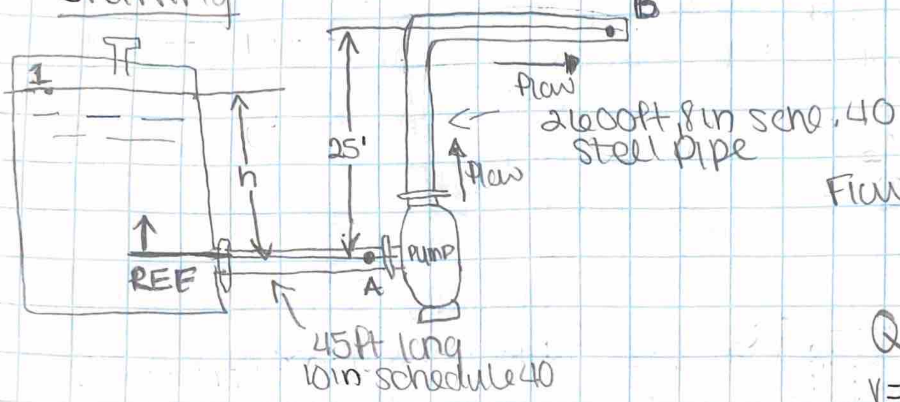
Amber Samm
MET 330
Homework #4

8.33 Purpose: a) Calculate the required height of h to maintain 5.0psig pressure at pt.A
b) calculate power delived by pump to water to maintain pt B pressure @ 85 psig

Drawing



Data:
$1 HP = 550 ft \cdot lb/s$
$\gamma_{water} = 62.4 lb/ft^3$
$D_{i_8} = 0.6651 ft$
$D_{i_{10}} = 0.8350 ft$
Flow Area:
$8'' = 0.347 ft^2$
$10'' = 0.5479 ft^2$
$Q = 1500 gal/min = 3.342 ft^3/s$
$\nu = 1.21 \times 10^{-5} ft^2/s$
$\varepsilon_{steel} = 1.5 \times 10^{-4} ft$ (table 8.2)

Procedure / Calculations: ⓐ

velocity

$$v_{A_{10}} = \frac{Q}{A} = \frac{3.342 ft^3/s}{0.5479 ft^2} = 6.10 ft/s$$

velocity head:

$$\frac{v^2_{A_{10}}}{2g} = \frac{(6.10 ft/s)^2}{2 \times 32.2 ft/s^2} = 0.578 ft$$

$$Re = \frac{6.10 ft/s \cdot 0.8350 ft}{1.21 \times 10^{-5}} = 4.2 \times 10^5$$

friction factors:

$$f_A = \frac{0.25}{\left[\log_{10}\left(\frac{1.5 \times 10^{-4}}{3.7 \times 0.8350} + \frac{5.74}{4.2 \times 10^5 (0.9)}\right)\right]^2} = 0.0156$$

headloss

$$h_{L_A} = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} = 0.0156 \cdot \frac{45 ft}{0.8350 ft} \cdot 0.578 ft = 0.485 ft$$

Energy Equation between (2pts: pt1 + ptA)

$$z_1 + \frac{\cancel{P_1}^{0}}{\gamma} + \frac{\cancel{v_1^2}^{0}}{2g} - h_{LA} = \cancel{z_A}^{0} + \frac{P_A}{\gamma} + \frac{v^2_A}{2g}$$

$$h = \frac{P_A}{\gamma} + \frac{v_A^2}{2g} + h_{LA}$$

$$h = \frac{5.0 lb/in^2 \times 144 in^2/ft^2}{62.4 lb/ft^3} + 0.578 ft + 0.485 ft$$

$$= \boxed{12.60 ft}$$

$$v_{B_8} = \frac{Q}{A} = \frac{3.342 ft^3/s}{0.347 ft^2} = 9.63 ft/s$$

$$\frac{v^2_{B_8}}{2g} = \frac{(9.63 ft/s)^2}{2 \times 32.2 ft/s^2} = 1.44 ft$$

$$Re = \frac{9.63 \times 0.6650}{1.21 \times 10^{-5}} = 5.2 \times 10^5$$

$$f_B = \frac{0.25}{\left[\log_{10}\left(\frac{1.5 \times 10^{-4}}{3.7 \times 0.6650} + \frac{5.74}{5.2 \times 10^5 (0.9)}\right)\right]^2} = 0.0157$$

