6-energy loss

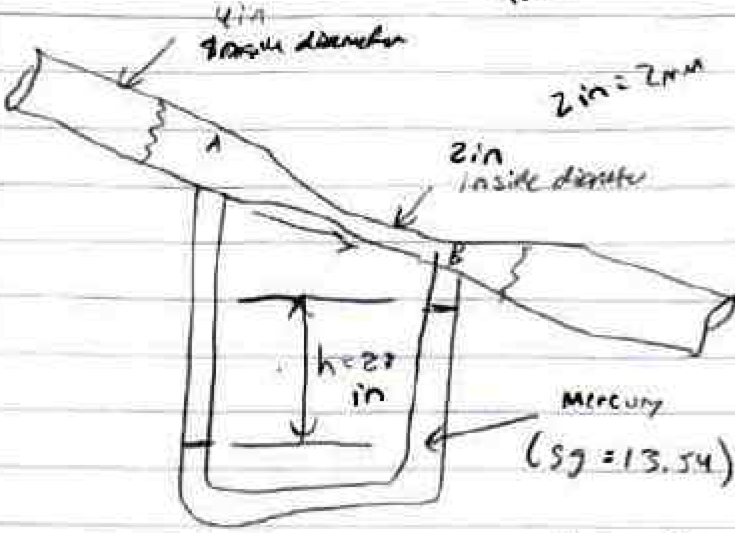
* What We Learned: *

During these two classes, we talked about Bernoulli's equation, Reynolds number, Laminar Flow, Turbulent Flow, + Energy losses due to Friction. Bernoulli's is an equation shows the balance of fluid forces + energy. Reynold's number is Fluid Initia Forces divided by Viscous forces. When Looking at the equation for Energy Loss, it uses Friction, Length, Pipe diameter, Velocity, + gravity.

HW 1.3

Chapter 6 : 79

4 in = 4 mm



$g = 0.90$

2 in = 2 mm

$h = 28$

$= 711.2\,mm$

$= 0.71\,m$

$$\frac{v_2^2}{2g} + \frac{P_2}{\gamma g} + z_2 = \frac{V_1}{2g} + \frac{P_1}{2g} + z_1$$

$$A_1 = \left(\frac{\pi}{4}\right)(0.1^2\,m^2) \qquad A_2 = \left(\frac{\pi}{4}\right)(0.05^2)$$

$$= 0.00785\,m^2 \qquad 0.00196\,m^2$$

$$Q = \frac{(0.00785)(0.00196)}{\sqrt{(0.00785)^2 - (0.00196)^2}}\left(\sqrt{(2)(9.81)(0.71)\left(\frac{13.54}{0.9} - 1\right)}\right)$$

