MET330 Test #3

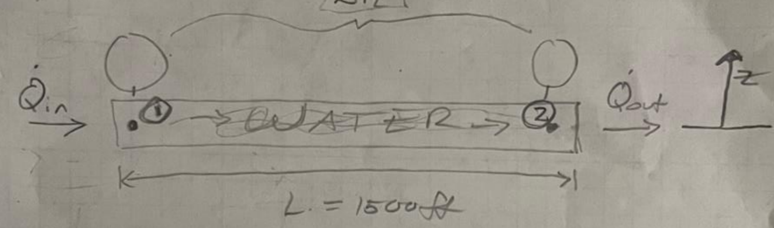
Davis Takhvar

Problem #2 is the problem I would like to have graded for Test #3

Test #3 | DAVIS TAKHVAR

Problem #2: Part 1 – "Series system parameters" (pg. 1)

$\boxed{\Delta P_L}$



Given: • Schedule 40 2" pipe – steel // fluid is water

$\cdot\ \dot{Q} = 65\,GPM = \dot{Q}_{in} = \dot{Q}_{out}$ (since Series)

$$= 65\,GPM\left(\frac{1\,ft^3/s}{449\,GPM}\right)$$

$$= \underline{0.1448\,ft^3/s}$$

Required: • Find pressure drop from 1-2, ΔP_L

Bernoulli's setup: $0 \rightarrow$ since: $\boxed{Q_1 = Q_2 \text{ \& } A_1 = A_2 \therefore V_1 = V_2}$

$$\frac{P_1}{\gamma} + \cancel{z_1}^{\,0} + \cancel{\frac{V_1^2}{2g}} = \frac{P_2}{\gamma} + \cancel{z_2}^{\,0} + \cancel{\frac{V_2^2}{2g}} + h_L$$

$$\therefore \boxed{\frac{\Delta P_L}{\gamma} = h_{L_{1\text{-}2}}} \text{ or } \boxed{\Delta P_L = h_{L_{1\text{-}2}} \cdot \gamma_{water}}$$

where: $\gamma_{water} = \underline{62.4\,lb/ft^3}$

$$\frac{\Delta P_{1-2}}{\gamma} = f_T\left(\frac{L}{D}\right)\left(\frac{\boxed{V^2}}{2g}\right) \rightarrow \boxed{V^2 = \frac{16 \cdot Q^2}{\pi^2 \cdot D^4}}$$

$\varnothing_{pipe}$, D = ID of 2" Steel Tubing (Appendix G "Dimensions of steel Copper, and plastic Tubing")

$\therefore D = 0.1558 \text{ ft.}$

*Again, Inner Diameter was pulled from Appendix G (NOT F) which is the value for steel "tubing" as opposed to "piping".

$\varepsilon_{steel} = 1.5 \times 10^{-4}$ ft. - Table 8.2

Relative roughness ratio: $\left(\frac{D}{\varepsilon}\right) = \frac{0.1558 \text{ ft}}{0.00015 \text{ ft}} = 1038.67$

Reynold's #, $\boxed{R_e = \frac{\rho \cdot V \cdot D}{\eta}} = \frac{(62.41 \text{ lb/ft}^3)(V)(0.1558 \text{ ft})}{(1.905 \times 10^{-5} \text{ lb/ft s})}$

$\boxed{\eta_{water} = 1.905 \times 10^{-5} \text{ lb/ft s}}$

*KEY: It is Assumed that the water temp. is 75°F

$V = \frac{Q}{A} = \frac{0.1448 \text{ ft}^3/\text{s}}{\pi\left(\frac{0.1558 \text{ ft}}{2}\right)^2}$

$V = 7.595 \text{ ft/s}$

Reynold's # Calculation (... Contined)

$$R_e = \frac{(62.41\ lb/ft^3)(7.595\ ft/s)(0.1558\ ft)}{(6.13\times10^{-4}\ lb/ft{\cdot}s)}$$

