MET 330

11.23 COMPUTE THE TOTAL HEAD ON THE PUMP AND THE POWER DELIVERED BY THE PUMP TO THE COOLANT. $Q = 30\,GPM$, $sg = 0.92$, $\eta = 3.6\times10^{-5}$, $K_{FILTER} = 1.85$

SCH. 40 STEEL PIPE

$2'' \rightarrow D = 0.1723\,FT,\ A = 0.0233\,ft^2$

$1\frac{1}{4}'' \rightarrow D = 0.1150\,FT,\ A = 0.01039\,Ft^2$

$\epsilon = 1.5\times10^{-4}$

$\rho = 0.92(1.94\,\frac{slug}{ft^3}) = 1.7848$

SOLUTION:

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

$$z_1 + h_A - h_L = z_2$$

$$h_A = (z_2 - z_1) + h_L \quad *$$

SOLVING FOR ENERGY LOSS, $h_L = (h_{L_1} + h_{L_2} + h_{L_F} + h_{L_{GV}} + h_{L_{CV}} + h_{L_3})$

$Q = 30\,\frac{GAL}{MIN}\cdot\frac{1\,\frac{FT^3}{s}}{449\,\frac{GAL}{MIN}} = 0.06682\,\frac{FT^3}{s}$

For 2" $\rightarrow V = \frac{Q}{A} = \frac{0.06682\,\frac{FT^3}{s}}{0.02333\,FT^2}$

$= 2.86\,\frac{FT}{s}$

For $1\frac{1}{4}''$ $\rightarrow V = \frac{0.06682}{0.01039}$

$= 6.43\,\frac{FT}{s}$

$N_R = \frac{VD\rho}{\eta} \rightarrow \frac{(2.86)(0.1723)(1.7848)}{3.6\times10^{-5}}$

$= 24430.8$

$\frac{D}{\epsilon} = \frac{0.1723}{1.5\times10^{-4}} = 1148.67$

$f_1 = 0.0268$

$N_R = \frac{VD\rho}{\eta} \rightarrow \frac{(6.43)(0.1150)(1.7848)}{3.6\times10^{-5}}$

$= 36660.3$

$\frac{D}{\epsilon} = \frac{0.1150}{1.5\times10^{-4}} = 766.667$

$f_2 = 0.0262$

$h_{L_1} = 0.5\left(\frac{V^2}{2g}\right) \rightarrow 0.5\left(\frac{2.86\,\frac{FT}{s}^2}{2(32.2)}\right) = 0.06351\,FT$

$h_{L_2} = f\frac{L}{D}\frac{V^2}{2g} \rightarrow 0.0268\left(\frac{10}{0.1723}\right)\left(\frac{2.86^2}{2\cdot32.2}\right) = 0.19756\,FT$

$h_{L_F} = f_T\frac{Le}{D}\frac{V^2}{2g} \rightarrow 1.85\left(\frac{2.86^2}{2\times32.2}\right) = 0.23497\,FT$

$h_{L_{GV}} = f_T\frac{Le}{D}\frac{V^2}{2g} \rightarrow 0.019(8)\left(\frac{2.86^2}{2\cdot32.2}\right) = 0.01931\,FT$

$h_{L_{CV}} = f_T\frac{Le}{D}\frac{V^2}{2g} \rightarrow 0.021(100)\left(\frac{6.43^2}{2\times32.2}\right) = 1.3482\,FT$

$h_{L_3} = f\frac{L}{D}\frac{V^2}{2g} \rightarrow 0.0262\left(\frac{1.8\,FT}{0.1150\,FT}\right)\left(\frac{6.43\,\frac{FT}{s}^2}{2\times32.2\,\frac{FT}{s^2}}\right) = 2.63276\,FT$

$h_L = (0.06351 + 0.19756 + 0.23497 + 0.01931 + 1.3482 + 2.63276\,FT)$

$= 4.49631\,FT$

$h_A = (z_2 - z_1) + h_L \rightarrow (22\,FT - 0\,FT) + 4.49631\,FT$

$\underline{h_A = 26.4963\,FT}$

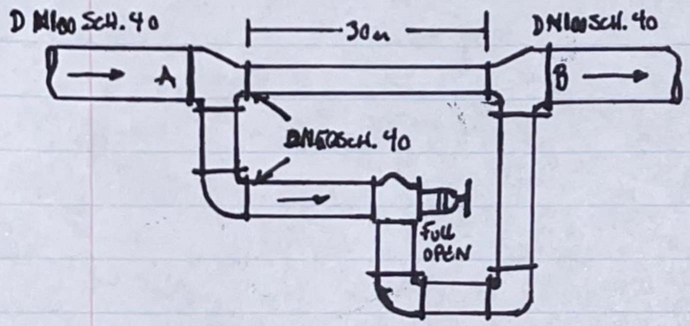
$P = \gamma Q h_A \rightarrow (0.92\cdot62.4\,\frac{lb}{ft^3})(0.06682\,\frac{FT^3}{s})(26.4963\,FT)$

