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 ft³/s of water at 20°C, determine the flow rate and direction in all pipes. If p_A = 120 lbf/in² gage, determine the pressures at points *B*, *C*, and *D*

Solution: For water at 20°C, take ρ = 1.94 slug/ft³ and μ = 2.09E–5 slug/ft·s. Each pipe has a head loss which is known except for the square of the flow rate:

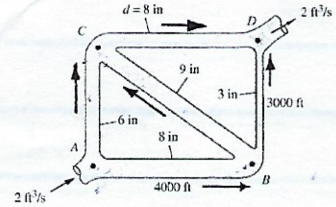

Fig. P6.127

$$h_f = f \frac{L}{D}\frac{V^2}{2g} = f \frac{L}{D}\frac{8Q^2}{g\pi^2 D^4} \qquad V^2 = \left(\frac{Q}{A}\right)^2 = \frac{16Q^2}{\pi^2 D^4}$$

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

if f not known
$f = f(Re_{D_h}, \frac{\varepsilon}{D_h})$

$h_{AC} = K_{AC} Q^2_{AC}$ $\quad K_{AC} = 60.42 = \dfrac{8(.025)(3000)}{\pi^2(32.2)(6/12)^5}$

$h_{AB} = K_{AB} Q^2_{AB}$ $\quad K_{AB} = 19.12$

$h_{BC} = K_{BC} Q^2_{BC}$ $\quad K_{BC} = 13.26$

$h_{CD} = K_{CD} Q^2_{CD}$ $\quad K_{CD} = 19.12$

$h_{BD} = K_{BD} Q^2_{BD}$ $\quad K_{BD} = 1933$

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

$Q_{AB} = 1.19$

$Q_{AC} = .81$ ft³/s

$Q_{BC} = .99$

$Q_{CD} = 1.8$

$Q_{BD} = .2$

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

$p_A = 120$ psi

$$p_B = p_A - \gamma h_{AB} = p_A - \rho g K_{AB} Q_{AB}^2$$
$$= 120 \times 144 - 62.4\,(19.12)(1.19)^2$$
$$= 15590 \text{ psf}/144$$
$$= 108 \text{ psi}$$

$$p_C = p_A - \gamma h_{AC}$$
$$= 103 \text{ psi}$$

$$p_D = p_C - \gamma h_{AC}$$
$$= 76 \text{ psi}$$