$$h_{LB} = 0.0157 \cdot \frac{2600 ft}{0.6650 ft} \cdot 1.44 ft = 88.39 ft$$

ⓑ general energy equation (A-B)

$$\frac{P_A}{\gamma} + z_A + \frac{v^2_A}{2g} + h_p - h_{L_B} = \frac{P_B}{\gamma} + z_B + \frac{v^2_B}{2g}$$

$$h_p = \frac{P_B - P_A}{\gamma} + (z_B - z_A) + \left(\frac{v^2_B}{2g} - \frac{v^2_A}{2g}\right) + h_{LB}$$

$$h_p = \frac{(85 psig - 5 psig) \times 144 in^2/ft^2}{62.4 lb/ft^3} + (25 ft) + 0.861 ft + 88.39 ft = 298.87 ft$$

$$Power = h_p \cdot \gamma \cdot Q$$

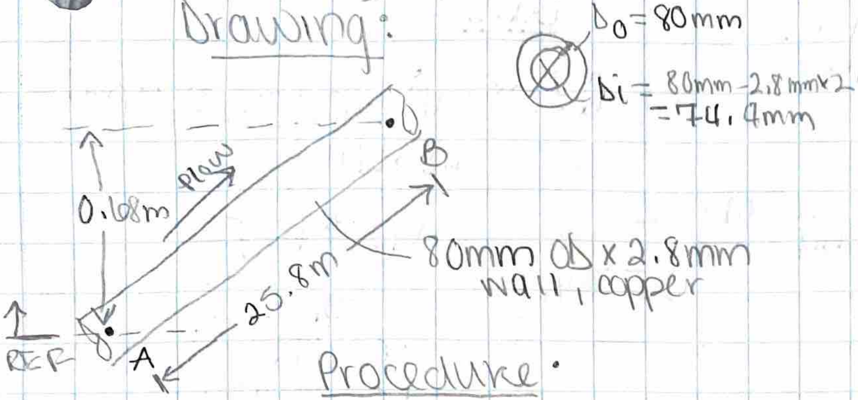
$$= 298.87 ft \times 62.4 lb/ft^3 \times 3.342 ft^3/s = 63325.8 ft \cdot lb/s / 550 ft \cdot lb/s \cdot hp =$$

$$\boxed{hp = 113.32}$$

8.49

Purpose: compute pressure difference between two pts. (A+B)

Drawing:



Data: $t = 2.8mm = 0.0028m$

$D_0 = 80mm = 0.080m$

$D_i = 74.4mm = 0.0744m$

$Q = 180L/min = 0.003 m^3/s$

$L = 25.8m$

$A = \pi/4 (0.0744)^2 = 0.00435$

$\rho_{gly} = 1258 kg/m^3$

$\eta = 9.60 \times 10^{-1}$

Procedure:

Calculate velocity

$$V = \frac{Q}{A} = \frac{0.003 m^3/s}{0.00435 m^2} = 0.69 m/s$$

$$Re = \frac{\rho V D}{\eta} = \frac{1258 kg/m^3 (0.69 m/s)(0.0744m)}{9.60 \times 10^{-1} Pa \cdot s} = 67.27 \text{(laminar)}$$

head loss

$$h_L = \frac{32 \eta L v}{\rho g D^2} = \frac{32 \cdot (9.60 \times 10^{-1}) \cdot 25.8m \cdot 0.690 m/s}{1258 kg/m^3 \times 9.81 m/s^2 \cdot (0.0744m)^2} = 8.01m$$

