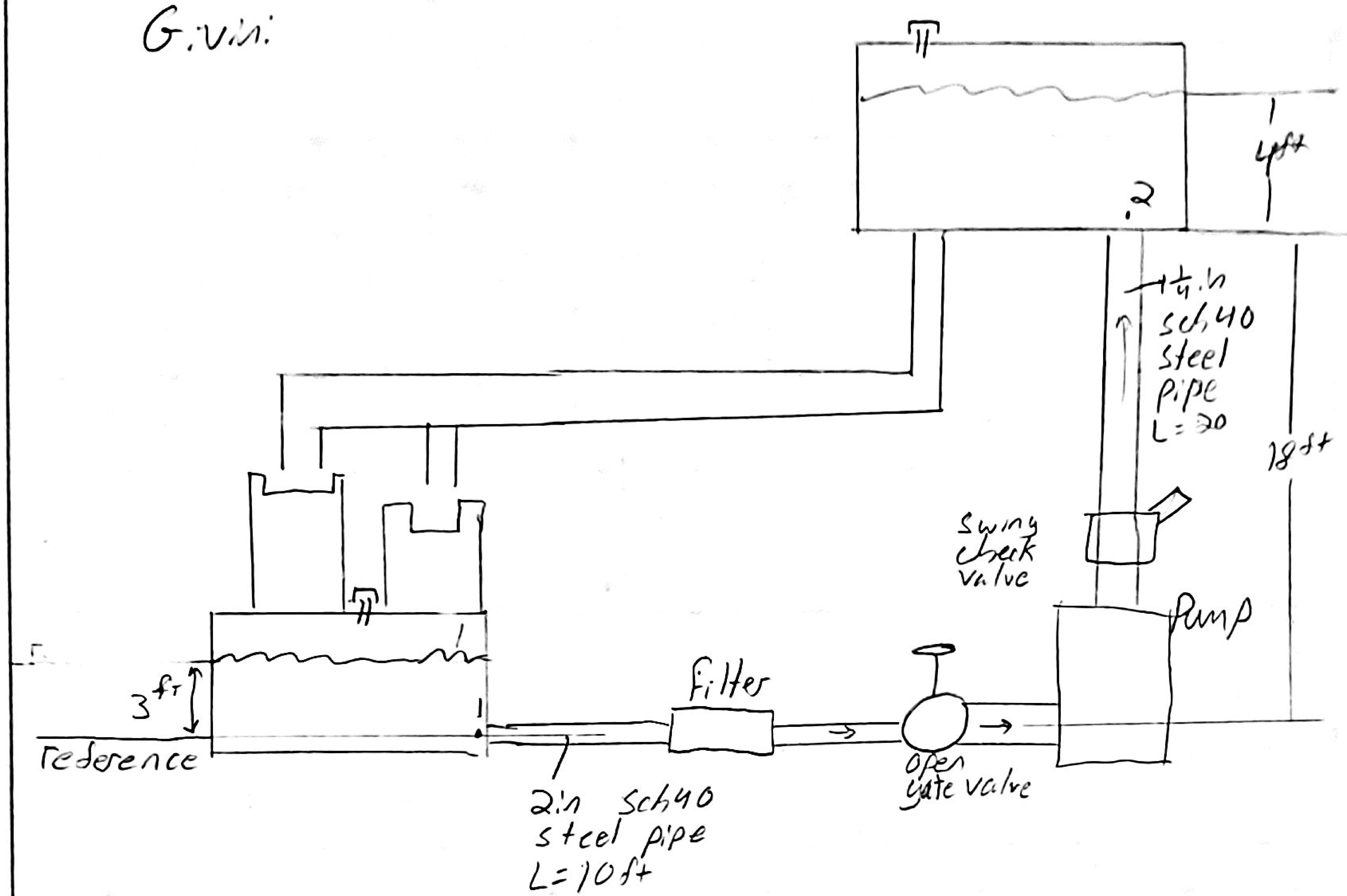
Problem 11.23

Given:



Find: total pump head and power delivered to the coolent

Solution:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$$

suction pipe and discharge pipe are different sizes therefor they have different velocities.

$$\frac{P_1 - P_2}{\gamma} - z_2 = \frac{V_1^2 - V_2^2}{2g} + h_L$$

$$P_1 = H \cdot \rho = 3^{ft} \cdot 1.94 \frac{slug}{ft^3} = 5.82 \frac{slug}{ft^2}$$

$$P_2 = H \cdot \rho = 4^{ft} \cdot 1.94 \frac{slug}{ft^3} = 7.76 \frac{slug}{ft^2}$$

$$H_L = h_{suction} + h_{filter} + h_{gate} + h_{check} + h_{discharge}$$

$$h_{suction} = f \cdot \frac{L}{D_1} \cdot \frac{V_1^2}{2g} = f \frac{L}{D_1} \cdot \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_1^4}$$

$$h_{filter} = K_{filter} \cdot \frac{V_1^2}{2g} = K_{filter} \cdot \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_1^4}$$

$$h_{gate} = K_{gate} \cdot \frac{V_1^2}{2g} = 8f_T \cdot \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_1^4}$$

$$h_{check} = K_{check} \cdot \frac{V_2^2}{2g} = 150f_T \cdot \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_2^4}$$

$$h_{discharge} = f \cdot \frac{L}{D_2} \cdot \frac{V_2^2}{2g} = f \cdot \frac{L}{D_2} \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_2^4}$$

$$H_L = \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_1^4}\left(f_1 \frac{L}{D_1} + K_{filter} + K_{gate}\right) + \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_2^4}\left(f_2 \frac{L_2}{D_2} + K_{check}\right)$$

$$\frac{P_1 - P_2}{\gamma} - z_2 = \frac{1}{2g} \cdot \frac{16 \cdot Q^2}{\pi^2 D_1^4} - \frac{1}{2g} \frac{16 \cdot Q^2}{\pi^2 D_2^4} + \left[\frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_1^4}\left(f_1 \frac{L_1}{D_1} + K_{filter} + 8f_T\right) + \frac{1}{2g} \cdot \frac{16Q^2}{\pi^2 D_2^4}\left(f_2 \frac{L_2}{D_2} + 150f_T\right)\right]$$

Now I will do LHS and RHS iterations

- guess Q
- Compute V_1 and V_2 based on Q
- Compute f_1 and f_2 based on V_1 and V_2
- Compute RHS and LHS
- Compare RHS and LHS

I will then have the correct Q to find correct h_L to find h_a and pump power.