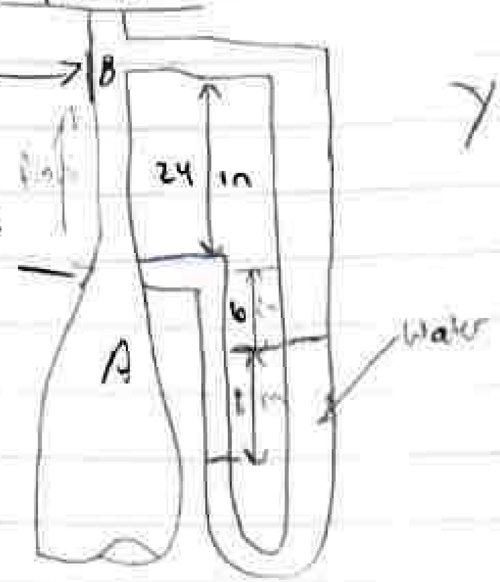
$$Q = (0.00202)(14.44)$$

$$\boxed{Q = 0.029\,m^3}$$

Chapter 82

$0.17 = \frac{2\text{in}}{12}$

$0.33 = 4\text{-in}$



$\gamma = 55.0\ \text{lb/ft}^3$

$h = 8\left(\frac{62.4}{55} - 1\right)$

$8(0.135)$

$= 1.076/12 = 0.0897\ \text{ft}$

$A_1 = \frac{\pi}{4}(0.33)^2$

$= 0.086\ \text{ft}^2$

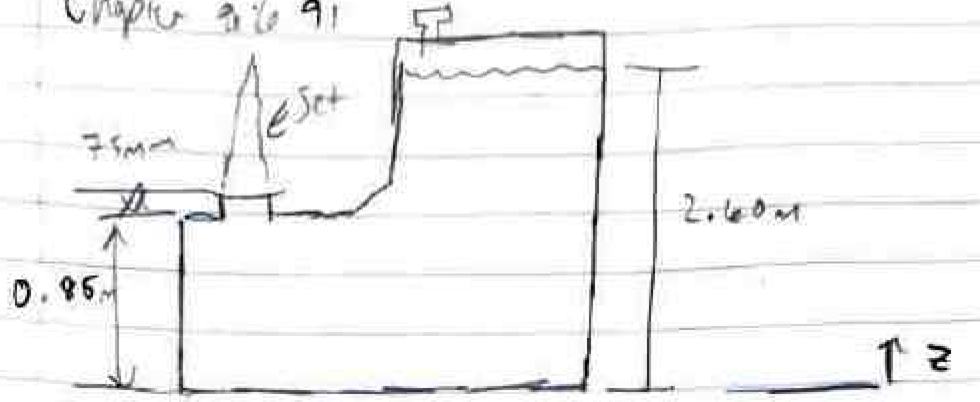
$A_2 = \frac{\pi}{4}(0.17)^2$

$= 0.022\ \text{ft}^2$

$$Q = \frac{(0.086)(0.022)\sqrt{2(32.2)(0.897)}}{\sqrt{(0.0895)^2 - (0.022)^2}}$$

$$Q = \frac{0.014}{0.083} = \boxed{0.1\ \text{ft}^3/\text{s}}$$

Chapter 9.6 91



$$\cancel{h_A} + \cancel{\frac{P_1}{\gamma}} + \cancel{\frac{v_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \frac{v_2^2}{2g} + z_2 + \cancel{h_L}$$

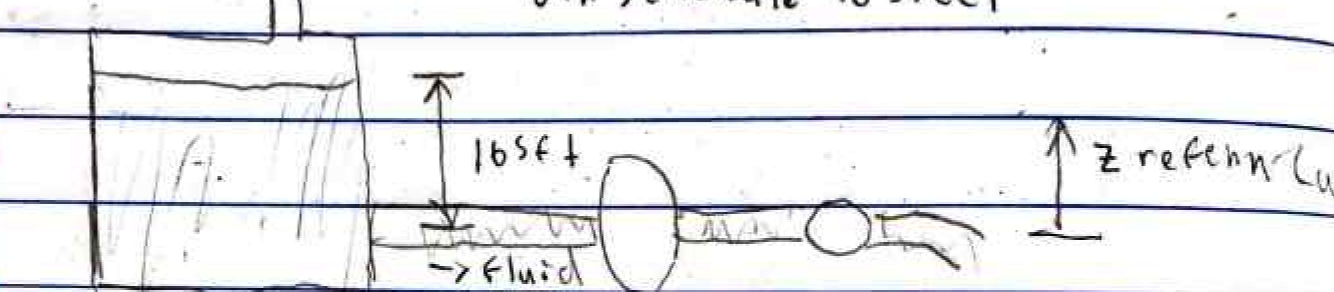
$0.85 + 0.075 +$ 2.6

$$h + 0.85 + 0.075 = 2.6$$

$$\boxed{1.625\,m = h}$$

7.30 $Q_{water} = 1000 \frac{gal}{min}$ $h = 165\ ft$ $h_L = ?$

8 in schedule 40 steel



Energy loss: $h_L = (z_1 - z_2) - \frac{v_2^2}{2g}$

$Q_{water} = (1000 \frac{gal}{min})\left(\frac{1\ ft^3/s}{449\ \frac{gal}{min}}\right) = 2.23 \frac{ft^3}{s}$

Flow area $= 0.3472\ ft^2$ (Fadd.)

