MET 330

HOME WORK 2.1

CHAPTER 10

TEAM BERNOULLI

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10-20) GIVEN: PIPE CONTRACTION,

DN 125 SCHEDULE 80 STEEL PIPE TO DN 50 SCHEDULE 80 PIPE

FLOW RATE $= Q = 500$ L/min

EQUATION FOR SUDDEN CONTRATION $= h_L = K\left(\frac{v_2^2}{2g}\right)$

$$\frac{D_1}{D_2} = \frac{122.3 \text{ mm}}{49.3 \text{ mm}} = 2.48$$

$$v_2 = \frac{Q}{A_2} = \left(\frac{500 \text{ L/min}}{1.905 \times 10^{-3} \text{ m}^2}\right)\left(\frac{1 \text{ m}^3/\text{s}}{60000 \text{ L/min}}\right) = 4.37 \text{ m/s}$$

FROM TABLE 10.3 $\longrightarrow K = 0.38$

$$h_L = \frac{(0.38)(4.37 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} \longrightarrow h_L = 0.371 \text{ m}$$

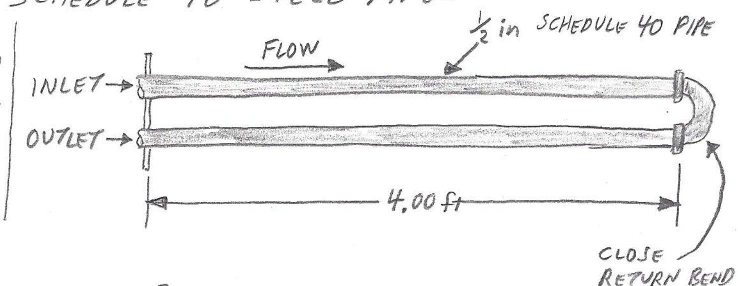
10-37) GIVEN:

CLOSE RETURN BEND IN TWO $\frac{1}{2}$-in SCHEDULE 40 STEEL PIPES

FLOW RATE $= Q = 12.5$ gal/min

FLUID = ETHYLENE GLYCOL AT 77° F

POINT 1 AT INLET, POINT 2 AT OUTLET



BERNOULLI'S EQUATION:

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_{L_{PIPE}} - h_{L_{BEND}} = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$v_1 = v_2$

ASSUME $z_1 = z_2$

$$P_1 - P_2 = \gamma\left(h_{L_{PIPE}} + h_{L_{BEND}}\right)$$

CONTINUED ON NEXT PAGE

10-37) CONTINUED

CLOSE RETURN BEND: $\frac{Le}{D} = 50$ $\quad f_r = 0.027$ (FROM TABLE 10.5)

$$v = \frac{Q}{A} = \left(\frac{12.5\ gal/min}{0.00211\ ft^2}\right)\left(\frac{1\ ft^3/s}{449\ gal/min}\right) = 13.19\ ft/s$$

$$N_R = \frac{vD\rho}{\mu} = \frac{(13.19\ ft/s)(0.0518\ \ )(2.13)}{3.38 \times 10^{-4}} = 4.31 \times 10^3$$

$$\frac{D}{\varepsilon} = \frac{0.0518}{1.5 \times 10^{-4}} = 345 \qquad f = 0.041$$

$$h_{L\,BEND} = f_r \frac{Le}{D}\frac{v^2}{2g} = (0.027)(50)\left[\frac{(13.19\ ft/s)^2}{2(32.2\ ft/s^2)}\right] = 3.65\ ft$$

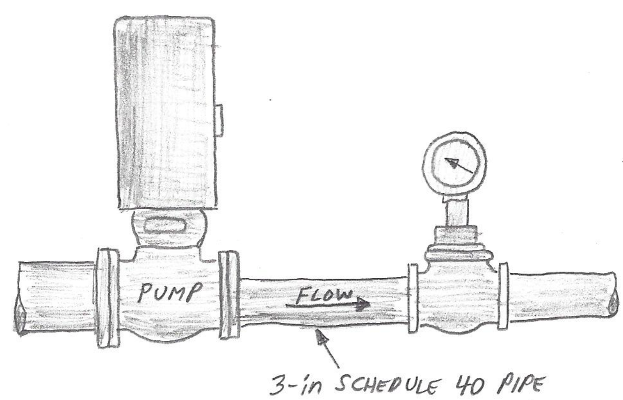
$$h_{L\,TUBE} = f_r \frac{L}{D}\frac{v^2}{2g} = (0.041)\left[\frac{8.00}{0.0518}\right]\left[\frac{(13.19\ ft/s)^2}{2(32.2\ ft/s^2)}\right] = 17.12\ ft$$

$$P_1 - P_2 = \frac{(68.47)(17.12\ ft + 3.65\ ft)}{144} = 9.87\ psi$$

10-39) GIVEN:

FLOW RATE = $Q = 0.40\ ft^3/s$

WATER TEMPERATURE = $50°F$



$$v = \frac{Q}{A} = \frac{0.40\ ft^3/s}{0.05132\ ft^2} = 7.79\ ft/s$$

TEE-FLOW THROUGH RUN: $\frac{Le}{D} = 20$

$f_r = 0.018$ (FROM TABLE 10.5)

$$h_L = f_r \frac{Le}{D}\frac{v^2}{2g} = (0.018)(20)\left[\frac{(7.79\ ft/s)^2}{2(32.2\ ft/s^2)}\right]$$

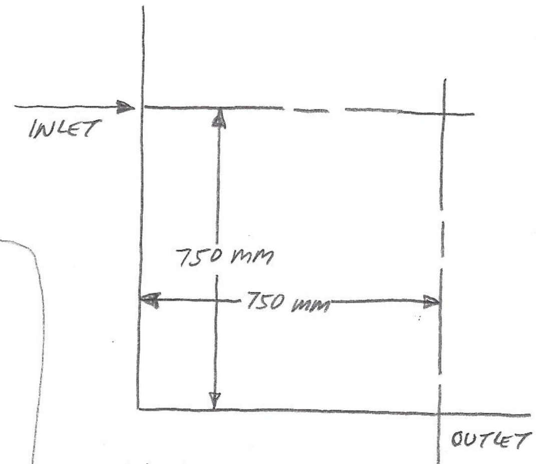
ENERGY LOSS = $h_L = 0.340\ ft$

10-43) GIVEN:

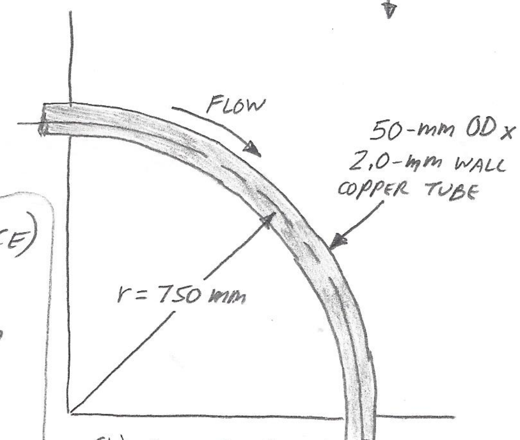
COPPER TUBE = 50 mm OD × 2.0 mm WALL

FLOW RATE = Q = 750 L/min

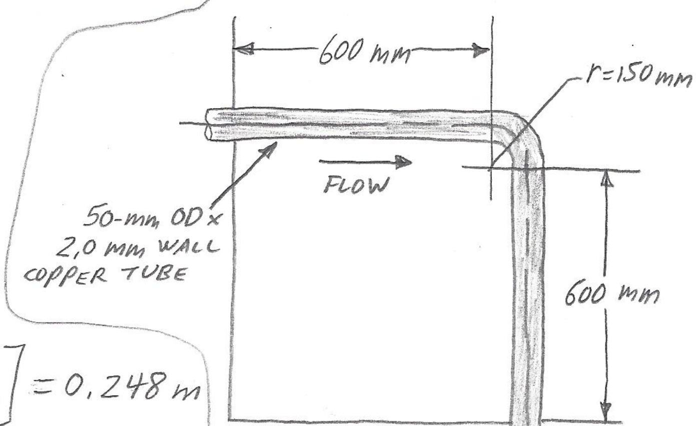
PROPYL ALCOHOL AT 25°C



(a) BASIC LAYOUT



(b) PROPOSAL 1



(c) PROPOSAL 2

PROPOSAL 1 - PIPE BEND:

$$\frac{r}{D} = \frac{750\ mm}{49.8\ mm} = 15.1 \qquad \frac{L_e}{D} = 40.5 \text{ (FIGURE 10.23)}$$

$$v = \frac{Q}{A} = \left(\frac{750\ L/min}{1.945 \times 10^{-3}\ m^2}\right)\left(\frac{1\ m^3/s}{60000\ L/min}\right) = 6.43\ m/s$$

$$N_R = \frac{vD\rho}{\mu} = \frac{(6.43\ m/s)(0.0498)(802)}{1.92 \times 10^{-3}} = 1.34 \times 10^5$$

$$\frac{D}{\varepsilon} = \frac{0.0498}{1.5 \times 10^{-6}} = 33200$$

$f = 0.017 \qquad f_T = 0.010$ (IN ZONE OF COMPLETE TURBULENCE)

$$h_L = f_T \frac{L_e}{D}\frac{v^2}{2g} = (0.010)(40.5)\left[\frac{(6.43\ m/s)^2}{2(9.81\ m/s^2)}\right] = 0.85\ m$$

ENERGY LOSS - PROPOSAL 1 = $h_L = 0.85\ m$

PROPOSAL 2 - BEND + TUBE:

$$\frac{r}{D} = \frac{150\ mm}{49.8\ mm} = 3.01$$

$$\frac{L_e}{D} = 11.8$$

$$h_{L_{BEND}} = f_T \frac{L_e}{D}\frac{v^2}{2g} = (0.010)(11.8)\left[\frac{(6.43\ m/s)^2}{2(9.81\ m/s^2)}\right] = 0.248\ m$$

$$h_{L_{TUBE}} = f \frac{L}{D}\frac{v^2}{2g} = (0.017)\left[\frac{1.20}{0.0498}\right]\left[\frac{(6.43\ m/s)^2}{2(9.81\ m/s^2)}\right] = 0.862\ m$$

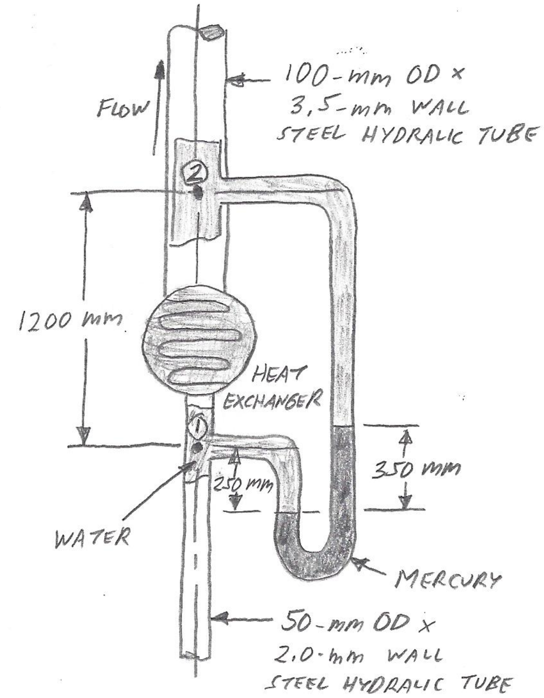
$$h_{L_{TOTAL}} = h_{L_{BEND}} + h_{L_{TUBE}} = 0.248\ m + 0.862\ m = 1.11\ m$$

ENERGY LOSS - PROPOSAL 2 = $h_{L_{TOTAL}} = 1.11\ m$

10-46) GIVEN:

WATER TEMPERATURE = $50^\circ C$

FLOW RATE = $Q = 6.0 \times 10^{-3}\ m^3/s$



BERNOLLI'S EQUATION:

$$\frac{P_1}{\gamma_w} + z_1 + \frac{v_1^2}{2g} - h_L = \frac{P_2}{\gamma_w} + z_2 + \frac{v_2^2}{2g}$$

