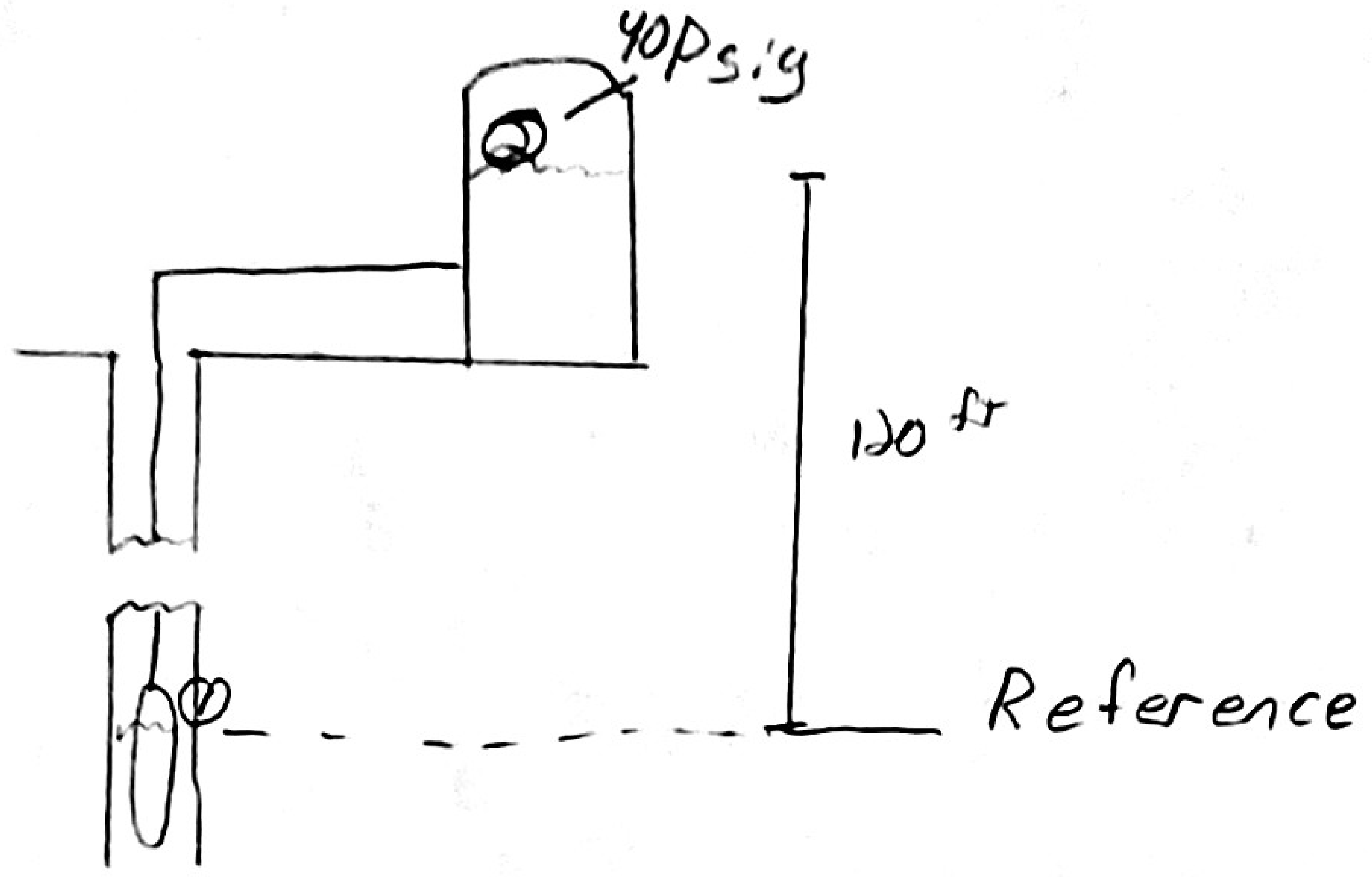
Problem 7.11

Given: pump delivers 745 $\frac{gal}{h}$ of water through a 1 in schedul 40 pipe. An energy loss of 10.5 $\frac{lb\text{-}ft}{lb}$ is occuring

Diagram:



Find: - power delivered by pump to water
- If pump input is 1hp then find efficiency

Solution:

equations

$$h_a + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_r + h_L$$

$$P_a = \gamma \cdot Q \cdot h_a$$

$$\varepsilon_A = \frac{P_a}{P_{input}}$$

using bernoulli's

$$h_a + \cancel{\frac{p_1}{\gamma}}^{0} + \cancel{\frac{v_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{p_2}{\gamma} + \cancel{\frac{v_2^2}{2g}}^{0} + z_2 + \cancel{h_r}^{0} + h_L$$

$$h_a = \frac{p_2}{\gamma} + z_2 + h_L$$

$$h_a = \frac{5760.03 \frac{lb}{ft^2}}{62.4 \frac{lb}{ft^3}} + 120\,ft + 10.5\,\frac{lb\text{-}ft}{ft}$$

