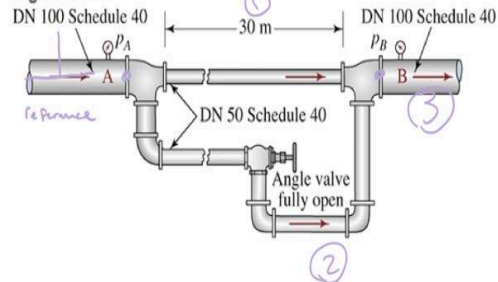


12.3 In the branched pipe system shown in Fig. P12.3, 850 L/min of water at 10°C is flowing in a DN 100 Schedule 40 pipe at A. The flow splits into two DN 50 Schedule 40 pipes as shown and then rejoins at B. Calculate (a) the flow rate in each of the branches and (b) the pressure difference PA-PB. Include the effect of the minor losses in the lower branch of the system. The total length of pipe in the lower branch is 60 m. The elbows are standard.

Figure P12.3



A horizontal pipe A of DN 100 Schedule 40 has a pressure gauge p subscript A attached close to the right end. The pipe connects to the left side of an unequal T-joint. The right side of the unequal T-joint connects to a 30-meters-long horizontal DN 50 Schedule 40 pipe that on the right end connects to another unequal T. The right end of the second unequal T further connects to a horizontal pipe B of DN 100 Schedule 40. An arrow in each flow to the right in the horizontal DN 100 Schedule 40 pipes. A pressure gauge p subscript B is fit beyond the right end of the second unequal T. The bottom end of the first unequal T connects downward to a short vertical pipe that connects to a horizontal DN 50 Schedule 40 pipe through an unequal elbow. The right end of the pipe of reduced size connects to an angle valve fully open. The angle valve connects downward to a short vertical pipe, and then to a horizontal pipe through an elbow. The horizontal pipe again connects upward to a vertical pipe through another elbow. The vertical pipe connects to the bottom end of the second unequal T close to the pipe B.

a) flow rate in each branch

b) pressure diff. point a & point b

design considerations

1) incompressible fluid

2) isothermal process

3) steady state

$$Q_{\text{total}} = 850 \text{ L/min} = 0.014167 \text{ m}^3/\text{s}$$

$$10^\circ\text{C water: } \gamma \text{ specific weight } 9.81 \frac{\text{kN}}{\text{m}^3}, \rho = 1000 \frac{\text{kg}}{\text{m}^3}, \nu = 1.30 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\text{DN 50 schedule 40: } D_1 = D_2 = 0.0525 \text{ m}, A_1 = A_2 = 2.168 \times 10^{-3} \text{ m}^2, \text{ Pipe Roughness } \epsilon = 4.6 \times 10^{-5} \text{ m}$$

$$\text{DN 100 schedule 40: } D_3 = 0.1023 \text{ m}, A_3 = 8.213 \times 10^{-3} \text{ m}^2$$

$$\frac{L_e}{D_{\text{flow}}} = 30 ? \quad \frac{L_e}{D_{\text{angle v}}} = 150 ?$$

$$\textcircled{2} \quad h_{L1} = \left[f_1 \left(\frac{30}{0.0525} \right) \right] C \cdot Q_1^2 = [571.43 \cdot f_1] C \cdot Q_1^2$$

$$K_{friction} = [3(30)(1(150)) \cdot f_T = 240 \cdot 0.0192 = 4.608$$

$$h_{L2} = \left[4.608 + f_2 \left(\frac{60}{0.0525} \right) \right] C \cdot Q_2^2 = [4.608 + 1142.86 \cdot f_2] C \cdot Q_2^2$$

$$[571.43 \cdot f_1] Q_1^2 = [4.608 + 1142.86 \cdot f_2] Q_2^2$$

$$\textcircled{3} \quad f_1 = f_2 = f_T = 0.0192$$

$$[571.43 \cdot (0.0192)] Q_1^2 = [4.608 + 1142.86 \cdot (0.0192)] Q_2^2$$

$$10.971 \cdot Q_1^2 = 26.551 \cdot Q_2^2 \rightarrow Q_1 = \sqrt{\frac{26.551}{10.971}} Q_2 = 1.556 \cdot Q_2$$