$$h_L = \frac{P_1 - P_2}{\gamma_w} + z_1 - z_2 + \frac{v_1^2 - v_2^2}{2g}$$

$$A_1 = \frac{\pi D_1^2}{4} = \pi(0.050\ m)^2 = 0.001963\ m^2$$

$$A_2 = \frac{\pi D_2^2}{4} = \frac{\pi(0.10\ m)^2}{4} = 0.007854\ m^2$$

$$z_1 - z_2 = -1.20\ m$$

$$v_1 = \frac{Q}{A_1} = \frac{6.0 \times 10^{-3}\ m^3/s}{0.001963\ m^2} = 3.056\ m/s \longrightarrow \frac{v_1^2}{2g} = \frac{(3.056\ m/s)}{2(9.81\ m/s^2)} = 0.476\ m$$

$$v_2 = \frac{Q}{A_2} = \frac{6.0 \times 10^{-3}\ m^3/s}{0.007854\ m^2} = 0.764\ m/s \longrightarrow \frac{v_2^2}{2g} = \frac{(0.764\ m/s)}{2(9.81\ m/s^2)} = 0.0297\ m$$

MANOMETER:

$$P_1 + \gamma_w(0.25\ m) - \gamma_m(0.35\ m) - \gamma_w(1.10\ m) = P_2$$

$$P_1 - P_2 = \gamma_m(0.35\ m) + \gamma_w(1.10\ m - 0.25\ m)$$

$$\frac{P_1 - P_2}{\gamma_w} = \frac{\gamma_m(0.35\ m)}{\gamma_w} + \frac{\gamma_w(0.85\ m)}{\gamma_w} = \frac{132.8(0.35\ m)}{9.69} + 0.85\ m$$

$$\frac{P_1 - P_2}{\gamma_w} = 4.80\ m + 0.85\ m = 5.65\ m$$

$$h_L = 5.65\ m - 1.20\ m + 0.476\ m - 0.0297 = 4.90\ m$$

ENERGY LOSS BETWEEN POINTS 1 AND 2 = $h_L = 4.90\ m$

LET $h_L = K\dfrac{v_1^2}{2g}$

$\therefore$ RESISTANCE COEFFICIENT $\longrightarrow K = \dfrac{h_L}{v_1^2/2g} = \dfrac{4.90\ m}{0.476\ m} \longrightarrow K = 10.3$

10-48) GIVEN:

STEEL TUBE = $1\frac{1}{4}$ in OD AND WALL THICKNESS OF 0.083 in
MEAN BEND RADIUS = 3.25 in
FLOW RATE OF HYDRALIC OIL = $Q = 27.5$ gal/min
STEEL TUBE HAS A 90° BEND

MEAN BEND RADIUS = $r = 3.25$ ft
INSIDE DIAMETER OF TUBE = $D = 1.084$ in = 0.09033 ft

$$\frac{D}{\varepsilon} = \frac{0.09033 \text{ ft}}{1.5 \times 10^{-4}} = 602$$

$f_T = 0.023$ (IN FULLY TURBULENT ZONE)

$A = 6.409 \times 10^{-3} \text{ ft}^2$

$Q = 27.5 \text{ gal/min} = 0.0612 \text{ ft}^3/\text{s}$

$$v = \frac{Q}{A} = \frac{0.0612 \text{ ft}^3/\text{s}}{0.006409 \text{ ft}^2} = 9.556 \text{ ft/s}$$

$$\frac{v^2}{2g} = \frac{9.556 \text{ ft/s}}{2(32.2 \text{ ft/s}^2)} = 1.418 \text{ ft}$$

$$\frac{r}{D} = \frac{3.25 \text{ in}}{1.084 \text{ in}} = 3.0$$

$$\frac{L_e}{D} = 12.5 \quad \text{(SEE FIG. 10.27)}$$

$$K = f_T\left(\frac{L_e}{D}\right) = 0.023(12.5) = 0.288$$

$$h_L = K\left(\frac{v^2}{2g}\right) = 0.288(1.418 \text{ ft})$$

ENERGY LOSS IN 90° BEND = $h_L = 0.408$ ft

11-5) GIVEN:

FLOW RATE = $Q = 0.015\ m^3/s$

OIL SPECIFIC WEIGHT = $\gamma_o = 8.80\ KN/m^3$

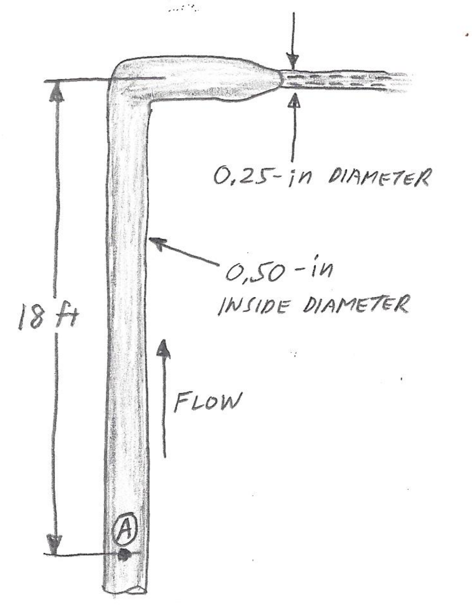
OIL KINEMATIC VISCOSITY = $\nu = 2.12 \times 10^{-5}\ m^2/s$

LENGTH OF DN 150 PIPE = 180 m

LENGTH OF DN 50 PIPE = 8 m

ELBOWS ARE LONG-RADIUS TYPE

PRESSURE AT B = 12.5 MPa



CLASS I; $\frac{P_A}{\gamma} + Z_A + \frac{V_A^2}{2g} - h_L = \frac{P_B}{\gamma} + Z_B + \frac{V_B^2}{2g}$

$$\therefore P_A = P_B + \gamma_o\left[(Z_A - Z_B) + \frac{V_B^2 - V_A^2}{2g} + h_L\right]$$

$$V_A = \frac{Q}{A_A} = \frac{0.015\ m^3/s}{1.682 \times 10^{-2}\ m^2} = 0.892\ m/s \longrightarrow \frac{V_A^2}{2g} = \frac{(0.892\ m/s)^2}{2(9.81\ m/s^2)} = 0.0405\ m$$

$$V_B = \frac{Q}{A_B} = \frac{0.015\ m^3/s}{1.905 \times 10^{-3}\ m^2} = 7.87\ m/s \longrightarrow \frac{V_B^2}{2g} = \frac{(7.87\ m/s)^2}{2(9.81\ m/s^2)} = 3.16\ m$$

$$N_{R_A} = \frac{V_A D_A}{\nu} = \frac{(0.892\ m/s)(0.1463\ m)}{2.12 \times 10^{-5}\ m^2/s} = 6.15 \times 10^3$$

$$\frac{D}{\varepsilon} = \frac{0.1463\ m}{4.6 \times 10^{-5}} = 3180 \qquad f_A = 0.035$$

FROM TABLE F.2

DN 150 SCHEDULE 80 PIPE:
INSIDE DIAMETER = $D_A = 0.1463\ m$

DN 50 SCHEDULE 80 PIPE:
INSIDE DIAMETER = $D_B = 0.0493\ m$

$$N_{R_B} = \frac{V_B D_B}{\nu} = \frac{(7.87\ m/s)(0.0493\ m)}{2.12 \times 10^{-5}\ m^2/s} = 1.83 \times 10^4$$

$$\frac{D}{\varepsilon} = \frac{0.0493\ m}{4.6 \times 10^{-5}} = 1072 \qquad f_B = 0.028$$

$$f_{T_B} = 0.019$$

$$h_L = \underbrace{f_A \frac{180\ m}{0.1463\ m}(0.0405\ m)}_{\text{FRICTION 6-in}} + \underbrace{0.37(3.16\ m)}_{\text{CONTRACTION}} + \underbrace{2(20)(f_{T_B})(3.16\ m)}_{\text{ELBOWS}} + \underbrace{f_B \frac{8}{0.0493\ m}(3.16\ m)}_{\text{FRICTION 2-in}}$$

WHERE $\frac{D_1}{D_2} = \frac{0.1463\ m}{0.0493\ m} = 2.97 \longrightarrow K = 0.37$ (FIGURE 10.8, PAGE 234)

$$h_L = 19.68\ m$$

$$P_A = 12.5\ MPa + \frac{8.80\ kN}{m^2}\left[4.5\ m + 3.16\ m - 0.0405\ m + 19.68\ m\right] = 12.5\ MPa + 240\ kPa$$

$$P_A = 12.74\ MPa$$

11.13

$D = 0.5 in$

$\frac{D}{\varepsilon} = \frac{0.5}{1.5 \cdot 12 \cdot 10^{-4}} = 277.7\overline{7}$