$R_e \approx 120{,}475$

Using Moody chart App (SCR Maxflow)
★ as approved by the proffessor ★

The precise friction factor of the pipe, $f_T = \underline{0.02211}$

$$\frac{\Delta P_{1-2}}{\gamma} = (0.02211)\left(\frac{1500\ ft.}{0.1558\ ft.}\right)\left(\overbrace{\frac{(7.595\ ft/s)^2}{2\cdot(32.174\ ft/s^2)}}^{\frac{V^2}{2g}}\right)$$

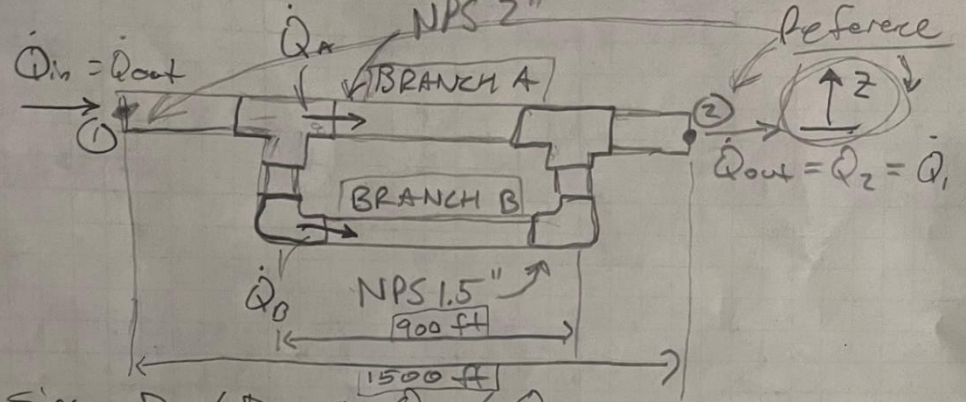
$$\frac{\Delta P_{1-2}}{\gamma_w} = (212.89)\left(\frac{57.684\ ft^{\cancel{2}}/\cancel{s^2}}{64.35\ \cancel{ft/s^2}}\right)$$

$$\Delta P_{L} = (190.842\ \cancel{ft.})(62.4\ lb/ft^{\cancel{3}})$$

$$\Delta P = 11908.55\ lb/ft^2\left(\frac{1\ psi}{144\ lb/ft^2}\right)$$

$$\boxed{\Delta P \approx 82.7\ psi}$$

Problem #2 – PART 2 – "Parrellel Configuration" (Pg. 4)



Since $D_A \neq D_B \therefore Q_A \neq Q_B$

Also, pipe is laid horizontally, $\therefore$ $z_1 = z_2 = z_A = z_B = \emptyset$

Objective: Assuming the same pressure drop ($\Delta P = 82.7$ psi)
- Find change in flow rate, ΔQ

Next, setup Bernoulli's eq.,

$$\frac{P_1}{\gamma} + \cancel{z_1}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} = \frac{P_2}{\gamma} + \cancel{z_2}^{0} + \cancel{\frac{V_2^2}{2g}}^{0} + h_{L_{1-2}}$$

$$\boxed{\frac{\Delta P}{\gamma} = h_{L_{1-2}}} \Rightarrow 190.842 \text{ ft.} = h_{L_A} + h_{L_B}$$

Also, $\Delta P_{SYSTEM} = \Delta P_{BRANCH\ A} = \Delta P_{BRANCH\ B}$ (in "||" pipelines)

Not the same

PS. 5

Branch A

$$190.482\ ft = \left(2\left(k_T \frac{V_{in}^2}{2g}\right) + f_T\left(\frac{L}{D_A}\right)\left(\frac{V_{Branch\ A}^2}{2g}\right)\right)$$

