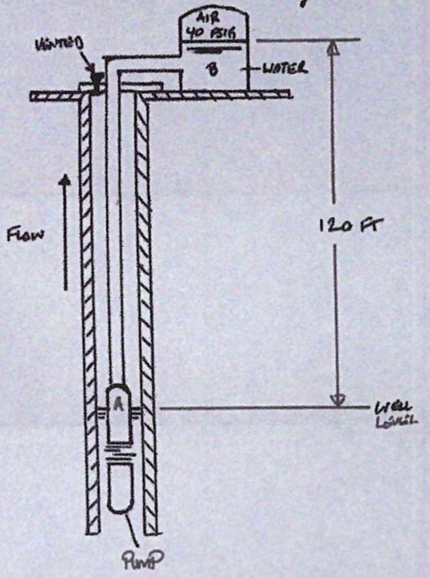
Group 4
MET 330
09/29/2022

MET 330 Homework 1.4

Similarly, to the practice problems last week, chapter 7 and 8 both revolved around using Bernoulli's equation and manipulating as needed. The additional layer was having to determine the energy losses due to friction by calculating Reynold's number and the friction factor, f. Chapter 10 was a bit of a divergence, with a focus on calculating the losses without really needing to use Bernoulli's equation. The overarching takeaway for this week's homework was how important solving multiple different types of problems is. The first problem would take a bit longer, but by the time we got the final problems in each group, it felt almost simple. Repetition and practice seems to be key for this course.

MET 330 HW-1.4

7.11) A SUBMERSIBLE DEEP-WELL PUMP DELIVERS 745 gph OF WATER THROUGH A 1-INCH SCHEDULE 40 PIPE WHEN OPERATING. 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, FIND ITS EFFICIENCY.



GIVEN: 1-INCH SCH. 40 pipe: $A = 0.006\ FT^2$ (App. F, TABLE F.1)

$Q = 745 \frac{gal}{h}$ $\quad P_A = h_A \cdot \gamma \cdot Q \quad \gamma_w = 62.4 \frac{lb}{FT^3}$

$h_L = 10.5 \frac{lb\text{-}FT}{lb}$ $\quad P_B = 40 \frac{lb}{in^2} \cdot \frac{144\ in^2}{1\ FT^2} = 5760 \frac{lb}{FT^2}$

$$\frac{P_A}{\gamma} + z_A + \frac{V_A^2}{2g} + h_A + h_R - h_L = \frac{P_B}{\gamma} + z_B + \frac{V_B^2}{2g}$$

$P_I = 1\ Hp$

SOLUTION: 1. $z_A + h_A + \cancel{h_R}^{\,0} - h_L = \frac{P_B}{\gamma} + z_B + \frac{V_B^2}{2g}$

$$\rightarrow \quad z_A + h_A - h_L = \frac{P_B}{\gamma} + z_B + \frac{V_B^2}{2g}$$

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

2. FIND UNKNOWNS...

$$V_B = \frac{Q}{A} \rightarrow 745 \frac{gal}{h} \cdot \frac{1h}{60\,min} \cdot \frac{1\,min}{60\,sec} \cdot \frac{0.134\,ft^3}{1\,gal} = \frac{0.02773056\ ft^3}{1\ sec}$$

$$\rightarrow \frac{0.02773056 \frac{FT^3}{s}}{0.006\ FT^2} = 4.62176 \frac{FT}{s} = V_B$$

3. $h_A = \frac{P_B}{\gamma} + z_B - z_A + \frac{V_B^2}{2g} + h_L$

$$= \frac{5760 \frac{lb}{FT^2}}{62.4 \frac{lb}{FT^3}} + 120\ FT + \frac{\left(4.62176 \frac{FT}{s}\right)^2}{2\left(32.2 \frac{FT}{s^2}\right)} + 10.5 \frac{lb\text{-}FT}{lb}$$

$$= 92.3077\ FT + 120\ FT + 0.331687\ FT + 10.5\ FT$$

$$h_A = 223.14\ FT$$

4. $P_A = h_A \cdot \gamma \cdot Q$

$$= 223.14\ FT \cdot 62.4 \frac{lb}{FT^3} \cdot 0.02773056 \frac{FT^3}{s} = 386.119$$

$$\rightarrow 386.119 \frac{FT\cdot lb}{s} \cdot \frac{1\ HP}{550 \frac{FT\cdot lb}{s}} = 0.702034\ Hp$$