$A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(8in(\frac{1ft}{12in}))^2 = 0.349 ft^2$

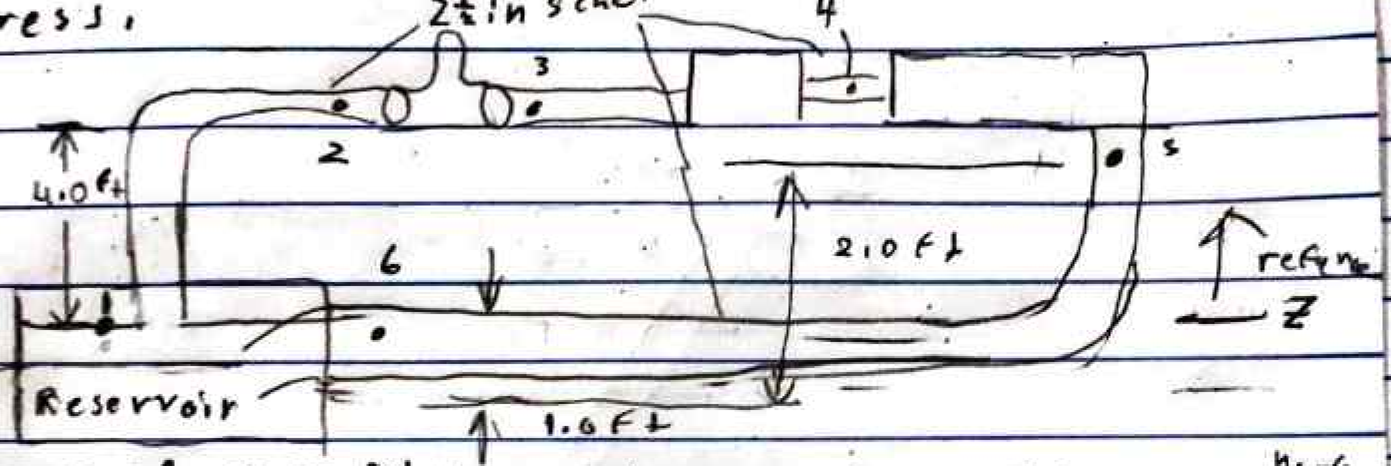
$V = \frac{Q}{A} = \frac{2.23 \frac{ft^3}{s}}{0.349 ft^2} = 6.388 \frac{ft}{s}$

$h_R = \frac{P_R}{\gamma Q} = \frac{(37\ hp)(\frac{550}{1hp})}{(62.4 \frac{lb}{ft^3})(2.23 \frac{ft^3}{s})} = 146.24\ ft$

$h_L = (z_2 - z_1) - \frac{v^2}{2g} - h_R = 165 - \frac{(6.388)^2}{2(32.2)} - 146.24$

$\boxed{h_L = 18.12\ ft}$

7.33 Compute the power removed from the fluid by the press.



Pump eff = 80%, $V = 175 \frac{gal}{min}$, $\gamma_{oil} = 0.9$, hp = 28.4 hp, $h_{L1-2} = 2.8$, $h_{L3-4} = 28.5$, $h_{L5-6} = 3.5$

Bernoulli's equation

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_6}{\gamma} + \frac{v_6^2}{2g} + z_6 -$$

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} - h_{L1-6} + h_A - h_R + z_1 = \frac{p_6}{\gamma} + \frac{v_6^2}{2g} + z_6$$

$$0 + 0 - h_{L1-6} + h_A - h_R + z_1 = \frac{v_6^2}{2g} + z_6$$

$$h_R = z_1 - z_6 - \frac{v_6^2}{2g} - h_{L1-6} + h_A$$

$z_1 = 0\,ft$, $z_6 = 1\,ft$, $V = \frac{Q}{A} = \frac{0.3899\,ft^3/s}{\frac{\pi}{4}(0.2058\,ft)^2} = 11.72\,\frac{ft}{s}$

$$h_{L1-6} = 2.8 + 28.5 + 3.5 = 34.8\,ft$$

$$P_A = P_{in} \times \eta_p = 28.4\,hp(0.8) = 22.72\,hp$$

$$h_A = \frac{P_A}{\gamma Q} = \frac{22.72\,hp\left(\frac{550\,lb\text{-}ft/s}{1\,hp}\right)}{(62.4\,\frac{lb}{ft^3})(0.9)(0.3899\,\frac{ft^3}{s})} = 570.68\,ft$$