Branch B:

$$190.482\ ft = \left(2\left(k_T \cdot \frac{V_{in}^2}{2g}\right) + 2\left(k_{elb} \cdot \frac{V_{Branch\ B}^2}{2g}\right) + f_T\left(\frac{L}{D_B}\right)\left(\frac{V_{Branch\ B}^2}{2g}\right) + \left(K_{red} - K_{enlarg}\right)\frac{V_B^2}{2g}\right)$$

$$\star \boxed{V^2 = \frac{16 \cdot Q^2}{\pi^2 \cdot D^4}}$$

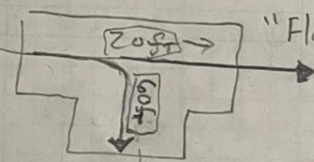
- $D_A = 0.1558\ ft$
- $D_B = 0.1142\ ft$

Appendix G

Plug-in Values to obtain equations:

- $K_T(\text{BRANCH A}) = 20 f_T$
- $K_T(\text{BRANCH B}) = 60 f_T$

f_T represents friction factor At tees



"Flow through Run"

"Flow through Branch"

- $K_{elbow} = 30 \cdot f_B$ (STANDARD)
- $K_{red} \approx 0.06$ // $K_{enlarge} = 0.33$

Assuming 30° gradual transition and $\frac{D_1}{D_2} = \frac{0.1558\ ft}{0.1142\ ft} = 1.36$

BRANCH A

$$190.482\ ft = 2 \cdot 20 \cdot f_T \left(\frac{16 \cdot Q_{in}^2}{2(32.174\ ft/s^2) \cdot \pi^2 \cdot (0.1558\ ft)^4}\right) + f_A\left(\frac{1500\ \cancel{ft}}{0.1558\ \cancel{ft}}\right)\left(\frac{16 \cdot Q_A^2}{\pi^2 \cdot (0.1558\ ft)^4 \cdot 2 \cdot (32.174\ ft/s^2)}\right)$$

$$'' = 2 \cdot (60 f_B)\left(\frac{16 \cdot Q_{in}^2}{2(32.174\ ft/s^2) \cdot \pi^2 (0.1558)^4}\right) + 2\left(30 \cdot f_B\right)\left(\frac{16 \cdot Q_B^2}{2 \cdot (32.174\ ft/s^2) \cdot \pi^2 \cdot (0.1142\ ft)^4}\right)$$

$$+ f_B\left(\frac{900\ \cancel{ft}}{0.1142\ \cancel{ft}}\right)\left(\frac{16 \cdot Q_B^2}{2 \cdot (32.174\ ft/s^2) \cdot \pi^2 \cdot (0.1142\ ft)^4}\right) + \left(K_{red} + K_{enlargement}\right)\frac{8 Q_B^2}{g \cdot D_B^4 \cdot \pi^2}$$

BRANCH B

Simplify:

Branch A

$$190.48\,ft. = 1710.31\,ft^5/s^2 \cdot f_T \cdot Q_{in}^2$$

$$+ 411660.48\,ft^5/s^2 \cdot f_A \cdot Q_A^2$$

P96

$$190.48\,ft = 5130.94\,ft^5/s^2 \cdot f_T \cdot Q_{in}^2$$

$$+ 8887.34\,ft^5/s^2 \cdot f_B \cdot Q_B^2$$

BRANCH B

$$+ 1167339.5\,ft^5/s^2 \cdot f_B \cdot Q_B^2$$

$$+ 57.77 \cdot Q_B^2$$

Combine like terms:

$$190.48\,ft = 5130.94\,ft^5/s^2 \cdot f_T \cdot Q_{in}^2$$

$$+ 1,176,226.8\,ft^5/s^2 \cdot f_B \cdot Q_B^2 + 57.77\,Q_B^2$$

Setup Relationship equations:

factored "Q_B^2" out

$$\frac{(1,176,226.8 \cdot f_B + 57.77)\,Q_B^2}{(1,176,226.8 \cdot f_B + 57.77)} = \frac{190.48\,ft - 5130.94 \cdot f_T \cdot Q_{in}^2}{(1,176,226.8 \cdot f_B + 57.77)}$$

$$\boxed{Q_B = \sqrt{\frac{190.48 - 5130.94 \cdot f_T \cdot Q_{in}^2}{(1,176,226.8 \cdot f_B + 57.77)}}}$$