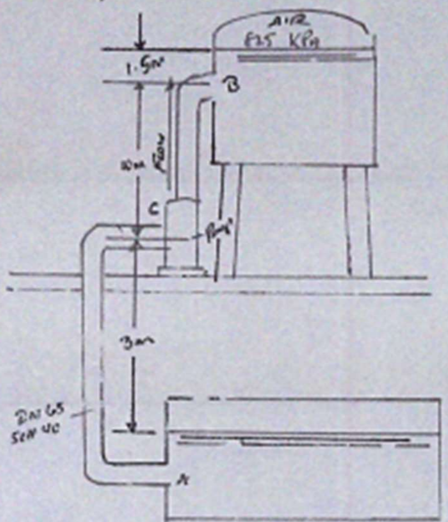
$$\boxed{P_A = 0.7\ Hp}$$

5. GIVEN $e_M = \frac{P_A}{P_I}$,

$$e_M = \frac{0.7\ Hp}{1\ Hp} = 0.7$$

$$\boxed{e_M = 0.7 \text{ OR } 70\%}$$

7.16) FIG. 7.21 SHOWS A PUMP DELIVERING 840 $\frac{L}{min}$ OF CRUDE OIL ($sg = 0.85$) 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 $\frac{N\cdot m}{N}$ OF OIL FLOWING, CALCULATE THE POWER DELIVERED BY THE PUMP. (b) IF THE ENERGY LOSS IN THE SUCTION PIPE IS 1.4 $\frac{N\cdot m}{N}$ OF OIL FLOWING, FIND THE PRESSURE AT THE INLET OF THE PUMP.



GIVEN: $h_{L_S} = 1.4 \frac{N\cdot m}{N}$ $\quad h_{L_T} = 4.2 \frac{N\cdot m}{N}$ $\quad P_B = 825$ Kpa

$Q = 840 \frac{L}{min}$ $\quad P_A = h_A \gamma Q$

$Sg_{oil} = 0.85$ $\quad$ DN 65, sch 40: $A = 3.09\times10^{-3}\ m^2$

$\gamma_{oil} = 0.85(9.81 \frac{KN}{m^3}) = 8.3385 \frac{KN}{m^3}$

SOLUTION: 1. $h_A = \frac{P_B - \cancel{P_A}^{0}}{\gamma} + \frac{\cancel{V_B^2}^{0} - \cancel{V_A^2}^{0}}{2g} + Z_B - \cancel{Z_A}^{0} + h_L$

$\rightarrow h_A = \frac{P_B}{\gamma_{oil}} + Z_B + h_L$

$P_B = 825\ Kpa \cdot \frac{1000 \frac{N}{m^2}}{1 KPa} = 825{,}000 \frac{N}{m^2}$

$Z_B = 1.5m + 10m + 3m = 14.5m$

$\gamma_{oil} = 8.3385 \frac{KN}{m^3} \cdot \frac{1000N}{1KN} = 8338.5 \frac{N}{m^3}$

$h_{L_T} = 4.2 \frac{N\cdot m}{N}$

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

$= 98.9387m + 14.5m + 4.2m = 117.639m$

$\rightarrow P = h_A \gamma_{oil} Q = (117.639m)(8338.5 \frac{N}{m^3})(840 \frac{L}{min} \cdot \frac{0.001m^3}{60sec})$

$\boxed{P = 13733.1\ W}$ $(\frac{N\cdot m}{s})$

2. $\frac{\cancel{P_A}^{0}}{\gamma_{oil}} + \frac{\cancel{V_A^2}^{0}}{2g} + \cancel{Z_A}^{0} = \frac{P_C}{\gamma_{oil}} + \frac{V_C^2}{2g} + Z_C + h_{L_S}$

