_{H2S})\, \varepsilon_3 \quad \ldots\ldots 8$$

where is the mole fraction of hydrogen sulfide (natural gas with a high content of H2S is often referred to as a "sour" gas) and the term *e3* is a function of the H2S and CO2 concentrations, which can be obtained from Figure 3.

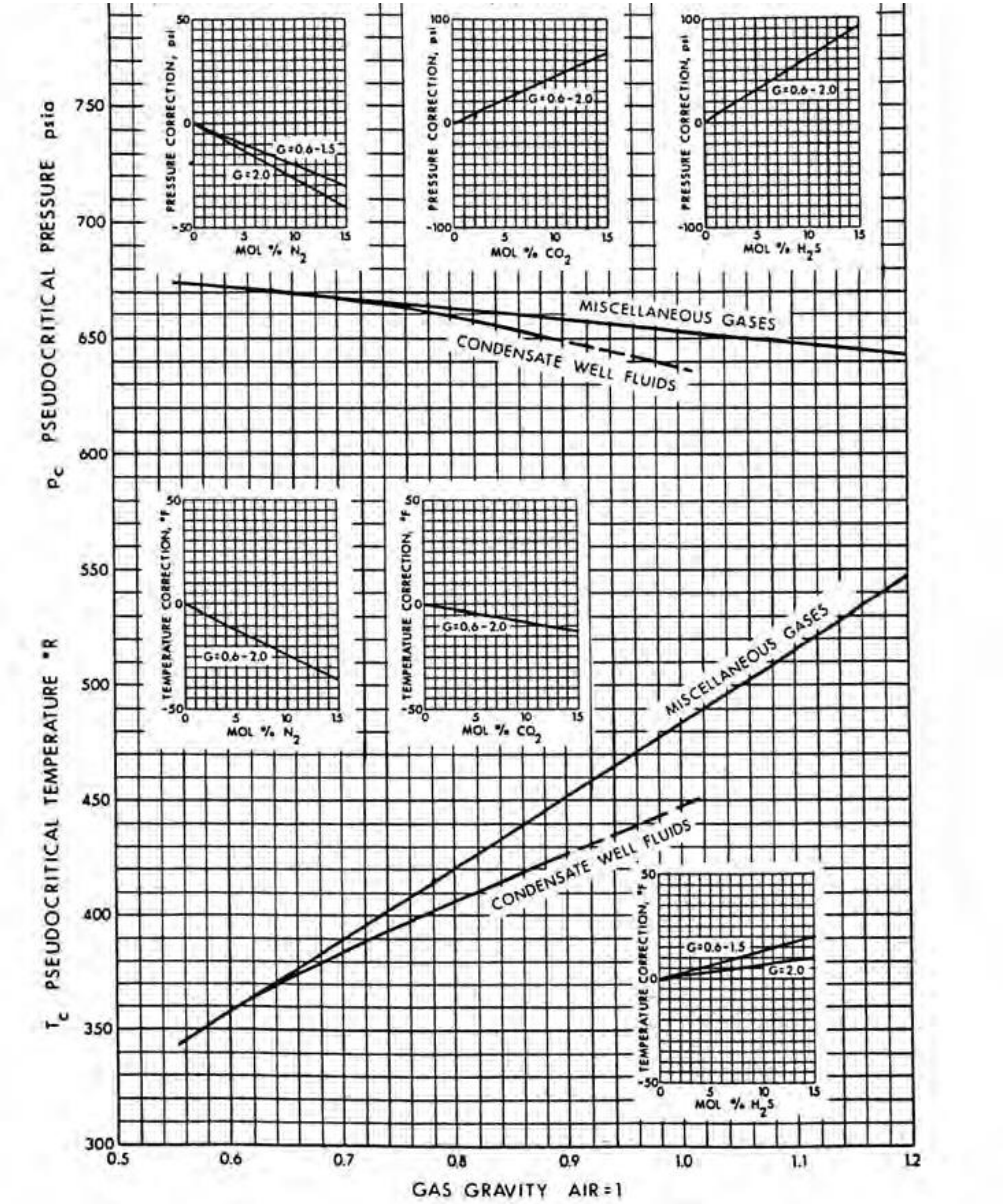

Figure 2 *Pseudocritical properties of natural gases* (Brown et al., 1948; inserts from Carr et al., 1954)

