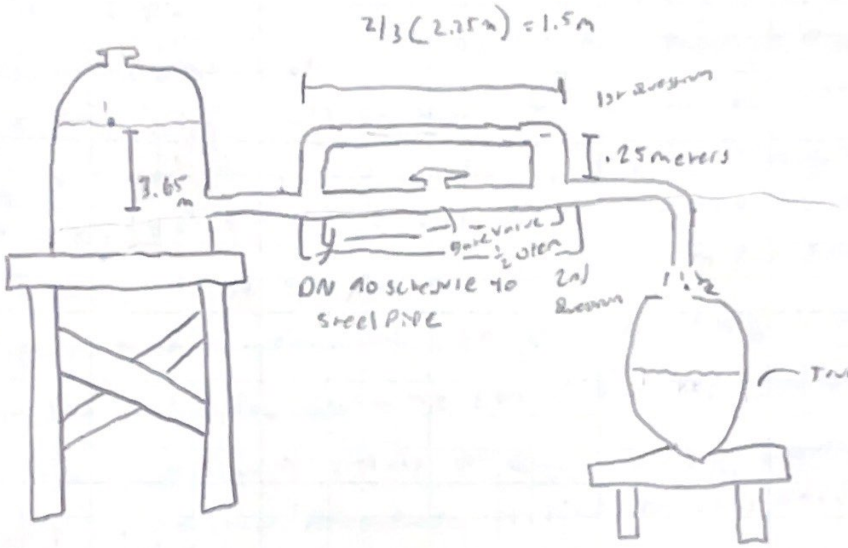
TEST 3 | GAVYN PIFER | FLUID MECHANICS | A

PURPOSE

① Calculate the new flow rate using the modified diagram as depicted in figure two.

② Assume that the flow rate is equal to the total flow rate calculated in problem one.

DRAWINGS AND DIAGRAMS



SOURCES

• Mott, R., Untener, J.A., "Applied Fluid Mechanics", 7th edition Pearson Education Inc. (2015)

DESIGN CONSIDERATIONS

• Incompressible fluid • Constant properties

• Isothermal conditions • Steady state

DATA AND VARIABLES

$Z_1 = 4.15\,m$ $K_{elb} = 30 f_t$ $K_{ent} = .5$

$L = 1.5\,m$ $K_{valve\,1/2} = 160\,f_t$ $f_T = f = .017$ Zone of complete turbulence

$D = 90.1\times10^{-3}\,m$ $L_e/D_{valve} = 160$

TEST 3	GAVYN DIPER	FLUID MECHANICS	B

PROCEDURE

① I will start this problem by setting a reference, then determine my points A and B, simplifying my Bernoulli's equation I will consider all energy losses. By splitting my flow rates, Q_1 on top, and Q_2 on the bottom each section will have different energy losses. The energy losses on the first Q, Q_I, will include the Kent, 2 K valves, and the K elbow. There will be three K elbows. Two that include Q_I and one that includes Q_{total}. For the energy losses on Q_{II}, there will be the K valve and the elbow that includes Q_T. I will then solve for Q_I and Q_{II} using my two equations. Plugging these two equations into $Q_T = Q_I + Q_{II}$ I will compare my LHS and RHS, which the LHS is just Q_T. Iteration will be required to find the values of Q_I and Q_{II}. Lastly, I will compare my percent differences to find the real values to find Q_T.

②

For this next part, since I know that the values for Q_T should equal Q_T in the second part due to symmetry, I will use the same process as calculated in question one. The only difference is, I know Q_T for sure and will use this value to calculate Q_I (the top part) and Q_{II} the bottom part. I will then add those values to see if it matches the Q_T I calculated in question 1.

