Chp 7.11

pump = 795 $\frac{gal}{h}$

pipe = 1" schedule 40 pipe

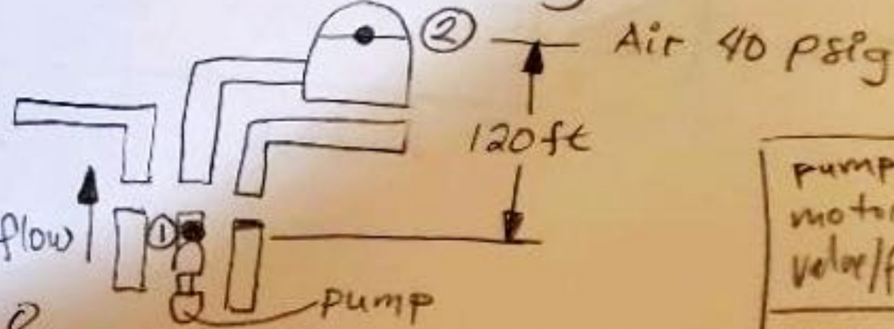
(a) Energy loss of 10.5 $\frac{lb-ft}{lb}$

(b) power delivered ?

pump = 1hp, what is efficiency

Solution:

FBD



$$h_1 + \cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_2}{\gamma} + \frac{V_2}{2g} + z_2 + h_L + \cancel{h_R}^{0}$$

$$h_1 = \frac{P_2}{\gamma_w} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$Q = \left(\frac{795\,[gal]}{1[h]}\right)\left(\frac{1\,[h]}{60\,[min]}\right)\left(\frac{1\ ft^3/s}{449\ \frac{gal}{min}}\right) = 0.028\ \frac{ft^3}{s}$$

$$h_1 = \frac{P_2}{\gamma_w} + \frac{\left(\frac{Q_2}{A_2}\right)^2}{2g} + z_2 + h_L$$

$$h_1 = \frac{\left(40\frac{lb}{in^2}\right)\left(\frac{144\,in^2}{1ft^2}\right)}{62.4\left[\frac{lb}{ft^3}\right]} + \frac{\left(\frac{0.028\left[\frac{ft^3}{s}\right]}{0.006\,ft^2}\right)^2}{\left(2\left(32.2\left[\frac{ft}{s^2}\right]\right)\right)} + 120[ft] + 10.5\frac{lb\,ft}{lb}$$

---

pump - h_A

motor - h_R

valve/fitting - h_L

TABLE F.1

1[in] = 0.006[ft²]

$Q = \left(\frac{1\,gal}{min}\right)\left(\frac{1\,ft^3/s}{449\frac{gal}{min}}\right)$

$Q = \frac{ft^3}{s}$

Pump Efficiency

$e_m = \frac{\text{power delivered}}{\text{power put to pump}}$

$1psi = 144\left[\frac{lb}{ft}\right]$

$\gamma_w = 62.4\,\frac{lb}{ft^3}$

$$\boxed{h_1 = 222.87\,[ft]}$$

(b) Efficiency e_m if $P_I = 1\ hp$

$$e_m = \frac{P_A}{P_I} = \frac{h_1 \gamma_w Q}{P_I} = \frac{(222.87[ft])(62.4\frac{lb}{ft^3})(0.028[\frac{ft^3}{s}])}{1\ hp}$$

$$e_M = \frac{(389.4[\cancel{\frac{lb \cdot ft}{s}}])\left(\frac{1\ \cancel{hp}}{550\ \cancel{\frac{lb\ ft}{s}}}\right)}{1\ \cancel{hp}} = .7$$