EQ#1

"Branch A:"

B.7

$$\frac{411660.48\,\cancel{ft^5/s^2}\cdot f_A \cdot Q_A^2 = 190.48\,\cancel{ft} - 1710.31\,\cancel{ft^5/s^2}\, f_T \cdot Q_{in}^2}{411660.48 \cdot f_A}$$

$$\boxed{Q_A = \sqrt{\frac{0.00046271}{f_A} - \frac{0.004154 \cdot f_T \cdot Q_{in}^2}{f_A}}} \longrightarrow \text{Eq \#2}$$

Now, since in parallel systems $Q_{in} = Q_{TOTAL} = Q_A + Q_B$

$$\therefore \boxed{\underset{\text{"(TOTAL)"}}{Q_{in}} = \sqrt{\frac{0.00046271}{f_A} - \frac{0.004154 \cdot f_T \cdot Q_{in}^2}{f_A}} + \sqrt{\frac{190.48 - 5130.94 \cdot f_T \cdot Q_{in}^2}{(1{,}176{,}226.8 \cdot f_B + 57.77)}}}$$

Final Equation to iterate upon using Excel

or $$0 = \sqrt{\frac{0.00046271}{f_A} - \frac{0.004154 (f_T) \cdot Q_{in}^2}{f_A}} + \sqrt{\frac{190.48 - 5130.94\, f_T \cdot Q_{in}^2}{1176226.8 \cdot f_B + 57.77}} - Q_{in}$$

EXTRA CREDIT PROBLEM (#1):

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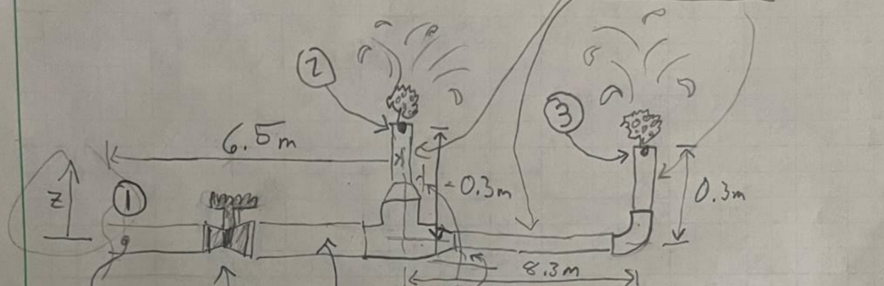
B.8

Problem #1: EXTRA CREDIT OPPURTUNITY

$\boxed{\varnothing = D_2 = 1\text{'' NPS}}$



$\theta_{contraction}$ = Gradual 30° (Assumed)

$\boxed{P_1 = 400 \text{ kPa (Gage)}}$ $\boxed{\varnothing = D_1 = 1.5 \text{ NPS}}$ (Schedule 40 steel)

"Wide open ball valve"

$\boxed{\text{Objective: Determine Flow rate, } \underline{Q}\text{, delivered to each sprinkler head.}}$

- $K_{sprinkler\,heads\,2,3}$ $(K_{2,3}) = \underline{50}$
- $P_{sprinklers\,2,3.}$ $(P_{2,3}) = \varnothing$; ∵since: exposed to the atmosphere pressure and P_1 = (Gage pressure).

Solution:

Setup bernoulli's eq'n for each section:

$$\frac{P_1}{\gamma} + \overset{0\ \text{"horizontal"}}{\cancel{z_1}} + \frac{V_1^2}{2g} = \overset{0\,(\text{atm})}{\cancel{\frac{P_2}{\gamma}}} + \overset{0}{\cancel{z_2}} + \frac{V_2^2}{2g} + h_{L,1\text{-}2}$$