$\rightarrow P_C = \left(-\frac{V_C^2}{2g} - Z_C - h_{L_S}\right)\gamma_{oil}$

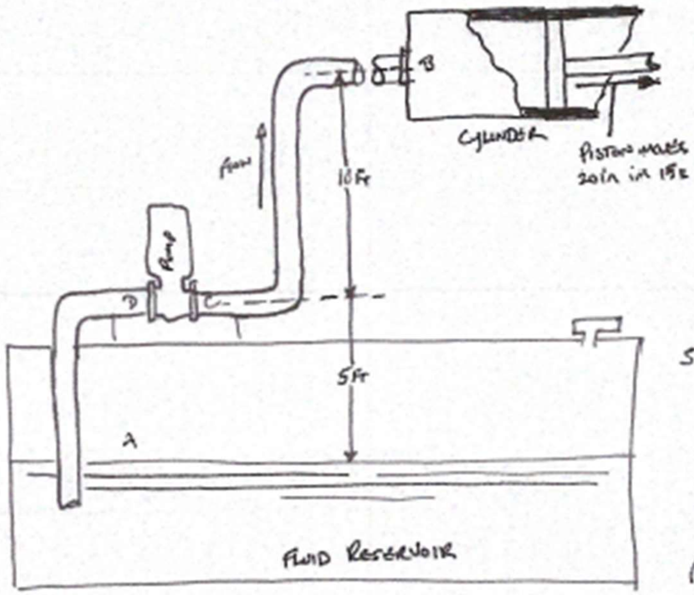
$V_C = \frac{Q}{A} = \frac{(840 \frac{L}{min} \cdot \frac{0.001m^3}{60sec})}{(3.09\times10^{-3} m^2)}$ $(\frac{m}{s})$

$V_C = 4.53074 \frac{m}{s}$

$\rightarrow P_C = \left(-\frac{(4.53074 \frac{m}{s})^2}{2(9.81 \frac{m}{s^2})} - 3m - 1.4 \frac{N\cdot m}{N}\right)(8338.5 \frac{N}{m^3})$

$\boxed{P_C = -45413.6\ Pa \text{ or } -45.413\ Kpa}$

7.22) THE FIGURE SHOWS THE ARRANGEMENT OF A CIRCUIT FOR A HYDRAULIC SYSTEM. THE PUMP DRAWS OIL W/ A SG OF 0.9 FROM A RESERVOIR AND DELIVERS IT TO THE HYDRAULIC CYLINDER. THE CYLINDER HAS AN INSIDE DIAMETER OF 5", AND IN 15 SEC THE PISTON MUST TRAVEL 20" WHILE EXERTING FORCE OF 11,000 lb. IT IS ESTIMATED THERE ARE ENERGY LOSSES OF 11.5 $\frac{lb\,ft}{lb}$ IN THE SUCTION PIPE, AND 35 $\frac{lb\,ft}{lb}$ IN THE DISCHARGE PIPE. BOTH PIPES ARE 3/8" SCH. 80 STEEL PIPES. FIND: (a) VOLUME FLOW RATE THROUGH PUMP. (b) PRESSURE AT THE CYLINDER. (c) PRESSURE AT OUTLET. (d) PRESSURE AT INLET. (e) POWER DELIVERED TO OIL.



GIVEN: $SG_{oil} = 0.9$, $D_{cyl} = 5"$, $z_B = 15\,ft$, $F = 11{,}000\,lb$

$h_{LS} = 11.5\,\frac{lb\,ft}{lb}$, $h_{LD} = 35\,\frac{lb\,ft}{lb}$

3/8" SCH. 80 STEEL

$D_{ip} = \cancel{0.0411\,ft}\ 0.03525\,ft$

$A_p = \cancel{0.00133\,ft^2}\ 0.000976\,ft^2$ OR ~~0.1912 in²~~

$\gamma_{oil} = 0.9(62.4\,\frac{lb}{ft^3}) = 56.16\,\frac{lb}{ft^3}$

$A_{cyl} = \frac{\pi}{4}(5\,in)^2 = 19.635\,in^2$

SOLUTION: (a) $Q = v \cdot A$

$\rightarrow Q = (19.635\,in^2)\left(\frac{20\,in}{15\,s}\right) = 26.18\,\frac{in^3}{s}$

