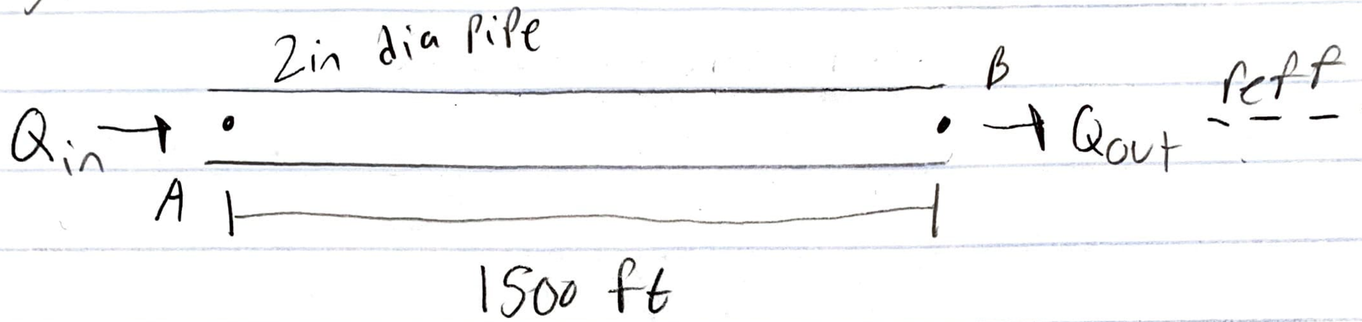
1

Test 3

Zachary Zum Brunnen MET 330 04/06/22

2) Determine the change in pressure for the pipe shown.

Diagram:



Sources: Applied fluid mechanics by; Robert L Mott, Joseph A. Untener.

Assumptions: Isothermal at 60°F, water working fluid, Incompressable fluid, steady flow,

Data: $Q_{in} = Q_{out} = 65$ gpm $= 0.145\ ft^3/s$

$L = 1500\ ft$ $\quad D = 0.1658\ ft$ $\quad A = 1.907 \times 10^{-2}\ ft^2$

$\epsilon = 1.5 \times 10^{-4}\ ft$ $\quad \gamma = 62.4\ lb/ft^3$ $\quad \nu = 1.21 \times 10^{-5}\ ft^2/s$

Procedure: Using Bernoulli's equation from points A & B will yeild that ΔP_{A-B} is equal to energy Loss times Specific weight.

Calculations:

$$\frac{P_A}{\gamma_w} + \frac{\cancel{V_A^2}}{\cancel{2g}} + \cancel{z_A} = \frac{P_B}{\gamma_w} + \frac{\cancel{V_B^2}}{\cancel{2g}} + \cancel{z_B} + h_{L\,A-B}$$

$z_A = z_B$ $\quad V_A = V_B$ $\quad$ Q or A dose not change

$$\Delta P_{A-B} = \gamma_w (h_{L\,A-B})$$

(2)

Calculations: $h_{L\,A-B} = f \frac{L}{D} \frac{V^2}{2g}$

$V = Q/A = 0.145\ ft^3/s \,/\, 1.907\times10^{-2}\ ft^2$

$V = 7.6\ ft/s$

$R_e = VD/\nu = 7.6\ ft/s \cdot 0.1558\ ft \,/\, 1.21\times10^{-5}\ ft^2/s$

$R_e = 97857.85$

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7\frac{D}{\epsilon}} + \frac{5.74}{Re^{0.9}}\right)\right)^2} = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{0.1558\ ft}{1.5\times10^{-4}\ ft}\right)} + \frac{5.74}{97857.8^{0.9}}\right)\right)^2}$$

$f = 0.022242$

$$h_{L\,A-B} = 0.022242\left(\frac{1500\ ft}{0.1558\ ft}\right)\left(\frac{7.6^2\ ft/s}{2\cdot 32.2\ ft/s^2}\right)$$