$P = 101.64\,\frac{lbFT}{s}\cdot\frac{1\,HP}{550\,\frac{lbFT}{s}} = 0.1848\,HP$

$\underline{P = 0.1848\,HP}$

MET 330

12.3 IN THE BRANCHED PIPE SYSTEM, $850\frac{L}{MIN}$ OF WATER AT 10°C IS FLOWING IN A DN 100 SCHEDULE 40 PIPE AT A. THE FLOW SPLITS INTO TWO DN 50 SCHEDULE 40 PIPES AS SHOWN AND REJOINS AT B. CALCULATE (a) THE FLOW RATE IN EACH OF THE BRANCHES AND (b) THE PRESSURE DIFFERENCE $P_A - P_B$. INCLUDE EFFECT OF MINOR LOSSES IN LOWER BRANCH. TOTAL LENGTH IN LOWER BRANCH IS 60m.



$$Q = 850\frac{L}{M}\cdot\frac{1\frac{m^3}{s}}{60{,}000\frac{L}{M}} = 0.014167\frac{m^3}{s}$$

$$Q = V_A A_A + V_B A_B \qquad \nu = 1.3\times10^{-6}\frac{m^2}{s} \text{ @ } 10°C$$

$$DN50 \rightarrow D = 0.0525m,\; A = 2.168\times10^{-3}m^2 \; *$$

$$DN100 \rightarrow D = 0.1023m,\; A = 8.217\times10^{-3}m^2$$

1. (LOWER BRANCH)

$$\frac{P_A}{\gamma}+\cancel{z_A}+\cancel{\frac{V_A^2}{2g}}-h_L = \frac{P_B}{\gamma}+\cancel{z_B}+\cancel{\frac{V_B^2}{2g}}$$

$$\frac{P_A}{\gamma}-\frac{P_B}{\gamma} = h_L$$

$f_T = 0.019$

$\frac{Le}{D} = 150$ (OPEN VALVE)

$\frac{Le}{D} = 30$ (ELBOW)

$$h_{L_B} = f\frac{L}{D}\frac{V^2}{2g} + 3f_T\frac{Le}{D}\frac{V^2}{2g} + f_T\frac{Le}{D}\frac{V^2}{2g}$$

$$h_{LB} = \left[f\left(\frac{60m}{0.0525}\right)+3(0.019\times30)+0.019(150)\right]\cdot\frac{V^2}{2g}$$

$$\cancel{h_{LB} = f(1147.42)\left(\frac{V^2}{2g}\right)}$$ FORGOT TO SEPARATE,

$$=\left(f(1142.86)+4.56\right)\left(\frac{V^2}{2g}\right)$$

2. (UPPER BRANCH)

$$\frac{P_A}{\gamma}+\cancel{z_A}+\cancel{\frac{V_A^2}{2g}}-h_L = \frac{P_B}{\gamma}+\cancel{z_B}+\cancel{\frac{V_B^2}{2g}}$$

$$\frac{P_A}{\gamma}-\frac{P_B}{\gamma} = h_L \qquad \text{GUESS } f=0.02 \text{ BELOW}$$

$$h_{L_A} = f\frac{L}{D}\frac{V^2}{2g} \rightarrow f\frac{30m}{0.0525m}\cdot\frac{V^2}{2g} \rightarrow 571.429f\frac{V^2}{2g}$$

3. $$h_{L_B} = h_{L_A} = f\,571.429\frac{V_A^2}{2g} = \cancel{f\,1147.42\frac{V_B^2}{2g}}$$

$$=(0.02)571.429V_A^2 = \cancel{(0.02)1147.42V_B^2}$$

$$=11.4286V_A^2 = (0.02(1142.86)+4.56)V_B^2$$

$$=11.4286V_A^2 = 27.4172V_B^2$$

$$V_A = 1.5489V_B$$

$$Q = 1.5489V_B(A_A)+V_B A_B$$

$$0.014167 = 1.5489V_B(2.168\times10^{-3})+V_B(2.168\times10^{-3})$$

$$V_B = 2.5637\frac{m}{s},\; V_A = 1.5489(2.5637) = 3.97091\frac{m}{s}$$

$$N_{R_A} = \frac{VD}{\nu} = \frac{(3.9709)(0.0525)}{1.3\times10^{-6}} = 160363,\; \frac{D}{\varepsilon} = \frac{0.0525}{4.6\times10^{-5}} = 1141.3$$