$Q = 26.18\,\frac{in^3}{s} \cdot \frac{1\,ft^3}{1728\,in^3}$

$\boxed{Q = 0.01515\,\frac{ft^3}{s}}$

(b) $P_{cyl} = \frac{F}{A_{cyl}} = \frac{11{,}000\,lb}{19.635\,in^2} = 560.225\,\frac{lb}{in^2}$

$\boxed{P_{cyl(B)} = 560.225\,\frac{lb}{in^2} \text{ or psi}}$

$560.225\,\frac{lb}{in^2} \cdot \frac{144\,in^2}{1\,ft^2} = 80{,}672\,\frac{lb}{ft^2}$

(c) $\frac{P_C}{\gamma_{oil}} + \frac{v_C^2}{2g} + z_C = \frac{P_B}{\gamma_{oil}} + \frac{v_B^2}{2g} + z_B + h_{LD}$

$v_B = \frac{20\,in}{15\,s} \cdot \frac{1\,ft}{12\,in} = 0.111\,\frac{ft}{s}$

$v_C = \frac{Q}{A} = \frac{0.01515\,ft^3}{0.000976\,ft^2} = 15.525\,\frac{ft}{s}$

$\rightarrow P_C = \left(\frac{P_B}{\gamma_{oil}} + \frac{v_B^2 - v_C^2}{2g} + z_B - z_C + h_{LD}\right)(\gamma_{oil})$

$= \left(\frac{80{,}672\,\frac{lb}{ft^2}}{56.16\,\frac{lb}{ft^3}} + \frac{0.111^2 - 15.525^2\,\frac{ft^2}{s^2}}{2(32.2\,\frac{ft}{s^2})} + 15\,ft - 5\,ft + 35\,\frac{lb\,ft}{lb}\right)(56.16\,\frac{lb}{ft^3})$

$\boxed{P_C = 82{,}989.25\,\frac{lb}{ft^2} \text{ or } 576.314\,psi}$

(d) $\frac{\cancel{P_A}^{0}}{\gamma_{oil}} + \frac{\cancel{v_A^2}^{0}}{2g} + \cancel{z_A}^{0} = \frac{P_D}{\gamma_{oil}} + \frac{v_D^2}{2g} + z_D + h_{LS}$

$\rightarrow P_D = \left(-\frac{v_D^2}{2g} - z_D - h_{LS}\right)(\gamma_{oil})$

$= \left(-\frac{15.525^2\,\frac{ft^2}{s^2}}{2(32.2\,\frac{ft}{s^2})} - 5\,ft - 11.5\,\frac{lb\,ft}{lb}\right)(56.16\,\frac{lb}{ft^3})$

$= (-3.7443 - 5 - 11.5)(56.16)$

$\boxed{P_D = -1136.76\,\frac{lb}{ft^2} \text{ or } -7.89416\,psi}$

(e) $h_A = \frac{P_B - \cancel{P_A}^{0}}{\gamma_{oil}} + \frac{v_B^2 - \cancel{v_A^2}^{0}}{2g} + z_B - \cancel{z_A}^{0} + h_{LS} + h_{LD}$

$h_A = \frac{P_B}{\gamma_{oil}} + \frac{v_B^2}{2g} + z_B + h_{LS} + h_{LD}$

$= \frac{80{,}672\,\frac{lb}{ft^2}}{56.16\,\frac{lb}{ft^3}} + \frac{0.111\,\frac{ft^2}{s^2}}{2(32.2\,\frac{ft}{s^2})} + 15\,ft + 11.5\,ft + 35\,ft$

$= 1436.7\,ft + .000191\,ft + 15\,ft + 11.5\,ft + 35\,ft$

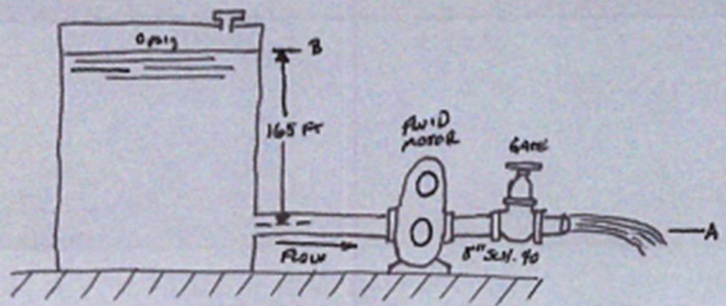
$h_A = 1498.2\,ft$

$P = h_A \gamma_{oil} Q = (1498.2\,ft)(56.16\,\frac{lb}{ft^3})(0.01515\,\frac{ft^3}{s})$