$h_{L\,A-B} = 192.06\ ft$

$\Delta P_{A-B} = 62.4\ lb/ft^3 \cdot 192.06\ ft$

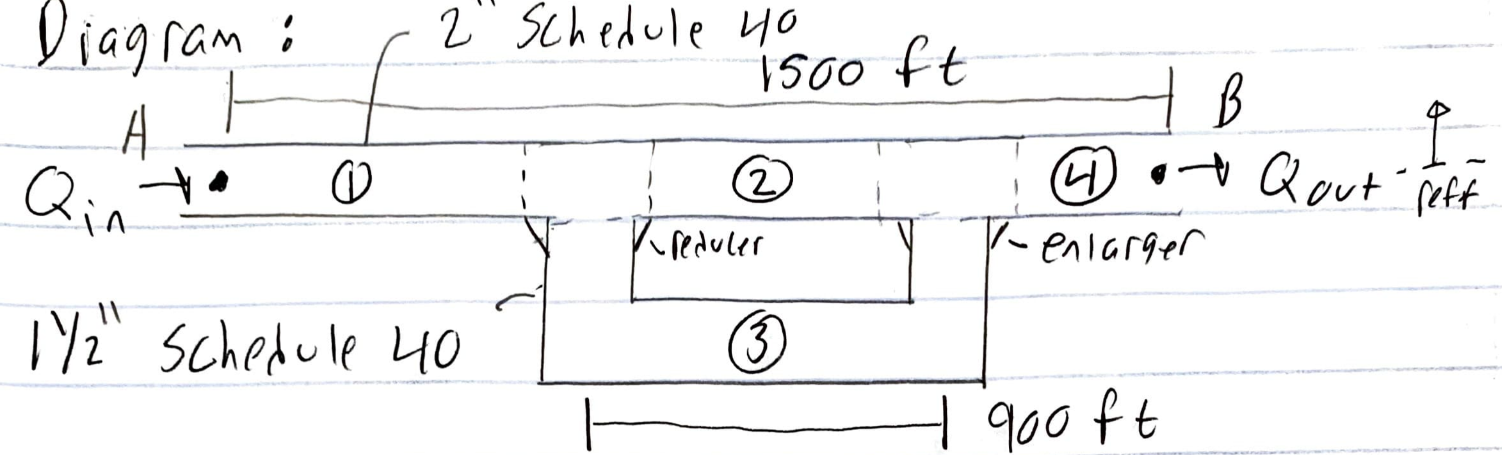
$\Delta P_{A-B} = 11984.5\ lb/ft^2 = 83.2\ psi$

Part B: Determine flow rate through the system shown using the same ΔP as calculated in last part.

Sources: Applied Fluid Mechanics by; Robert L Mott, Joseph A Untener.

(3)

Diagram:



Assumptions: Isothermal 60° F, water working fluid, Total length of pipe 3 is 900 ft, steady flow.

Data: $\Delta P_{A-B} = 83.24$ psi $= 11984.5$ lb/ft^2

$D_1 = D_2 = D_4 = 0.1558$ ft $\quad A_1 = 1.907 \times 10^{-2}$ ft^2

$D_3 = 0.1142$ ft $\quad A_3 = 1.024 \times 10^{-2}$ ft^2

$\epsilon = 1.5 \times 10^{-4}$ ft $\quad \gamma_w = 62.4$ lb/ft^3

$\nu = 1.21 \times 10^{-5}$ ft^2/s

$K_{Tee(2)} = 20 f_T \quad K_{Tee(3)} = 60 f_T$

$K_{elbow} = 30 f_T \quad$ reducers and enlargers 30°

$K_{reducer} = 0.04 \quad K_{enlarg} = 0.36$

Procedure: Using Bernoulli's equation from points A & B using pipe 2 and another equation for using pipe 3, knowing $Q_1 = Q_4 = Q_2 + Q_3$ will allow all 3 Q's to be found.

4

Calculations: Pipe 2.

$$\frac{P_A}{\gamma_w} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_A} = \frac{P_B}{\gamma_w} + \cancel{\frac{V_4^2}{2g}} + \cancel{z_B} + h_{LAB2}$$