$$\boxed{e_m = .7}$$

7.16

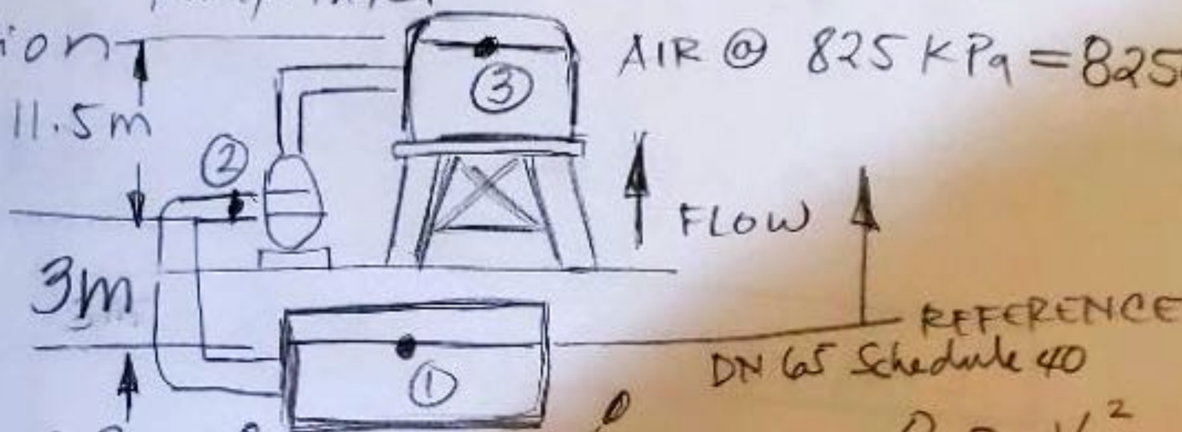
Problem: pump $= 840 \frac{L}{min}$

$Sg_{oil} = 0.85$

(a) Total loss $= 4.2 \frac{N \cdot m}{N}$, power delivered

(b) Energy suction pipe $= 1.4 \frac{N \cdot m}{m}$, Calculate the pressure @ the pump inlet

Solution



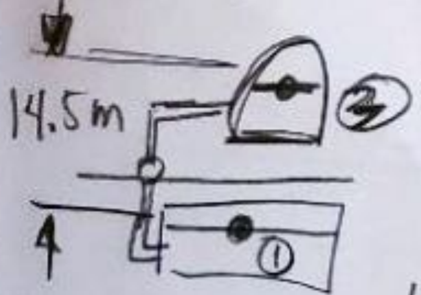
$$h_1 + \cancel{\frac{P_1}{\gamma_w}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_2}{\gamma_w} + \cancel{\frac{V_2^2}{2g}}^{0} + z_2 + h_{L_2} + \cancel{h_{R_2}}^{0} + \frac{P_3}{\gamma_w} + \frac{V_3^2}{2g} + z_3 + h_{L_3} + \cancel{h_{R_3}}^{0}$$

$$h_1 = \frac{P_2 + P_3}{\gamma_w} + \frac{V_3^2}{2g} + z_2 + z_3 + h_{L_2} + h_{L_3}$$

$$Q = \left(\frac{840 [L]}{1 [min]}\right)\left(\frac{1.0 \frac{m^3}{s}}{60\,000 [L/min]}\right) = 0.014 \left[\frac{m^3}{s}\right]$$

$$h_1 = \frac{\left(825000 \frac{N}{m^2}\right) + P_2}{9.81 \times 10^3 \left[\frac{N}{m^2}\right]} + \frac{\left(\frac{0.014 \left[\frac{m^3}{s}\right]}{3.090 \times 10^{-3} m^2}\right)^2}{2\left(9.81 \left[\frac{m}{s^2}\right]\right)} + 3m + 11.5m + 4.2 \frac{N \cdot m}{N} + 1.4 \frac{N \cdot m}{m}$$

