

6.79 Oil with a specific gravity of 0.90 is flowing downward through the venturi meter shown in Fig. P6.79. If the manometer deflection h is 28 in, calculate the volume flow rate of oil.

bernoulli's law equation & Volume flow rate

$$Q = A \times v$$

$$\cancel{h_A} + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + \cancel{h_L} + \cancel{h_R}$$

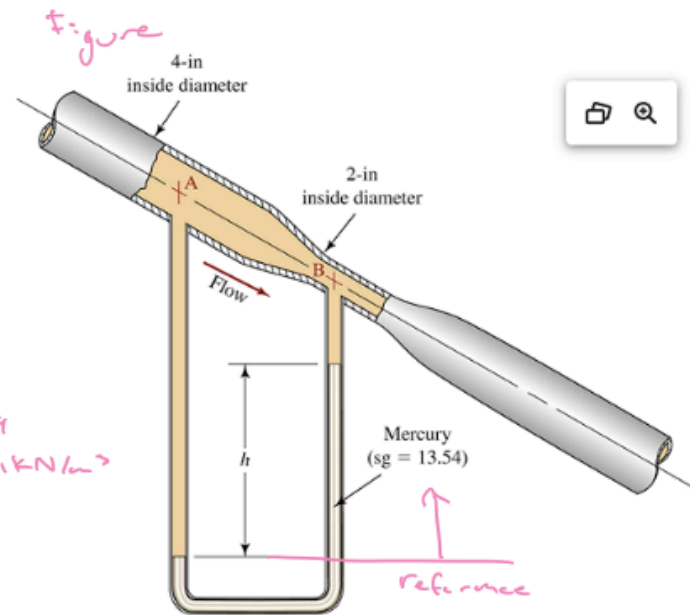
added energy

considerations

- 1) incompressible fluid
- 2) isothermal fluid
- 3) steady state
- 4) no energy loss

variables

Diameter A = 4" $sg_{Hg} = 13.54$
 Diameter B = 2" $\gamma_{water} = 9.81 \text{ kN/m}^3$
 $h = 28 \text{ in}$
 $sg_{oil} = 0.90$



Find Reference

manometry principle to obtain pressure difference $\Delta P = \gamma \cdot h$

$$\frac{Q^2}{2g} \left(\frac{1}{A_A^2} - \frac{1}{A_B^2} \right) = \frac{P_B - P_A}{\gamma} + (Z_A - Z_B)$$

$$Q = \sqrt{\frac{2g \left(\frac{P_B - P_A}{\gamma} + (Z_A - Z_B) \right)}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}$$

$$Q = AV$$

$$V = \frac{Q}{A}$$

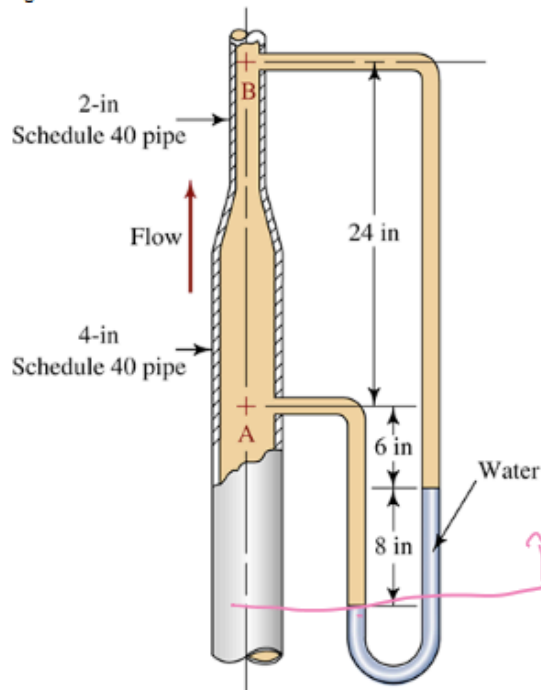
$$Q = \sqrt{\frac{2g \left(1 - \frac{sg_{Hg}}{sg_{oil}} \right) h}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}$$