$$N_{R_B} = \frac{(2.5637)(0.0525)}{1.3\times10^{-6}} = 103534,\; \frac{D}{\varepsilon} = \frac{0.0525}{4.6\times10^{-5}} = 1141.3$$

$$f_A = 0.0208,\; f_B = 0.0217$$

$$(0.0208)(571.429)V_A^2 = (0.0217(1142.86)+4.56)V_B^2$$

$$V_A = 1.5717V_B$$

4. $$Q = V_A A_A + V_B A_B = 0.014167 = 1.5717V_B(2.168\times10^{-3}) + V_B(2.168\times10^{-3})$$

$$V_B = 2.54096\frac{m}{s}$$

$$V_A = 1.5717(2.54096) = 3.9936\frac{m}{s}$$

$$N_{R_A} = \frac{(3.9936)(0.0525)}{1.3\times10^{-6}} = 161280,\; \frac{D}{\varepsilon} = 1141.3$$

$$N_{R_B} = \frac{(2.54096)(0.0525)}{1.3\times10^{-6}} = 102616,\; \frac{D}{\varepsilon} = 1141.3$$

$$f_A = 0.0208,\; f_B = 0.0217$$

(CONTINUED ON NEXT PAGE)

12.3 (CONT.)

5. $Q_A = V_A A_A$

$= 3.9936(2.168 \times 10^{-3})$

$= 0.008658 \frac{m^3}{s}$

$0.008658 \frac{m^3}{s} \cdot \frac{60{,}000 \frac{L}{MIN}}{1 \frac{m^3}{s}} = 519.48 \frac{L}{MIN}$

$\underline{\underline{Q_A = 519.48 \frac{L}{MIN}}}$ (UPPER BRANCH)

$Q_B = V_B A_B$

$= 2.54096(2.168 \times 10^{-3})$

$= 0.005509 \frac{m^3}{s}$

$0.005509 \frac{m^3}{s} \cdot \frac{60{,}000 \frac{L}{MIN}}{1 \frac{m^3}{s}} = 330.54 \frac{L}{MIN}$

$\underline{\underline{Q_B = 330.54 \frac{L}{MIN}}}$ (LOWER BRANCH)

6. $\frac{P_A - P_B}{\gamma} = h_{L_A}$ (CHOSE h_{L_A} DUE TO BEING A SHORTER EQ.)

$\Delta P = \gamma h_{L_A}$

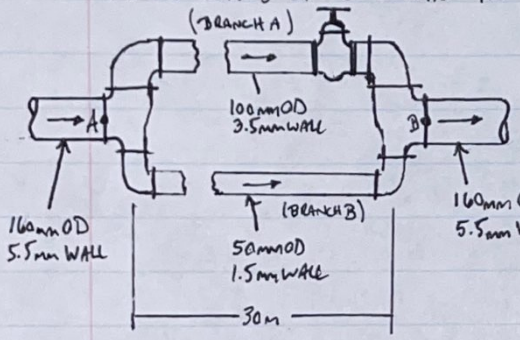
$= (9.81)\left(571.429(0.0208)\left(\frac{3.9936^2}{2 \cdot 9.81}\right)\right)$

$\Delta P = 94.7818 \frac{KN}{m^2}$ OR $94.782 KPa$

$\underline{\underline{\Delta P = 94.782\ KPa}}$

MET 330

12.5 A 160 mm PIPE BRANCHES INTO A 100 mm AND 50 mm PIPE. BOTH PIPES ARE HYDRAULIC COPPER TUBING AND 30m LONG. THE FLUID IS WATER @ 10°C. DETERMINE WHAT THE RESISTANCE COEFFICIENT K OF THE VALVE MUST BE TO OBTAIN EQUAL VOLUME FLOW RATES OF $500 \frac{L}{MIN}$ IN EACH BRANCH.