$V_1 = V_4$ since Q and area do not change

$$\frac{\Delta P_{A-B}}{\gamma_w} = h_{LAB2} \text{ using Pipe 2}$$

$$h_{LAB2} = f_1\left(\frac{L}{D}\right)\frac{V_1^2}{2g} + 2\left(20 f_{T_2}\frac{V_2^2}{2g}\right) + f_2\left(\frac{L}{D}\right)\frac{V_2^2}{2g}$$

$$h_{LAB3} = f_1\left(\frac{L}{D}\right)\frac{8Q_1^2}{g\pi^2 D_1^4} + \left(2(20 f_{T_2}) + f_2\frac{L}{D}\right)\frac{8Q_2^2}{g\pi^2 D_2^4}$$

$$f_T = \frac{0.25}{\left(\log\left(\frac{1}{3.7\frac{D}{\epsilon}}\right)\right)^2} \qquad f_{T_2} = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{0.1558\text{ ft}}{1.5\times10^{-4}\text{ ft}}\right)}\right)\right)^2}$$

$f_{T_2} = 0.0194$

now, using pipe 3

$$\frac{P_A}{\gamma_w} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_A} = \frac{P_B}{\gamma_w} + \cancel{\frac{V_4^2}{2g}} + \cancel{z_B} + h_{LAB3}$$

$$\frac{\Delta P_{AB}}{\gamma_w} = h_{LAB3}$$

$$h_{LAB3} = f_1\left(\frac{L_1}{D}\right)\frac{V_1^2}{2g} + \left(2K_{Tee} + 2K_{elbow} + K_{red} + K_{enlg}\right)\frac{V_3^2}{2g} + f_3\frac{L}{D}\frac{V_3^2}{2g}$$

$$h_{LAB3} = f_1\left(\frac{L}{D}\right)\frac{8Q_1^2}{g\pi^2 D_1^4} + \left(2(60 f_{T3}) + 2(30 f_T) + 0.04 + 0.36\right)\frac{8Q_3^2}{g\pi^2 D_3^4} + f_3\left(\frac{L}{D}\right)\frac{8Q_3^2}{g\pi^2 D_3^4}$$

(5)

Calculations:

$$h_{L\,AB2} = f_1 \frac{L}{D} \frac{8Q_1^2}{\pi^2 g D_1^4} + \left(120 f_{T3} + 60 f_{T3} + 0.04 + 0.36 + f_3 \frac{L}{D}\right) \frac{8Q_3^2}{g\pi D_3^4}$$

$$f_{T3} = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{0.1142ft}{1.5\times10^{-4}ft}\right)}\right)\right)^2} \qquad f_{T3} = 0.021$$

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{D}{\epsilon}\right)} + \frac{5.7}{Re^{0.9}}\right)\right)^2} \qquad Re = VD/\nu$$

for pipe 2,

$$\frac{\Delta P_{AB}}{\gamma_w} = f_1\left(\frac{L}{D}\right)\frac{8Q_1^2}{g\pi^2 D_1^4} + \left(2(20 f_{T2}) + f_2 \frac{L}{D}\right)\frac{8Q_2^2}{g\pi^2 D_2^4}$$

$$\sqrt{\frac{\frac{\Delta P_{AB}}{\gamma_w} - f_1 \frac{L}{D} \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(\left(2(20 f_{T2}) + f_2 \frac{L}{D}\right)\frac{8}{g\pi^2 D_2^4}\right)}} = Q_2$$

$$\frac{\Delta P_{AB}}{\gamma_w} = f_1 \frac{L}{D} \frac{8Q_1^2}{g\pi^2 D_1^4} + \left(120 f_{T3} + 60 f_{T3} + 0.4 + f_3 \frac{L}{D}\right)\frac{8Q_3^2}{g\pi^2 D_3^4}$$

$$Q_3 = \sqrt{\frac{\frac{\Delta P_{AB}}{\gamma_w} - f_1 \frac{L}{D} \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(\left(120 f_{T3} + 60 f_{T3} + 0.4 + f_3 \frac{L}{D}\right)\frac{8}{g\pi^2 D_3^4}\right)}}$$

$$Q_1 = Q_3 + Q_2$$

(6)

Calculations: Once the iterations showd a 0.39% differance in Q, I stoped.

$Q_1 = 0.174\ ft^3/s$ or 78.1 gpm.

$Q_2 = 0.122\ ft^3/s$ $Q_3 = 0.052\ ft^3/s$

Summary: The increas in flow rate the system saw after the 1½ in pipe was added is 13.1 gpm or $0.029\ ft^3/s$. The added section of pipe allows another route for the water to go, increasing the total flow rate through the pipe.

Analysis: The velocity at points A and B are just over 9.1 ft/s which is just under the standard 3m/s.