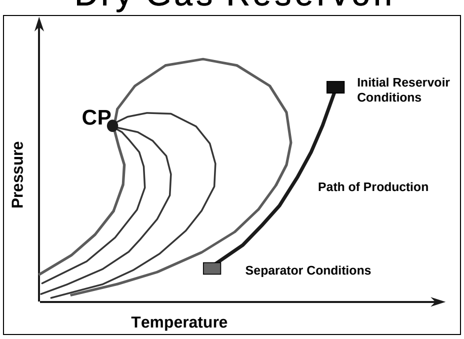
PETE 310

Lectures # 12 -13

Properties of Dry Gases

(pages 165-187)

Phase Diagram of a Dry Gas Reservoir



DRY GAS RESERVOIRS:

- GOR > 100,000 SCF/STB
- No liquid produced at surface
- Mostly methane

Standard Conditions

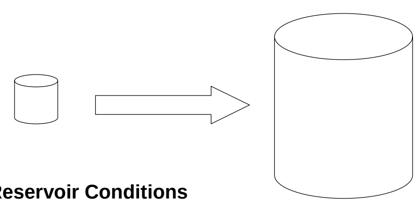
- Unify volumes to common grounds for sales and regulatory purposes
  - T = 60 ^{0}F
  - P = 14.65 – 15.025 (State dependent)

  Then

  $V_M = RT_{sc}/P_{sc}$

Reservoir Engineering Properties of Dry Gases

- Gas formation volume factor Bg



Gas Formation Volume Factor

[res bbl/SCF] or [ft^3/SCF]

Volume of an arbitrary amount of gas at reservoir T & P

Volume of SAME amount at standard T & P

$$B_g = \frac{V_R}{V_{SC}}$$

Gas Formation Volume Factor

[res bbl/SCF] or [ft^3/SCF]

$$Bg = \frac{\dfrac{ZnRT}{P}}{\dfrac{Z_{SC}\,nRT_{SC}}{P_{SC}}}$$

Gas Formation Volume Factor

Since in this book $T_{sc} = 520°R$, $p_{sc} = 14.65$ psia, and for all practical purposes $z_{sc} = 1$, then

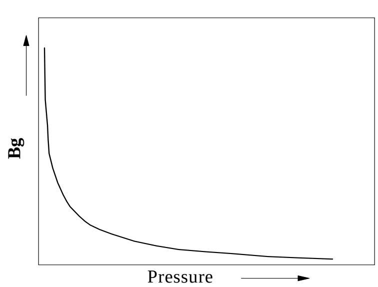
$$B_g = \frac{zT(14.65)}{(1.0)(520)p} = 0.0282\,\frac{zT}{p}\,\frac{\text{cu ft}}{\text{scf}}. \qquad (6\text{–}2)$$

Also,

$$B_g = \left(0.0282\,\frac{zT}{p}\,\frac{\text{cu ft}}{\text{scf}}\right)\left(\frac{\text{bbl}}{5.615\ \text{cu ft}}\right) = 0.00502\,\frac{zT}{p}\,\frac{\text{res bbl}}{\text{scf}}, \qquad (6\text{–}3)$$

Gas Formation Volume Factor

[res bbl/SCF] or [ft^3/SCF]

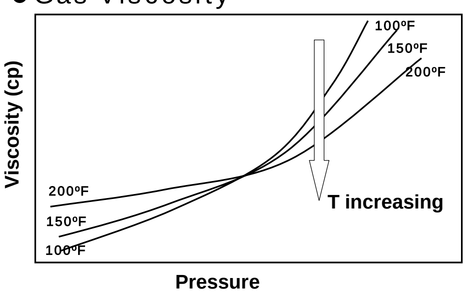


Viscosity Definition & Units

- Viscosity is a measure of the resistance to flow exerted by a fluid
- This is called dynamic viscosity and has units of
  centipoise = g mass / 100 sec cm
- Kinematic viscosity is viscosity / density, units are in
  centistokes = centipoise /g/cc