COPPER TUBING (APP. G, TABLE G.2)
$$\begin{cases} 160mmOD \rightarrow D = 0.149\ m,\ A = 1.744 \times 10^{-2}\ m^2 \\ 50mmOD \rightarrow D = 0.047\ m,\ A = 1.735 \times 10^{-3}\ m^2 \\ 100mmOD \rightarrow D = 0.093\ m,\ A = 6.793 \times 10^{-3}\ m^2 \\ \varepsilon = 1.5 \times 10^{-6}\ m \end{cases}$$

$$Q = 500 \frac{L}{MIN} \cdot \frac{1 \frac{m^3}{s}}{60{,}000 \frac{L}{MIN}} = 0.008333 \frac{m^3}{s}$$

$$\nu = 1.3 \times 10^{-6} \frac{m^2}{s} \text{ (App. A, TABLE A.1)}$$

1. $$V_A = \frac{Q_A}{A_A} \rightarrow \frac{0.008333 \frac{m^3}{s}}{6.793 \times 10^{-3}\ m^2} = 1.2267 \frac{m}{s}$$

$$N_R = \frac{VD}{\nu} \rightarrow \frac{(1.2267 \frac{m}{s})(0.093m)}{1.3 \times 10^{-6} \frac{m^2}{s}} = 87756.2$$

$$\frac{D}{\varepsilon} = \frac{0.093\ m}{1.5 \times 10^{-6}\ m} = 62{,}000, \quad f_A = 0.018$$

$$V_B = \frac{Q_B}{A_B} \rightarrow \frac{0.008333 \frac{m^3}{s}}{1.735 \times 10^{-3}\ m^2} = 4.8029 \frac{m}{s}$$

$$N_R = \frac{VD}{\nu} \rightarrow \frac{(4.8029 \frac{m}{s})(0.047m)}{1.3 \times 10^{-6} \frac{m^2}{s}} = 173643$$

$$\frac{D}{\varepsilon} = \frac{0.047\ m}{1.5 \times 10^{-6}\ m} = 31333.3, \quad f_B = 0.016$$

2. (UPPER BRANCH)

$$\frac{P_A}{\gamma} + \cancel{z_A} + \cancel{\frac{V_A^2}{2g}} - h_L = \frac{P_B}{\gamma} + \cancel{z_B} + \cancel{\frac{V_B^2}{2g}}$$

$$\frac{P_A - P_B}{\gamma} = h_L = (h_{L_P} + h_{L_V} + h_{L_e})$$

$$h_{L_A} = f\frac{L}{D}\frac{V^2}{2g} + K\frac{V^2}{2g} + 2\left(f_T \frac{Le}{D}\frac{V^2}{2g}\right)$$

$$h_{L_A} = \left[f\frac{L}{D} + K + 2f_T\frac{Le}{D}\right]\left(\frac{V^2}{2g}\right)$$

$$= \left[0.018\left(\frac{30m}{0.093m}\right) + K + 2(0.018)(30)\right]\left(\frac{1.2267^2 \frac{m}{s}}{2 \times 9.81 \frac{m}{s^2}}\right)$$

$$= \left[6.8865 + K\right]\left(\frac{0.0767}{\cancel{0.06252}}\right) \text{ (FORGOT TO SQUARE)}$$

$$h_{L_A} = \cancel{0.43054 + 0.06252K}\ 0.52817 + 0.0767K$$

3. (LOWER BRANCH)

BERNOULLI'S EQUATION IS IDENTICAL,

$$h_{L_B} = (h_{L_P} + h_{L_e}) = f\frac{L}{D}\frac{V^2}{2g} + 2\left(f_T \frac{Le}{D}\frac{V^2}{2g}\right)$$

$$= \left[f\frac{L}{D} + 2f_T\frac{Le}{D}\right]\left(\frac{V^2}{2g}\right)$$

$$= \left[0.016\left(\frac{30m}{0.047m}\right) + 2(0.016)(30)\right]\left(\frac{4.8029^2 \frac{m}{s}}{2 \times 9.81 \frac{m}{s^2}}\right)$$

$$h_{L_B} = 13.1362\ m$$

4. SOLVING FOR K, $h_{L_A} = h_{L_B}$

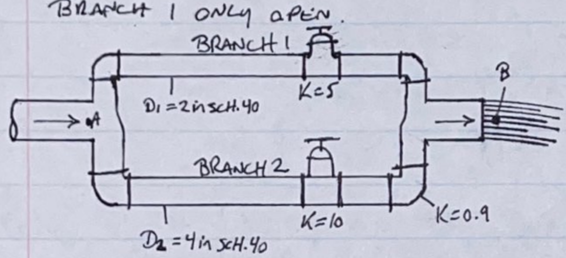
$$0.52817 + 0.0767K = 13.1362\ m$$

$$\underline{K = 164.38}$$

THE RESISTANCE COEFFICIENT OF THE VALVE MUST BE K=164.38 TO OBTAIN EQUAL FLOW.

