

6.127 In the five-pipe horizontal network of Fig. P6.127, assume that all pipes have a friction factor $f = 0.025$. For the given inlet and exit flow rate of $2 \text{ ft}^3/\text{s}$ of water at 20°C , determine the flow rate and direction in all pipes. If $p_A = 120 \text{ lbf/in}^2$ gage, determine the pressures at points B, C, and D.

Solution: For water at 20°C , take $\rho = 1.94 \text{ slug/ft}^3$ and $\mu = 2.09 \times 10^{-5} \text{ slug/ft}\cdot\text{s}$. Each pipe has a head loss which is known except for the square of the flow rate:

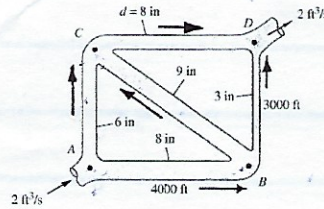


Fig. P6.127

$$h_f = f \frac{L}{D} \frac{V^2}{2g} = f \frac{L}{D} \frac{8Q^2}{\pi^2 D^5}$$

$$V^2 = \left(\frac{Q}{A}\right)^2 = \frac{16Q^2}{\pi^2 D^4}$$

$$= \underbrace{\left[\frac{8fL}{\pi^2 g D^5} \right]}_K Q^2 \quad \text{or} \quad = \left[\frac{8L}{\pi^2 g D^5} \right] f Q^2$$

if f not known
 $f = f(\text{Re}_{\text{Dn}}, \frac{L}{D_{\text{h}}})$

$$h_{AC} = K_{AC} Q_{AC}^2$$

$$K_{AC} = 60.42 = \frac{8(0.025)(3000)}{\pi^2 (32.2)(6/12)^5}$$

$$h_{AB} = K_{AB} Q_{AB}^2$$

$$K_{AB} = 19.12$$

$$h_{BC} = K_{BC} Q_{BC}^2$$

$$K_{BC} = 13.26$$

$$h_{CD} = K_{CD} Q_{CD}^2$$

$$K_{CD} = 19.12$$

$$h_{BD} = K_{BD} Q_{BD}^2$$

$$K_{BD} = 1933$$

5 equations
5 unknowns

$$h_{AB} + h_{BC} - h_{AC} = 0$$

loop ABC

$$h_{BC} + h_{CD} - h_{BD} = 0$$

loop BCD

$$-2 + Q_{AC} + Q_{AB} = 0$$

junction A

$$-Q_{AB} + Q_{BC} + Q_{BD} = 0$$

junction B

$$-Q_{AC} - Q_{BC} + Q_{CD} = 0$$

junction C

$$Q_{AB} = 1.19$$

$$Q_{AC} = .81$$

$$Q_{BC} = .99$$

$$Q_{CD} = 1.8$$

$$Q_{BD} = .2$$

ft^3/s

$$P_A/\gamma + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B + h_{AB}$$

$$P_A = 120 \text{ psi}$$

$$\begin{aligned} P_B &= P_A - \gamma h_{AB} = P_A - \rho g K_{AB} Q_{AB}^2 \\ &= 120 \times 144 - 62.4 (19.12) (1.19)^2 \\ &= 15590 \text{ psf} / 144 \\ &= 108 \text{ psi} \end{aligned}$$

$$\begin{aligned} P_C &= P_A - \gamma h_{AC} \\ &= 103 \text{ psi} \end{aligned}$$

$$\begin{aligned} P_D &= P_C - \gamma h_{CD} \\ &= 76 \text{ psi} \end{aligned}$$