$h_a = 222.8 \text{ ft}$

$P_a = \left(62.4 \frac{lb}{ft^3}\right) \cdot \left(745 \frac{gal}{h} \cdot 0.000037 \frac{\frac{ft^3}{s}}{\frac{gal}{hr}}\right) \cdot 222.8 ft$

$P_a = 383.22 \frac{lb\text{-}ft}{s} \times \cdot \frac{1 hp}{550 \frac{lb\text{-}ft}{s}}$

$\underline{P_a = 0.7 \text{ hp}}$

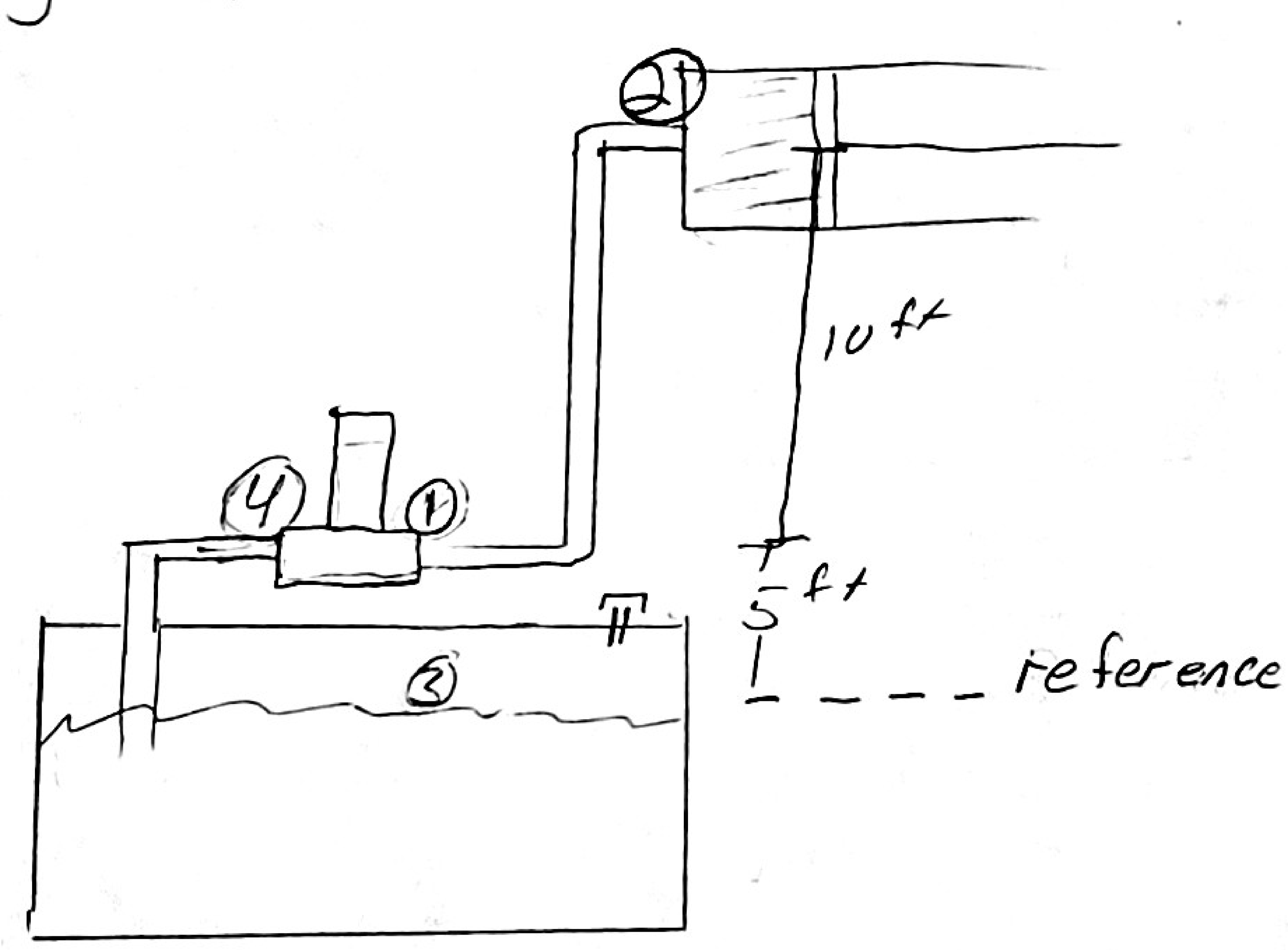
$\varepsilon_a = \frac{0.7 hp}{1 hp} = 0.7$

$\underline{\varepsilon_a = 70\%}$

Problem 7.22

Given: The pump draws oil with specific gravity of 0.90 from reservoir and delivers it to the hydraulic cylinder. The cylinder has an inside diameter of 5.0 in and in 15 s the piston must travel 20 in while exerting 11000 lb force. There are energy losses of 11.5 $\frac{lb\text{-}ft}{lb}$ in suction pipe and 35 $\frac{lb\text{-}ft}{lb}$ in the discharge pipe. pipes are $\frac{3}{8}$ in schedule 80 steel pipes

diagram:



Find:
- Volume flow rate through pump
- pressure in cylinder
- pressure at outlet of pump
- pressure at inlet of pump
- power delivered to oil by pump

Solution:

$$Q = \frac{A_{cyl} \cdot L}{t} = \frac{\frac{\pi \cdot \left(\frac{5}{12}\right)^2}{4} \cdot \left(\frac{20}{12}\right)}{15\ s} = \underline{0.01515\ \frac{ft^3}{s}}$$

$$P_2 = \frac{F}{A_{cyl}} = \frac{11000\ lb}{\frac{\pi\left(\frac{5}{12}\right)^2}{4}} = \underline{80672.45\ \frac{lb}{ft^2}}$$

$$V_1 = \frac{Q}{A_3} = \frac{0.01515\ \frac{ft^3}{s}}{0.000976\ ft^2} = 15.52\ \frac{ft}{s}$$

$\frac{3}{8}$ in 80 sch

$$V_2 = \frac{L}{t} = \frac{\frac{20}{12}}{15\ s} = 0.111\ \frac{ft}{s}$$

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

$$P_1 = P_2 + \gamma\left[\left(\frac{V_2^2 - V_1^2}{2g}\right) + (z_2 - z_1) + h_L\right]$$

$$P_1 = 80672.45\,\tfrac{lb}{ft^2} + (0.9 \cdot 62.4\,\tfrac{lb}{ft^3}) \cdot \left[\left(\frac{0.111^2 - 15.52^2}{2 \cdot 32.2}\right) + (15^{ft} - 5^{ft}) + 35\,\tfrac{lb-ft}{lb}\right]$$

$$P_1 = 80672.45\,\tfrac{lb}{ft^2} + (56.16\,\tfrac{lb}{ft^3})(41.25\,ft)$$

$$P_1 = \underline{\underline{82984.05\,\tfrac{lb}{ft^2}}}$$

$$\cancel{h_a}^{0} + \cancel{\frac{P_3}{\gamma}}^{0} + \cancel{\frac{V_3^2}{2g}}^{0} + \cancel{z_3}^{0} = \frac{P_4}{\gamma} + \frac{V_4^2}{2g} + z_4 + \cancel{h_r}^{0} + h_L$$

$$P_4 = \gamma\left(\frac{V_4^2}{2g} + z_4 + h_L\right)$$

$$P_4 = (0.9 \cdot 62.4\,\tfrac{lb}{ft^3})\left(-\frac{(15.52\,\frac{ft}{s})^2}{2 \cdot 32.2\,\frac{ft}{s^2}} - 5^{ft} - 11.5\,\tfrac{lb-ft}{lb}\right)$$

$$P_4 = 56.16\,\tfrac{lb}{ft^3} \cdot (-20.24\,ft)$$

$$P_4 = \underline{\underline{-1136.69\,\tfrac{lb}{ft^2}}}$$

$P = h_A\,\gamma \cdot Q$ need h_A

$$h_a + \cancel{\frac{P_3}{\gamma}}^{0} + \cancel{\frac{V_3^2}{2g}}^{0} + \cancel{z_3}^{0} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + \cancel{h_r}^{0} + h_L$$

$$h_a = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$h_a = \frac{80672.45\,\frac{lb}{ft^2}}{0.9\cdot 62.4\,\frac{lb}{ft^3}} + \frac{\left(0.111\,\frac{ft}{s}\right)^2}{2\cdot 32.2\,\frac{ft}{s^2}} + 15\,ft + \left(11.5 + 35\,\frac{lb\cdot ft}{lb}\right)$$

$$h_a = 1436.47\,ft + 0.0001913\,ft + 15\,ft + 46.5\,ft$$

$$h_a = 1497.97\,ft$$

$$P = 1497.97\,ft\cdot\left(0.9\cdot 62.4\,\frac{lb}{ft^3}\right)\cdot 0.01515\,\frac{ft^3}{s}$$