CALCULATIONS

(1)

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + \cancel{z_2} + h_{L\,A\text{-}B}$$

$$\boxed{z_1 = \frac{V_2^2}{2g} + h_{L\,A\text{-}B}} \qquad V_2^2 = \frac{16Q^2}{\pi^2 D^4}\cdot\frac{1}{2g}$$

$$h_{L(1)} = h_{L\,line(1)} + 2\,h_{loss\,elbow}$$

$$h_{L(2)} = h_{ent} + h_{L\,line} + h_{L\,valve} + h_{L\,elbow}$$

$$(1)\ h_L = .5 + f\frac{L_1}{D}\frac{16Q_1^2}{\pi^2 D^4}\cdot\frac{1}{2g} + 2k_{elb}\frac{16Q_1^2}{\pi^2 D^4}\cdot\frac{1}{2g} + k_{elb}\frac{16Q_T^2}{\pi^2 D^4}\cdot\frac{1}{2g}$$

$$(2)\ h_L = .5 + f\frac{L_2}{D}\frac{16Q_2^2}{\pi^2 D^4}\cdot\frac{1}{2g} + k_{valve}\frac{16Q_2^2}{\pi^2 D^4}\cdot\frac{1}{2g} + k_{elb}\frac{16Q_T^2}{\pi^2 D^4}\cdot\frac{1}{2g}$$

$$(1)\ h_{L(1)} = .5 + f\frac{L_1}{D}\frac{8Q_1^2}{\pi^2 D^4 g} + 2k_{elb}\frac{8Q_1^2}{\pi^2 D^4 g} + k_{elb}\frac{8Q_T^2}{\pi^2 D^4 g}$$

$$(2)\ h_{L(2)} = .5 + f\frac{L_2}{D}\frac{8Q_2^2}{\pi^2 D^4 g} + k_{valve}\frac{8Q_2^2}{\pi^2 D^4 g} + k_{elb}\frac{8Q_T^2}{\pi^2 D^4 g}$$

$$z_1 = .5 + f\frac{L_1}{D}\frac{8Q_1^2}{\pi^2 D^4 g} + 2k_{el}\frac{8Q_1^2}{\pi^2 D^4 g} + k_{elb}\frac{8Q_T^2}{\pi^2 D^4 g} + \frac{8Q_1^2}{\pi^2 g D^4}$$

$$z_1 - .5 - k_{elb}\frac{8Q_T^2}{\pi^2 D^4 g} = Q_1^2\left(f\frac{L_1}{D}\frac{8}{\pi^2 D^4 g} + 2k_{el}\frac{8}{\pi^2 D^4 g}\right)$$

$$Q_1 = \sqrt{\frac{z_1 - .5 - k_{elb}\frac{8Q_T^2}{\pi^2 D^4 g}}{f\frac{L_1}{D}\frac{8}{\pi^2 D^4 g} + 2k_{el}\frac{8}{\pi^2 D^4 g} + \frac{8}{\pi^2 D^4 g}}}$$

$$Q_2 = \sqrt{\frac{z_1 - .5 - k_{elb}\frac{8Q_T^2}{\pi^2 D^4 g}}{f\frac{L_2}{D}\frac{8}{\pi^2 D^4 g} + k_{valve}\frac{8}{\pi^2 D^4 g} + \frac{8}{\pi^2 D^4 g}}}$$

$$Q_1 + Q_2 = Q_T$$

⋮

TEST 3 | GAVYN PIFER | FLUID MECHANICS | D

$K_{elb} = 30 f_T = .51$

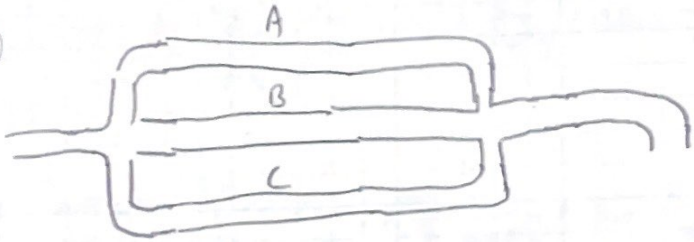
$h_{valve} = 160 f_T = 2.72$

$$f_T = \frac{.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}\right)\right]^2} \qquad D/\varepsilon = \frac{40.1 \times 10^{-3} m}{4.6 \times 10^{-5}} = 1458.7$$

table 8.2 & F.1

$f_T = .0167$ or $\boxed{.017}$

(2)