$P = 1274.7\,\frac{ft\,lb}{s} \cdot \frac{1\,HP}{550\,\frac{ft\,lb}{s}}$

$\boxed{P = 2.31764\,HP}$

7.30) WATER AT 60°F FLOWS FROM A LARGE RESERVOIR THROUGH A FLUID MOTOR AT THE RATE OF 1000 gpm IN THE SYSTEM SHOWN IN THE FIGURE. IF THE MOTOR REMOVES 37 HP FROM THE FLUID, CALCULATE THE ENERGY LOSSES IN THE SYSTEM.



GIVEN: $Q = 1000 \frac{GAL}{MIN}$

$Z_A = 0$

$Z_B = 165 FT$

$P_A =$

$P_B = 0$ psig

$V_1 = 0 \frac{FT}{S}$

$V_2 = ?$

8" SCH. 40 APE

$A = 0.3472 \; FT^2$

$g = 32.2 \frac{FT}{S^2}$

$P_R = h_R \gamma_w Q$ (CH. 7)

$\gamma_w = 62.4 \frac{lb}{FT^3}$

SOLUTION:

$$\cancel{\frac{P_A}{\gamma}}^{0\,psig} + \cancel{Z_A}^{0\,FT} + \frac{V_A^2}{2g} = \cancel{\frac{P_B}{\gamma}}^{0\,psig} + Z_B + \cancel{\frac{V_B^2}{2g}}^{0\,FT} + \cancel{h_A}^{0\,\frac{lbFT}{lb}} - h_R - h_L$$

$$\rightarrow h_L = Z_B - h_R - \frac{V_A^2}{2g} \quad \star$$

$$P_R = h_R \gamma_w Q \rightarrow h_R = \frac{P_R}{\gamma_w Q} = \frac{20{,}350 \frac{lbFT}{SEC}}{(62.4 \frac{lb}{FT^3})(2.22816 \frac{FT^3}{SEC})}$$

$$h_R = 146.364 \frac{lbFT}{lb}$$

$$V_A = \frac{Q}{A_A}$$

$$Q = 1000 \frac{GAL}{MIN} \cdot \frac{1 \; FT^3}{7.48 \; GAL} \cdot \frac{1 MIN}{60 \; SEC}$$

$$= 2.22816 \frac{FT^3}{SEC}$$

$$V_A = \frac{2.22816 \frac{FT^3}{SEC}}{0.3472 \; FT^2} = 6.41752 \frac{FT}{SEC}$$

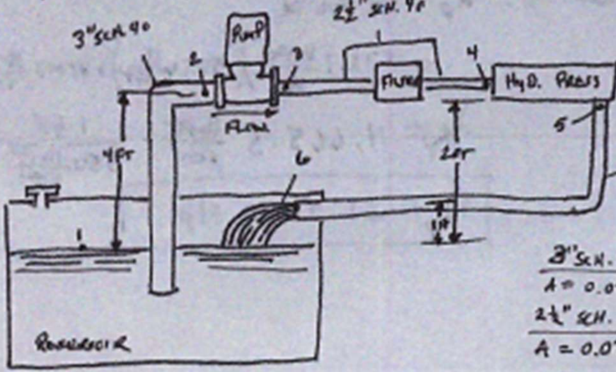
$$P_R = 37 \cancel{HP} \cdot \frac{550 \frac{lbFT}{SEC}}{1 \cancel{HP}} = 20{,}350 \frac{lbFT}{SEC}$$

$$\star \; h_L = Z_B - h_R - \frac{V_A^2}{2g}$$

$$= 165 FT - 146.364 \frac{lbFT}{lb} - \frac{(6.41752 \frac{FT}{SEC})^2}{2(32.2 \frac{FT}{SEC^2})}$$

$$\boxed{h_L = 17.9965 \frac{lbFT}{lb}}$$

7.35) COMPUTE THE POWER REMOVED FROM THE FLUID BY THE PRESS.