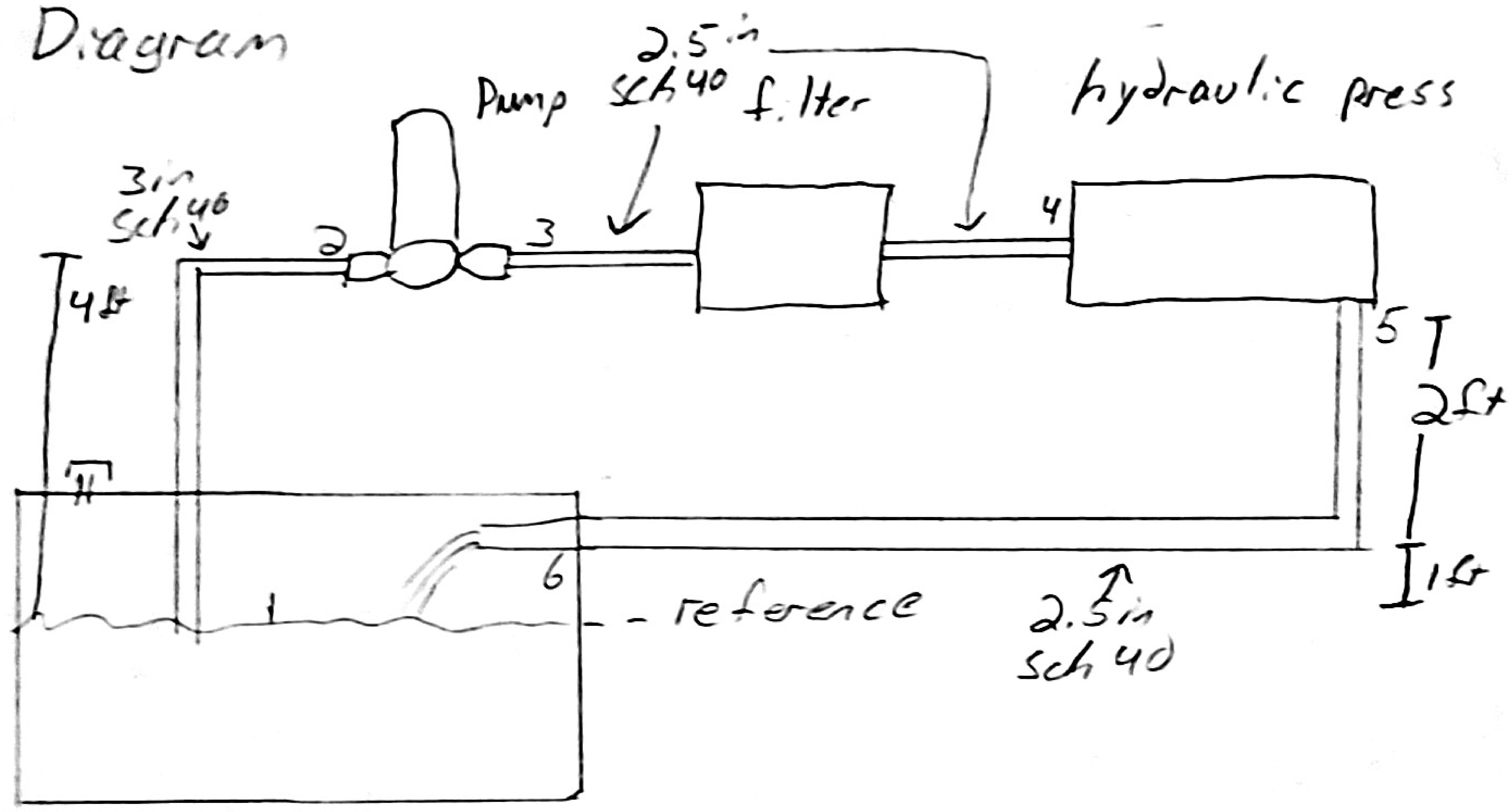
$$P = 1274.5\,\frac{lb\cdot ft}{s}\times\frac{1}{550\,\frac{lb\cdot ft/s}{hp}}$$

$$\underline{P = 2.31\,hp}$$

Problem 7.35

Given: hydraulic press
- sg = 0.93
- Volume flow = 175 $\frac{gal}{min}$ = 0.3899 $\frac{ft^3}{s}$
- Power input = 28.4 hp
- E_p = 80%
- energy loss 1→2 : 2.8 $\frac{lb-ft}{lb}$
- energy loss 3→4 = 28.5 $\frac{lb-ft}{lb}$
- energy loss 5→6 = 3.5 $\frac{lb-ft}{lb}$

Diagram



Find: power removed from fluid by the hydraulic press

Solution:

$$P_r = h_r \cdot \gamma \cdot Q$$

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

$$P_2 = \gamma\left(-\frac{V_2^2}{2g} - z_2 - h_L\right)$$

$$V_2 = \frac{Q}{A} = \frac{0.3899 \frac{ft^3}{s}}{0.05132 ft^2} = 7.57 \frac{ft}{s}$$

$$P_2 = (0.93 \cdot 64.2)\left(\frac{7.57^2}{2 \cdot 32.2} - 4 ft - 2.8 ft\right)$$

$$P_2 = -459.12 \frac{lb}{ft^2} = -3.1\ Psi$$

$$h_a + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \cancel{z_2}^{0} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + \cancel{z_3}^{0} + \cancel{h_r}^{0} + \cancel{h_L}^{0}$$

$$h_a = \frac{P_A}{\gamma \cdot Q}$$

$$P_A = \varepsilon_p \cdot P_{input} = 0.8 \cdot 28.4\,hp = 22.72\,hp$$

$$P_A = 12496\ lb\cdot\frac{ft}{s}$$

$$h_a = \frac{12496\ lb\cdot\frac{ft}{s}}{(0.93\cdot 64.2)\cdot 0.3894\,\frac{ft^3}{s}} = 552.18\ \frac{lb\cdot ft}{lb}$$

