Frictional Losses in Pipe Fittings

Pipe fittings are hardware used in most piping installations such as valves, elbows, T's, sudden expansions and contractions. Such pipe fittings introduce additional frictional losses in a piping system and sometimes frictional losses due to pipe fittings are high and comparable to the frictional losses through the pipe itself. In order to quantify the frictional losses due to pipe fittings, the concept of equivalent length is introduced.

Equivalent Length:

Equivalent length of a pipe fitting is defined as the frictional losses caused due to the pipe fitting that is equivalent to frictional losses caused by a straight pipe of length $(L/D)_e$, where L_e is the equivalent length and D is the diameter of the pipe. Table 3.4 of your textbook shows $(L/D)_e$ for different types of pipe fittings.

Table 3.4 Equivalent Lengths of Pipe Fittings†‡

Type of Fitting	$(L/D)_e$
Angle valve (open)	160
Close return bend	75
Gate valve (open)	6.5
Globe valve (open)	330
Square 90° elbow	70
Standard 90° elbow	30
Standard "T" (through side outlet)	70
45° elbow	15
Sudden contraction, 4:1	15
Sudden contraction, 2:1	11
Sudden contraction, 4:3	6.5
Sudden expansion, 1:4	30
Sudden expansion, 1:2	20
Sudden expansion, 3:4	6.5

Example:

A 6-in schedule 40 commercial steel pipe of total length 1000 ft is equipped with the following pipe fittings: 7 standard 90^o elbows, 1 close return bend, 2 open gate valves and 2 standard T's (side outlet).

(a) Calculate the total equivalent length of the pipe and the fittings.

(b) If water is flowing in the above horizontal pipe at flow rate 15 ft^3/s calculate the pressure drop.

Solution:

(a) From Table 3.3 for 6-in schedule 40 pipe D = 6.065 in. From Table 3.4 $(L/D)_e$ for fittings is as follows:

1. 7 standard elbows x 30 ➔ $(L/D)_e$ = 210
2. 1 close return bend x 75 ➔ $(L/D)_e$ = 75
3. 2 open gate valves x 6.5 ➔ $(L/D)_e$ = 13
4. 2 standard T's (side outlet) x 70 ➔ $(L/D)_e$ = 140

$(L/D)_e$ = 210+75+13+140 = 438. The equivalent length due to fittings L_e = 438 x D = 438 x 6.065 in = 2656.5 in = 221.4 ft.

$$\text{The total equivalent length} = \underbrace{1000\ \text{ft}}_{\text{Original Length of Pipe}} + \underbrace{221.4\ \text{ft}}_{\text{Equivalent Length Due to Fittings}} = \underbrace{1221.4\ \text{ft}}_{\text{Total Equivalent Length}} .$$

(b) $u = \dfrac{Q}{\frac{\pi}{4}D^2} = \dfrac{15}{\frac{\pi}{4}\left(\frac{6.065}{12}\right)^2} = 74.77$ ft/s $\qquad \mathrm{Re} = \dfrac{(62.4)(74.77)\left(\frac{6.065}{12}\right)}{0.000672} = 3.51 \times 10^6$

For commercial steel ε = 0.046 in ➔ ε/D = 0.046/6.065 = 0.00076

$$\text{For Tubulent flow } (\mathrm{Re} > 4000) \qquad f_F = \frac{1}{\left\{-1.737\ln\left(0.269\dfrac{\varepsilon}{D} - \dfrac{2.185}{\mathrm{Re}}\ln\left(0.269\dfrac{\varepsilon}{D} + \dfrac{14.5}{\mathrm{Re}}\right)\right)\right\}^2}$$

$$f_F = \frac{1}{\left\{-1.737\ln\left(0.269(0.00076) - \dfrac{2.185}{3.51*10^6}\ln\left(0.269(0.00076) + \dfrac{14.5}{3.51*10^6}\right)\right)\right\}^2} = 0.00462$$

$$\underbrace{-\Delta P}_{\text{Pressure Drop In Pipe}} = \underbrace{\rho\, g\, \Delta z}_{\text{Pressure Drop due to Gravity}} + \overbrace{2\,\rho\, u^2 \frac{L}{D} f_F}^{\text{Pressure Drop due to Friction}} = 0 + 2\,(62.4)(74.77)^2\left(\frac{1221.4}{6.065/12}\right)(0.00462)$$

$$\Delta P = 7.79x10^6\ \frac{\text{lbm}}{\text{ft s}^2} = 1680\ \text{psi}$$

Note in you ignore frictional losses due to fittings:

$$\Delta P = 0 + 2\,(62.4)(74.77)^2\left(\frac{1000}{6.065/12}\right)(0.00462) = 1375\ \text{psi}\ \ (18\%\ \text{error}\,!)$$