3" SCH. 40
$A = 0.05132\ ft^2$

2½" SCH. 40
$A = 0.03326\ ft^2$

GIVEN: $Sg_{oil} = 0.9(62.4\ \frac{lb}{ft^3}) = 56.16\ \frac{lb}{ft^3} = \gamma_{oil}$

$Q = 175\ \frac{gal}{min} \cdot \frac{1\ ft^3}{7.48\ gal} \cdot \frac{1\ min}{60\ sec} = 0.38993\ \frac{ft^3}{sec}$

$P_A = 28.4\ hp \cdot \frac{550\ \frac{lb\ ft}{sec}}{1\ hp} = 15{,}620\ \frac{lb\ ft}{sec}$

$E = 0.8 \quad = P \cdot E = 15{,}620(0.8) = 12{,}496\ \frac{lb\ ft}{s}$

$h_{L_{1-2}} = 2.8\ \frac{lb\ ft}{lb}$

$h_{L_{3-4}} = 28.5\ \frac{lb\ ft}{lb}$

$h_{L_{5-6}} = 3.5\ \frac{lb\ ft}{lb}$

SOLUTION:

$$\cancel{\frac{P_1}{\gamma_{oil}}}^{0} + z_1 + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{h_A}^{0} - \cancel{h_R}^{0} - h_L = \frac{P_2}{\gamma_{oil}} + z_2 + \frac{V_2^2}{2g} \longrightarrow z_1 - h_L = \frac{P_2}{\gamma_{oil}} + z_2 + \frac{V_2^2}{2g}$$

$$\longrightarrow P_2 = \left(z_1 - z_2 - \frac{V_2^2}{2g} - h_{L_{1-2}}\right)(\gamma_{oil}) \ *$$

FIND $V_2 \longrightarrow V_2 = Q/A_2 = \frac{0.38993\ \frac{ft^3}{sec}}{0.05132\ ft^2} = 7.59801\ \frac{ft}{s}$

$$* \ P_2 = \left(\cancel{0} - 4\ ft - \frac{(7.59801\ \frac{ft}{s})^2}{2(32.2\ \frac{ft}{s^2})} - 2.8\ \frac{lb\ ft}{lb}\right)\left(56.16\ \frac{lb}{ft^3}\right) = \cancel{-7.0488\ \frac{lb}{ft^2}} -432.231\ \frac{lb}{ft^2}$$

$$\frac{P_3}{\gamma_{oil}} + \cancel{z_3}^{same} + \frac{V_3^2}{2g} = \frac{P_2}{\gamma_{oil}} + \cancel{z_2}^{same} + \frac{V_2^2}{2g} + h_A - \cancel{h_R}^{0} - \cancel{h_L}^{0} \longrightarrow P_3 = \left(\frac{P_2}{\gamma_{oil}} + \frac{V_2^2}{2g} - \frac{V_3^2}{2g} + h_A\right)(\gamma_{oil}) \ *$$

NEED TO FIND V_3, $h_A \longrightarrow h_A = \frac{P_A}{\gamma_{oil} Q} \longrightarrow \frac{12{,}496\ \frac{lb\ ft}{sec}}{(56.16\ \frac{lb}{ft^3})(0.38993\ \frac{ft^3}{sec})} = 570.634\ \frac{lb\ ft}{lb}$

$\longrightarrow V_3 = Q/A_3 = \frac{0.38993\ \frac{ft^3}{sec}}{0.03326\ ft^2} = 11.7237\ \frac{ft}{s}$

$$* \ P_3 = \left(\frac{-432.231\ \frac{lb}{ft^2}}{56.16\ \frac{lb}{ft^3}} + \frac{(7.59801\ \frac{ft}{s})^2}{2(32.2\ \frac{ft}{s^2})} - \frac{(11.7237\ \frac{ft}{s})^2}{2(32.2\ \frac{ft}{s^2})} + 570.634\ \frac{lb\ ft}{lb}\right)\left(56.16\ \frac{lb}{ft^3}\right) = 31545.1\ \frac{lb}{ft^2}$$

$$\frac{P_4}{\gamma_{oil}} + \cancel{z_4}^{same} + \cancel{\frac{V_4^2}{2g}}^{V_3} + h_{L_{3-4}} = \frac{P_3}{\gamma_{oil}} + \cancel{z_3}^{same} + \cancel{\frac{V_3^2}{2g}}^{V_4} \longrightarrow P_4 = \left(\frac{P_3}{\gamma_{oil}} - h_{L_{3-4}}\right)(\gamma_{oil})$$

