MET 330
HOMEWORK 1.4
CHAPTERS 7 & 8

TEAM BERNOULLI

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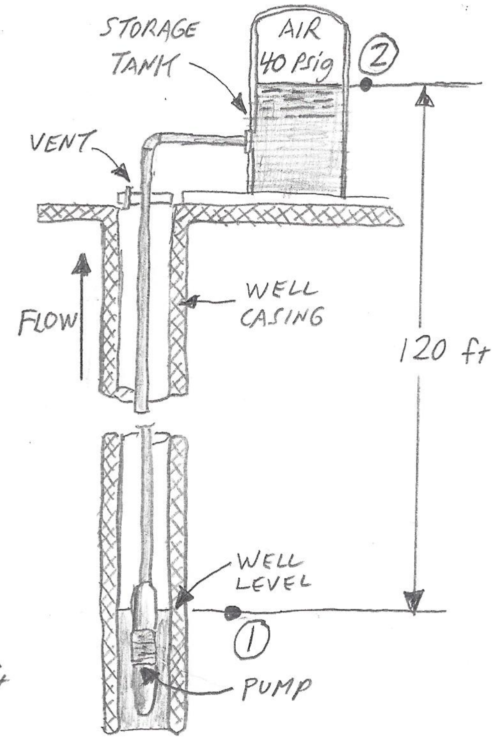
7-11) GIVEN: PUMP DELIVERS 745 GAL/H OF WATER
PIPE = 1 in SCHEDULE 40
ENERGY LOSS = 10.5 lb-ft/lb $= h_L$

BERNOULLI'S EQUATION:



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

AT THE WELL SURFACE ① $\longrightarrow P_1 = 0$ AND $V_1 = 0$

AT THE TANK SURFACE ② $\longrightarrow V_2 = 0$

$$\therefore \cancelto{0}{\frac{P_1}{\gamma_w}} + Z_1 + \cancelto{0}{\frac{V_1^2}{2g}} + h_A - h_L = \frac{P_2}{\gamma_w} + Z_2 + \cancelto{0}{\frac{V_2^2}{2g}}$$

$$h_A = \frac{P_2}{\gamma_w} + (Z_2 - Z_1) + h_L$$

$$h_A = \frac{(40\ lb\ ft^3)(144\ in^2)}{in^2\ 62.4\ lb\ ft^2} + 120\ ft + 10.5\ ft$$

$$h_A = 222.8\ lb \cdot ft/lb$$

$$Q = \left(\frac{745\ gal/h}{60\ min/h}\right)\left(\frac{1\ ft^3/s}{449\ gal/min}\right) = 0.0277\ ft^3/s$$

a) POWER DELIVERED BY PUMP TO THE WATER:

$$P_A = h_A \gamma_w Q = \left(\frac{222.8\ lb \cdot ft}{lb}\right)\left(\frac{62.4\ lb}{ft^3}\right)\left(\frac{0.0277\ ft^3}{s}\right) = \left(\frac{385\ lb \cdot ft}{lb}\right)\left(\frac{1\ hp}{550\ lb \cdot ft/lb}\right)$$

$$P_A = 0.70\ hp$$

b) EFFICIENCY OF PUMP:

$$e_M = \frac{P_A}{P_I} = \frac{0.70\ hp}{1.0\ hp} = 0.700 \longrightarrow e_M = 70\%$$

7-16) GIVEN: PUMP DELIVERS 840 L/min OF CRUDE OIL $= Q$

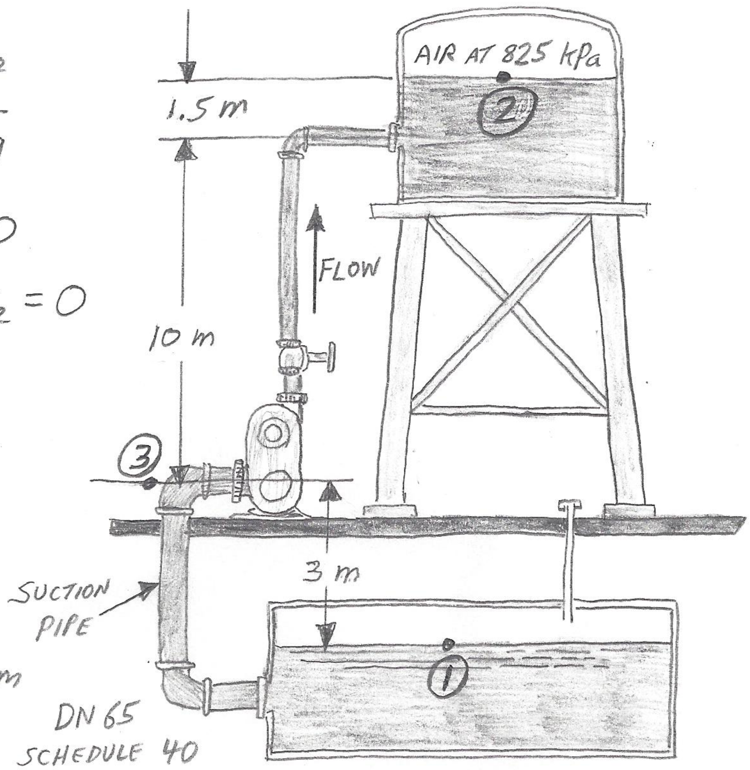
SPECIFIC GRAVITY OF CRUDE OIL: $sg = 0.85$

(a) TOTAL ENERGY LOSS IN SYSTEM $= 4.2\ N\cdot m/N = h_L$

(b) ENERGY LOSS IN SUCTION PIPE $= 1.4\ N\cdot m/N = h_{Ls}$

BERNOULLI'S EQUATION:

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



AT LOWER TANK SURFACE ① $\longrightarrow P_1 = 0$

AT UPPER TANK SURFACE ② $\longrightarrow V_1 = V_2 = 0$

$$\therefore \cancel{\frac{P_1}{\gamma_o}}^{0} + Z_1 + \cancel{\frac{V_1^2}{2g}}^{0} + h_A - h_L = \frac{P_2}{\gamma_o} + Z_2 + \cancel{\frac{V_2^2}{2g}}^{0}$$

$$h_A = \frac{P_2}{\gamma_o} + (Z_2 - Z_1) + h_L$$

$$h_A = \frac{825\ kN\, m^3}{m^2(0.85)(9.81\ kN)} + 14.5\ m + 4.2\ m$$

$$h_A = 117.6\ m$$

a) $P_A = h_A \gamma_o Q = (117.6\ m)(0.85)\left(\frac{9.81\ kN}{m^3}\right)\left(\frac{840\ L/min\ (1\ m^3/s)}{60000\ L/min}\right) = \frac{13.73\ kN\cdot m}{s}$

$P_A = 13.73\ kW$ = POWER DELIVERED BY PUMP

b) $$\frac{P_1}{\gamma_o} + Z_1 + \frac{V_1^2}{2g} - h_{Ls} = \frac{P_3}{\gamma_o} + Z_3$$

$$V_3 = \frac{Q}{A_3} = \left(\frac{840\ L/min\ (1\ m^3/s)}{60000\ L/min}\right)\left(\frac{1}{3.090 \times 10^{-3}\ m^2}\right) = 4.53\ m/s$$

$$P_3 = \gamma_o\left[(Z_1 - Z_3) - \frac{V_3^2}{2g} - h_{Ls}\right] = \frac{(0.85)(9.81\ kN)}{m^3}\left[-3.0\ m - \frac{(4.53\ m/s)^2}{2(9.81\ m/s^2)} - \frac{1.4\ N\cdot m}{N}\right]$$

$P_3 = -45.4\ kPa$ = PRESSURE AT THE PUMP INLET

7-22) GIVEN: SPECIFIC GRAVITY OF OIL $\rightarrow$ $sg = 0.90$

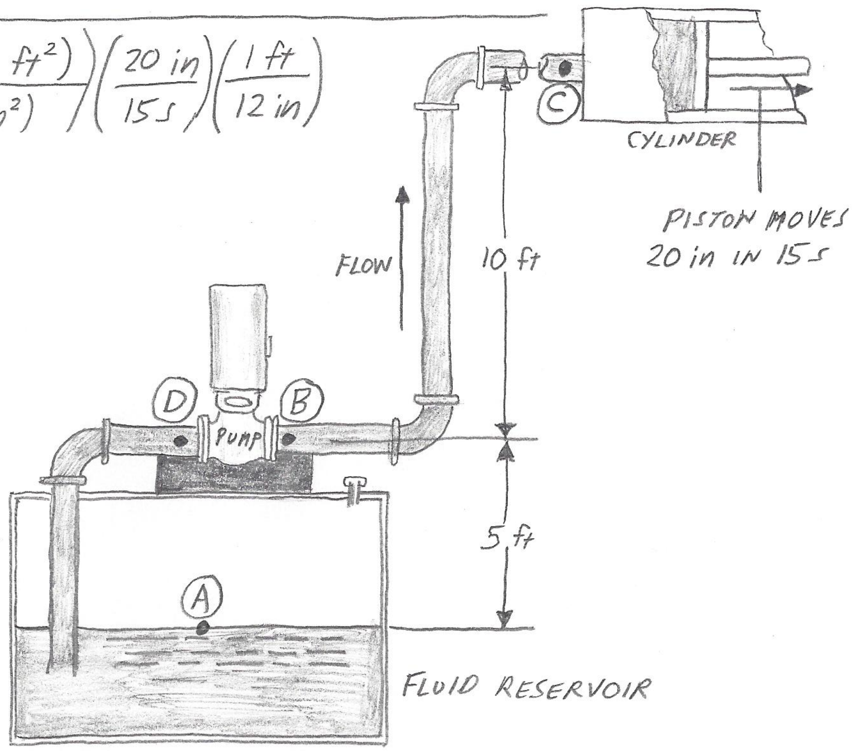
CYLINDER = 5.0 in (INSIDE DIAMETER)

PISTON $\rightarrow$ TRAVELS 20 in IN 15 SECONDS, WHILE EXERTING FORCE OF 11000 lb.

ENERGY LOSSES IN SUCTION PIPE = 11.5 lb-ft/lb $= h_{LS}$

ENERGY LOSSES IN DISCHARGE PIPE = 35.0 lb-ft/lb $= h_{LD}$

PIPES ARE 3/8" SCHEDULE 80 STEEL PIPES



a) $$Q = A_{CYL}\left(\frac{\text{STROKE}}{\text{TIME}}\right) = \left(\frac{\pi(5.0\text{ in})^2(1\text{ ft}^2)}{4(144\text{ in}^2)}\right)\left(\frac{20\text{ in}}{15\text{ s}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right)$$

$$Q = 0.01515\ \text{ft}^3/\text{s}$$

b) $$P_{CYL} = \frac{F}{A_{CYL}} = \frac{11000\text{ lb}}{\pi(5.0)^2/(4)\text{in}^2}$$

$$P_{CYL} = (560\text{ lb/in}^2)(144\text{ in}^2/\text{ft}^2)$$

$$P_{CYL} = 80672\text{ lb/ft}^2$$

c) $$\frac{P_B}{\gamma_o} + Z_B + \frac{V_B^2}{2g} - h_{LD} = \frac{P_C}{\gamma_o} + Z_C + \frac{V_C^2}{2g}$$

$$P_B = P_C + \gamma_o\left[(Z_C - Z_B) + \frac{V_C^2 - V_B^2}{2g} + h_{LD}\right]$$

$$V_C = \left(\frac{20\text{ in}}{15\text{ s}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right) = 0.1111\ \frac{\text{ft}}{\text{s}}$$