according to excel iterations $Q = 0.0543 \frac{ft^3}{s}$

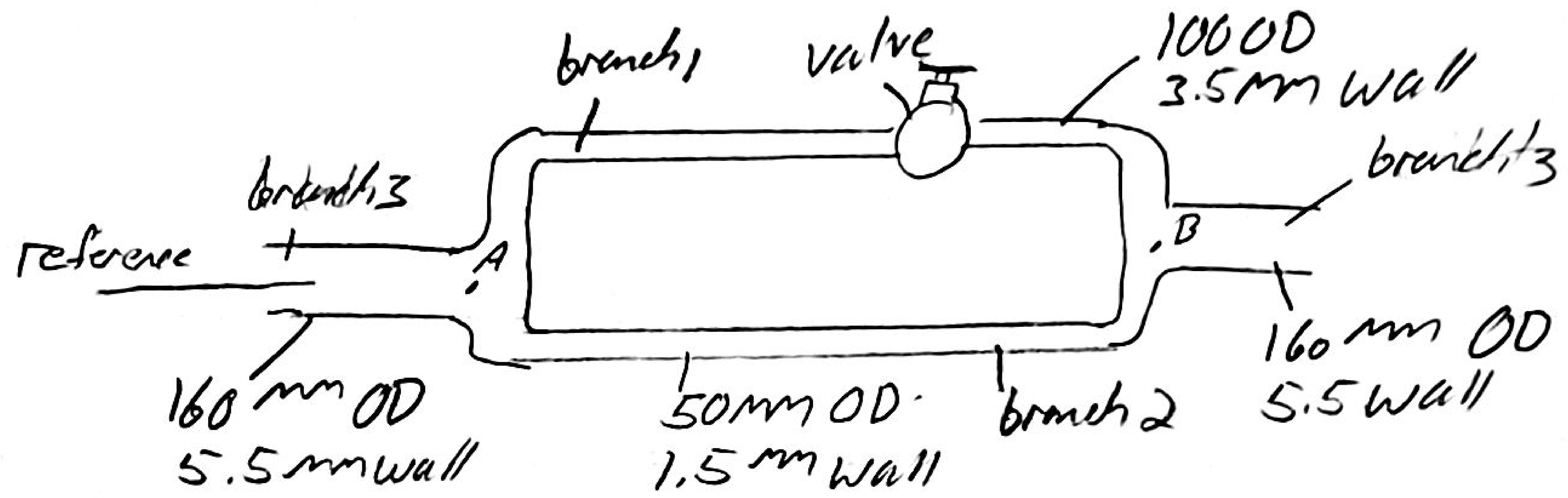
$$h_a = h_L + (z_2 - z_1) \Rightarrow 3.605^{ft} + 18^{ft} = \underline{21.6^{ft}}$$

$$P_{power} = Q \cdot \gamma \cdot h_a = 0.0543 \frac{ft^3}{s} \cdot 64.4 \frac{lb}{ft^3} \cdot 21.6^{ft} = 75.53 \frac{lb\text{-}ft}{s}$$

$$75.53 \frac{lb\text{-}ft}{s} = \underline{0.1373\, HP}$$

Problem 12.5

Given: A 160-mm pipe branches into a 100mm and a 50mm pipe. Both pipes are hydraulic copper tubing and 30m long. The fluid is water at 10°C.



Find: what is the resistance coefficient K of the valve so that both branches have 500 L/min flow rate

Solution:

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_L$$

$$\frac{\Delta p}{\gamma} = h_{L1} \quad \underline{\text{and}} \quad \frac{\Delta p}{\gamma} = h_{L2}$$

$$h_{L1} = h_{L\,tee} + h_{L\,reduction} + h_{L\,elbow} + h_{L\,pipe} + h_{L\,valve} + h_{L\,elbow} + h_{L\,expansion} + h_{L\,tee}$$

$$h_{L1} = k_{tee}\frac{V_3^2}{2g} + k_{red}\frac{V_1^2}{2g} + 2\cdot k_{elB}\frac{V_1^2}{2g} + f_1\frac{L_1}{D_1}\frac{V_1^2}{2g} + k_{valve}\frac{V_1^2}{2g} + k_{exp}\frac{V_1^2}{2g} + k_{tee}\frac{V_1^2}{2g}$$

$k_{elbow} = 20 f_{t_1}$

$k_{tee} = 60 f_{t_3}$

$k_{exp} = 0.41$

$k_{red} = 0.19$

$$h_{L1} = 2\cdot 60 f_{t3}\frac{V_3^2}{2g} + 0.19\frac{V_1^2}{2g} + 2\cdot 20 f_{t1}\cdot\frac{V_1^2}{2g} + f_1\frac{L_1}{D_1}\frac{V_1^2}{2g} + 0.41\frac{V_1^2}{2g} + k_{valve}\frac{V_1^2}{2g}$$

$$h_{L2} = h_{L\,tee} + h_{L\,reduction} + h_{L\,elbow} + h_{L\,pipe} + h_{L\,elbow} + h_{L\,expansion} + h_{L\,tee}$$

$$h_{L2} = k_{tee}\frac{V_3^2}{2g} + k_{red}\frac{V_2^2}{2g} + 2k_{elb}\frac{V_2^2}{2g} + f_2\frac{L_2}{D_2}\cdot\frac{V_2^2}{2g} + k_{exp}\frac{V_2^2}{2g} + k_{tee}\frac{V_3^2}{2g}$$