Reservoir Engineering Properties of Dry Gases

- Gas Viscosity



Viscosity of Ethane

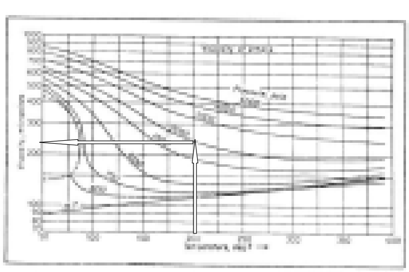


Fig. 6–6. Viscosities of ethane. (From Handbook of Natural Gas Engineering by Katz et al. Copyright 1959 by McGraw-Hill Book Co. Used with permission of McGraw-Hill Book Co.)

Viscosity of Gases at Atmospheric Pressure

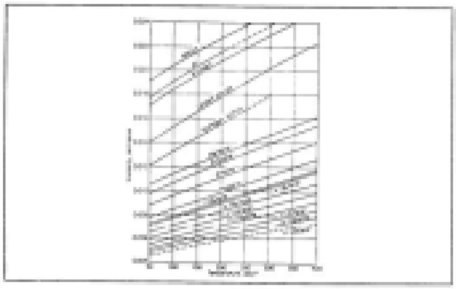


Fig. 6-7. Viscosities of pure gases at atmospheric pressure.

Viscosity of Gas Mixtures

$$\mu_g = \frac{\sum_j \mu_{gj} y_j M_j^{1/2}}{\sum_i y_i M_i^{1/2}} \qquad (6-16)$$

See example 6-9

Example

EXAMPLE 6-9: *Calculate the viscosity of the gas mixture given below at 200°F and a pressure of one atmosphere absolute.*

Component	Composition, mole fraction
Methane	0.850
Ethane	0.090
Propane	0.040
n-Butane	0.020
	1.000

Example

- Read Molecular Weights table A-1 page 492
- Read Viscosities figure 6-7
- Apply formula...

$$\mu_g = \frac{\sum_j \mu_{gj} y_j M_j^{1/2}}{\sum_i y_j M_i^{1/2}} \qquad (6-16)$$

Gas Viscosity if Composition is Unknown

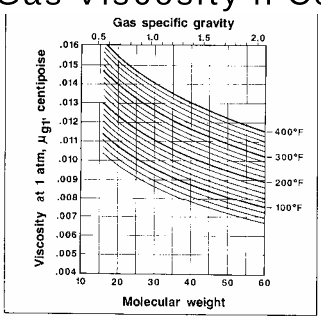
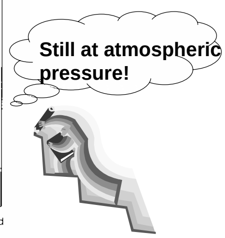
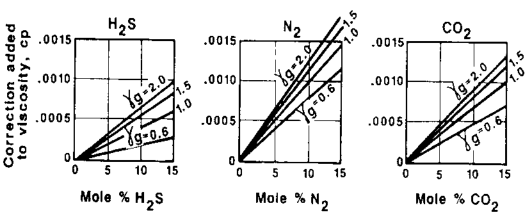


Fig. 6-8. Viscosities of natural gases at atmospheric pressure. (Adapted from Carr et al., *Trans.*, AIME, *201*, 997.)



Viscosity Corrections



Viscosity of Gases at High Pressure

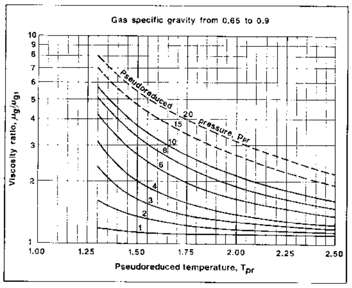


Fig. 6–9. Viscosity ratios for natural gases with specific gravities from 0.65 to 0.9.