FROM TABLE F-2
APPENDIX F

$$V_B = \frac{Q}{A_B} = \frac{0.01515\text{ ft}^3/\text{s}}{0.000976\text{ ft}^2} = 15.52\text{ ft/s}$$

$$P_B = 560\text{ psig} + 0.90\left(\frac{62.4\text{ lb}}{\text{ft}^3}\right)\left[10\text{ ft} + \frac{(0.1111^2 - 15.52^2)}{2(32.2)} + 35.0\text{ ft}\right]\left(\frac{1\text{ ft}^2}{144\text{ in}^2}\right)$$

$$P_B = 576.1\text{ psig}$$

CONTINUED

7-22) CONTINUED

d) PLEASE REFER TO DRAWING ON PREVIOUS PAGE FOR POINT D LOCATION

$$\cancel{\frac{P_A}{\gamma_o}}^{0} + Z_A + \cancel{\frac{V_A^2}{2g}}^{0} - h_{L_S} = \frac{P_D}{\gamma_o} + Z_D + \frac{V_D^2}{2g}$$

$P_A = 0$

$V_A = 0$

$$\therefore\ P_D = \gamma_o\left[Z_A - Z_D - \frac{V_D^2}{2g} - h_{L_S}\right]$$

$V_D = V_B = 15.52\ ft/s$

$$P_D = \left[\frac{(0.90)(62.4\ lb)}{ft^3}\right]\left[-5.0\ ft - \frac{(15.52\ ft/s)^2}{2(32.2\ ft/s^2)} - 11.5\ ft\right]\left(\frac{1\ ft^2}{144\ in^2}\right)$$

$P_D = -4.98\ psig$

e) $$\frac{P_A}{\gamma_o} + Z_A + \frac{V_A^2}{2g} + h_A - h_{L_S} - h_{L_D} = \frac{P_C}{\gamma_o} + Z_C + \frac{V_C^2}{2g}$$

$P_A = 0$

$V_A = 0$

$$h_A = \frac{P_C}{\gamma_o} + (Z_C - Z_A) + \frac{V_C^2}{2g} + h_{L_S} + h_{L_D} = \frac{80672\ lb\cdot ft^3}{ft^2(0.9)(62.4\ lb)} + 15\ ft + \frac{(0.1111)^2}{2g} + 11.5\ ft + 35\ ft$$

$\therefore\ h_A = 1498\ ft$

$$P_A = h_A\gamma_o Q = (1498\ ft)(0.90)(62.4\ lb/ft^2)(0.01515\ ft^3/s)$$

$$P_A = \frac{1275\ ft\cdot lb/s}{550}$$

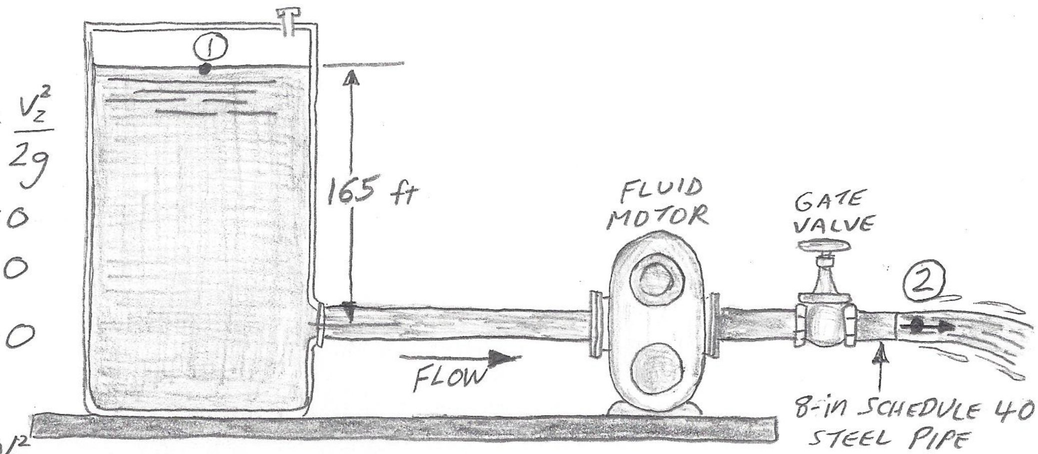
$P_A = 2.32\ hp$

7-30) GIVEN: TEMPERATURE OF WATER = 60°F

FLOW RATE IN SYSTEM = 1000 GAL/MIN

MOTOR REMOVES 37 hp FROM FLUID

BERNOULLI'S EQUATION:



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

AT RESERVOIR SUFACE ① → $P_1 = 0$

$V_1 = 0$

AT OUTLET STREAM ② → $P_2 = 0$

$$\overset{0}{\cancel{\frac{P_1}{\gamma_w}}} + Z_1 + \overset{0}{\cancel{\frac{V_1^2}{2g}}} - h_R - h_L = \overset{0}{\cancel{\frac{P_2}{\gamma_w}}} + Z_2 + \frac{V_2^2}{2g}$$

$$\therefore\ h_L = (Z_1 - Z_2) - \frac{V_2^2}{2g} - h_R$$

FROM APPENDIX F, TABLE F_1

FLOW AREA OF 8-in SCHEDULE 40 STEEL PIPE

$A_2 = 0.3472\ ft^2$

$$V_2 = \frac{Q}{A_2} = \left(\frac{1000\ GAL/MIN}{0.3472\ ft^2}\right)\left(\frac{1\ ft^3/s}{449\ GAL/MIN}\right) = 6.41\ ft/s$$