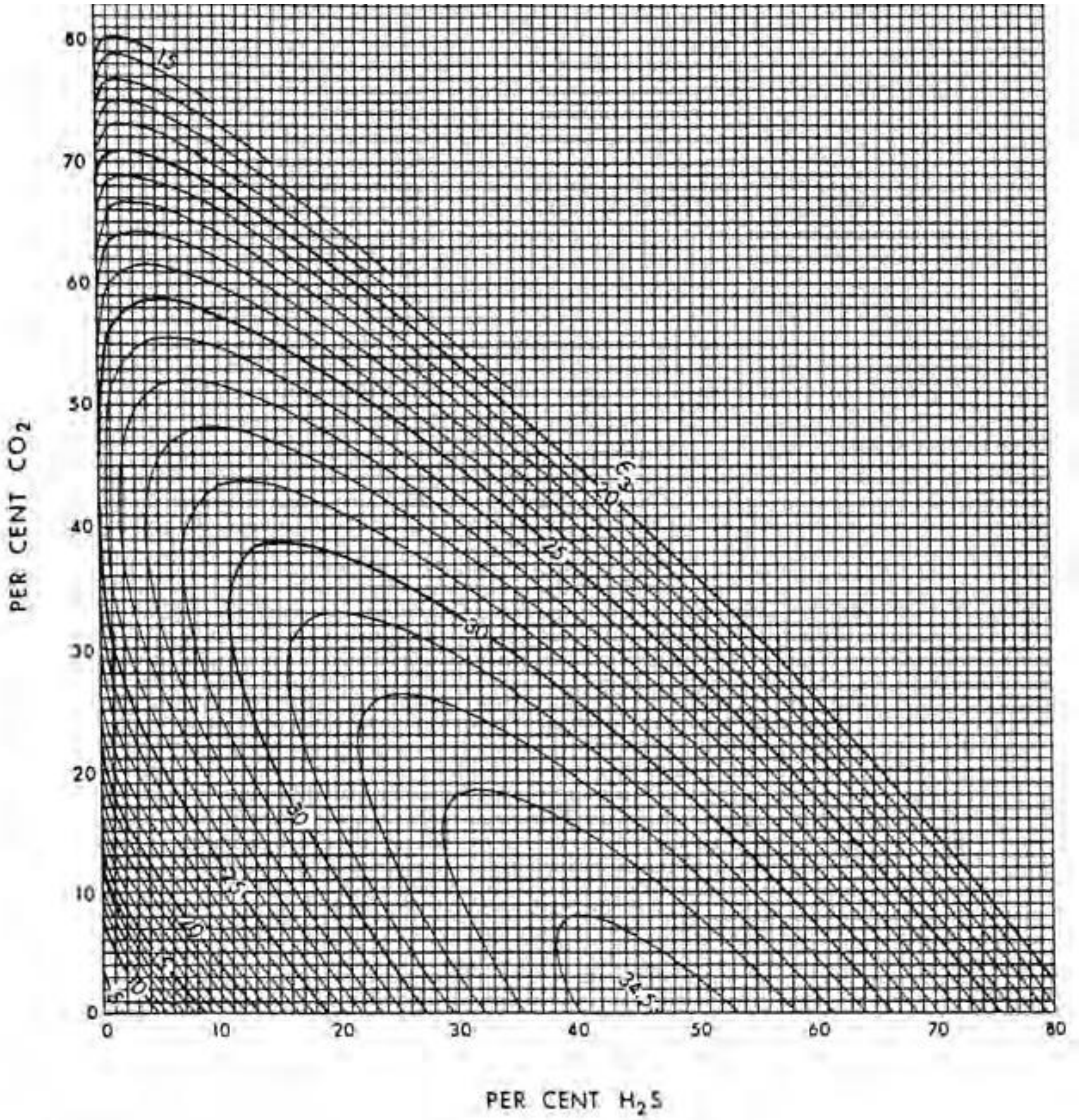

Figure 3 *Pseudocritical temperature adjustment factor, e3* (Wichert and Aziz, 1972)

Example 1–4 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:

C1	C2	C3	i-C4	n-C4	i-C5	n-C5	C6+	N2	CO2	H2S
0.784	0.028	0.007	0.0008	0.0005	0.0008	0.0003	0.0006	0.005	0.021	0.152

Solution

OPTION 1—From Figure 1–10 and using the compositions of CO2 and H2S, the adjustment factor ε_3 = 23.5 R. The pseudocritical properties are calculated as shown. Therefore,: MW*t*= 20.19, *Ppc*= 777 psi, *Tpc*= 407R from Eq. (1.7):

T'_{PC}= 407-23.5=383.5

and from Eq. (1.8):

P'_{PC}= 777 X 383 5/ 407+(0.152(1-0.152)X23.5) = 726.7 psi

The pseudoreduced properties are then, *Tpr* = (190 + 460)/383.5 = 1.70 and *Ppr* = 4,000/726.7=5.5, respectively. From Figure 1, *Z* = 0.9.

OPTION 2—Calculate the pseudocritical properties from Figure 2. The molecular weight is 20.19, so *Yg* = 20.19/28.97 = 0.697.

Therefore, from Figure 2, *Tpc* = 390 R and *Ppc* = 668 psi. These must be corrected by the inserts in Figure 2. Thus,

Tpc = 390 – 2 – 2 + 20 = 406 R

Ppc = 668 – 2 + 9 + 92 = 767 psi