$$P_3 = \gamma\left[\frac{P_2}{\gamma} + \frac{V_2^2 - V_3^2}{2g} + h_A\right]$$

$$P_3 = 0.93\cdot 64.2\left[\frac{-459.12}{0.93\cdot 64.2} + \frac{\left(7.57\,\frac{ft}{s}\right)^2 - \left(\frac{0.3894\,\frac{ft^3}{s}}{0.03326\,ft^2}\right)^2}{2\cdot 32.2\,\frac{ft}{s^2}} + 552.18\ \frac{lb\cdot ft}{lb}\right]$$

$$P_3 = 59.706\left(-7.68^{ft} - 1.24^{ft} + 552.18\right)$$

$$P_3 = 32435.88\ \frac{lb}{ft^2} = 225.2\ Psi$$

$$\cancel{h_a}^{0} + \frac{P_3}{\gamma} + \cancel{\frac{V_3^2}{2g}}^{0} + \cancel{z_3}^{0} = \frac{P_4}{\gamma} + \cancel{\frac{V_4^2}{2g}}^{0} + \cancel{z_4}^{0} + \cancel{h_r}^{0} + h_L$$

$V_3 = V_4 \qquad z_3 = z_4$

$$P_4 = \gamma\left(\frac{P_3}{\gamma} - h_L\right)$$

$$P_4 = (0.93\cdot 64.2)\left(\frac{32435.88\ \frac{lb}{ft}}{0.93\cdot 64.2} - 28.5\ \frac{lb\cdot ft}{lb}\right)$$

$$P_4 = 59.706\,(543.23 - 28.5)$$

$$P_4 = 30733.65\ \frac{lb}{ft^2} = 213.42\ Psi$$

$$\cancel{h_a}^{0} + \frac{P_5}{\gamma} + \cancel{\frac{V_5^2}{2g}}^{0} + z_5 = \cancel{\frac{P_6}{\gamma}}^{0} + \cancel{\frac{V_6^2}{2g}}^{0} + z_6 + \cancel{h_r} + h_L$$

$V_5 = V_6$

$$P_5 = \gamma((z_6 - z_5) + h_L)$$

$$P_5 = (0.93 \cdot 64.2)((1-2) + 3.5)$$

$$P_5 = 145 \frac{lb}{ft^2} = 1 \text{ Psi}$$

$$\cancel{h_a}^{0} + \frac{P_4}{\gamma} + \cancel{\frac{V_4^2}{2g}}^{0} + z_4 = \frac{P_5}{\gamma} + \cancel{\frac{V_5^2}{2g}}^{0} + z_5 + h_r + \cancel{h_L}^{0}$$

$V_4 = V_5$

$$h_r = -\left(\frac{P_5 - P_4}{\gamma} + (z_5 - z_4)\right)$$

$$h_r = -\left(\frac{145 - 30733.65}{0.93 \cdot 64.2} + (2-4)\right)$$

$$h_r = 514.32 \text{ ft}$$

$$P_r = h_r \cdot \gamma \cdot Q$$

$$P_r = 514.32 \text{ ft} \cdot (0.93 \cdot 64.2) \cdot 0.3899 \frac{ft^3}{s}$$

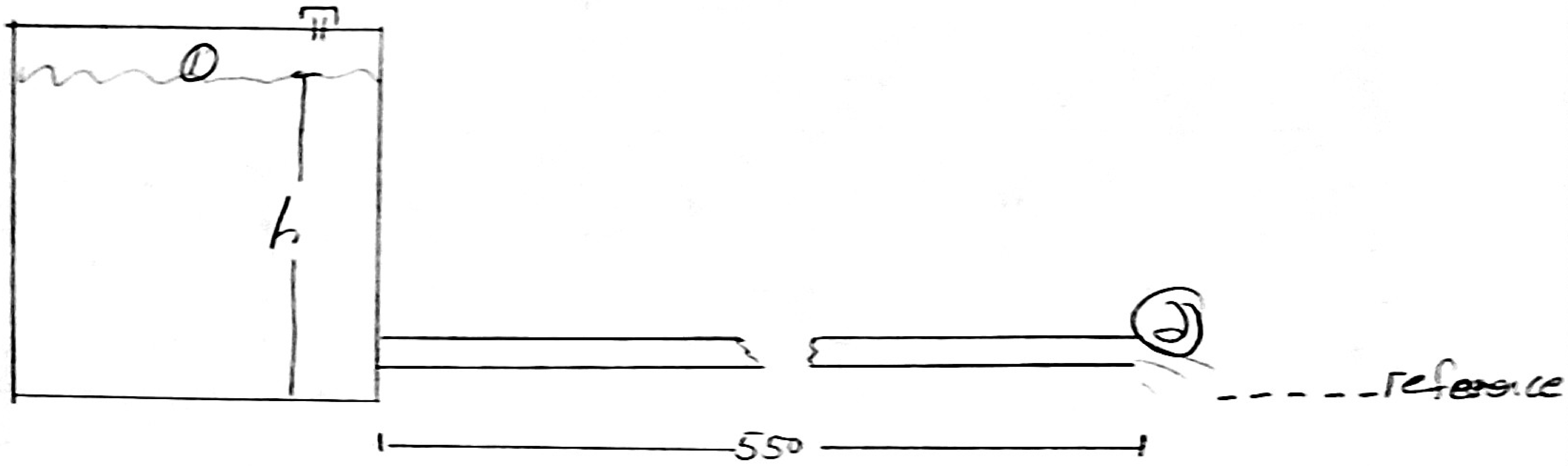
$$P_r = 11973.04 \frac{lb \cdot ft}{s}$$