A.) $A = \frac{\pi \cdot D^2}{4}$ $\quad A = 0.0013635\ ft^2$

$P_A = 2880\ pft^2$
$P_B = 0$
$\gamma = 62.4\ lb/ft^3$
$V_A = 0 \quad V_B = 0$
$z_A = 0 \quad z_B = 18\ ft$

$$h_L = \left(\frac{P_A - P_B}{\gamma}\right) + \left(\frac{V_A^2}{2g} - \frac{V_B^2}{2g}\right) + z_A - z_B$$

$$= \left(\frac{2880}{62.4}\right) + \left(0 - \frac{0}{2g}\right) + z_A - z_B$$

$= 28.15\ ft$

$$Q = -2.22 \cdot D^2 \sqrt{\frac{g \cdot D \cdot h_L}{L}} \log\left(\frac{1}{3.7 D/\varepsilon} + \frac{1.784 \cdot \nu}{D\sqrt{\frac{g \cdot D \cdot h_L}{L}}}\right)$$

$L = 20\ ft$
$h_L = 28.15$
$D = 0.041667$
$\nu = 8.23 \cdot 10^{-6}$
$g = 32.2\ ft/s$

$Q = 0.0425\ ft^3/s$

$$V = \frac{Q}{A} = \frac{0.04250}{0.0013635} = \boxed{31.17\ ft/s}$$

B.) $h_L = \left(\frac{P_A - P_B}{\gamma}\right) + \left(\frac{V_A^2}{2g} - \frac{V_B^2}{2g}\right) + z_A - z_B$

$P_A = 11520$ $\quad V_A = 0$
$P_B = 0$ $\quad V_B = 0$
$\gamma = 62.4$ $\quad z_A = 0$
$z_B = 18\ ft$

$h_L = 166.615\ ft$

$$Q = -2.22 \cdot D^2 \sqrt{\frac{g \cdot D \cdot h_L}{L}} \log\left(\frac{1}{3.7 D/\varepsilon} + \frac{1.784 \cdot \nu}{D\sqrt{\frac{g \cdot D \cdot h_L}{L}}}\right)$$

$D/\varepsilon = 2777.778$
$L = 20\ ft$
$h_L = 166.6\ ft$
$D = 0.041667\ ft$
$\nu = 8.23 \cdot 10^{-6}\ ft^2/s$
$g = 32.2\ ft/s$

$Q = 0.088\ ft^3/s$

$$V = \frac{Q}{A} = \frac{0.088}{0.0013635} = \boxed{64.53\ ft/s}$$

11.20)

$h_1 = \cancel{\text{zz}}\,(12-x)\ ft$

$h_2 = 0$

$z_1 = x \quad z_2 = 0$

$h_1 + z_1 - h_L = h_2 + z_2$

$(12-x) + x - h_L = 0 + 0$

$h_L = 12 ft$

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

$\nu = 9.\cancel{1}5 \cdot 10^{-6} ft^2/s$ @ $80°F$

$$D = 0.66 \left\{ \varepsilon^{1.25} \left[\frac{LQ^2}{gh_L} \right]^{4.75} + \nu Q^{9.4} \left[\frac{L}{gh_L} \right]^{5.2} \right\}^{0.04}$$

$g = 32.2 ft/s^2$

$L = 25 ft$

$Q = 400$ gal/min

$$D = 0.66 \left[(1.5 \cdot 10^{-4})^{1.25} \left(\frac{75 \cdot \left(\frac{400 \cdot 1}{449}\right)^2}{32.2 \cdot 12} \right)^{4.75} + (9.\cancel{1}5 \cdot 10^{-6}) \cdot \left(\frac{400 \cdot 1}{449} \right)^{9.4} \cdot \left(\frac{75}{32.2 \cdot 12} \right)^{5.2} \right]^{0.04}$$

$$D = 0.66 \left[(2.29\cancel{5} \cdot 10^{-9}) + (6.12 \cdot 10^{-10}) \right]^{0.04}$$

$$\boxed{D = 0.300\cancel{6}\ ft}$$