FBD #1



$$h_1 + \cancel{\frac{P_1}{\gamma_w}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_3}{\gamma_w} + \cancel{\frac{V_3^2}{2g}}^{0} + z_3 + h_{L3} + \cancel{h_{R3}}^{0}$$

$$h_1 = \frac{P_3}{\gamma_w} + z_3 + h_{L3}$$

$$h_1 = \frac{825000\,[\frac{N}{m^2}]}{(0.85)\,9.81\times10^3\,[\frac{N}{m^3}]} + 14.5[m] + 4.2\left[\frac{N\cdot m}{N}\right]$$

$$\boxed{h_1 = 99 + 18.7[m] = 117.7[m]}$$

FBD #2

$$\cancel{h_1}^{0} + \cancel{\frac{P_1}{\gamma_w}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_2}{\gamma_w} + \frac{V_2^2}{2g} + z_2 + h_{L2} + \cancel{h_{R3}}^{0}$$

$$0 = \frac{P_2}{\gamma_w} + \frac{V_2^2}{2g} + z_2 + h_{L2}$$

$$0 = \frac{P_2}{(0.85)(9.81\times10^3[\frac{N}{m^3}])} + \frac{\left(\frac{0.014\,[\frac{m^3}{s}]}{3.09\times10^{-3}\,m^2}\right)^2}{2(9.81[\frac{m}{s^2}])} + 3[m] + 1.4\,\frac{N\cdot m}{N}$$

$$0 = \frac{P_2}{8338.5[\frac{N}{m^3}]} + \frac{1075.84\,\frac{m^2}{s^2}}{19.62[\frac{m}{s^2}]} + 4.4[m]$$

$$0 = P_2\left(\frac{1}{8338.5[\frac{N}{m^3}]}\right) + 59.2[m]$$

$8338.5\ \frac{N}{m^3}$

$$x - 59.2\,[m] = P_2\left(\frac{1}{8338.5\left[\frac{N}{m^3}\right]}\right)\left(8338.5\ \frac{N}{m^3}\right)$$

$$\boxed{P_2 = -493921.4\left[\frac{N}{m^2}\right]}$$

Chp 8

8.33 Problem: Water @ 80°F

pipe = 6 in Schedule 40 steel pipe

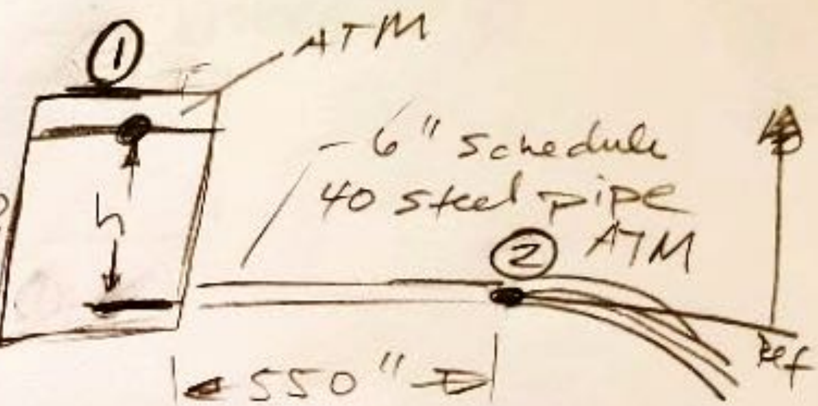
* Energy loss due to friction

Calculate h above the pipe inlet to produce a

$Q = 2.50 \frac{ft^3}{s}$

Solution: FBD

$$\cancel{h_1} + \cancel{\frac{P_1}{\gamma_w}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma_w}} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2} + h_L + h_L$$