$$\underline{\underline{P_r = 21.76 \text{ Psi}}}$$

Problem 8.33

Given: water at 80°F flows from a storage tank through 550ft of 6in schedule 40 steel pipe

diagram:



Find: required h to produce flow rate of 2.5 $\frac{ft^3}{s}$

Solution:

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

$$z_1 = \frac{v_2^2}{2g} + h_L$$

$$v = \frac{Q}{A} = \frac{2.5\frac{ft^3}{s}}{0.2006ft^2} = 12.46\frac{ft}{s}$$

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

to find f, I need N_R and R_r

$$N_R = \frac{v \cdot D}{\nu} = \frac{12.46\frac{ft}{s} \cdot 0.5054ft}{9.15\times10^{-6}\frac{ft^2}{s}}$$ ← viscosity of water at 80°F

$$N_R = \underline{6.8\times10^5}$$

$$R_r = \frac{D}{\varepsilon} = \frac{0.5054ft}{1.5\times10^{-4}ft}$$ ← roughness of steel

$$R_r = \underline{3364.3}$$

$\therefore$ f = 0.016

$$h_L = 0.016 \cdot \frac{550^{ft}}{0.5054^{ft}} \cdot \frac{(12.46\frac{ft}{s})^2}{2 \cdot 32.2\frac{ft}{s^2}}$$

$$h_L = 43.28^{ft}$$

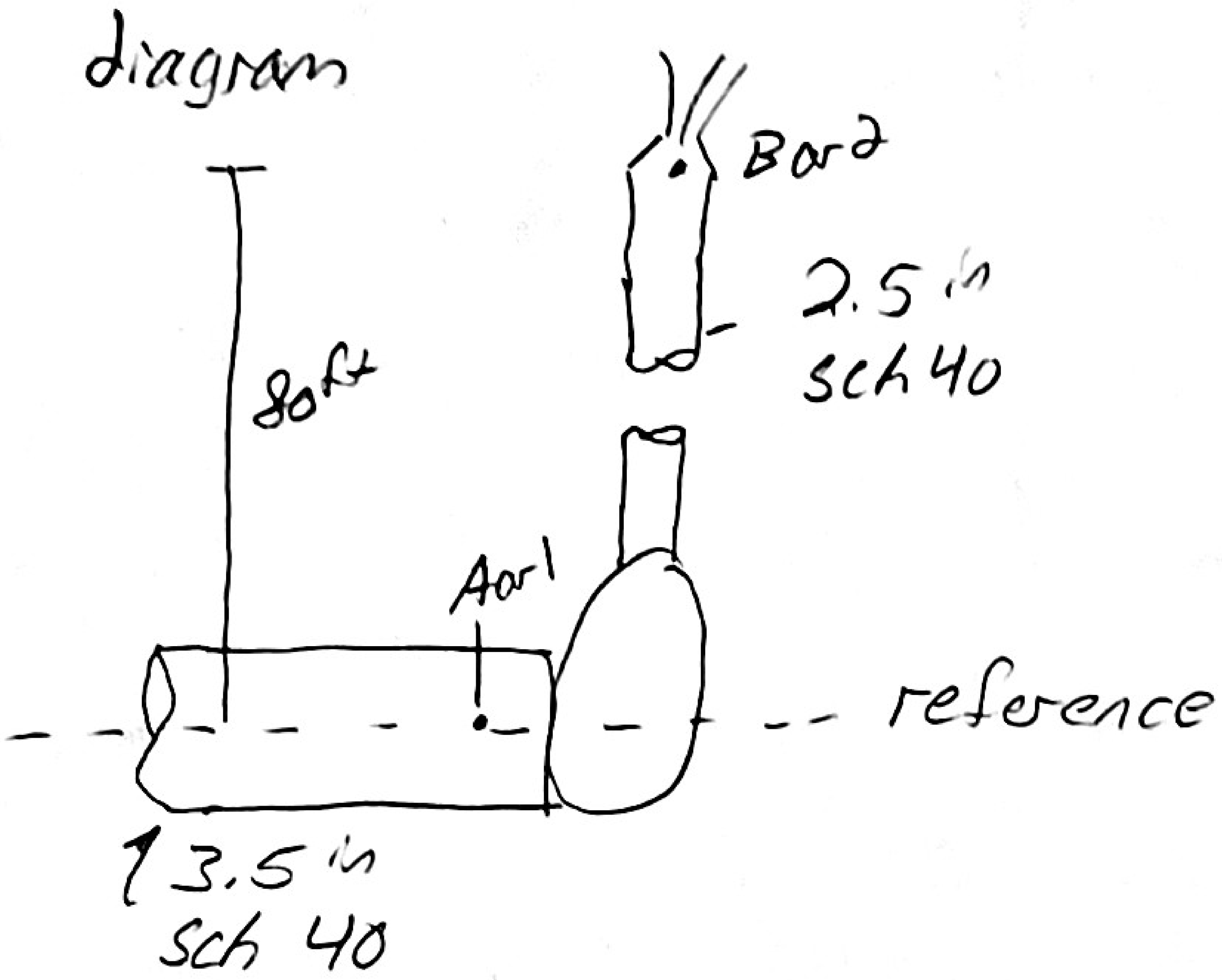
$$h = \frac{(12.46\frac{ft}{s})^2}{2 \cdot 32.2\frac{ft}{s^2}} + 43.28^{ft}$$