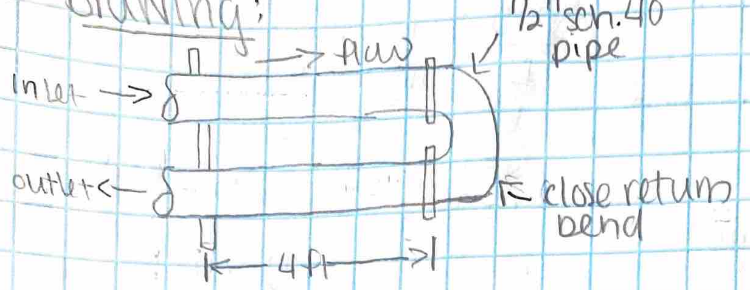
Energy equation (ptA-ptB)

$$\frac{P_A}{\gamma} + z_A + \cancel{\frac{v_A^2}{2g}} = \frac{P_B}{\gamma} + z_B + \cancel{\frac{v_B^2}{2g}} + h_L$$

$$\Delta p = \gamma (z_B - z_A + h_L)$$
$$= (1258 kg/m^3 \times 9.81 m/s^2) \cdot (0.68m + 8.01)$$
$$= 12341 \cdot 8.69$$
$$= \boxed{107243 Pa \text{ or } 107kPa}$$

10.37 Purpose: compute the pressure difference between the inlet + outlet.

Drawing:



Data:

$Q = 125 gal/min = 0.02785 ft^3/s$

$\gamma_{ethy} = 68.47 lb/ft^3$

$\nu = 1.59 \times 10^{-4} ft^2/s$

1/2" pipe: $D_i = 0.0518 ft$

$A_f : 0.00211 ft^2$

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

$L = 8 ft$

Procedure calculations:

Calculate velocity

$$v = \frac{Q}{A} = \frac{0.02785 ft^3/s}{0.00211 ft^2} = 13.199 ft/s$$

Velocity Head

$$\frac{v^2}{2g} = \frac{(13.199 ft/s)^2}{2(32.2 ft/s^2)} = 2.705 ft$$

$$Re = \frac{v \cdot D}{\nu} = \frac{13.199 ft/s \cdot 0.0518 ft}{1.59 \times 10^{-4} ft^2/s} = 4300$$

Roughness

$$\frac{D}{\varepsilon} = \frac{0.0518 ft}{1.5 \times 10^{-4} ft} = 345.33$$

Friction

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{1.5 \times 10^{-4} ft}{3.7(0.0518 ft)} + \frac{5.74}{4300^{0.9}}\right)\right]^2}$$

$= 0.0429$

Headloss due to Friction

$$h_{L friction} = f \cdot \left(\frac{L}{D}\right) \cdot \frac{v^2}{2g}$$

$$= 0.0429 \cdot \left(\frac{8 ft}{0.0518 ft}\right) \cdot 2.705 ft$$

$= 17.92 ft$

Close Return (Minor Loss)

$L_e = 50$ (Table 10.4)

$f_T = 0.026$ (Table 10.5)

$K = (L_e/D) \cdot f_T = 50 \cdot 0.026 = 1.30$

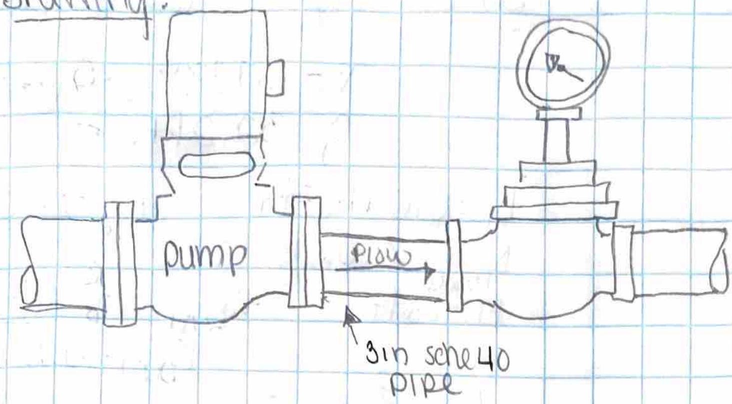
$h_{L bend} = 1.30 \cdot 2.70 = 3.51 ft$

$h_{L net} = 17.92 ft + 3.51 ft = 21.43 ft$

$$\Delta p = \gamma \cdot h_{net} = 68.47 lb/ft^3 \cdot 21.43 ft = \frac{1467.44 lb/ft^2}{144 in^2/ft^2} = \boxed{10.19 psi}$$

10.39 Purpose: compute the energy loss as water flows through the tee.

Drawing:



Data:

$D_{L_{3in}} = 3.068 in = 0.2557 ft$

$A_{flow} = 0.05132 ft^2$

$f_{T_{3in}} = 0.017$ (Table 10.5)