$z_1 = h_L$

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

$$z_1 = f \times \frac{L}{D} \times \frac{V^2}{2g}$$

$Q = VA$

$$V = \frac{Q}{A} = \frac{2.50 \frac{ft^3}{s}}{.2006}$$

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$$* \quad N_R = \frac{VD}{\nu} = \frac{\left(\frac{2.50 \frac{ft^3}{s}}{.2006 [ft^2]}\right)(0.5054 [ft])}{9.15 \times 10^{-6} \left[\frac{ft^2}{s}\right]} = \frac{6.29 [ft^2]}{9.15 \times 10^{-6} \left[\frac{ft^2}{s}\right]}$$

$$N_R = 688372 \frac{1}{s}$$

$$* \quad \frac{D}{\varepsilon} = \frac{0.5054 [ft]}{1.5 \times 10^{-4} [ft]} = 3369.3$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{(3.7)(3369.3)} + \left(\frac{5.74}{688572^{0.9}}\right)\right]^2} = .016$$

$$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g} = (0.016)\left(\frac{550\,(ft)}{.5054\,(ft)}\right)\left(\frac{\left(\frac{25\ \frac{ft^3}{s}}{.2006\ ft^2}\right)^2}{2\left(32.2\ \frac{ft}{s^2}\right)}\right)$$

$$\boxed{h_L = 42\ ft}$$

Chp 10.20 problem:

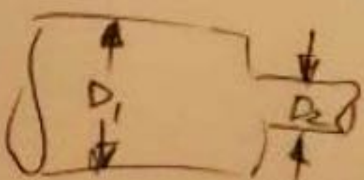
* Determine the energy loss for a sudden contraction from a DN 125 schedule 80 steel pipe to a DN 50 schedule 80 pipe for a $Q = 500 \frac{L}{min}$

	ϕ(mm)	ϕ(m)	Flow Area (m^2)
DN 125 =	122.3	.1223	1.173×10^{-2}
DN 50 =	49.3	.0493	1.905×10^{-3}

$$Q = \left(\frac{500\ \cancel{L}}{\cancel{min}}\right)\left(\frac{1\left[\frac{m^3}{s}\right]}{60000\left[\cancel{\frac{L}{min}}\right]}\right) = .0083\ \left[\frac{m^3}{s}\right]$$

* sudden contraction

$$h_L = k\left(\frac{V_2^2}{2g}\right)$$



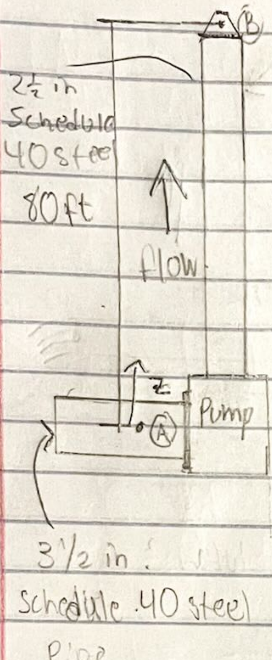
$$\frac{D_1}{D_2} = \frac{.1223\ [m]}{.0493\ [m]} = 2.48\ [m]$$

$$V = \frac{Q}{A} = \frac{.0083\left[\frac{m^3}{s}\right]}{1.905 \times 10^{-3}\ [m^2]} = 4.36\ \frac{m}{s}$$

$$h_L = (.4)\left(\frac{\left(4.4\left[\frac{m}{s}\right]\right)^2}{2(9.81\ \frac{m}{s^2})}\right) = .39\ m$$

$$\boxed{h_L = .39\ m}$$

8.44 The pressure at point B just ahead of the nozzel must be 25 Psig for proper nozzel performance. Pressure at A is -3.5 psig $Q = 0.50\ ft^3/s$ + $\eta = 4.0\times10^{-5}\ lb\cdot s/ft^2$. The SG = 1.026 compute the power delivered by the pump to the fluid considering friction energy loss.