$$\underline{\underline{h = 45.69^{ft}}}$$

Problem 8.44

Given: system showed is used to spray water into the air. pressure at B is 25 Psig. pressure at A is -3.5 Psig. Volume flow rate is 0.5 $\frac{ft^3}{s}$. Dynamic Viscosity is 4×10^{-6} $\frac{lb \cdot s}{ft^2}$, SG is 1.026

diagram



Find: power delivered by pump to fluid

Solution:

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

$$h_a = \left(\frac{P_2 - P_1}{\gamma}\right) + z_2 + \left(\frac{V_2^2 - V_1^2}{2g}\right) + h_L$$

$$V_1 = \frac{Q}{A_1} = \frac{0.5 \frac{ft^3}{s}}{0.06868 ft^2} = 7.28 \frac{ft}{s}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.5 \frac{ft^3}{s}}{0.03326 ft^2} = 15.03 \frac{ft}{s}$$

$$h_L = f \cdot \frac{L}{D} \cdot \frac{V_2^2}{2g}$$

need N_L and R_r

$$N_L = \frac{V_2 \cdot D_B \cdot \rho_f}{\eta}$$

$$\rho_f = sg \cdot \rho_w = 1.026 \cdot 1.94 \frac{s}{ft^3} = 1.99 \frac{slug}{ft^3}$$

$$N_L = \frac{15.03 \frac{ft}{s} \cdot 0.2058\,ft \cdot 1.99 \frac{slug}{ft^3}}{4 \times 10^{-5} \frac{lb \cdot s}{ft^2}}$$

$$N_L = 1.54 \times 10^5$$

$$R_r = \frac{D_B}{\varepsilon} = \frac{0.2058\,ft}{1.5 \times 10^{-4}\,ft} = 1372$$

$\therefore$ $f = 0.03787$ → This friction factor is from online calculator

$f = 0.021$ → this friction factor is from moody's chart

$$h_L = 0.021 \cdot \frac{80\,ft}{0.2058\,ft} \cdot \frac{(15.03 \frac{ft}{s})^2}{2 \cdot 32.2 \frac{ft}{s^2}}$$

$$h_L = 28.63\,ft$$

$$h_a = \left(\frac{25 - -3.5}{1.026 \cdot 64.2} \cdot \frac{144\,in^2}{ft^2}\right) + 80 + \frac{15.03^2 - 7.28^2}{2 \cdot 32.2} + 28.63$$

$$h_a = 175.84\,ft$$

$$P = h_a \cdot \gamma \cdot Q = 175.84\,ft \cdot (1.026 \cdot 64.2) \cdot 0.5 \frac{ft^3}{s}$$