$$A_A = \frac{\pi}{4} D_A^2 = 0.08736 \text{ ft}^2$$

$$A_B = \frac{\pi}{4} D_B^2 = 0.0218 \text{ ft}^2$$

$$Q = \sqrt{\frac{2 \cdot 32.2 \frac{\text{ft}}{\text{s}^2} \left(1 - \frac{13.54}{0.90} \right) \cdot 28 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}}}{\left(\frac{1}{(0.08736 \text{ ft}^2)^2} - \frac{1}{(0.0218 \text{ ft}^2)^2} \right)}} \quad Q = 1.07 \text{ ft}^3/\text{s}$$

6.82 Oil with a specific weight of 55.0 lb/ft^3 flows from A to B through the system shown in Fig. P6.82. Calculate the volume flow rate of the oil.



steady state, no energy loss

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

$$Q = AV$$

$$P_A = 4 \text{ in } \left(\frac{1}{3} \text{ ft} \right)$$

$$A_A = \frac{\pi}{4} \left(\frac{1}{3} \right)^2 = 0.08727 \text{ ft}^2$$

$$A_B = \frac{\pi}{4} \left(\frac{1}{6} \right)^2 = 0.02182 \text{ ft}^2$$

$$\frac{P_A - P_B}{\gamma_{oil}} - (z_B - z_A) = \frac{V_B^2 - V_A^2}{2g}$$

$$\frac{114.93}{55.0} - 2 = \frac{V_B^2 - 0.0625 V_B^2}{2(32.2)}$$

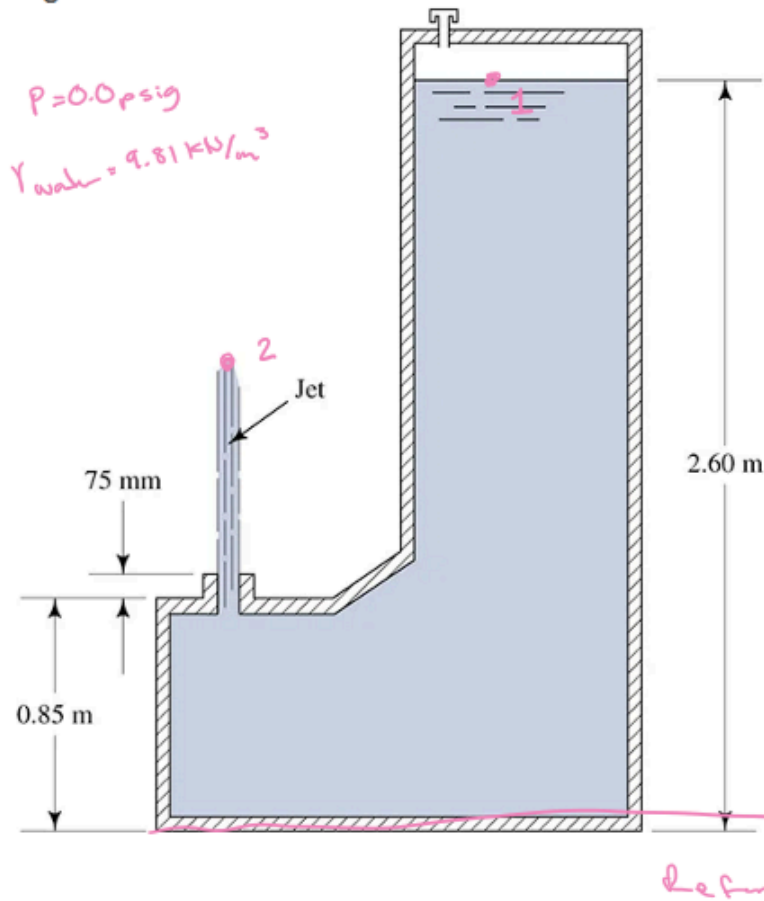
$$2.0896 - 2 = \frac{0.9375 V_B^2}{64.4}$$