$k_{elbow} = 20 f_{t2}$

$k_{tee} = 60 f_{t3}$

$k_{red} = 0.23$

$k_{exp} = 0.48$

$$h_{L2} = 2\cdot 60 f_{t3}\frac{V_3^2}{2g} + 0.23\frac{V_2^2}{2g} + 2\cdot 20 f_{t2}\frac{V_2^2}{2g} + f_2\frac{L_2}{D_2}\frac{V_2^2}{2g} + 0.48\frac{V_2^2}{2g}$$

$h_{L1} = h_{L2}$ $\quad Q_3 = Q_1 + Q_2 \Rightarrow Q_3 = 0.00833 + 0.00833$

$Q_3 = 0.0166\ \frac{m^3}{s}$

$$V_3 = \frac{Q_3}{A_3} = \frac{Q_3}{\pi\left(\frac{d_3}{2}\right)^2} = \frac{0.0166}{\pi\left(\frac{0.149\,m}{2}\right)^2} = 0.952\ \frac{m}{s}$$

$$V_1 = \frac{Q_1}{A_1} = \frac{Q_1}{\pi\left(\frac{d_1}{2}\right)^2} = \frac{0.00833}{\pi\left(\frac{0.093}{2}\right)^2} = 1.226\ \frac{m}{s}$$

$$V_2 = \frac{Q_2}{A_2} = \frac{Q_2}{\pi\left(\frac{d_2}{2}\right)^2} = \frac{0.00833}{\pi\left(\frac{0.047}{2}\right)^2} = 4.801\ \frac{m}{s}$$

I will put velocities into energy loss equations and solve for $\underline{k_{valve}}$

$$Re_1 = \frac{V_1 D_1}{\nu} = \frac{1.226\frac{m}{s} \cdot 0.043^m}{1.3\times10^{-6}\frac{m^2}{s}} = 91478.46$$

$$R_{r1} = \frac{D_1}{\varepsilon} = \frac{0.097^m}{1.5\times10^{-6}m} = 64666.66$$

$$f_1 = 0.0138 \qquad f_{t1} = 0.0086$$

$$Re_2 = \frac{V_2 \cdot D_2}{\nu} = \frac{4.801\frac{m}{s} \cdot 0.047^m}{1.3\times10^{-6}\frac{m^2}{s}} = 173574.6$$

$$R_{r2} = \frac{D_2}{\varepsilon} = \frac{0.047^m}{1.5\times10^{-6}m} = 31333.33$$

$$f_2 = 0.016 \qquad f_{t2} = 0.0097$$

$$Re_3 = \frac{V_3 D_3}{\nu} = \frac{0.953\frac{m}{s} \cdot 0.149^m}{1.3\times10^{-6}\frac{m^2}{s}} = 109228.4$$

$$R_{r3} = \frac{D_3}{\varepsilon} = \frac{0.149^m}{1.5\times10^{-6}m} = 99333.33$$

$$f_3 = 0.012 \qquad f_{t3} = 0.00807$$

$$h_{L1} = 2\cdot60\cdot0.00807\cdot\frac{0.953^2}{2\cdot9.81} + 0.19\frac{1.226^2}{2\cdot9.81} + 2\cdot20\cdot0.0086\cdot\frac{1.226^2}{2\cdot9.81} + 0.0138\cdot\frac{30}{0.043}\cdot\frac{1.226^2}{2\cdot9.81} + 0.41\frac{1.226^2}{2\cdot9.81} + k_{valve}\cdot\frac{1.226^2}{2\cdot9.81}$$

$$h_{L1} = 0.0447 + 0.014 + 0.027 + 0.34 + 0.031 + 0.076\,k_{valve}$$

$$h_{L1} = 0.4567 + 0.076\,k_{valve}$$

$$h_{L2} = 2\cdot60\cdot0.00807\,\frac{0.953^2}{2\cdot9.81} + 0.23\frac{4.801^2}{2\cdot9.81} + 2\cdot30\cdot0.0097\cdot\frac{4.801^2}{2\cdot9.81} + 0.016\cdot\frac{30}{0.047}\cdot\frac{4.801^2}{2\cdot9.81} + 0.48\cdot\frac{4.801^2}{2\cdot9.81}$$