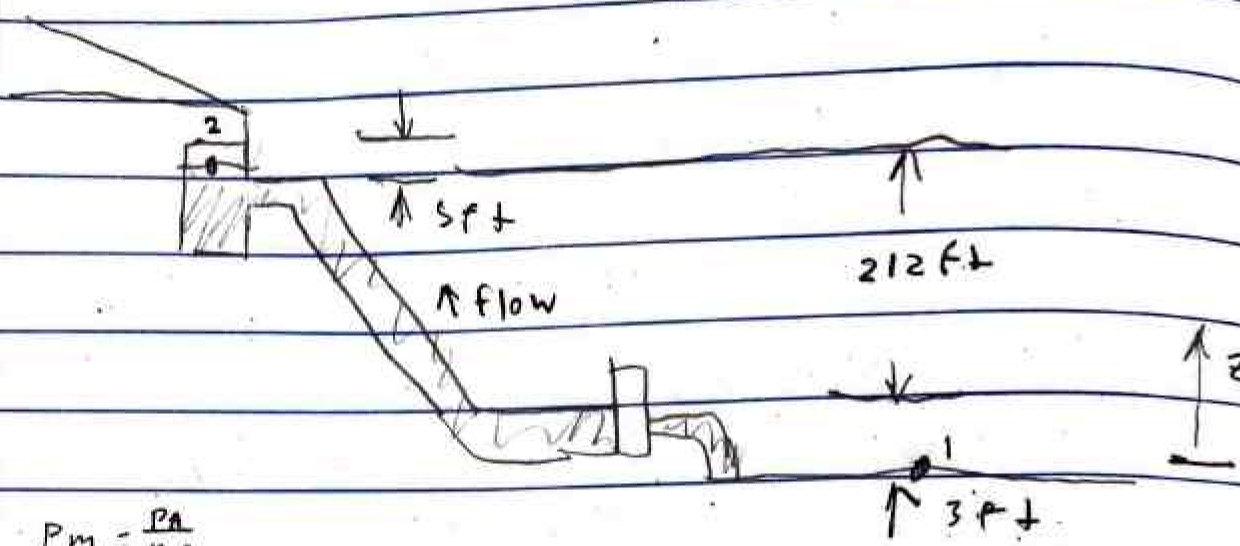
$$h_R = 0 - 1\,ft + \frac{(11.72\,\frac{ft}{s})^2}{2(32.2\,\frac{ft}{s^2})} - 34.8\,ft + 570.68\,ft$$

$$h_R = 534.95\,ft$$

$$P_R = h_R \gamma Q = (534.95\,ft)(62.4\,\frac{lb}{ft^3})(0.3899\,\frac{ft^3}{s}) = 13015\,W$$

$$\boxed{P_R = 13.015\,kW}$$

7.42 $h_L = 15.5 \frac{lb\text{-}ft}{ft}$, $Q = 40 \frac{gal}{min}$, $P_2 = 30\,psig$, $P_M = ?$



$P_M = \frac{P_A}{\eta_A}$

Equation: $h_A = \frac{P_2 - P_1}{\gamma} + \frac{v_2^2 - v_1^2}{2g} + z_2 - z_1 + h_{L\,1-2}$

$h_A = \frac{P_2}{\gamma} + z_2 + h_{L\,2-1}$

$P_2 = 30\,psig = 30 \frac{lb}{in^2}\left(\frac{144\,in^2}{1\,ft^2}\right) = 4320 \frac{lb}{ft^2}$