$ft \cdot \frac{lb}{ft^3} = \frac{lb}{ft^2}$

$$= \left(\frac{31545.1\ \frac{lb}{ft^2}}{56.16\ \frac{lb}{ft^3}} - 28.5\ \frac{lb\ ft}{lb}\right)\left(56.16\ \frac{lb}{ft^3}\right)$$

$$P_4 = 29944.5\ \frac{lb}{ft^2}$$

$$\frac{P_4}{\gamma_{oil}} + z_4 + \cancel{\frac{V_4^2}{2g}}^{0} + \cancel{h_A}^{0} - h_R - \cancel{h_L}^{0} = \frac{P_5}{\gamma_{oil}} + z_5 + \cancel{\frac{V_5^2}{2g}}^{0} \longrightarrow \text{ENERGY REMOVED, } h_R = \frac{P_5 - P_4}{\gamma_{oil}} + z_5 - z_4$$

$\longrightarrow -h_R = \frac{P_5 - P_4}{\gamma_{oil}} + z_5 - z_4$ ☆ NEED P_5.

$$\frac{P_5}{\gamma} + z_5 + \cancel{\frac{V_5^2}{2g}}^{same} + \cancel{h_A}^{0} - \cancel{h_R}^{0} - h_{L_{5-6}} = \cancel{\frac{P_6}{\gamma}}^{0\ psig} + z_6 + \cancel{\frac{V_6^2}{2g}}^{same} \longrightarrow P_5 = (h_{L_{5-6}} + z_6 - z_5)(\gamma_{oil})$$

$$= (3.5\ \tfrac{lb\ ft}{lb} + 1\ ft - 2\ ft)(56.16\ \tfrac{lb}{ft^3})$$

$$= 140.4\ \frac{lb}{ft^2}$$

$$☆ \ -h_R = \frac{140.4\ \frac{lb}{ft^2} - 29944.5\ \frac{lb}{ft^2}}{56.16\ \frac{lb}{ft^3}} + 2\ ft - 4\ ft = -532.7\ \frac{lb\ ft}{lb} = +532.7\ \frac{lb\ ft}{lb}$$

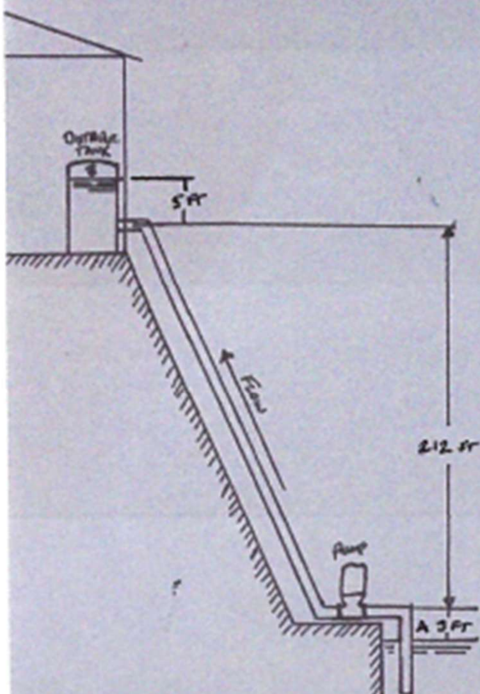
7.35 CONT.) $h_R = 532.7 \frac{lb\,ft}{lb} \longrightarrow$ POWER REMOVED, $P_{Rp} = h_R \gamma_{oil} Q$

$$= \left(532.7 \frac{lb\,ft}{lb}\right)\left(56.16 \frac{lb}{ft^3}\right)\left(0.38993 \frac{ft^3}{sec}\right)$$