$\varepsilon = 1.5\times10^{-4}\ ft$

$V_A = \frac{Q}{A}$ $\quad D_A = 0.2957\ ft \quad A_A = 0.06868\ ft^2$

$\quad D_B = 0.2058\ ft \quad A_B = 0.03326\ ft^2$

$V_A = \frac{0.5\ ft^3/s}{0.06868\ ft^2} \quad V_A = 7.28\ ft/s \quad V_A A_A = V_B A_B$

$(7.28)(0.06868) = V_B(0.03326)$

$SG = 1.026 \quad (1.026)(1.94\ \frac{slug}{ft^3}) \quad V_B = 15.0\ ft/s$

$\rho = 2.0\ \frac{lb\cdot s^2}{ft}$

$\nu = \eta/\rho = \frac{4.0\times10^{-5}\ lb\cdot s/ft^2}{2.0\ lb\cdot s^2/ft^3}$

$\nu = 2.0\times10^{-5}\ ft^2/s$

$N_R = \frac{VD}{\nu} = \frac{(15\ ft/s)(0.2058\ ft)}{2.0\times10^{-5}\ ft^2/s}$

$N_R = 1.54\times10^5$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.2058\ ft}{1.5\times10^{-4}\ ft}\right)}\right) + \left(\frac{5.74}{(1.54\times10^5)^{0.9}}\right)\right]^2}$$

$f = 0.02047$

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

$h_L = (0.02047)\left(\frac{80\ ft}{0.2058\ ft}\right)\left(\frac{15\ ft^2/s}{64.4\ ft/s^2}\right)$

$h_L = 27.8\ ft \quad h_A - \frac{504\ lb/ft^2}{64.4\ lb/ft^3} + \frac{(7.28\ ft/s)^2}{2\cdot32.2\ ft/s^2} = \frac{3600\ lb/ft^2}{64.4\ lb/ft^3} + \frac{(15\ ft/s)^2}{2\cdot32.2\ ft/s^2} + 80\ ft$

$\gamma = \rho g \quad + 27.8\ ft$

$\gamma = 2.0\ \frac{lb\cdot s^2}{ft^3}\cdot32.2\ ft/s^2$

$= 64.4\ lb/ft^3$

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$h_A = 174.21 \text{ ft}$

$P_A = h_A \gamma Q$

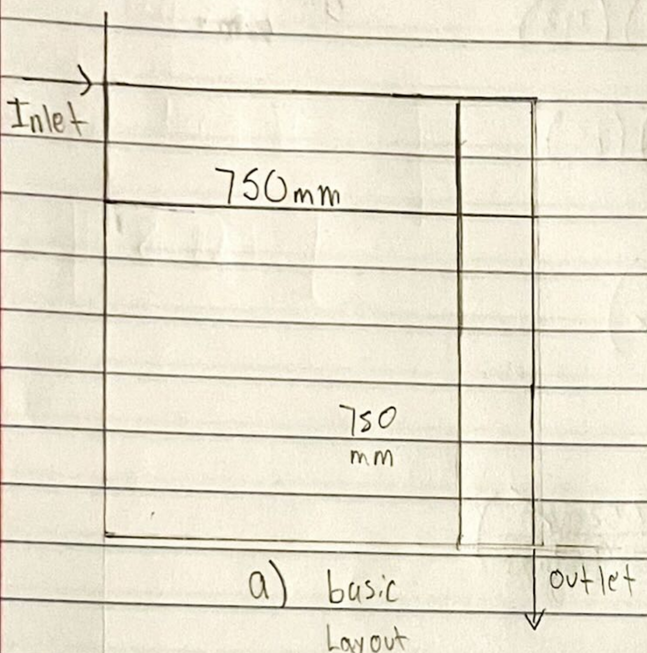
$P_A = (174.21 \text{ ft})(64.4 \text{ lb/ft}^3)(0.5 \text{ ft}^3/\text{s})$

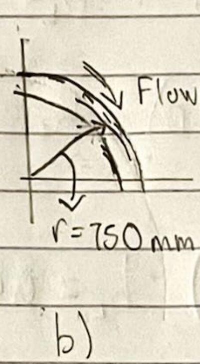
$P_A = 5609.6 \frac{\text{ft-lb}}{\text{s}}$