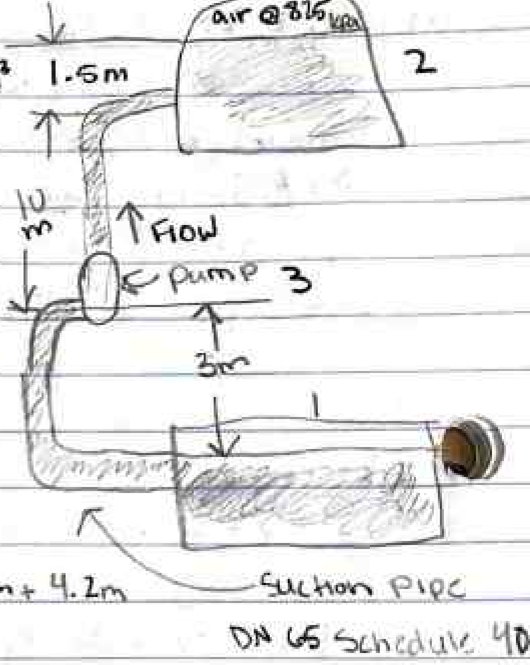
$h_A = \frac{4320 \frac{lb}{ft^2}}{62.4\,lb/ft^3} + 220\,ft + 15.5\,ft = 304.73\,ft$

$P_A = \gamma Q h_A = (62.4 \frac{lb}{ft^3})(0.089 \frac{ft^3}{s})(304.73\,ft) = 1692.35 \frac{lb \cdot ft}{s}$

$P_A = (1692.35 \frac{lb \cdot ft}{s})\left(\frac{1\,hp}{550 \frac{lb \cdot ft}{s}}\right)$

$\boxed{P_A = 3.077\,hp}$

7.16 The figure below shows a pump delivering 840 L/min of crude oil ($sg = 0.85$) from an underground storage drum to the 1st stage of the processing system. a) if the total energy loss in the system is 4.2 N·m/N of oil flowing, calculate the power delivered by the pump. b) if the energy loss in the suction pipe is 1.4 N·m/N of oil flowing, calculate the pressure at the pump inlet.



a) $Sg = .85 = \dfrac{\gamma_{oil}}{\gamma_w} \rightarrow .85 = \dfrac{\gamma_{oil}}{9810\ N/m^3} \rightarrow 8338.5\ N/m^3$

$Q = \dfrac{840L}{min} \times \dfrac{1min}{60sec} \times \dfrac{.001\ m^3}{1L} = .014\ m^3/s$

$h_{L\ system} = 4.2\ m$

$h_{L\ suction} = 1.4\ m$

$P = \gamma Q h_A$

$h_A = \dfrac{P_2 - \cancel{P_1}^{0}}{\gamma} + \dfrac{\cancel{V_2^2}^{0} - \cancel{V_1^2}^{0}}{2g} + Z_2 - \cancel{Z_1}^{0} + h_{L_{12}}$ (system)

$h_a = \dfrac{P_2}{\gamma} + Z_2 + h_{LS} \rightarrow \dfrac{825000\ N/m^2}{8338.5\ N/m^3} + 14.5m + 4.2m$

$h_a = 117.64m$

A → back of book

$P = (8338.5\ N/m^3)(.014\ m^3/s)(117.64m) = 13733.17W$ or $13.73\ kW$

b) $V_3 = Q/A_3 \rightarrow \dfrac{.014\ m^3/s}{3.09\times10^{-3}\ m^2} - V_3 = 4.53\ m/s$

$\dfrac{P_3}{\gamma} = -\dfrac{V_3^2}{2g} - Z_3 - h_{Lsu} \rightarrow P_3 = \gamma\left(-\dfrac{V_3^2}{2g} - Z_3 - h_{L_{12}}\right)$ (suction)

$P_3 = 8338.5\ N/m^2\left(-\dfrac{(4.53\ m/s)^2}{2(9.81\ m/s^2)} - 3m - 1.4m\right)$

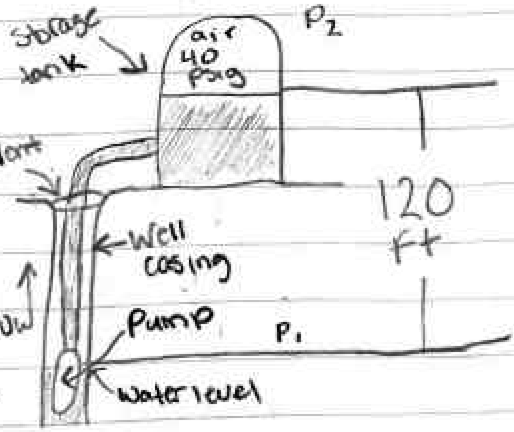
$P_3 = -27968.02\ N/m$ or $-27.97\ kPa$

HW 1.3

11, 16, 22

7.11 A Submersible deep-well pump delivers 745 gal/h of water through a 1-in Schedule 40 pipe when operating in the system sketched below. An energy loss of 10.5 lb-ft/lb occurs in the piping system. a) Calculate the power delivered by the pump to the water. b) if the pump draws 1 hp, calculate its efficiency