$$0.0896 = \frac{0.9375 V_B^2}{64.4}$$

$$V_B^2 = \frac{0.0896 \times 64.4}{0.9375} = \sqrt{6.155} = 2.481 \text{ ft/s}$$

$$\begin{aligned} P_A - P_B &= \gamma_{oil} \left(\frac{10}{12} \right) + \gamma_w \left(\frac{8}{12} \right) \\ &= 55.0 \left(1.33 \right) + 62.4 \left(0.667 \right) \\ &= 114.93 \text{ lb/ft}^2 \end{aligned}$$

6.91 To what height will the jet of fluid rise for the conditions shown in Fig. P6.91



$$Z_2 = \frac{P_1 - P_2}{\gamma} + \frac{V_1^2 - V_2^2}{2g} + Z_1$$

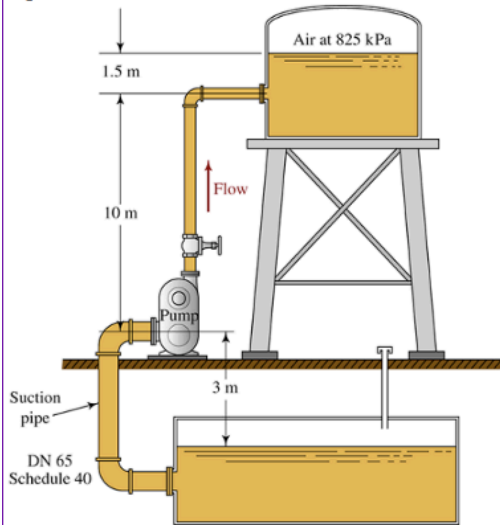
$$Z_2 = \frac{P_1 - P_2}{\gamma} + Z_1$$

$$Z_2 = Z_1$$

highest point the jet will reach 2.60 m

7.16 Figure P7.16 shows a pump delivering 840 L/min of crude oil ($\text{sg}=0.85$) from an underground storage drum to the first stage of a processing system. (a) If the total energy loss in the system is 4.2 Nm/N of oil flowing, calculate the power delivered by the pump. (b) If the energy loss in the suction pipe is 1.4 Nm/N of oil flowing, calculate the pressure at the pump inlet.

Figure P7.16



$$\rho_{\text{oil}} = 0.85 \times 1000 \text{ kg/m}^3 = 850 \text{ kg/m}^3$$

$$\text{Density} = 0.85 \times 1000 \text{ kg/m}^3 = 850 \text{ kg/m}^3$$

$$\text{Specific weight} = \gamma = 850 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 = 8338.5 \text{ N/m}^3$$

$$Q = 840 \text{ L/min} = 0.014 \text{ m}^3/\text{s}$$

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

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

$$P_1 = 0 \text{ kPa}, V_1 = 0 \text{ m/s}$$

$$\text{Total elevation: } z_2 = 3 \text{ m} + 10 \text{ m} + 1.5 \text{ m} = 14.5 \text{ m}$$

$$P_2 = 825 \text{ kPa} = 825,000 \text{ N/m}^2$$

$$V = 0 \text{ m/s}$$

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_A - h_{L, \text{total}} = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

$$h_A = \frac{825,000 \text{ N/m}^2}{8338.5 \text{ N/m}^3} + 14.5 \text{ m} + 4.2 \text{ m}$$

$$= 17.64 \text{ m}$$

$$P_{\text{ower}} = h_A \gamma Q$$

$$= 17.64 \text{ m} \times 8338.5 \text{ N/m}^3 \times 0.014 \text{ m}^3/\text{s} =$$

$$= 13,733 \text{ W}$$

$$= 13.73 \text{ kW}$$

$$V_s = \frac{Q}{A_s} = \frac{0.014 \text{ m}^3/\text{s}}{0.002085 \text{ m}^2} = 4.534 \text{ m/s}$$

$$\frac{V_s^2}{2g} = \frac{(4.534 \text{ m/s})^2}{2 \times 9.81 \text{ m/s}^2} = 1.048 \text{ m}$$