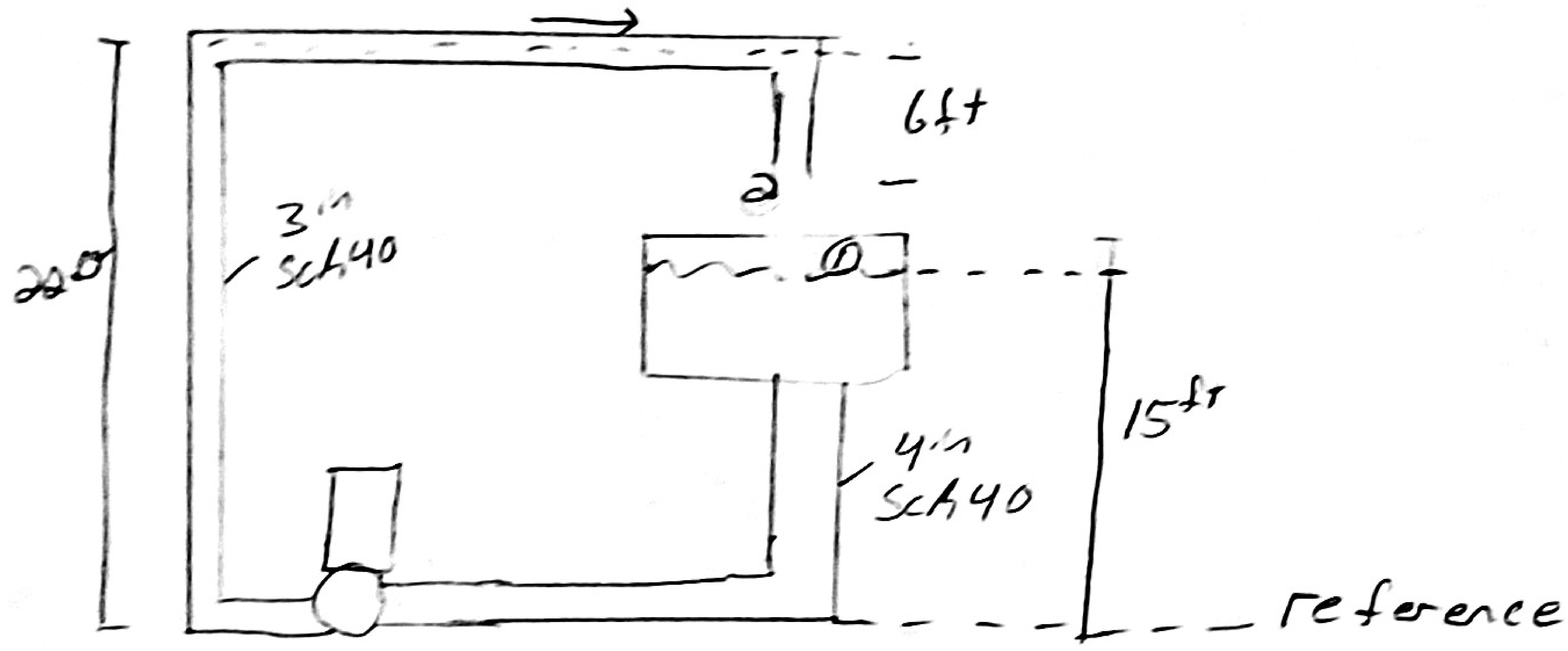
$$P = 5763.5 \frac{lb \cdot ft}{s} = \underline{10.47\,hp}$$

Problem 8.49

Given: A pump recirculating 300 $\frac{gal}{min}$ of machine oil at 104°F. Total length of 4" pipe is 25 ft and total length of 3" pipe is 75 ft

diagram

$Q = 300 \frac{gal}{min} = 0.6684 \frac{ft^3}{s}$



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

$$h_a = \frac{V_2^2}{2g} + z_2 - z_1 + h_L$$

$$V_s = \frac{Q}{A_{40}} = \frac{0.668}{0.0884} = 7.56 \frac{ft}{s}$$

$$h_{LD} = f_D \cdot \frac{L_D}{D_D} \cdot \frac{V_D}{2g}$$

$$N_{RD} = \frac{V_D \cdot D_D}{\nu} = \frac{\frac{Q}{A_D} \cdot D_D}{\nu}$$

$$N_{RD} = \frac{\frac{0.6684}{0.05132} \cdot 0.2557}{2.15 \times 10^{-3}} = 1548.947$$

flow in delivery pipe is laminar because N_{RD} is < 2100

$$\therefore f_D = \frac{64}{1548.947} = 0.0413$$

$$N_{RS} = \frac{V_S \cdot D_S}{\nu} = \frac{\frac{Q}{A_S} \cdot D_S}{\nu}$$

$$N_{RS} = \frac{\frac{0.6684}{0.0884} \cdot 0.3355}{2.15 \times 10^{-3}} = 1179.71$$

flow is laminar $\therefore$ $f_s = \frac{64}{1179.71} = 0.054$

$$h_{LD} = 0.0413 \cdot \frac{75}{0.2557} \cdot \frac{\left(\frac{0.6684}{0.05132}\right)}{2 \cdot 32.2} = 31.92^{ft}$$

$$h_{LS} = 0.054 \cdot \frac{25}{0.3355} \cdot \frac{\left(\frac{0.6684}{0.0884}\right)}{2 \cdot 32.2} = 3.57^{ft}$$

$$h_L = h_{LD} + h_{LS} = 35.49^{ft}$$

$$ha = \frac{\left(\frac{0.6684}{0.05132}\right)^2}{2 \cdot 32.2} + (16-15) + 35.44$$

$$ha = 39.1^{ft}$$

$$P = ha \cdot \gamma \cdot Q$$

$$P = (39.1^{ft}) \cdot (0.89 \cdot 62.4 \tfrac{lb}{ft^3})(0.6684 \tfrac{ft^3}{s})$$

$$P = 1451.4 \ \frac{ft\text{-}lb}{s} = \underline{\underline{2.63\ hp}}$$