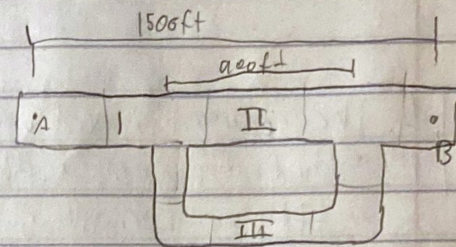
MET330 Test 3 Hunter Young

Purpose - to identify pressure drop caused by minor loss and then to find flow rate increase due to a new branch between the inlet and outlet

Drawings and Diagrams -



Sources - "Applied Fluid Mechanics" 7th ed, Mott

Design considerations - steady state, incompressible fluid
Assuming H_2O $T = 60°F$

Data And Variables

$L_1 = 1500\ ft$, $L_2 \,\&\, L_3 = 900ft$ gamma $= 62.4\ lb/ft^3$
$\nu = 1.21E{-}5\ ft^2/s$ $\varepsilon = 1.50\,E{-}4$ $D_1 \,\&\, D_2 = 0.1558$
$D_3 = 0.1142\ ft$ $K_{Tee} = 20$ $K_{Tee\,branch} = 60$ $K_{elb} = 30$

Procedure -

- To begin I used bernoullis to relate pressure difference to energy loss.
- Using the flow rate and tube dimensions I got velocity, and with velocity I calculated reynolds, then D/ε
- Using Reynolds and D/ε I calculated friction factor, and then the loss, Allowing me to find pressure difference
- To start Part 2 I made a bernoullis for each path down a branch, then I plugged in the minor loss equations
- I then related all loss equations to Q instead of V, And manipulated both equations so Q_2 and Q_3 were alone on the outside
- I then assumed a Q_1 and began iterating

Calculations - on next pages

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$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right)^2}$$

$$= \frac{0.25}{\left(\log\left(\frac{1}{3.7(1077.33)} + \frac{5.74}{(97780.59)^{0.9}}\right)\right)^2}$$

$$f = 0.02213$$

$$h_L = 0.02213 \cdot \frac{1500\ ft}{0.1558} \cdot \frac{7.594^2\ ft/s}{2(32.2\ ft/s^2)}$$

$$h_L = 190.792\ ft$$

$$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} + h_L$$

$$\frac{P_1 - P_2}{62.4\ lb/ft^3} = 190.792\ ft$$

$$\Delta P = 11905.431\ lb/ft^2$$

$$\Delta P = 82.67\ lb/in^2 \to Psi$$

$$h_L = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$

$$Q = V \cdot A$$

$$65\ Gpm = V \cdot 1.907 \cdot 10^{-2}\ ft^2$$

$$0.144821\ ft^3/s = V \cdot 1.907 \cdot 10^{-2}\ ft^2$$

$$V = \frac{0.144821}{1.907 \cdot 10^{-2}} = 7.594\ ft/s$$

Standard Steel $\varepsilon = 1.5 \cdot 10^{-4}\ ft$

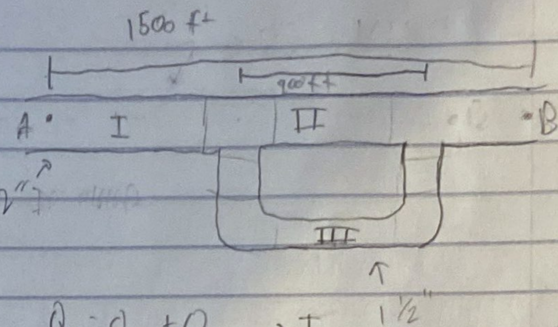
Assuming H_2O is $60°F$: $\nu = 1.21 \cdot 10^{-5}\ ft^2/s$

$$D/\varepsilon = \frac{0.1616\ ft}{1.5 \cdot 10^{-4}\ ft} = 1077.33$$

$$Re = \frac{VD}{\nu} = \frac{7.594\ ft/s \cdot 0.1558}{1.21 \cdot 10^{-5}}$$

$$Re = 97780.59$$

$$\frac{P_A}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_B}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L$$



$$\frac{P_A - P_B}{\gamma} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} + h_L$$

$$\cancel{\frac{P_1 - P_2}{\gamma} = f_1 \frac{L}{D} \frac{V_1^2}{2g} + K_{Tee}\left(\frac{V_1^2}{2g}\right) + K_{Tee}\left(\frac{V_2^2}{2g}\right)}$$

$$Q_1 = Q_{II} + Q_{III} \rightarrow I$$

$$\frac{V^2}{2g} \rightarrow \frac{8Q^2}{g\pi^2 D^4}$$

$$\frac{P_A - P_B}{\gamma} = f_1 \frac{L_1}{D_1} \frac{V_1^2}{2g} + f_{II} \frac{L_{II}}{D_{II}} \cdot \frac{V_{II}^2}{2g} + K_{Tee}\left(\frac{V_1^2}{2g}\right) + K_{Tee}\left(\frac{V_{II}^2}{2g}\right)$$

$$\frac{P_A - P_B}{\gamma} = \left(f_1 \frac{L_1}{D_1} + K_{Tee}\right) \frac{8Q_1^2}{g\pi^2 D_1^4} + \left(f_{II} \frac{L_{II}}{D_{II}} + K_{Tee}\right) \frac{8Q_{II}^2}{g\pi^2 D_{II}^4} \longrightarrow II$$