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} - h_{L, \text{suction}} = \frac{P_s}{\gamma} + z_s + \frac{V_s^2}{2g}$$

$$\frac{P_s}{\gamma} = -1.4 \text{ m} - 1.048 \text{ m} = -5.448 \text{ m}$$

$$P_s = -5.448 \text{ m} \times \gamma$$

$$= -5.448 \text{ m} \times 8338.5 \text{ N/m}^3$$

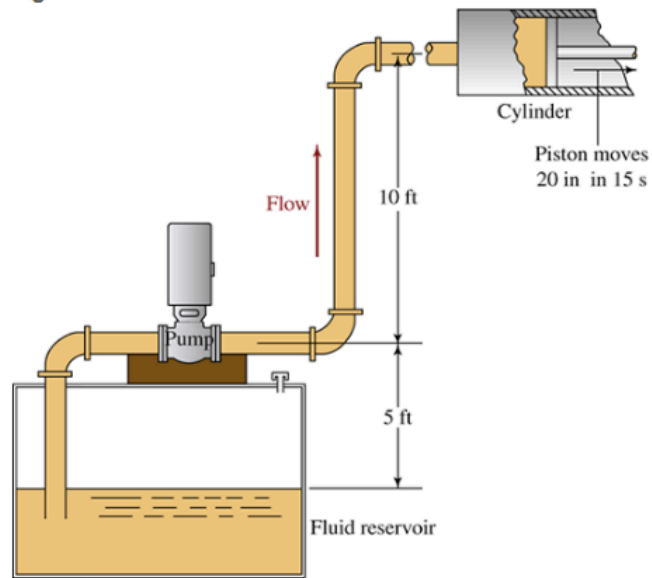
$$= -45,431 \text{ N/m}^2$$

$$= -45.43 \text{ kPa}$$

7.22 Figure P7.22 shows the arrangement of a circuit for a hydraulic system. The pump draws oil with a specific gravity of 0.90 from a 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 a force of 11000 lb. It is estimated that there are energy losses of 11.5 lb-ft/lb in the suction pipe and 35.0 lb-ft/lb in the discharge pipe. Both pipes are ¾-in Schedule 80 steel pipes. Calculate:

1. The volume flow rate through the pump.
2. The pressure at the cylinder.
3. The pressure at the outlet of the pump.
4. The pressure at the inlet to the pump.
5. The power delivered to the oil by the pump.

Figure P7.22



$$S_g = 0.90$$

$$\gamma = 0.90 \times 62.4 \text{ lb/ft}^3 = 56.16 \text{ lb/ft}^3$$

$$D_{\text{piston}}: 5.0 \text{ in} = \frac{5}{12} \text{ ft} \approx 0.4167 \text{ ft}$$

$$A_{\text{piston}}: \frac{\pi}{4} \left(\frac{5}{12} \right)^2 \approx 0.13635 \text{ ft}^2$$

$$\text{Stroke (L)}: 20 \text{ in} = \frac{20}{12} \text{ ft} \approx 1.6667 \text{ ft}$$

$$\text{Time (t)}: 15 \text{ s}$$

$$\text{Force (F)}: 11000 \text{ lb}$$

Energy Loss

$$h_{L \text{ suction}}: 11.5 \text{ ft}$$

$$h_{L \text{ discharge}}: 35.0 \text{ ft}$$

$$h_{L \text{ total}}: 11.5 + 35.0 = 46.5 \text{ ft}$$

$$D_{\text{pipe}}: \frac{3}{8} \text{ in} = 0.03125 \text{ ft}$$

$$A_{\text{pipe}}: \frac{\pi}{4} (0.03125)^2 \approx 0.000767 \text{ ft}^2$$

$$\text{Volume} = A_{\text{piston}} \times L = 0.13635 \text{ ft}^2 \times 1.6667 \text{ ft} = 0.22725 \text{ ft}^3$$