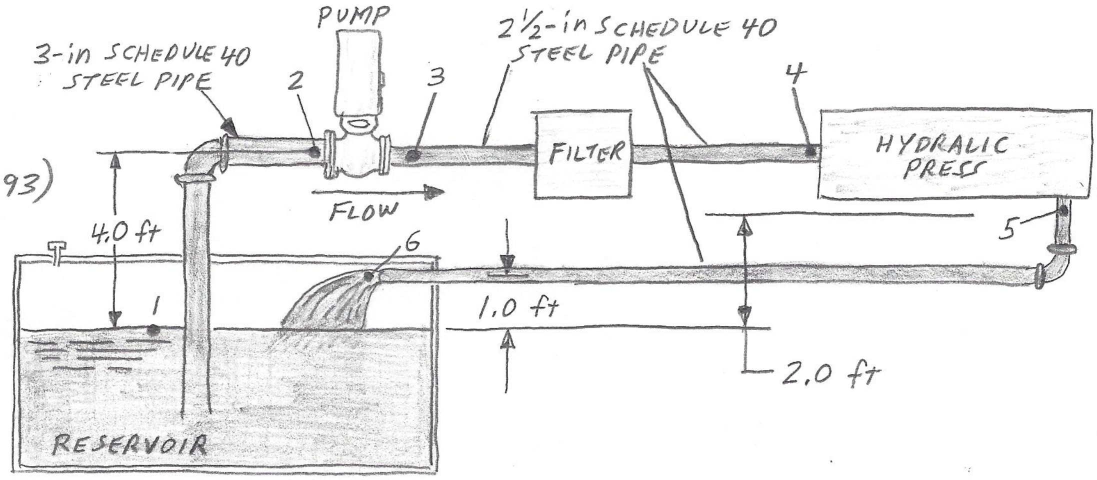
$$h_R = \frac{P_R}{\gamma_w Q} = \frac{37.0\ hp\,(550\ ft\cdot lb/s)}{1\ hp\,(62.4\ lb/ft^3)(2.227\ ft^3/s)} = 146.4\ ft$$

$$h_L = 165\ ft - \frac{(6.41\ ft/s)^2}{2(32.2\ ft/s^2)} - 146.4\ ft = 17.9\ ft$$

$$h_L = 17.9\ ft\cdot lb/lb$$

7-35)

GIVEN:



- THE FLUID IS OIL (sg = 0.93)
- VOLUME FLOW RATE IS 175 GAL/MIN
- POWER INPUT TO THE PUMP IS 28.4 hp
- PUMP EFFICIENCY IS 80 %
- ENERGY LOSS FROM POINT 1 TO 2 IS 2.80 lb-ft/lb
- ENERGY LOSS FROM POINT 3 TO 4 IS 28.50 lb-ft/lb
- ENERGY LOSS FROM POINT 5 TO 6 IS 3.50 lb-ft/lb

$$\gamma_o = sg_o \gamma_w = 0.93(62.4 \text{ lb/ft}^3) = 58.03 \text{ lb/ft}^3$$

$$Q = (175 \text{ GAL/MIN})\left(\frac{1 \text{ ft}^3/\text{s}}{449 \text{ GAL/MIN}}\right) = 0.390 \text{ ft}^3/\text{s}$$

$$P_A = P_{in} \cdot e_M = 28.4 \text{ hp}(0.80) = 22.7 \text{ hp}(550 \text{ ft}\cdot\text{lb/s/hp}) = 12496 \text{ ft}\cdot\text{lb/s}$$

$$\overset{0}{\cancel{\frac{P_1}{\gamma}}} + z_1 + \overset{0}{\cancel{\frac{v_1^2}{2g}}} - h_{L_{1-6}} + h_A - h_R = \overset{0}{\cancel{\frac{P_6}{\gamma}}} + z_6 + \frac{v_6^2}{2g} \quad \begin{cases} P_1 = P_6 = 0 \\ v_1 = 0 \end{cases}$$

$$\therefore \ h_R = (z_1 - z_6) - \frac{v_6^2}{2g} - h_{L_{1-6}} + h_A$$

$$z_1 - z_6 = -1.0 \text{ ft}$$

$$V_6 = \frac{Q}{A_6} = \frac{0.390 \text{ ft}^3/\text{s}}{0.03326 \text{ ft}^2} = 11.72 \text{ ft/s} = V_3 = V_4 = V_5$$

$$\frac{V_6^2}{2g} = \frac{(11.72)^2}{2(32.2)} = 2.13 \text{ ft}$$

$$h_{L_{1-6}} = 2.80 + 28.50 + 3.50 = 34.8 \text{ ft.}$$

$$P_A = h_A \gamma Q \longrightarrow h_A = \frac{P_A}{\gamma Q} = \frac{12496 \text{ ft}\cdot\text{lb/s}}{(58.03 \text{ lb/ft}^3)(0.390 \text{ ft}^3/\text{s})} = 552.5 \text{ ft}$$

$$h_R = -1.0 - 2.13 - 34.8 + 552.5 = 514.5 \text{ ft}$$

$$P_R = h_R \gamma Q = \frac{(514.5 \text{ ft})(58.03 \text{ lb/ft}^3)(0.390 \text{ ft}^3/\text{s})}{550 \text{ ft}\cdot\text{lb/s/hp}}$$

$$P_R = 21.16 \text{ hp}$$

7-42) GIVEN:

PRESSURE AT DISTRIBUTION TANK = 30.0 psig

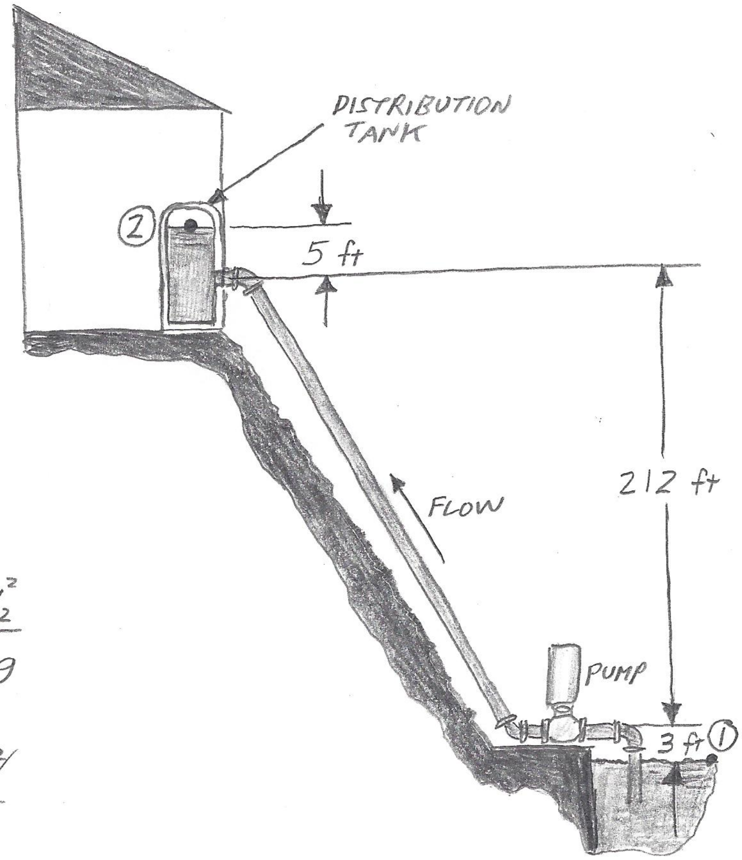
ENERGY LOSS IN PIPING = 15.5 lb-ft/lb

PUMP DELIVERS WATER AT 40 gal/min

AT CREEK SURFACE ① → $p_1 = 0$

$v_1 = 0$

AT TANK SURFACE ② → $v_2 = 0$



BERNOULLI'S EQUATION:

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

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

$$\therefore\ h_A = \frac{p_2}{\gamma} + (z_2 - z_1) + h_L$$

$$h_A = \left(\frac{30\ lb}{in^2}\right)\left(\frac{ft^3}{62.4\ lb}\right)\left(\frac{144\ in^2}{ft^2}\right) + 220\ ft + 15.5\ ft = 304.7\ ft$$

$$P_A = h_A \gamma Q = 304.7\ ft\left(\frac{62.4\ lb}{ft^3}\right)\left(\frac{40\ gal/min}{449\ gal/min}\right)\left(\frac{(1\ ft^3/s)\ hp}{550\ ft \cdot lb/s}\right)$$

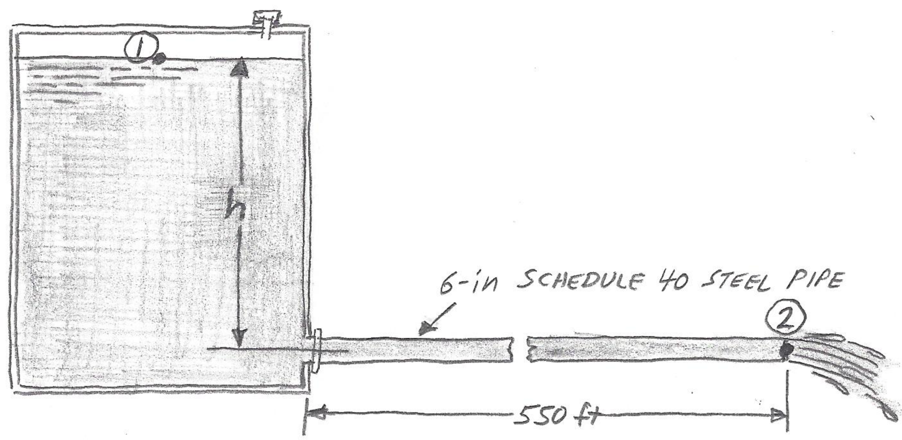
$$P_A = 3.08\ hp$$

8-33) GIVEN:

- WATER TEMPERATURE = 80°F
- VOLUME FLOW RATE = 2.50 ft^3/s

AT TANK SURFACE ① → $P_1 = 0$, $V_1 = 0$

IN OUTLET STREAM ② → $P_2 = 0$



FROM TABLE F.1 (APPENDIX F)

FOR 6-in SCHEDULE 40 STEEL PIPE:

INSIDE DIAMETER = D = 0.5054 ft

FLOW AREA = A = 0.2006 ft^2

BERNOULLI'S EQUATION:

$$\cancel{\frac{P_1}{\gamma_w}}^{0} + z_1 + \cancel{\frac{V_1^2}{2g}}^{0} - h_L = \cancel{\frac{P_2}{\gamma_w}}^{0} + z_2 + \frac{V_2^2}{2g}$$