$\boxed{\text{Section 1-2}}$

$$\frac{P_1}{\gamma} + \frac{\Delta V_1^2 - V_2^2}{2g} = \boxed{h_{L_{1-2}}}$$

$$= K_{\substack{ball \\ valve}}\left(\frac{V_1^2}{2g}\right) + K_T\left(\frac{V_1^2}{2g}\right) + K_{contraction}\left(\frac{V_1^2}{2g}\right)$$

$$+ f_1\left(\frac{Le}{D_1}\right)\left(\frac{V_1^2}{2g}\right) + f_2\left(\frac{Le}{D_2}\right)\left(\frac{V_2^2}{2g}\right)$$

$$+ K_{sprinkler\,2}\left(\frac{V_2^2}{2g}\right)$$

Now, resistance coefficients, K:

- $K_{2,3} = 50$
- K_{T_1} (Section 1-2 only: Considered "flow through branch")
- $K_{\substack{ball \\ Valve}} = 150 f_1$ $K_{T_1} = 60 f_1$ // $K_{T_2} = 20 \cdot f_1$ ("flow through run")
- $K_{contraction} \approx 0.051 \cdot f_1$ (Using chart 10.12)
- $K_{elbow} = 30 \cdot f_2$ (section 1-3)

Plug in values to simplify:

Also,: $\boxed{V_n^2 = \frac{16\, Q_n^2}{\pi^2 \cdot d_n^4}}$

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$$\text{''}\ldots = 150\cdot f_1\left(\frac{8\cdot Q_1^2}{\pi^2\cdot(0.0409m)^4(9.81m/s^2)}\right) + 60\cdot f_1\left(\frac{8\cdot Q_1^2}{\pi^2\cdot(0.0409m)^4(9.81m/s^2)}\right)$$

$$+ (0.051)\cdot f_1\left(\frac{8\cdot Q_1^2}{\pi^2\cdot(0.0409m)^4(9.81m/s^2)}\right) + \left(\frac{6.5\cancel{m}}{0.0409\cancel{m}}\right) f_1\left(\frac{8\cdot Q_1^2}{\pi^2\cdot(0.0409m)^4(9.81m/s^2)}\right)$$

$$+ \left(\frac{0.3m}{0.0266m}\right) f_2\left(\frac{8\cdot Q_2^2}{\pi^2\cdot(0.0266m)^4\cdot(9.81m/s^2)}\right) + 50\left(\frac{8\cdot Q_2^2}{\pi^2\cdot(0.0266m)^4\cdot(9.81m/s^2)}\right)$$

Simplify:

$$\text{''}\ldots = 4429138.5\cdot f_1\cdot Q_1^2 + 1771655.4\cdot f_1\cdot Q_1$$

$$+ 1505.9\cdot f_1\cdot Q_1^2 + 4692648.8\cdot f_1\cdot Q_1^2$$

$$+ 1861376.8\cdot f_2\cdot Q_2^2 + 8252104\cdot Q_2^2$$

Combine like terms:

$$= 10894948.6\cdot f_1\cdot Q_1^2 + 1861376.8\cdot f_2\cdot Q_2^2 + 8252104\cdot Q_2^2$$

LHS: (Section 1-2)

"PS"

$$\therefore \frac{400\,\cancel{kPa}}{9.81\,\cancel{kN}/m^3} + \frac{8\cdot Q_1^2}{(9.81\,m/s^2)(0.0409\,m)^4\pi^2} + \frac{8\cdot Q_2^2}{(9.81\,m/s^2)(0.0266)^4(\pi^2)} = \text{"...."}$$

$1\,kPa = 1\,kN/m^2$

$$40.77\,m + 29527.6\cdot Q_1^2 + 165042.1\cdot Q_2^2 = \text{"RHS..."}$$

Set LHS $= Q_2$:

$$165042.1\cdot Q_2^2 - 8252104\cdot Q_2^2 - 1861376.8\cdot f_2\cdot Q_2^2 = \text{"RHS"}$$

$$-8087061.9\,Q_2^2 - 1861376.8\cdot f_2\cdot Q_2^2 = 108949486\cdot f_1\cdot Q_1^2 - 29527.6\cdot Q_1^2 - 40.77\,m$$

$$\frac{(-8087061.9 - 1861376.8\cdot f_2)\cdot Q_2^2 = 10894948.6\cdot f_1\,Q_1^2 - 29527.6\cdot Q_1^2 - 40.77}{(-8087061.9 - 1861376.8\cdot f_2)}$$

$$\boxed{\therefore Q_2 = \sqrt{\frac{10894948.6\cdot f_1\cdot Q_1^2 - 29527.6\cdot Q_1^2 - 40.77}{-8087061.9 - 1861376.8\,(f_2)}}}$$