$$\frac{P_A}{\gamma} + \frac{V_1^2}{2g} = \frac{P_B}{\gamma} + \frac{V_{III}^2}{2g} + h_L$$

$$\frac{P_A - P_B}{\gamma} = \frac{V_1^2}{2g} - \frac{V_{III}^2}{2g} + h_L$$

$$\frac{P_A - P_B}{\gamma} = f_{III} \frac{L_{III}}{D_{III}} \frac{V_{III}^2}{2g} + K_{Tee}\left(\frac{V_1^2}{2g}\right) + 2 \cdot K_{elb}\left(\frac{V_{III}^2}{2g}\right) + K_{Tee}\left(\frac{V_{III}^2}{2g}\right) + f_1 \frac{L_1 - L_{III}}{D_1} \cdot \frac{V_1^2}{2g}$$

$$\frac{P_A - P_B}{\gamma} = f_{III} \frac{L_{III}}{D_{III}} \cdot \frac{8Q_{III}^2}{g\pi^2 D_{III}^4} + K_{Tee}\left(\frac{8Q_1^2}{g\pi^2 D_1^4}\right) + 2 \cdot K_{elb}\left(\frac{8Q_{III}^2}{g\pi^2 D_{III}^4}\right) + K_{Tee}\left(\frac{8Q_{III}^2}{g\pi^2 D_{III}^4}\right) + f_1 \frac{L_1 - L_{III}}{D_1} \cdot \frac{8Q_I^2}{g\pi^2 D^4}$$

$$\frac{P_A - P_B}{\gamma} = \left(f_{III} \frac{L_{III}}{D_{III}} + 2K_{elb} + K_{Tee}\right) \cdot \frac{8Q_{III}^2}{g\pi^2 D_{III}^4} + \left(K_{Tee} + f_1 \frac{L_1 - L_{III}}{D_1}\right) \cdot \frac{8Q_I^2}{g\pi^2 D_1^4} \longrightarrow III$$

$$II \rightarrow \frac{\Delta P}{\gamma} - \left(f_1 \frac{L_1}{D_1} + K_{Tee}\right) \frac{8Q_1^2}{g\pi^2 D_1^4} = \left(f_{II} \frac{L_{II}}{D_{II}} + K_{Tee}\right) \frac{8Q_{II}^2}{g\pi^2 D_{II}^4}$$

$$\frac{8Q_{II}^2}{g\pi^2 D_{II}^4} = \frac{\frac{\Delta P}{\gamma} - \left(f_1 \frac{L_1}{D_1} + K_{Tee}\right) \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_1 \frac{L_{II}}{D_{II}} + K_{Tee}\right)} \rightarrow Q_2 = \sqrt{\frac{\frac{\Delta P}{\gamma} - \left(f_1 \frac{L_1}{D_1} + K_{Tee}\right) \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_{II} \frac{L_{II}}{D_{II}} + K_{Tee}\right) \frac{8}{g\pi^2 D_{II}^4}}}$$

$$\text{III} \rightarrow \frac{\Delta P}{\gamma} - \left(K_{Tee_2} + f_1 \frac{L_1 - L_{III}}{D_1}\right) \cdot \frac{8Q_1^2}{g\pi^2 D_1^4} = \left(f_{III} \frac{L_{III}}{D_{III}} + 2K_{elb} + K_{Tee_2}\right) \frac{8Q_{III}^2}{g\pi^2 D_{III}^4}$$

$$\frac{8Q_{III}^2}{g\pi^2 D_{III}^4} = \frac{\frac{\Delta P}{\gamma} - \left(K_{Tee} + f_1 \frac{L_1 - L_{III}}{D_1}\right) \cdot \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_{III} \frac{L_{III}}{D_{III}} + 2K_{elb} + 2K_{Tee_2}\right)}$$

$$Q_{III} = \sqrt{\frac{\frac{\Delta P}{\gamma} - \left(K_{Tee_2} + f_1 \frac{L_1 - L_{III}}{D_1}\right) \cdot \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_{III} \frac{L_{III}}{D_{III}} + 2K_{elb} + 2K_{Tee_2}\right) \frac{8}{g\pi^2 D_{III}^4}}}$$

Iteration time

$K_{Tee_1} = 20$
$K_{Tee_2} = 60$
$K_{elb} = 30$

$$Re = \frac{VD}{\nu} = \frac{Q}{A} \cdot \frac{D}{\nu} = \frac{Q}{\frac{1}{4}\pi D^2} \cdot \frac{D}{\nu} = \frac{4 \cdot Q}{\pi D \nu}$$

After iterating $\rightarrow Q_1 = 0.132 \, ft^3/s = 59.24 \, GPM$

$65 - 59.24 = 5.76 \, gpm$

So a decrease of 5.76 GPM

Summary - I found that the flow rates decreased, by 5.76 GPM, with Q_2 equaling 31.7 GPM and Q_3 equalling 29.17 GPM

Materials - 2in Steel tubing, 1 1/2 in Steel tubing, Water at 60°F

Analysis - I was surprised to find my spreadsheet iterate to a smaller flow rate than the previous one, so I double checked my work and caught a mistake in pipe diameter. After fixing everything I still got a smaller Q. I double, then triple checked my formulas first on excel, then on my paper and found nothing. I even referenced your spreadsheet and still could not find what I did wrong. I don't generally get this frustrated, but I've done this before and I don't understand where I went wrong. I hope I can get partial credit and only messed up somewhere small in the spreadsheet.