$\mu = ratio * \mu_{at}$

Viscosity of Gases at High Pressure

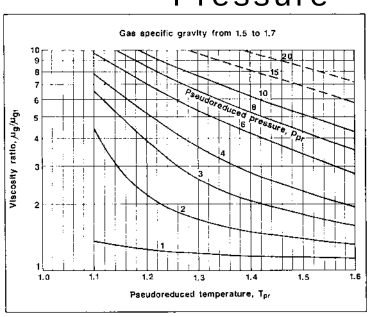


Fig. 6–12. Viscosity ratios for natural gases with specific gravities from 1.5 to 1.7.

make sure you check the specific gravity range

Accuracy for Viscosity Correlations?

- At low P_{pr} and low gravities $\pm$ 2%
- Agreement is less accurate as specific gravity increases (fig. 6-12 has about 20% accuracy)

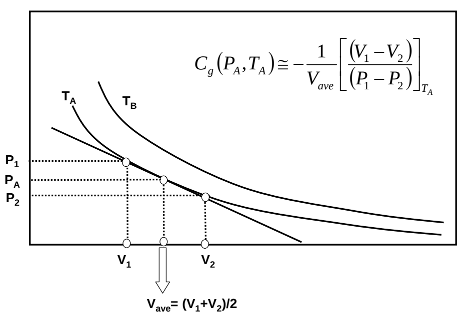
Isothermal Compressibility

- Definition

$$C_g\left(P_A,T_A\right)=-\frac{1}{V}\left[\frac{\partial V}{\partial P}\right]_{T_A}$$

  – Derivative is evaluated at constant T = T_A and specified pressure P = P_A

Isothermal Gas Compressibility



Isothermal Compressibility (Cg)

EXAMPLE 6–4: *The following table gives volumetric data at 150°F for a natural gas. Determine the coefficient of isothermal compressibility for this gas at 150°F and 1000 psia.*

Pressure, psia	Molar volume, cu ft/lb mole
700	8.5
800	7.4
900	6.5
1000	5.7
1100	5.0
1200	4.6
1300	4.2

Solution

Isothermal Compressibility

- Using ideal gas equation

The simplest equation of state is that for ideal gases.

$$pV = nRT \text{ or } V = \frac{nRT}{p} \qquad (3\text{-}14)$$

We wish to eliminate the term $\partial V/\partial p$ in Equation 6-4, so we derive this term from Equation 3-14 as

$$\left(\frac{\partial V}{\partial p}\right)_T = -\frac{nRT}{p^2}. \qquad (6\text{-}5)$$

Combining Equation 6-5 with Equation 6-4 gives

$$c_g = \left(-\frac{1}{V}\right)\left(-\frac{nRT}{p^2}\right)$$

$$c_g = \left(-\frac{p}{nRT}\right)\left(-\frac{nRT}{p^2}\right) = \frac{1}{p}.$$

Isothermal Compressibility

- Using real gas equation

$$V = nRT\frac{z}{p} \qquad (3\text{-}39)$$

Thus,

$$\left(\frac{\partial V}{\partial p}\right)_T = nRT\frac{p\left(\frac{\partial z}{\partial p}\right)_T - z}{p^2} \qquad (6\text{-}7)$$

$$c_g = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T \qquad (6\text{-}4)$$

$$c_g = \left[-\frac{p}{znRT}\right]\left\{\frac{nRT}{p^2}\left[p\left(\frac{\partial z}{\partial p}\right)_T - z\right]\right\}$$

$$c_g = \frac{1}{p} - \frac{1}{z}\left(\frac{\partial z}{\partial p}\right)_T. \qquad (6\text{-}8)$$

Gas Compressibility

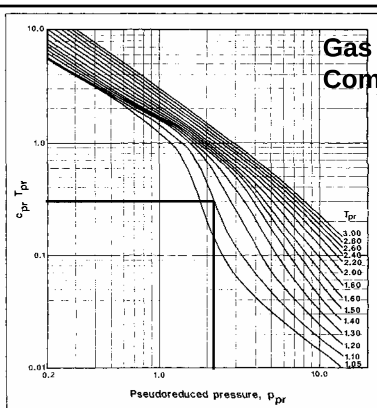


Fig. 6–4. Pseudoreduced compressibilities of natural gases.