$Q = 0.40 ft^3/s$

$\frac{L_e}{D} = 20$ (Table 10.4)

Procedure / Calculation:

Calculate Velocity of flow

$$V = \frac{Q}{A} = \frac{0.40 ft^3/s}{0.05132 ft^2} = 7.794 ft/s$$

Friction Factor (Turbulent)

$$K = f_T\left(\frac{L_e}{D}\right) = 0.017(20) = 0.34$$

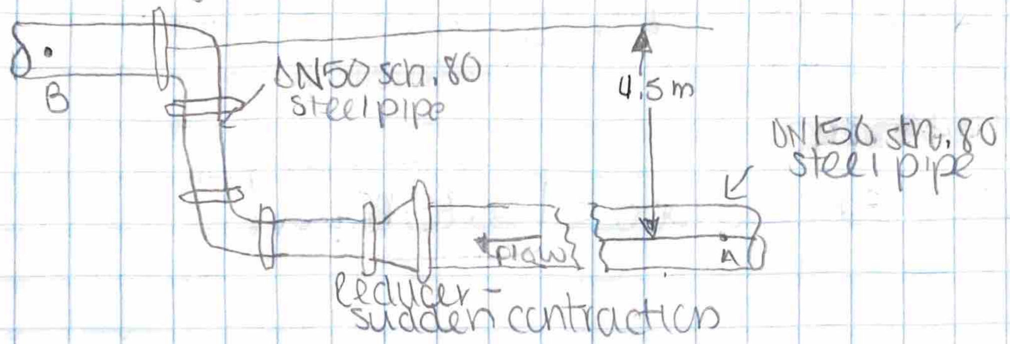
minor head loss:

$$h_L = K\left(\frac{V^2}{2g}\right) = 0.34 \cdot \frac{(7.794 ft/s)^2}{2 \times 32.2 ft/s^2}$$

$$= \boxed{0.321 ft}$$

11.5 Purpose: Calculate the pressure at A.

Drawing:



Data:

$\gamma_{oil} = 8.80 kN/m^3$

$\nu_{oil} = 2.12 \times 10^{-5} m^3/s$

$L_{150} = 180m$, $d_{150} = 146.3mm = 0.1463m$, $A = 1.682 \times 10^{-2} m^2$

$L_{50} = 80m$, $d_{150} = 49.3mm = 0.0493m$, $A = 1.908 \times 10^{-3} m^2$

Elbows = long radius

$P_B = 12.5 Mpa$

DN150:
$$V = \frac{Q}{A} = \frac{0.015 m^3/s}{0.01682 m^2} = 0.892 m/s$$

velocity head
$$\frac{V_1^2}{2g} = \frac{(0.892)^2}{2(9.81)} = 0.041m$$

$$Re = \frac{v_1 D_1}{\nu} = \frac{0.892 \cdot 0.1463}{2.12 \times 10^{-5} m^3/s} = 6,156$$

$$\frac{D}{\varepsilon} = \frac{0.1463 ft}{4.6 \times 10^{-5}} = 3,180$$

$f = 0.0358$

Energy head losses:
$$h_{f1} = f_1 \left(\frac{L}{D}\right) \frac{v^2}{2g} =$$
$$= 0.0358 \left(\frac{180}{0.1463}\right)(0.041)$$
$$= 1.81m$$

Minor losses - contraction
$$\frac{D_2}{D_1} = \frac{49.3}{146.3} = 0.337 = K_c$$
$$h_c = 0.37 (3.150) = 1.17m$$

DN50:
$$V = \frac{Q}{A} = \frac{0.015 m^3/s}{1.908 \times 10^{-3} m^2} = 7.862 m/s$$