$$Q = \frac{\text{Volume}}{t} = \frac{0.22725 \text{ ft}^3}{15_s} = 0.01515 \text{ ft}^3/\text{s}$$

$$P_{\text{cyl}} = \frac{F}{A_{\text{piston}}} = \frac{11000 \text{ lb}}{0.13635 \text{ ft}^2} = 80675.16 \text{ lb/ft}^2$$

$$= \frac{80675.16 \text{ lb/ft}^2}{1.44 \text{ in}^2/\text{ft}^2} = 560.2 \text{ psig}$$

$$V_{\text{pipe}} = \frac{Q}{A_{\text{pipe}}} = \frac{0.01515 \text{ ft}^3/\text{s}}{0.0076704 \text{ ft}^2} = 19.75 \text{ ft/s}$$

$$\frac{V_{\text{pipe}}^2}{2g} = \frac{(19.75)^2}{2(32.2)} = 6.06 \text{ ft}$$

o1

$$Z_{\text{cyl}} - Z_{\text{out}} = 10 \text{ ft}$$

$$V_{\text{out}} = V_{\text{pipe}} = 19.75 \text{ ft/s}$$

$$V_{\text{cyl}} = 0 \text{ ft/s}$$

$$\frac{P_{\text{out}}}{\gamma} + Z_{\text{out}} + \frac{V_{\text{out}}^2}{2g} - h_{\text{L discharge}} = \frac{P_{\text{cyl}}}{\gamma} + Z_{\text{cyl}} + \frac{V_{\text{cyl}}^2}{2g}$$

$$\frac{P_{\text{out}}}{\gamma} + 0 + 6.06 - 35.0 = \frac{80675}{56.16} + 10$$

$$\frac{P_{\text{out}}}{\gamma} - 28.94 = 1456.52 + 10 \rightarrow \frac{P_{\text{out}}}{\gamma} = 1475.46 \text{ ft}$$

$$P_{\text{out}} = 1475.46 \text{ ft} \cdot 56.16 \text{ lb/ft}^3$$

$$= 82862 \text{ lb/ft}^2 \div 144 = 575.4 \text{ psig}$$

$$P_1 = 0 \text{ psig}, v_1 = 0 \text{ ft/s}$$

$$z_{in} - z_1 = 5 \text{ ft}$$

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_{\text{suction}} = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\frac{P_{in}}{\gamma} = -11.5 - 11.06 = -22.56 \text{ ft}$$

$$P_{in} = -22.56 \text{ ft} \times 56.16 \text{ lb/ft}^3$$

$$= \frac{-1267.14 \text{ lb/ft}^2}{144} = -8.80 \text{ psig}$$

e)

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_{L, \text{total}} = \frac{P_{cy1}}{\gamma} + z_{cy1} + \frac{v_{cy1}^2}{2g}$$

$$h_A = \frac{80675}{56.16} + 15 + 46.5$$

$$= 1438.52 + 15$$

$$= 1498.02 \text{ ft}$$

$$\text{Power} = h_A \times \gamma \cdot Q =$$

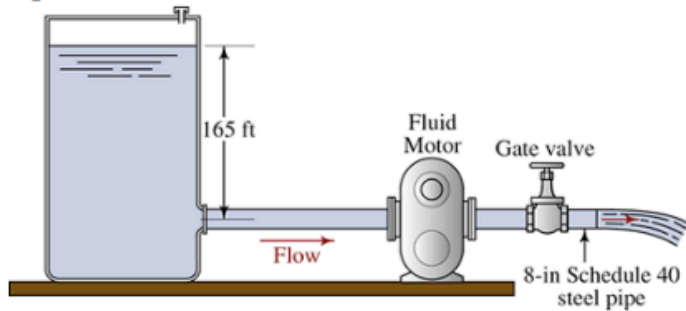
$$= 1498.02 \text{ ft} \times 56.16 \text{ lb/ft}^3 \times 0.01515 \text{ ft}^3/\text{s}$$

$$= 1274$$

$$\text{Power (hp)} = \frac{1274.616 \text{ ft/s}}{550} = 2.32 \text{ hp}$$

7.30 Water at 60F flows from a large reservoir through a fluid motor at the rate of 1000 gal/min in the system shown in Fig. P7.30. If the motor removes 37 hp from the fluid, calculate the energy losses in the system.