MET330

12.6 THE PRESSURE AT "A" IS MAINTAINED CONSTANT AT 20 psig. TOTAL VOLUME FLOW RATE EXITING FROM THE PIPE AT "B" DEPENDS ON WHICH VALVES ARE OPEN OR CLOSED. USE $K=0.9$ FOR EACH ELBOW, BUT NEGLECT THE ENERGY LOSSES AT THE TEES. ALSO, BECAUSE THE LENGTH OF EACH BRANCH IS SHORT, NEGLECT PIPE FRICTION LOSSES. THE STEEL PIPE IN BRANCH 1 IS 2in SCH.40, BRANCH 2 IS 4in SCH.40. CALCULATE THE VOLUME FLOW RATE OF WATER FOR EACH OF THE FOLLOWING CONDITIONS: (a) BOTH VALVES OPEN (b) VALVE IN BRANCH 2 ONLY OPEN (C) VALVE IN BRANCH 1 ONLY OPEN.



$Q_A = Q_B$, $Q_T = Q_A + Q_B$

$\gamma = 62.4\ \frac{lb}{ft^3}$

$P_A = 20\ \text{psig} \cdot \frac{\cancel{1\ ft^2}}{\cancel{144\ in^2}} = 20\frac{lb}{in^2}\cdot\frac{144\ in^2}{1\ ft^2} = 2880\ \frac{lb}{ft^2}$

$K_e = 0.9$ 2in sch 40 → $D = 0.1723\ ft$

$K_1 = 5$, $K_2 = 10$ 4in sch.40 → $D = 0.3355\ ft$

(BRANCH 1)

$$\frac{P_A}{\gamma} + \cancel{z_A} + \cancel{\frac{V_A^2}{2g}} - h_{L_A} = \cancel{\frac{P_B}{\gamma}} + \cancel{z_B} + \cancel{\frac{V_B^2}{2g}}$$

$$\frac{P_A}{\gamma} = h_{LA} = (h_{Le} + h_{Lv})$$

$$h_{LA} = 2\left(K_e\frac{V^2}{2g}\right) + K_v\frac{V^2}{2g} = \frac{2880\frac{lb}{ft^2}}{62.4\frac{lb}{ft^3}}$$

$$= \left[2K_e + K_v\right]\left(\frac{V_A^2}{2g}\right) = 46.1538\ ft$$

$$= \left[2(0.9)+5\right]\left(\frac{V_A^2}{2\times \cancel{9.81}\ 32.2}\right)$$

$$h_{LA} = 0.10559\, V_A^2 = 46.1538\ ft$$

$$V_A = 20.907\ \frac{ft}{s}$$

(BRANCH 2)

$$\frac{P_A}{\gamma} = h_{LB} = (h_{Le} + h_{Lv})$$

$$h_{LB} = 2\left(K_e\frac{V_B^2}{2g}\right) + K_v\frac{V_B^2}{2g}$$

$$= \left[2K_e + K_v\right]\left(\frac{V_B^2}{2g}\right)$$

$$= \left[2(0.9)+10\right]\left(\frac{V_B^2}{2\times 32.2}\right)$$

$$= 11.8\left(\frac{V_B^2}{2\times 32.2}\right)$$

$$46.1538 = 0.18323\, V_B^2$$

$$V_B = 15.871\ \frac{ft}{s}$$

$$A_1 = \frac{\pi D^2}{4} = \frac{\pi(0.1723\ ft)^2}{4} = 0.02333\ ft^2$$

$$A_2 = \frac{\pi D^2}{4} = \frac{\pi(0.3355\ ft)^2}{4} = 0.0884\ ft^2$$

$$Q_A = V_A A_A = (20.907\ \tfrac{ft}{s})(0.02333\ ft^2) = 0.48776\ \frac{ft^3}{s}$$

$$Q_B = V_B A_B = (15.871\ \tfrac{ft}{s})(0.0884\ ft^2) = 1.403\ \frac{ft^3}{s}$$

(a) FOR BOTH VALVES OPEN, $Q_T = Q_A + Q_B$

$$Q_T = 0.48776\ \frac{ft^3}{s} + 1.403\ \frac{ft^3}{s}$$

$$Q_T = 1.8908\ \frac{ft^3}{s}$$

(b) ONLY BRANCH 2 VALVE OPEN, $Q_T = Q_B$

$$Q_T = 1.403\ \frac{ft^3}{s}$$

(c) ONLY BRANCH 1 VALVE OPEN, $Q = Q_A$

$$Q_T = 0.48776\ \frac{ft^3}{s}$$