$$\frac{V_2^2}{2g} = \frac{(7.862)^2}{2 \cdot 9.81} = 3.150m$$

$$Re = \frac{7.862 \times 0.0493}{2.12 \times 10^{5}} = 18,282$$

$$\frac{D}{\varepsilon} = \frac{0.0493}{4.6 \times 10^{5}} = 1,072$$

$f = 0.036$

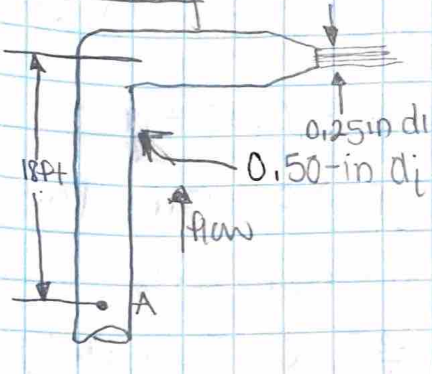
Friction loss:
$$h_{f2} = f_2 \left(\frac{L}{D}\right) \frac{v_2^2}{2g}$$
$$= 0.0306 \left(\frac{8}{0.0493}\right)(3.150)$$
$$= 15.63m$$

Elbow loss:
$$\frac{L_e}{D} = 20 \quad f_T = 0.019 \quad K = 2 \cdot (20 \cdot 0.019) = 0.76$$
$$h_e = 0.76 \cdot 3.150$$
$$= 2.39m$$

$$h_{Lnet} = 1.81m + 15.63m + 1.17m + 2.39m = 21m$$

11.13 Purpose: Determine the velocity of flow from the nozzle with pressure at bottom of ^{a}20psig ^{b}80psig

Drawing:



Data: $\gamma_{water}: 62.0\,\text{lb}/\text{ft}^3$

$\nu = 0.739\times10^{-5}\,\text{ft}^2/\text{s}$

$g = 32.2\,\text{ft}/\text{s}^2$

$D_1 = 0.04167\,\text{ft}$ $\quad L_T = 20\,\text{ft}$

$D_{nozzle} = 0.02083\,\text{ft}$

$h = 18\,\text{ft}$ $\quad K_{bend} = \frac{R}{D} = \frac{6}{0.5} = 12$

$K_{bend} = 0.12$

$\frac{L}{D_1} = \frac{20}{0.04167} = 480$ $\quad K_{nozzle} = 0.15$

Procedure / Calculation:

Continuity states: $A_1V_1 = A_2V_2$

$$V_1 = V_2\left(\frac{D_2}{D_1}\right)^2 = V_2\left(\frac{0.25}{0.50}\right)^2 = 0.25V_2$$

① $V_1^2 = 0.0625V_2^2$

Head loss:

$$h_L = f\left(\frac{L}{D_1}\right)\frac{V_1^2}{2g} + K_{bend}\frac{V_1^2}{2g} + K\frac{V_2^2}{2g}$$

$$= \left(f(480)(0.0625) + 0.12(0.0625) + 0.15\right)\frac{V_2^2}{2g}$$

$$= (30f + 0.1575)\frac{V_2^2}{2g}$$

Energy Equation:

$$\frac{P1}{\gamma} - 18 = \frac{V_2^2}{2g} - \frac{0.0625V_2^2}{2g} + (30f + 0.1575)\frac{V_2^2}{2g}$$

$$\frac{P1}{\gamma} - 18 = \frac{V_2^2}{2g}(1.108 + 30f)$$

(a) pressure head:

$$\frac{P_1}{\gamma} = \frac{20\,\text{ft}\cdot144\,\text{in}^2/\text{ft}^2}{62.0\,\text{lb}/\text{ft}^3}$$

$$= 46.45\,\text{ft} - 18\,\text{ft}$$

$$= 28.45\,\text{ft}$$

$f = 0.021$

$$Re = \frac{(8.1\cdot0.04167)}{7.39\times10^{-6}} = 4.6\times10^4$$

$$28.45 = \frac{V_2^2}{64.4}(1.108 + 30(0.021))$$

$$\boxed{V = 32.4\,\text{ft}/\text{s}}$$

$$f_2 = \frac{0.25}{\left[\log_{10}\left(\frac{5.74}{(4.6\times10^4)^{0.9}}\right)\right]^2}$$

$= 0.021$

ⓑ pressure head:

$$\frac{P_2}{\gamma} = \frac{80\cdot144\,\text{in}^2/\text{ft}^2}{62.0\,\text{lb}/\text{ft}^3} = 185.8\,\text{ft} - 18 = 167.8\,\text{ft}$$

$f = 0.017$

$$167.8 = \frac{V_2^2}{64.2}(1.10875 + 30(0.017))$$

$$\boxed{V = 81.4\,\text{ft}/\text{s}}$$