5.2.1 Incompressible Flow (continue)

- The K value for fittings is associated with a specific internal diameter. To use it with another internal diameter, adjust it as follows:

$$K = K_1 \left(\frac{D}{D_1} \right)^4$$

- If the frictional pressure drop for one pipe size is known, the pressure drop for another pipe size with the same fluid and flow rate is roughly:

$$\Delta P \approx \Delta P_1 \left(\frac{D_1}{D} \right)^5$$

- If the frictional pressure drop for a fluid is known, the pressure drop for a fluid with a different density is roughly:

$$\Delta P \approx \Delta P_1 \left(\frac{\rho_1}{\rho} \right) \quad \text{for the same weight flow}$$

$$\Delta P \approx \Delta P_1 \left(\frac{\rho}{\rho_1} \right) \quad \text{for the same volumetric flow}$$

- Case - A cone roof tank was used to store light distillate with a density of 800kg/ m^3 and a normal inflow of 50 m3/h. The level instrument failed and the tank overflowed. The weak roof-to-shell weld failing partly because the pressure drop through the vent increased by a factor of 800/1.18 = 678.

5.2.5 Moody Friction Factor

- Laminar flow (Re < 2000) is based on Pouseuille equation:

$$f = \frac{64}{Re} \tag{5.16}$$

- Turbulent flow (Re > 4000) is based on the implicit Colebrook equation (1939):

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\frac{\epsilon}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right]$$

The Chen equation below (Chem Eng, 1987) is an explicit approximation:

$$\frac{1}{\sqrt{f}} = -2\log_{10}(A - B\log_{10}(A - B\log_{10}(A - B\log_{10}(A - B\log_{10}(A - B\log_{10}(A + \frac{14}{Re})))))) \tag{5.17}$$

$$A = \frac{\epsilon}{3.7D}$$

$$B = \frac{5.02}{Re}$$

$$Re = \frac{C_{54}W}{D\mu}$$

The Churchill equation (Chem Eng, 1977) is another explicit approximation. It is less accurate than the Chen equation, but continuous between the laminar and turbulent regions.

- In the transitional zone (2000 < Re < 4000) the friction factor is between the two equations above. The turbulent friction factor is often used as it is conservative.

- Fully turbulent flow is given by the Von Karman equation (Daugherty eqn 8.36):

$$\frac{1}{\sqrt{f_T}} = -2\log_{10}\left[\frac{\epsilon}{D}\right] + 1.14$$

f = Moody friction factor ($f_{Moody} = 4 \times f_{Fanning}$)
f_T = Moody friction factor at fully turbulent flow
ϵ = Absolute pipe roughness (m)[ft]
W = Mass flow rate (kg/h)[lb/h]
D = Pipe ID (m)[ft]
μ = Viscosity (cP)[cP]
C_{54} = (0.3537) or [0.5263]