6.103 The reservoirs in Fig. P6.103 are connected by cast-iron pipes joined abruptly, with sharp-edged entrance and exit. Including minor losses, estimate the flow of water at 20°C if the surface of reservoir 1 is 45 ft higher than that of reservoir 2.

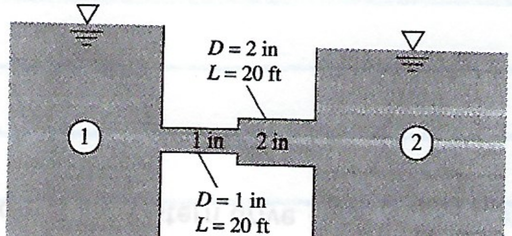

Fig. P6.103

$\rho = 1.94$ slug/ft^3 $\quad \mu = 2.09E{-5}$ slug/ft·s

$D_a = 1''$ $\quad D_b = 2''$

$\varepsilon = .00015$ ft $\quad \varepsilon/D_a = .0018$ $\quad \varepsilon/D_b = .0009$

$$Q_a = Q_b = V_a \frac{\pi}{4} D_a^2 = V_b \frac{\pi}{4} D_b^2 \Rightarrow V_b = \frac{V_a}{4}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_t + h_f + \Sigma h_m$$

$$\Delta z = h_{fa} + \Sigma h_{ma} + h_{fb} + \Sigma h_{mb}$$

$$\Delta z = \frac{V_a^2}{2g}\left(f_a \frac{L_a}{D_a} + .5 + .56\right) + \frac{V_b^2}{2g}\left(f_b \frac{L_b}{D_b} + 1\right)$$

$\Delta z = 45'$ $\quad V_b = V_a/4$

(.5: sharp entrance, Fig 6.21; .56: abrupt expansion, d/D = 1/2; 1: exit reservoir, d/D = 0; Fig 6.22)

$$45 = \frac{V_a^2}{2 \times 32.2}\left[240 f_a + 1.06 + \frac{120}{16} f_b + \frac{1}{16}\right]$$

$f_a = f_a(Re_{D_a}, \varepsilon/D_a)$ $\quad f_b = f_b(Re_{D_b}, \varepsilon/D_b)$

guess $f_a = f_b = .02 \Rightarrow V_a = 21.85$ ft/s $\quad Re_a = 169{,}000$

$f_{a2} = .0239$

$V_b = 5.46$ ft/s $\quad Re_b = 84{,}500$

$f_{b2} = .0222$

final: $f_a = .024$ $\quad f_b = .0224$

$V_a = 20.3$ ft/s

$Q = V_a A_a = .111$ ft^3/s

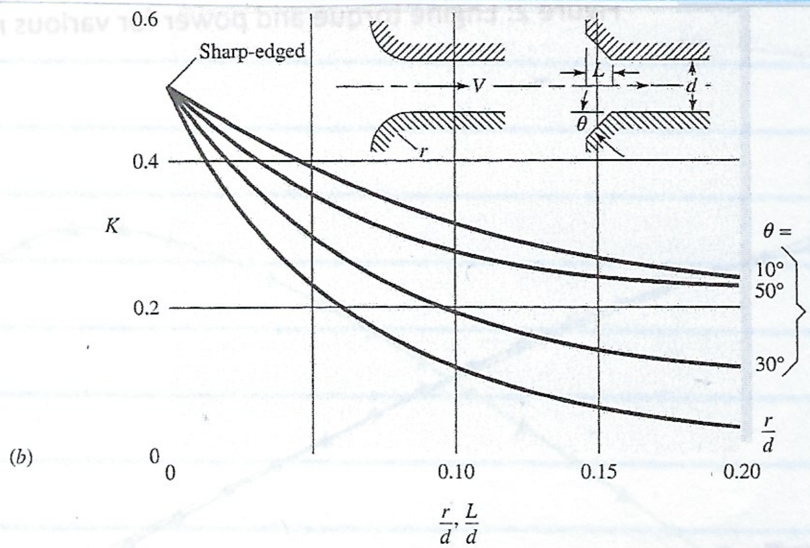

Fig. 6.21 Entrance and exit loss coefficients: (*a*) reentrant inlets; (*b*) rounded and beveled inlets. Exit losses are $K \approx 1.0$ for all shapes of exit (reentrant, sharp, beveled, or rounded).

Source: From ASHRAE Handbook-2012 Fundamentals, ASHRAE, Atlanta, GA, 2012.

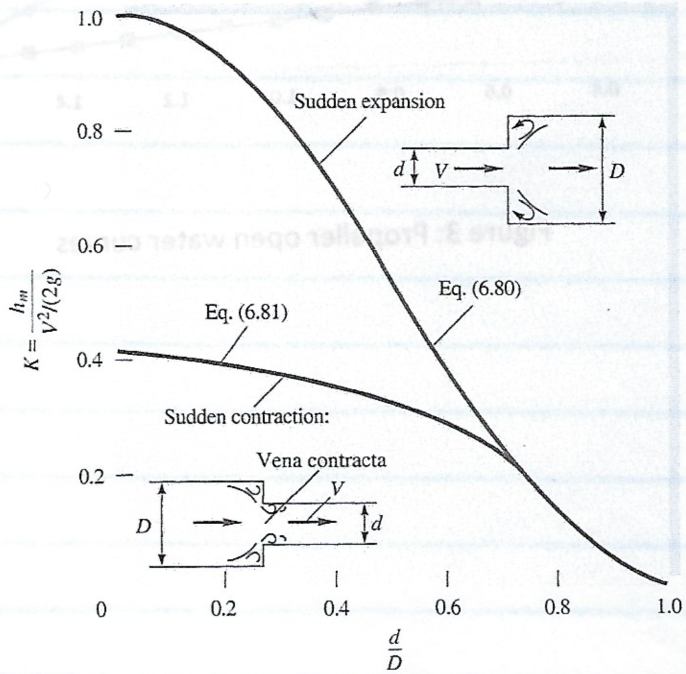

Fig. 6.22 Sudden expansion and contraction losses. Note that the loss is based on velocity head in the small pipe.