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

$$v = \frac{Q}{A} = \frac{2.50\ ft^3/s}{0.2006\ ft^2} = 12.46\ ft/s = \text{AVERAGE VELOCITY}$$

$$N_R = \frac{vD}{\nu} = \frac{(12.46)(0.5054)}{9.15 \times 10^{-6}} = 6.88 \times 10^5 = \text{REYNOLDS NUMBER}$$

$$\frac{D}{\varepsilon} = \frac{0.5054}{1.5 \times 10^{-4}} = 3369 = \text{RELATIVE ROUGHNESS}$$

FRICTION FACTOR = $f = 0.0165$ (FROM MOODY'S DIAGRAM)

$$h = f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right) + \frac{v^2}{2g} = (0.0165)\left(\frac{550}{0.5054}\right)\left(\frac{12.46^2}{2(32.2)}\right) + \frac{(12.46)^2}{2(32.2)}$$

$h = 45.7$ ft

8-38) GIVEN: PRESSURE REQUIRED AT HOSE NOZZLE = 140 kPa

SMOOTH PLASTIC HOSE INSIDE DIAMETER = 25 mm

SPECIFIC GRAVITY OF FERTILIZER SOLUTION = 1.10

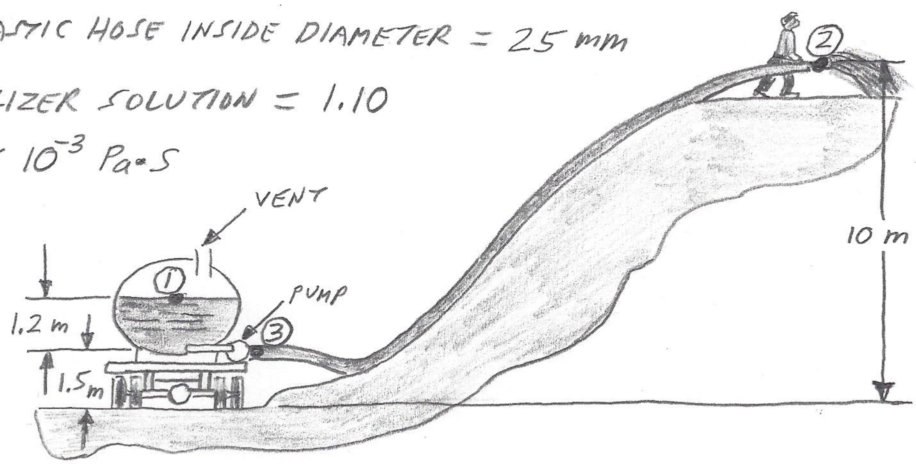
DYNAMIC VISCOSITY $= 2.0 \times 10^{-3}$ Pa·S

LENGTH OF HOSE = 85 m

FLOW RATE = 95 L/min

AT TANK SURFACE ① $\rightarrow P_1 = 0$

$V_1 = 0$



IN HOSE AT NOZZLE ⟶ ②

IN HOSE AT PUMP ⟶ ③

$V_3 = V_2$

BERNOULLI'S EQUATION:

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

a) $$h_A = \frac{P_2}{\gamma} + (Z_2 - Z_1) + \frac{V_2^2}{2g} + h_L$$

$$V = \frac{Q}{A} = \left(\frac{95\ L/min}{\pi(0.025\ m)^2/4}\right)\left(\frac{1\ m^3/s}{60000\ L/min}\right) = 3.23\ m/s$$

$$\frac{V^2}{2g} = \frac{(3.23)^2}{2(9.81)} = 0.530\ m$$

$$N_R = \frac{vD\rho}{\mu} = \frac{(3.23)(0.025)(1100)}{2.0 \times 10^{-3}} = 4.44 \times 10^4$$

$f = 0.021$ (SMOOTH)

$$h_L = f\frac{L}{D}\left(\frac{v^2}{2g}\right) = (0.021)\left(\frac{85}{0.025}\right)(0.530)\ m = 37.86\ m$$

$$h_A = \frac{140\ kN/m^3}{(1.10)(9.81\ kN/m^3)} + 7.3\ m + 0.530 + 37.86\ m = 58.67\ m$$

$$P_A = h_A \gamma Q = (58.67\ m)(1.10)(9.81\ kN/m^3)(95/60000)\ m^3/s = 1.00\ kN \cdot m$$

$P_A = 1.00$ kW

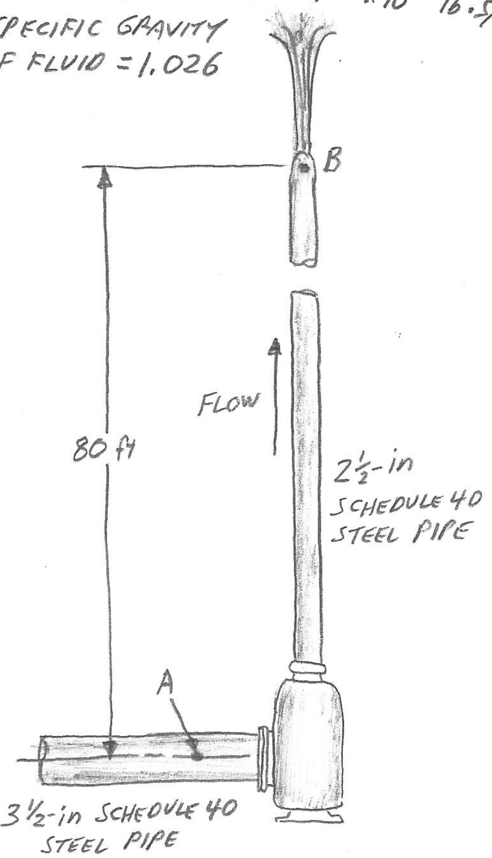
b) $$\frac{P_3}{\gamma} + Z_3 + \frac{V_3^2}{2g} - h_L = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g} \longrightarrow P_3 = P_2 + [(Z_2 - Z_3) + h_L]\gamma$$

$$P_3 = 140\ kPa + (1.10)(9.81\ kN/m^3)[8.5\ m + 37.86\ m]$$

$P_3 = 640$ kPa

GIVEN:

PRESSURE AT POINT B = 25.0 psig
PRESSURE AT POINT A = −3.50 psig
VOLUME FLOW RATE = 0.50 ft^3/s
DYNAMIC VISCOSITY = 4.0×10^{-5} $lb \cdot s/ft^2$
SPECIFIC GRAVITY OF FLUID = 1.026



8-44) $$\frac{P_A}{\gamma} + z_A + \frac{v_A^2}{2g} + h_A - h_L = \frac{P_B}{\gamma} + z_B + \frac{v_B^2}{2g}$$

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

$$v_A = \frac{Q}{A_A} = \frac{0.50\ ft^3/s}{0.06868\ ft^2} = 7.28\ ft/s$$

$$v_B = \frac{Q}{A_B} = \frac{0.50}{0.03326} = 15.03\ ft/s$$

$$N_{R_B} = \frac{v_B D \rho}{\mu} = \frac{(15.03)(0.2058)(1.026)(1.94)}{4.0 \times 10^{-5}}$$

$$N_{R_B} = 1.54 \times 10^5$$

$$\frac{D}{\varepsilon} = \frac{0.2058}{1.5 \times 10^{-4}} = 1372$$

$$f = 0.020$$

$$h_L = f\frac{L}{D}\left(\frac{v^2}{2g}\right) = (0.020)\left(\frac{80}{0.2058}\right)\left(\frac{(15.03)^2}{2(32.2)}\ ft\right) = 27.28\ ft$$

$$h_A = \frac{[25.0 - (-3.50)]\ lb\ ft^3 (144\ in^2)}{in^2 (1.026)(62.4\ lb)\ ft^2} + 80\ ft + \frac{(15.03)^2 - (7.28)^2\ ft^2/s^2}{2(32.2\ ft/s^2)} + 27.28\ ft$$

$$h_A = 174.1\ ft$$

$$P_A = h_A \gamma Q = \frac{(174.1\ ft)(1.026)(62.4\ lb/ft^3)(0.50\ ft^3/s)}{550}$$

$P_A = 10.13\ hp$ = POWER DELIVERED BY THE PUMP

8-46) GIVEN:

TEMPERATURE OF WATER = $60°F$

PIPE = 8-in SCHEDULE 40 STEEL PIPE

LENGTH OF PIPE = 2500 ft

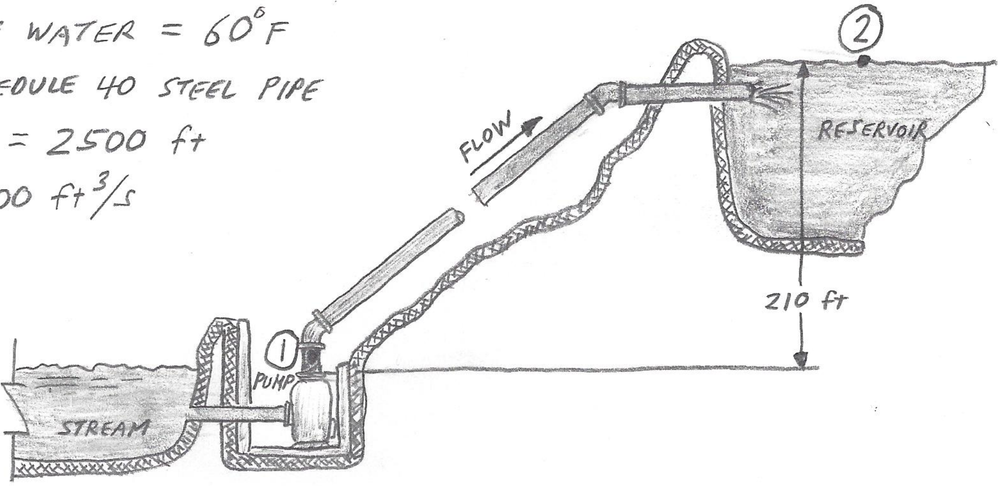
FLOW RATE = $4.00\ ft^3/s$

AT PUMP OUTLET = 1

AT RESERVOIR SURFACE = 2

$P_2 = 0$

$V_2 = 0$



$$V = \frac{Q}{A} = \frac{4.00\ ft^3/s}{0.3472\ ft^2} = 11.52\ ft/s$$

BERNOULLI'S EQUATION:

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

$$\frac{P_1}{\gamma_w} + Z_1 + \frac{V_1^2}{2g} - h_L = \cancel{\frac{P_2}{\gamma_w}}^{0} + Z_2 + \cancel{\frac{V_2^2}{2g}}^{0}$$

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

$$N_R = \frac{vD}{\nu} = \frac{(11.52)(0.6651)}{1.21\times10^{-5}} = 6.33\times10^5$$

$$\frac{D}{\varepsilon} = \frac{0.6651}{1.5\times10^{-4}} = 4434 \qquad f = 0.0155$$

$$h_L = f\frac{L}{D}\left(\frac{v^2}{2g}\right) = (0.0155)\left(\frac{2500}{0.6651}\right)\left(\frac{(11.52)^2}{2(32.2)}\,ft\right) = 120.1\ ft$$

$$P_1 = \frac{62.4\ lb}{ft^3}\left[210 - \frac{(11.52)^2}{2(32.2)} + 120.1\right]\frac{ft\cdot 1\ ft^2}{144\ in^2} = 142.1\ psi$$