$A = .006 \text{ ft}^2$



a) $\frac{P_1}{\gamma} + z_1 + \frac{v^2}{2g} + h_A - h_R - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v^2}{2g}$

Power$_1$ = 1 hp

$Q = 745 \text{ gal/h}$

$h_L = 10.5 \text{ lb-ft/lb}$

$P_2 = 40 \text{ psig} \times \frac{144 \text{ lb/ft}^2}{1 \text{ psig}} = 5760 \text{ lb/ft}^2$

$V = Q/A$

$\frac{745 \text{ gal}}{h} \times \frac{1h}{3600s} \times \frac{.133681 \text{ ft}^3}{1 \text{ gal}}$

$V = \frac{.028 \text{ ft}^3/s}{.006 \text{ ft}^2} = 4.61 \text{ ft/s}$

$P_A = h_A \gamma Q$

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

$h_A = \frac{P_2}{\gamma} + (z_2 - z_1) + \frac{v^2}{2g} + h_L$

$h_A = \frac{5760 \text{ lb/ft}^2}{62.4 \text{ lb/ft}^3} + (120 \text{ ft} - 0) + \frac{(4.61 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} + 10.5 \text{ lb-ft/lb}$

$h_A = 223.08 \text{ ft}$

$P_A = 223.08 \text{ ft} (62.4 \text{ lb/ft}^3)(.028 \text{ ft}^3/s)$

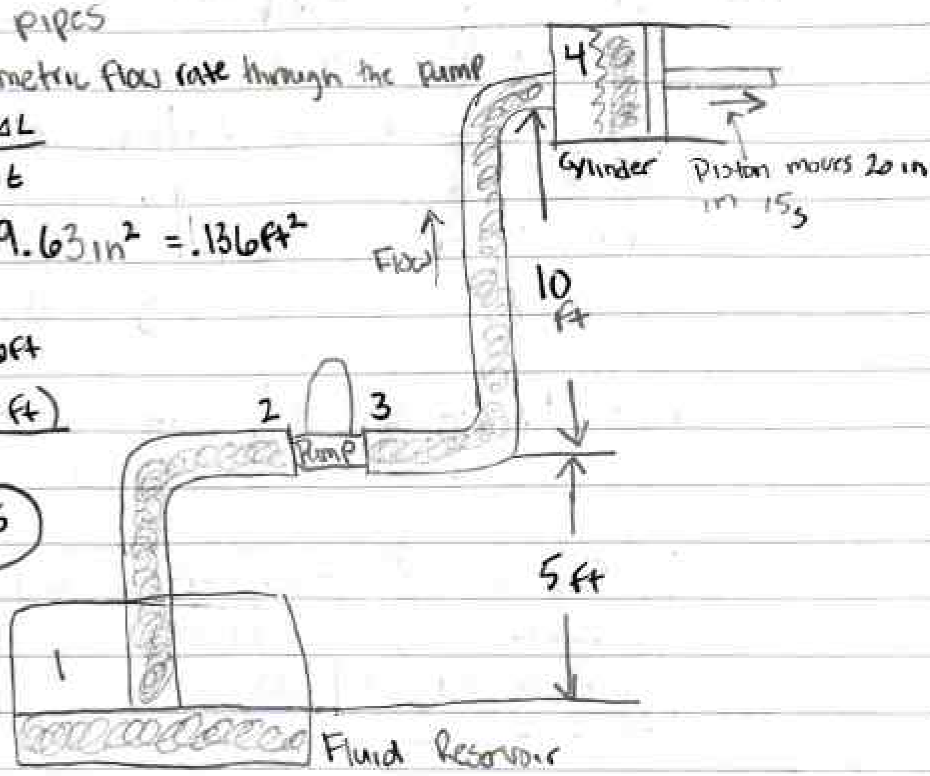
$= 389.77 \frac{\text{lb-ft}}{s} \times \frac{1 \text{ hp}}{550 \frac{\text{lb-ft}}{s}} \rightarrow P_A = .71 \text{ hp}$