$$Q_1 + Q_2 = Q_{total}$$

$$1.556 Q_2 + Q_2 = 0.014167 \text{ m}^3/\text{s} \rightarrow 2.556 Q_2 = 0.014167$$

$$Q_2 = 0.005543 \text{ m}^3/\text{s} \rightarrow 32.6 \text{ L/min}$$

$$Q_1 = 0.014167 - 0.005543 = 0.008624 \text{ m}^3/\text{s} \quad (517.4 \text{ L/min})$$

$$N_{R1} = \frac{1}{4(0.0525)(1.306 \times 10^{-6})} = 372,900$$

$$N_{R2} = \frac{4(0.005543)}{\pi(0.0525)(1.306 \times 10^{-6})} = 102,900$$

$$4. \quad f_1 = \frac{0.25}{\left[\log_{10} \left(\frac{1}{3.7(1141)} + \frac{5.74}{160100^{0.9}} \right) \right]^2} = 0.0211$$

$$f_2 = \frac{0.25}{\left[\log_{10} \left(\frac{1}{3.7(1141)} + \frac{5.74}{102900^{0.9}} \right) \right]^2} = 0.0221$$

iteration 2

$$f_1 = 0.0211, \quad f_2 = 0.0221$$

$$1. \quad [571.43 \cdot (0.0211)] Q_1^2 = [4.608 + 1142.86 \cdot (0.0221)] Q_2^2$$

$$12.057 \cdot Q_1^2 = 30.208 \cdot Q_2^2 \rightarrow Q_1 = 1.583 \cdot Q_2$$

$$2. \quad 2.583 Q_2 = 0.014167 \rightarrow Q_2 = 0.005485 \text{ m}^3/\text{s} \quad Q_1 = 0.008624$$

<

(4)

$$\frac{P_A - P_B}{\gamma} = h_{L \text{ total}}$$

$$h_{L \text{ total}} = 2 \left[f_{T,3} \left(\frac{L_2}{D} \right) \right] \frac{V_3^2}{2g} + \left(f_1 \frac{L_1}{D_1} \right) \frac{V_1^2}{2g}$$

$$1. \quad V_3 = \frac{Q_{\text{total}}}{A_3} = \frac{0.014167}{8.213 \times 10^{-3}} = 1.725 \text{ m/s} \rightarrow \frac{V_3^2}{2g} = \frac{(1.725)^2}{2(9.81)} = 0.1517 \text{ m}$$

$$2. \quad V_1 = \frac{Q_1}{A_1} = \frac{0.00869}{2.165 \times 10^{-3}} = 4.008 \text{ m/s} \rightarrow \frac{V_1^2}{2g} = \frac{(4.008)^2}{2(9.81)} = 0.8188 \text{ m}$$

$$3. \quad h_{L \text{ total}} = 2 \cdot [0.0165 \cdot 20] \cdot (0.1517 \text{ m}) + [0.0211 \cdot 571.43] \cdot (0.8188 \text{ m})$$

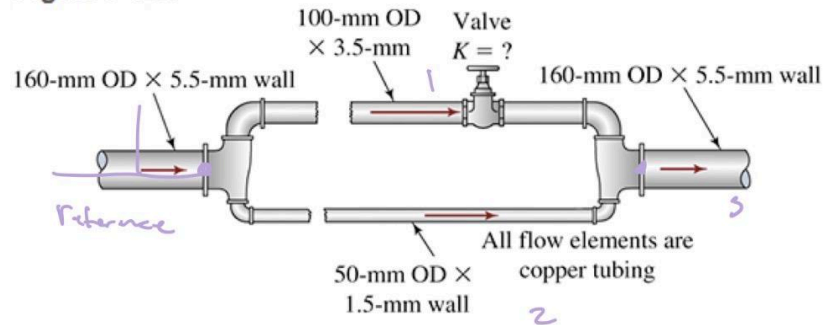
$$h_{L \text{ total}} = 0.1001 \text{ m} + 9.8724 \text{ m} = 9.9725 \text{ m of water}$$

$$4. \quad P_A - P_B = \gamma \cdot h_{L \text{ total}} = (9.81 \text{ kN/m}^3) \cdot (9.9725 \text{ m})$$

$$= 97.83 \text{ kPa}$$

12.5 A 160-mm pipe branches into a 100-mm and a 50-mm pipe as shown in Fig. P12.5. Both pipes are hydraulic copper tubing and 30 m long. (The fluid is water at 10°C.) Determine what the resistance coefficient K of the valve must be to obtain equal volume flow rates of 500 L/min in each branch.