PRESSURE AT THE OUTLET OF THE PUMP = $P_1 = 142.1\ psi$

8-49) GIVEN:

FLOW RATE $= Q = 300$ gal/min

TEMPERATURE OF OIL $= 104°F$

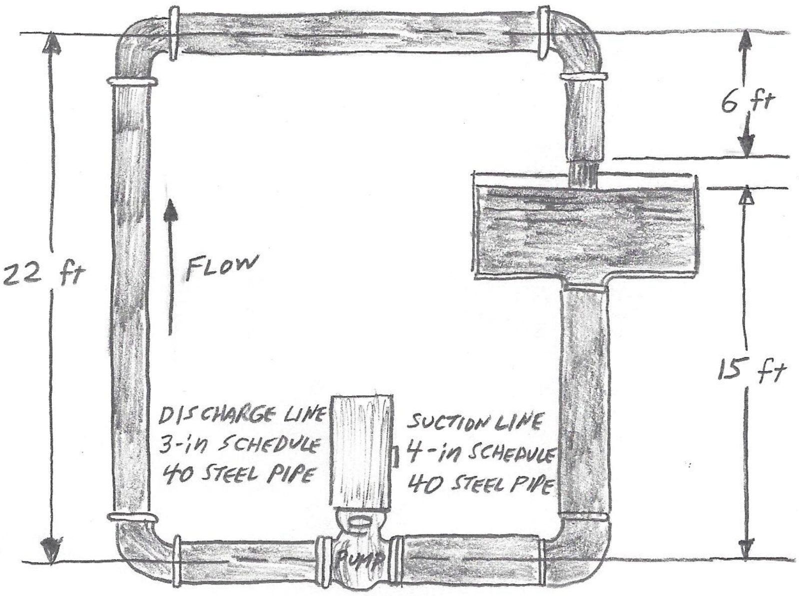
TOTAL LENGTH OF 4-in PIPE $= 25.0$ ft

TOTAL LENGTH OF 3-in PIPE $= 75.0$ ft

AT TANK SURFACE ① → $P_1 = 0$, $v_1 = 0$

AT OUTLET STREAM ② (3-in PIPE) → $P_2 = 0$

$$Q = \frac{300 \text{ gal/min} \cdot 1 \text{ ft}^3/\text{s}}{449 \text{ gal/min}} = 0.668 \text{ ft}^3/\text{s}$$



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

$$h_A = (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$$

$$v_4 = \frac{Q}{A_4} = \frac{0.668 \text{ ft}^3/\text{s}}{0.08840 \text{ ft}^2} = 7.56 \text{ ft/s}$$

$$v_3 = \frac{Q}{A_3} = \frac{0.668 \text{ ft}^3/\text{s}}{0.05132 \text{ ft}^2} = 13.02 \text{ ft/s} = v_2$$

$$h_L = h_{L_3} + h_{L_4} = f_3\left(\frac{L_3}{D_3}\right)\left(\frac{v_3^2}{2g}\right) + f_4\left(\frac{L_4}{D_4}\right)\left(\frac{v_4^2}{2g}\right)$$

$$N_{R_3} = \frac{v_3 D_3}{\nu} = \frac{(13.02)(0.2557)}{2.15 \times 10^{-3}} = 1548 \text{ (LAMINAR)} \longrightarrow f = \frac{64}{N_R} = 0.0413$$

$$N_{R_4} = \frac{v_4 D_4}{\nu} = \frac{(7.56)(0.3355)}{2.15 \times 10^{-3}} = 1180 \text{ (LAMINAR)} \longrightarrow f = \frac{64}{N_R} = 0.0543$$

$$h_L = 0.0413\left(\frac{75}{0.2557}\right)\left(\frac{(13.02)^2}{2(32.2)}\right) + 0.0543\left(\frac{25}{0.3355}\right)\left(\frac{(7.56)^2}{2(32.2)}\right) = 35.5 \text{ ft}$$

$$h_A = 1.0 \text{ ft} + \frac{(13.02)^2}{2(32.2)} \text{ ft} + 35.5 \text{ ft} = 39.1 \text{ ft}$$

$$P_A = h_A \gamma_o Q = (39.1 \text{ ft})(0.890)\left(\frac{62.4 \text{ lb}}{\text{ft}^3}\right)\left(\frac{0.668 \text{ ft}^3}{\text{s}}\right)\left(\frac{1 \text{ hp}}{550 \text{ ft} \cdot \text{lb/s}}\right) = 2.64 \text{ hp}$$

POWER DELIVERED BY THE PUMP TO THE OIL $= P_A = 2.64$ hp

8-62) GIVEN: TEMPERATURE OF HEAVY FUEL OIL = 77°F

PIPE = 6-in SCHEDULE 40 STEEL PIPE

HEAVY FUEL OIL FLOWS AT 12 ft/s

HEAVY FUEL OIL AT 77°F

$\rho = 1.76$ SLUGS/ft^3

$\mu = 2.24 \times 10^{-3}$ lb·s/ft^2

$v = 12$ ft/s

$D = 0.5054$ ft

$$N_R = \frac{vD\rho}{\mu} = \frac{(12.0)(0.5054)(1.76)}{2.24 \times 10^{-3}} = 4.77 \times 10^3$$

$$\frac{D}{\varepsilon} = \frac{0.5054}{1.5 \times 10^{-4}} = 3369$$

FRICTION FACTOR = $f = 0.0388$