b) $e_m = \frac{P_A}{P_I} \rightarrow \frac{.71}{1} \times 100$

$e_m = 70.9\%$

7.22' The figure below shows the arrangement of a circuit for a hydraulic system. The pump draws oil with a specific gravity of .90 from a reservoir + delivers it to the hydraulic cylinder. The cylinder has an inside diameter of 5 in. + in 15 sec the piston must travel 20 in while exerting a force of 11000 lb. It is estimated that there are energy losses of 11.5 lb-ft/lb in the suction pipe + 35 lb-ft/lb in the discharge pipe. Both pipes are 3/8-in Schedule 80 steel pipes

a) calculate the volumetric flow rate through the pump



$$Q = \frac{V}{\Delta t} \rightarrow Q = \frac{A \Delta L}{\Delta t}$$

$$A = \frac{\pi (5)^2}{4} = 19.63 \text{ in}^2 = .136 \text{ ft}^2$$

20 in → 1.66 ft

$$Q = \frac{.136 \text{ ft}^2 (1.66 \text{ ft})}{15 \text{ s}}$$

$$Q = .015 \text{ ft}^3/\text{s}$$

b) Calculate the pressure at the cylinder

$$P = F/A \rightarrow P = \frac{11000 \text{ lb}}{.136 \text{ ft}^2} = 80882.36 \text{ lb/ft}^2 \text{ or } 80882.36 \text{ Pa}$$

c) calculate the pressure at the outlet of the pump

$$\frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 - h_{L4} = \frac{P_4}{\gamma} + \frac{V_4^2}{2g} + z_4$$

$$P_3 = P_4 + \gamma \left[\left(\frac{V_4^2 - V_3^2}{2g} \right) + (z_4 - z_c) + h_{LD} \right]$$

→

$$.90 = \frac{\gamma_{oil}}{62.4\ ft/s^2} \rightarrow \gamma_{oil} = 56.14\ ft/s^2$$

$$\frac{L}{t} \rightarrow V_4 = \frac{1.66\ ft}{15\ s} = .11\ ft/s$$

$$V_3 = \frac{Q}{A} = \frac{.015\ ft^3/s}{.000976\ ft^2} = 15.37\ ft/s$$ pipe

$$P_3 = 80882.36\ lb/ft^2 + 56.16\ ft/s^2 \left[\left(\frac{(1.11\ ft/s)^2 - (15.37\ ft/s)^2}{2(32.2\ ft/s^2)} \right) + 10 + 35 \right]$$

$$P_3 = 83036.14\ lb/ft^2$$

d) Calculate the pressure at the inlet to the pump

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 - h_{LS} = \frac{P_2}{\gamma} + \frac{V_1^2}{2g} + z_2$$

$$P_2 = \gamma \left[(z_1 - z_2) - \frac{V_2^2}{2g} - h_{LS} \right]$$

$$P_2 = 56.16\ ft/s^2 \left(-5 - \frac{15.37^2}{2(32.2)} - 11.5 \right)$$

$$P_2 = -1132.65\ lb/ft^2$$

c) Calculate the power delivered to the oil by the pump

$$h_A = \frac{P_4}{\gamma_{oil}} + \frac{V_4^2}{2g} + (z_4 - z_1) + h_{LS} + h_{LD}$$

$$h_A = \frac{80882.36}{56.16} + \frac{.11^2}{2(32.2)} + (10 - (-5)) + 11.5 + 3.5$$

$$h_A = 1470.99\ ft$$

$$P = \frac{h_A \gamma Q}{550} \rightarrow \frac{1470\ ft\,(56.16\ ft/s^2)(.015\ ft^3/s)}{550}$$

$$P = 2.25\ hp$$