Figure P7.30



$$V_2 = \frac{Q}{A_2} = \frac{2.228 \text{ ft}^3/\text{s}}{0.3471 \text{ ft}^2} = 6.382 \text{ ft/s}$$

$$\frac{U_2^2}{2g} = \frac{(6.382 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} = 0.632 \text{ ft}$$

$$P_R = h_R \cdot \gamma \cdot Q$$

$$= 37 \text{ hp} \cdot 550 \frac{\text{ft} \cdot \text{lb}}{\text{s} \cdot \text{hp}}$$

$$= 20350 \text{ ft} \cdot \text{lb/s}$$

$$\eta_R = \frac{P_R}{\gamma \cdot Q} = \frac{20350 \text{ ft} \cdot \text{lb/s}}{62.416 \text{ lb/ft}^3 \cdot 2.228 \text{ ft}^3/\text{s}}$$

$$= \frac{20350}{139.03} = 146.37 \text{ ft}$$

$$Z_1 = 165 \text{ ft}$$

$$P_1 = 0 \text{ psig}$$

$$V_1 = 0 \text{ ft/s}$$

$$Z_2 = 0 \text{ ft}$$

$$P_2 = 0 \text{ psig}$$

$$V_2 = \text{Velocity inside } \phi_{in} \text{ pipe}$$

$$\text{water } 60\text{F } \gamma = 62.416 \text{ lb/ft}^3$$

$$P_R = 37 \text{ hp}$$

$$Q = 1000 \text{ gal/min} \cdot \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \cdot \frac{1 \text{ min}}{60 \text{ s}}$$

$$= 2.228 \text{ ft}^3/\text{s}$$

$$\phi_{in} = \frac{\gamma}{12} \text{ ft} = 0.667 \text{ ft}$$

$$A_2 = \frac{\pi}{4} (0.667)^2 = 0.3471 \text{ ft}^2$$

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} = h_R + h_L + \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$$

$$+165 \text{ ft} - 146.37 \text{ ft} - h_L = 0.632 \text{ ft}$$

$$18.63 \text{ ft} - h_L = 0.632 \text{ ft}$$

$$h_L = 18.63 - 0.632 = 18 \text{ ft}$$

or

$$18 \text{ ft} \cdot \text{lb/ft}^3$$

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

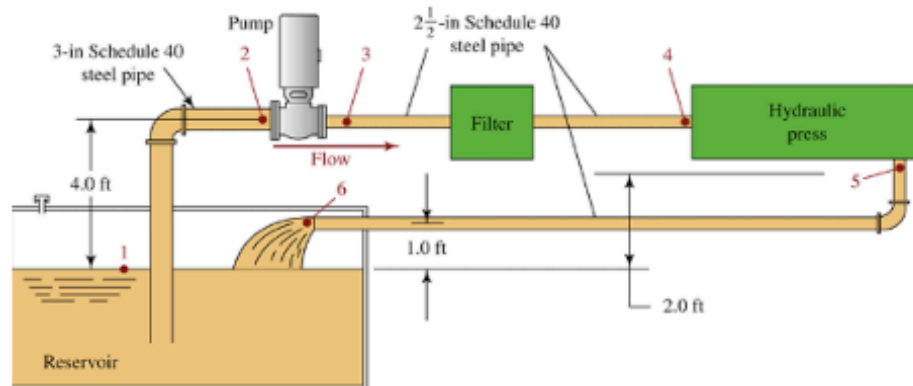
shows a diagram of a fluid power system for a hydraulic press used to extrude rubber parts.