Figure P12.5



A short horizontal pipe of size 160 millimeters O D by 5.5 millimeters wall branches into two pipes, a pipe of size 100 millimeters O D by 3.5 millimeters and another pipe of size 50 millimeters O D by 1.5 millimeters wall. From an unequal joint at the end of the pipe of size 160 millimeters O D by 5.5 millimeters wall, an elbow connects upward to the 100 millimeters horizontal pipe with a valve of unknown K value in it. An opening at the bottom side of the unequal joint connects to the 50 millimeters pipe at the bottom through an elbow of smaller radius. The branches of pipe again join to another unequal joint that again connects to a horizontal 160 millimeters O D by 5.5 millimeters wall pipe. An arrow points to the right in all the pipes. The pipe system reads all flow elements are copper tubing.

$$Q_1 = Q_2 = 500 \text{ L/min} = 0.008333 \text{ m}^3/\text{s}$$

$$\text{water } 10^\circ\text{C } \nu = 1.306 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\epsilon = 1.5 \times 10^{-6} \text{ m}$$

$$L_1 = L_2 = 30 \text{ m}$$

$$D_1 = 93 \text{ mm} = 0.0930 \text{ m}$$

$$A_1 = 6.793 \times 10^{-3} \text{ m}^2$$

$$\frac{z}{D_1} = 1.613 \times 10^{-5}$$

$$D_2 = 47 \text{ mm} = 0.0470 \text{ m}$$

$$A_2 = 1.735 \times 10^{-3} \text{ m}^2$$

$$\frac{z}{D_2} = 3.121 \times 10^{-5}$$

$$\textcircled{2} \quad V_1 = \frac{Q_1}{A_1} = 1.227 \text{ m/s} \rightarrow \frac{V_1^2}{2g} = \frac{(1.227)^2}{2(9.81)} = 0.07675 \text{ m}$$

$$N_{R1} = \frac{V_1 D_1}{\nu} = 87370 \rightarrow f_1 = 0.0183$$

$$V_2 = \frac{Q_2}{A_2} = 4.803 \text{ m/s} \rightarrow \frac{V_2^2}{2g} = \frac{(4.803)^2}{2(9.81)} = 1.1758 \text{ m}$$

$$N_{R2} = \frac{V_2 D_2}{\nu} = 172850 \rightarrow f_2 = 0.0163$$

$$\textcircled{3} \quad 2K_{\text{elbow}_1} = .80$$

$$2K_{\text{elbow}_2} = .70$$

$$5. \quad [6.703 + K_{\text{valve}}] \cdot 0.07675 = 13.06$$

$$6.703 + K_{\text{valve}} = \frac{13.06}{0.07675} = 170.16$$

$$K_{\text{valve}} = 162$$

$$\textcircled{4} \quad h_{L2} = \left[2K_{\text{elbow}_2} + f_2 \left(\frac{L_2}{D_2} \right) \right] \frac{V_2^2}{2g}$$

$$h_{L2} = \left[0.70 + 0.0163 \left(\frac{30}{0.0470} \right) \right] \cdot 1.1758 \text{ m} = 13.06 \text{ m}$$

$$h_{L1} = \left[2K_{\text{elbow}_1} + f_1 \left(\frac{L_1}{D_1} \right) + K_{\text{valve}} \right] \frac{V_1^2}{2g}$$

$$h_{L1} = \left[0.80 + 0.0183 \left(\frac{30}{0.0770} \right) + 162 \right] \cdot 0.07675 \text{ m}$$