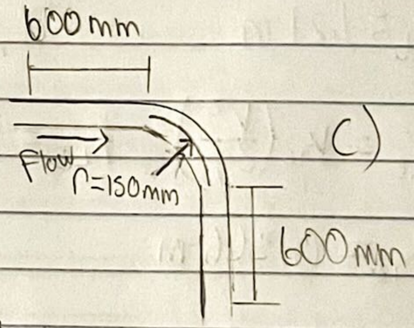
$P_A = 5609.6 \frac{\text{ft-lb}}{\text{s}} \left| \frac{1 \text{ hp}}{550 \frac{\text{ft-lb}}{\text{s}}} \right.$

$\boxed{P_A = 10.2 \text{ hp}}$

The inlet and outlet a) are to be connected with a 50 mm OD × 2.0 mm wall copper tube to carry 750 L/min of propyl alcohol at 25°C. Evaluate the 2 schemes b) + c) with regard to the energy loss. Include the losses due to both the bend and the friction in the straight tube







$D = 46.0\ mm$

$D_o = 50.0\ mm$

$A = 1.662 \times 10^{-3}\ m^2$

$Q = 750\ L/min$

$Q = 750\ \cancel{L/min} \left| \dfrac{1\ m^3/s}{60{,}000\ \cancel{L/min}} \right.$

$Q = 0.0125\ m^3/s$

$Q = VA \quad V = \dfrac{Q}{A} \quad V = \dfrac{0.0125\ m^3/s}{1.662 \times 10^{-3}\ m^2}$

$V = 7.52\ m/s$

$r_b/D = 750mm/46mm = 16.3$

$L_e/D = 43$

$r_b/D = 150mm/46mm = 3.26$

$L_e/D = 13$

$\varepsilon = 1.5 \times 10^{-6}$

$N_R = \dfrac{VD}{\nu} \quad \nu = 7.10 \times 10^{-7}\ m^2/s$

$N_R = \dfrac{(7.52\ \cancel{m/s})(0.046\ \cancel{m})}{7.10 \times 10^{-7}\ \cancel{m^2/s}}$

$N_R = 4.87 \times 10^{5}$

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$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.046m}{1.5\times10^{-4}m}\right)} + \frac{5.74}{(4.87\times10^{5})^{0.9}}\right)\right]^2}$$

$$f_T = 9.78\times10^{-3}$$

$K_b = f_T(L_e/D)$ $\quad$ $K_b = (9.78\times10^{-3})(43)$

$K_b = 0.421$

$K_c = f_T(L_e/D)$ $\quad$ $K_c = (9.78\times10^{-3})(13)$

$K_c = 0.127$

$h_{Lb} = K_b\left(\frac{V^2}{2g}\right)$ $\quad$ $h_{Lb} = 0.421\left(\frac{(7.52\,m/s)^2}{2\cdot9.81\,m/s^2}\right)$

$h_{Lb} = 1.21\,m$

$h_{Lc} = K_c\left(\frac{V^2}{2g}\right)$ $\quad$ $h_{Lc} = 0.127\left(\frac{(7.52\,m/s)^2}{2\cdot9.81\,m/s^2}\right)$

$h_{Lc} = 0.366\,m$

$h_{Ls} = \left(f\cdot\frac{L}{D}\cdot\frac{V^2}{2g}\right)\cdot2$ $\quad$ $h_L = \left[(9.78\times10^{-3})\left(\frac{0.60m}{0.046m}\right)\left(\frac{(7.52\,m/s)^2}{2\cdot9.81\,m/s^2}\right)\right]2$

$h_{Ls} = (0.368)\cdot2$

$h_{Ls} = (0.368)(2)$

$h_{Ls} = 0.735\,m$

$h_{Lc_{tot}} = h_{Ls} + h_{Lc}$

$h_{Lc_{tot}} = 0.735m + 0.366m$

$$\boxed{h_{Lc_{tot}} = 1.1\,m}$$