$Q_A = Q_C$

$$Z_1 = \frac{V_2^2}{2g} + h_{L,2}$$

Moving conservation of energy . equation head lore equal

$h_{LA} = h_{LC}$

$2Q_C + Q_B = Q_T$

$$Z_1 = \left(\frac{Q_T^2}{\pi^2 D^4 g} + \cancel{x} + f\frac{L}{D}\frac{8Q_T^2}{\pi^2 D^4 g} + 2K_{el}\frac{8Q_T^2}{\pi^2 D^4 g} + K_{el}\frac{8Q_T^2}{\pi^2 D^4 g}\right)2$$

$$\sqrt{\frac{Z_1 - .5 - K_{elb}\frac{8Q_T^2}{\pi^2 D^4 g}}{\frac{1}{\pi^2 D^4 g} + f\frac{L_3}{D}\frac{8}{\pi^2 D^4 g} + 2K_{el}}} = Q_C^{\cancel{2}}\left(\frac{1}{\pi^2 D^4} + f\frac{L_3}{D}\frac{8}{\pi^2 D^4 g} + 2K_{elb}\frac{8}{\pi^2 D^4 g}\right)$$

$$\overbrace{\left(\sqrt{\frac{Z_1 - .5 - K_{elb}\frac{8Q_T^2}{\pi^2 D^4 g}}{\frac{1}{\pi^2 D^4 g} + f\frac{L_3}{D}\frac{8}{\pi^2 D^4 g} + 2K_{elb}\frac{8}{\pi^2 D^4 g}}}\right)}^{Q_C} 2 + .002421 = Q_T$$

TEST 3 | GAVXN PIPER | FLUID MECHANICS | [illegible]

$$\left(\frac{Q_T - .002721}{2}\right) = \cancel{\left(\sqrt{\frac{z_1 - .5 - h_{e16}\frac{8Q_T^2}{\pi^2 D^4 g}}{\frac{1}{\pi^2 D^4 g} + f\frac{L_3}{D}\frac{8}{\pi^2 D^4 g}}}\right)^2}$$

$$\left(\frac{Q_T - .002721}{2}\right)^2 = \frac{z_1 - 5 - h_{e16}\frac{8Q_T^2}{\pi^2 D^4 g}}{\frac{1}{\pi^2}}$$

$$\left(\frac{Q_T^2 - .002721}{2}\right)^2\left(\frac{1}{\pi^2 D^4 g} + f\frac{L_3}{D}\frac{8}{\pi^2 D^4 g} + 2h_{e16}\frac{8}{\pi^2 D^4 g}\right) = z_1 - 5 - h_{e16}\frac{Q_T^2}{\pi^2 D^4 g}$$

$$\left(\frac{Q_T - .002721}{2}\right)^2\left(\frac{1}{\pi^2 D^4 g} + f\frac{L_3}{D}\frac{8}{\pi^2 D^4 g} + 2h_{e1}\frac{8}{\pi^2 D^4 g}\right) - 1.575 = -h_{e11}\frac{8Q_i^2}{\pi^2 D^4 g}$$

$$\left(\frac{Q_T^2 - .002721}{2}\right)^2(3.64\times10^{12}) - 1.575 = -.017\frac{Q_T^2}{\pi^2 D^4 g}$$

$$\left(\frac{Q_T - .002721}{2}\right)^2(3.64\times10^{12} = (-.017)\left(\frac{Q_i^2}{\pi^2 D^4 g}\right) + 1.575$$

$$\frac{(Q_i)^2 - (.002721)^2}{(2)^2}$$

$$\frac{(Q_i^2 - 5.86\times10^{-6})(3.64\times10^{12})}{4}$$

$$\frac{(3.64\times10^{12})(Q_i^2)}{4} - \frac{21627474.29}{4}$$

TEST 3	WARREN PFEIFER	FLUID MECHANICS	F

$$\frac{3.64\times10^{12}Q_i^2}{4} - 5406494 = -\frac{.017Q_i^2}{\pi^2D^4g} + \cancel{1.575}$$

$$\frac{3.64\times10^{12}Q_i^2}{4} - 5406446.5 = -\frac{.017Q_i^2}{\pi^2D^4g}$$

$$\frac{3.64\times10^{12}Q_i^2}{4} = -\frac{.017Q_i^2}{\pi^2D^4g} + 5406496.5$$

$$\frac{3.64\times10^{12}Q_i^2}{4} + \frac{.017Q_i^2}{\pi^2D^4g} = 5406496.5$$

$$Q_i^2\left(\frac{3.64\times10^{12}}{4} + \frac{.017}{\pi^2D^4g}\right) = 5406496.5$$

$$\boxed{Q_T = .0024210004}$$