EQ#1

Bernoulli's for section 1-3:

LHS same as before w/ V_3^2 instead

RHS: $K_{ball}\left(\frac{V_1^2}{2g}\right) + K_{T_2}\left(\frac{V_1^2}{2g}\right) + K_{contraction}\left(\frac{V_1^2}{2g}\right)$

$$+ f_1\left(\frac{Le_{1-T}}{D_1}\right)\left(\frac{V_1^2}{2g}\right) + f_3\left(\frac{Le_{T-3}}{D_2}\right)\left(\frac{V_3^2}{2g}\right)$$

$$+ K_{\substack{elbow \\ (90°)}}\left(\frac{V_3^2}{2g}\right) + K_{sprinkler(3)}\left(\frac{V_3^2}{2g}\right)$$

Plug-in values to simplify:

$$= \left(10894948.6 \cdot f_1 \cdot Q_1^2\right) + f_3\left(\frac{6.3m + 0.3m}{(0.0266m)}\right)\left(\frac{8 Q_3^2}{(9.81 m/s^2)(\pi^2)(0.0266m)^4}\right)$$

"Same As before"

$$+ 30 \cdot f_3\left(\frac{8 \cdot Q_3^2}{(9.81 m/s^2)(\pi^2)(0.0266m)^4}\right) + 50\left(\frac{8 \cdot Q_3^2}{(9.81 m/s^2)(\pi^2)(0.0266m)^4}\right)$$

Simplify: (Next page)

$$\text{"LHS..."} = (10894948.6) \cdot f_1 \cdot Q_1^2 + 4095029.0.5 \cdot f_3 \cdot Q_3^2$$

$$+ 4951262.4 \cdot f_3 \cdot Q_3^2 + 8252104 Q_3^2$$

Combine like terms:

$$\text{"LHS"...} = 10894948.6 \cdot f_1 \cdot Q_1^2 + 9001553 \cdot f_3 \cdot Q_3^2$$
$$+ 8252104 \cdot Q_3^2$$

$-$

Move to LHS

$$\therefore 40.77m + 29527.6 \cdot Q_1^2 + 165042.1 \cdot Q_3^2 = \text{"RHS..."}$$

$-$

Move to RHS

$$\therefore -8087062 \cdot Q_3^2 - 9001553 \cdot f_3 \cdot Q_3^2 = 10894948.6 \cdot f_1 \cdot Q_1^2$$
$$- 29527.6 \cdot Q_1^2$$
$$- 40.77m$$

Factor out Q_3^2 of LHS:

$$Q_3^2(-8087062 - 9001553 \cdot f_3) = \text{"...RHS"}$$

$$-8087062 - 9001553 \cdot f_3$$

$$\boxed{Q_3 = \sqrt{\frac{10894948.6 \cdot f_1 \cdot Q_1^2 - 29527.6 \cdot Q_1^2 - 40.77m}{-8087062 - 9001553 \cdot f_3}}}$$

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EQ#2

$$Q_1 = Q_2 + Q_3$$

$$\therefore \boxed{Q_1 = \sqrt{\frac{10894948.6 \cdot f_1 \cdot Q_1^2 - 29527.6 \cdot Q_1^2 - 40.77}{-8087061.9 - 1861376.8 (f_2)}} + \sqrt{\frac{10894948.6 \cdot f_1 Q_1^2 - 29527.6 \cdot Q_1^2 - 40.77m}{-8087062 - 9001553 \cdot f_3}}}$$

EQ#3

Final Eq'ns that we will Iterate upon using EXCEL