$h_{L2} = 0.0447 + 0.27 + 0.455 + 11.99 + 0.57$

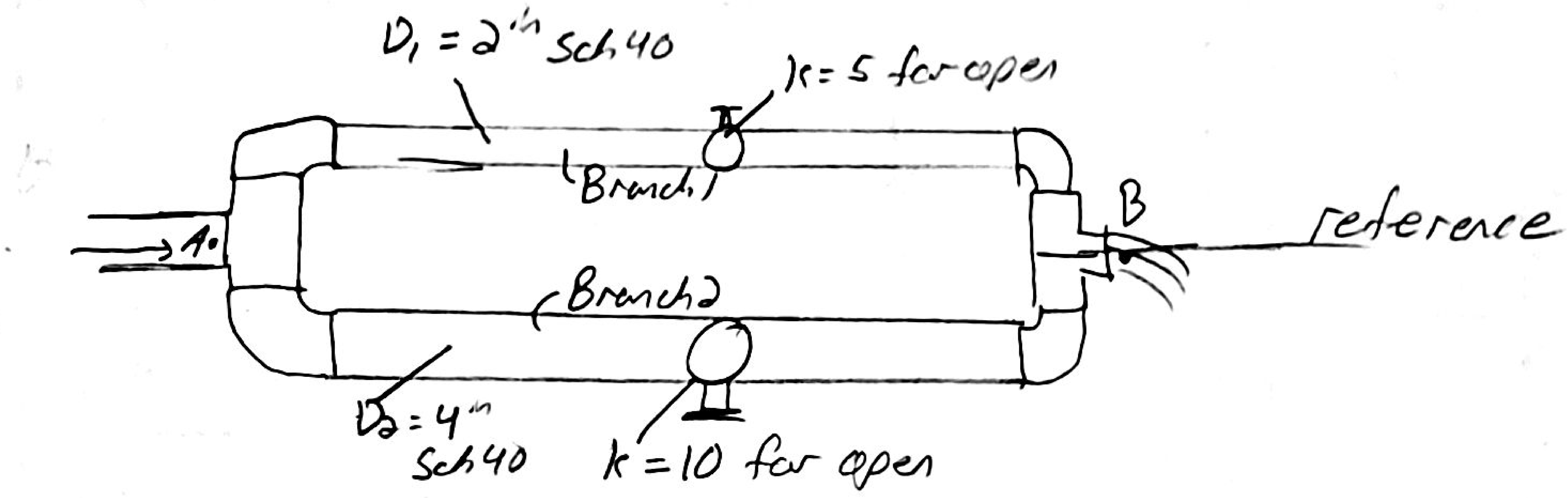
$h_{L2} = 13.32^m$

$13.32^m = 0.4567 + 0.076 k_{valve}$

$k_{valve} = 1169.25$

Problem 12.6

Given: The pressure at A is 20psig. Use $k = 0.4$ for each elbow. Neglect energy losses in the tees and pipe friction losses.



Find: Volume of flow when A) Both valves are open
B) Valve in branch 2 is open
C) Valve in branch 1 is open

Solution:

A) $$\frac{p_1}{\gamma} + \cancel{\frac{v_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \cancel{\frac{p_2}{\gamma}}^{0} + \cancel{\frac{v_2^2}{2g}}^{0} + \cancel{z_2}^{0} + h_L$$

$$\frac{p_1}{\gamma} = h_{L1} \quad \underline{\text{and}} \quad \frac{p_1}{\gamma} = h_{L2}$$

$$Q_3 = Q_2 + Q_1$$

$$h_{L1} = 2h_{L\,elbow} + h_{L\,valve}$$

$$h_{L1} = 2 \cdot 0.4 \cdot \frac{V_1^2}{2g} + k_{valve}\frac{V_1^2}{2g}$$

$$V^2 = \frac{16\,Q^2}{\pi^2 D^4}$$

$$h_{L1} = 0.8 \cdot \frac{1}{g} \cdot \frac{8 \cdot Q_1^2}{\pi^2 D_1^4} + 5 \cdot \frac{1}{g}\,\frac{8 \cdot Q_1^2}{\pi^2 D_1^4}$$

$$h_{L1} = Q_1^2\left[\frac{1.8 \cdot 8}{g \cdot \pi^2 \cdot D_1^4} + \frac{5 \cdot 8}{g \cdot \pi^2 \cdot D_1^4}\right]$$

$$h_{L1} = Q_1^2\left[51.41 + 192.81\right]$$

$$h_{L1} = Q_1^2 \cdot 194.22$$

$$\frac{2880 \frac{lb}{ft^2}}{64.4 \frac{lb}{ft^3}} = Q_1^2 \cdot 194.22$$

$$Q_1 = \sqrt{\frac{44.72}{194.22}} = 0.479 \frac{ft^3}{s}$$

$$h_{L2} = 2 h_L \text{ elbow} + h_L \text{ valve}$$

$$h_{L2} = 2 \cdot 0.4 \frac{V_2^2}{2g} + 10 \cdot \frac{V_2^2}{2g} \qquad V^2 = \frac{16 \cdot Q^2}{\pi^2 D^4}$$

$$h_{L2} = Q_2^2 \left[\frac{1.8 \cdot 8}{g \cdot \pi^2 \cdot D_2^4} + \frac{10 \cdot 8}{g \cdot \pi \cdot D_2^4} \right]$$

$$h_{L2} = Q_2^2 [3.57 + 19.86]$$

$$\frac{2880}{64.4} = Q_2^2 \cdot 23.42$$

$$Q_2 = \sqrt{\frac{44.72}{23.42}} = 1.38 \frac{ft^3}{s}$$

$$Q_3 = 0.479 + 1.38$$

$Q_3 = 1.859 \frac{ft^3}{s}$ when both valves are open

B) if valve in branch 1 is closed then $Q_1 = 0$

$\therefore Q_3 = Q_2$

$$h_{L2} = 2 h_L \text{ elbow} + h_L \text{ valve}$$

$$h_{L2} = 2 \cdot 0.4 \frac{V_2^2}{2g} + 10 \cdot \frac{V_2^2}{2g} \qquad V^2 = \frac{16 \cdot Q^2}{\pi^2 D^4}$$

$$h_{L2} = Q_2^2 \left[\frac{1.8 \cdot 8}{g \cdot \pi^2 \cdot D_2^4} + \frac{10 \cdot 8}{g \cdot \pi^2 \cdot D_2^4} \right]$$

$$h_{L2} = Q_2^2 [3.57 + 19.86]$$

$$\frac{2880}{64.4} = Q_2^2\left[3.57 + 19.86\right]$$

$$Q_2 = \sqrt{\frac{44.72}{23.42}} = 1.38\ \frac{ft^3}{s}$$

$Q_3 = 1.38\ \frac{ft^3}{s}$ when only valve in branch 2 is open

C) if valve in branch 2 is closed then $Q_2 = 0$

$\therefore Q_3 = Q_1$

$$h_{L1} = 2h_{L\,elbow} + h_{L\,valve}$$

$$h_{L1} = Q_1^2\left[\frac{1.8\cdot 8}{g\cdot\pi^2 D_1^4} + \frac{5\cdot 8}{g\cdot\pi^2\cdot D_1^4}\right]$$

$$h_{L1} = Q_1^2\left[51.41 + 192.81\right]$$

$$\frac{2880}{64.4} = Q_1^2\left[194.22\right]$$

$Q_3 = 0.479\ \frac{ft^3}{s}$ if only valve in branch 1 is open