The following data are known:

1. The fluid is oil ($sg = 0.93$)
2. Volume flow rate is 175 gal/min.
3. Power input to the pump is 28.4 hp.
4. Pump efficiency is 80 percent.
5. Energy loss from point 1 to 2 is 2.8 lb-ft/lb
6. Energy loss from point 3 to 4 is 28.50 lb-ft/lb
7. Energy loss from point 5 to 6 is 3.50 lb-ft/lb

The details of the hydraulic oil circuit are as follows:

- A large rectangular reservoir with a vent at the top. The fluid level in this reservoir is labeled as 1.
- A pipe goes up from this reservoir, turns right, and goes into a pump. This pipe (8-inch schedule 40 steel pipe) going into the pump is labeled as 2.
- From the right side of the pump, a pipe (two and a half-inch schedule 40 steel pipe) goes into a filter. This pipe is labeled 3.
- From the filter, a pipe (two and half-inch schedule 40 steel pipe) goes to the right into a hydraulic press. This pipe is labeled as 4.
- From the hydraulic press, a pipe goes down that is labeled as 5. This pipe (two and half-inch schedule 40 steel pipe) curves to the left and goes into the reservoir. The mouth of this pipe in the reservoir is labeled as 6.
- The height from point 1 to 2 is 4 feet. The height from point 1 to point 5 is labeled as 2 feet.



$$z_1 = 0 \text{ ft}, p_1 = 0 \text{ psig}, v_1 = 0 \text{ ft/s}$$

$$z_6 = 10 \text{ ft}, p_6 = 0 \text{ psig}, v_6 = \text{velocity inside } 2\frac{1}{2} \text{ pipe}$$

$$S_g = 0.93$$

$$\rho = 0.93 \times 62.4 \text{ lb/ft}^3 = 58.032 \text{ lb/ft}^3$$

$$Q = 175 \text{ gal/min} = 0.370 \text{ ft}^3/\text{s}$$

$$h_{\text{total}} = h_{L1-2} + h_{L3-4} + h_{L5-6}$$

$$= 2.8 + 28.50 + 3.50$$

$$= 34.8 \text{ ft}$$

$$P_A = \text{Power Input} \times \eta$$

$$= 28.4 \text{ hp} \times 0.80$$

$$= 22.72 \text{ hp}$$

$$P_A = 22.72 \text{ hp} \times 550 \frac{\text{lb} \cdot \text{ft/s}}{\text{hp}}$$

$$= 12496 \text{ lb} \cdot \text{ft/s}$$

$$h_A = \frac{P_A}{\gamma \times Q} = \frac{1249516 \cdot \text{ft}^3/\text{s}}{58.03217/\text{ft}^3 \times 0.390 \text{ ft}^3/\text{s}}$$

$$= \frac{12495}{22.632} = 552.14 \text{ ft}$$

$$V_b = \frac{Q}{A_b} = \frac{0.390 \text{ ft}^3/\text{s}}{0.03409 \text{ ft}^2} = 11.44 \text{ ft/s}$$

$$\frac{V_b^2}{2g} = \frac{11.44 \text{ ft/s}^2}{2 \times 32.2 \text{ ft/s}^2} = \frac{130.87}{64.4} = 2.03 \text{ ft}$$

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_A - h_R - h_{L_{\text{total}}} = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

$$+ 557.14 \text{ ft} - h_R - 34.8 \text{ ft} = 1.0 \text{ ft} + 2.03 \text{ ft}$$

$$517.34 \text{ ft} - h_R = 3.03 \text{ ft}$$

$$h_R = 514.31 \text{ ft}$$

$$P_R = h_R(\gamma)(Q) = (514.31 \text{ ft})(58.03217/\text{ft}^3)(0.390 \text{ ft}^3/\text{s})$$

$$= 1164316 \cdot \text{ft}^3/\text{s}$$

$$\text{Power Removed} = \frac{1164316 \cdot \text{ft}^3/\text{s}}{55016 \cdot \text{ft}^3/\text{s per hp}} = 21.17 \text{ hp}$$