$$P_{Rp} = 11,665.3 \frac{lb\,ft}{sec} \cdot \frac{1\ Hp}{550 \frac{lb\,ft}{sec}}$$

$$\boxed{P_{Rp} = 21.2097\ Hp}$$

7.42) THE DISTRIBUTION TANK IN THE CABIN MAINTAINS A PRESSURE OF 30 psig ABOVE THE WATER. THERE IS AN ENERGY LOSS OF 15.5 $\frac{lb\,ft}{lb}$ IN THE PIPING. WHEN THE PUMP IS DELIVERING 40 GAL/MIN OF WATER, COMPUTE THE HP DELIVERED BY THE PUMP TO THE WATER.



GIVEN: $P_B = 30 \frac{lb}{in^2} \cdot \frac{144 in^2}{1 ft^2} = 4320$ $\gamma_w = 62.4 \frac{lb}{ft^3}$ $Z_A = 0$ FT, $Z_B = 220$ FT

$h_L = 15.5 \frac{lb\,ft}{lb}$

$Q = 40 \frac{GAL}{MIN} \cdot \frac{1 ft^3}{7.48 GAL} \cdot \frac{1 MIN}{60 SEC} = 0.089127 \frac{ft^3}{sec}$

$P = \frac{P_A}{\eta_A} = \frac{\gamma Q h_A}{\eta_A}$

SOLUTION: $h_A + \cancel{\frac{P_A}{\gamma_w}}^{0} + \cancel{\frac{V_A^2}{2g}} + \cancel{Z_A}^{0} = \frac{P_B}{\gamma_w} + \cancel{\frac{V_B^2}{2g}}^{0} + Z_B + h_L$

$$\rightarrow h_A = \frac{P_B}{\gamma_w} + Z_B + h_L$$

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

$$h_A = 304.731\ FT$$

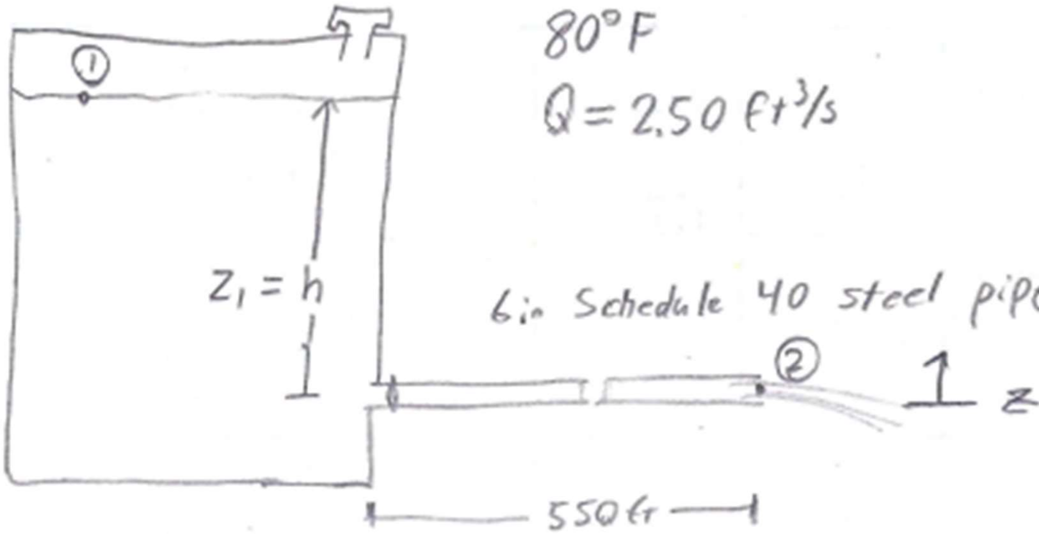
(POWER) $P_A = \gamma_w Q h_A$

$$= \left(62.4 \frac{lb}{ft^3}\right)\left(0.089127 \frac{ft^3}{sec}\right)(304.731\ ft)$$

(POWER) $P_A = 1694.77 \frac{lb\,ft}{sec} \cdot \frac{1\ HP}{550 \frac{lb\,ft}{sec}} = 3.0814$ HP

$$\boxed{\text{POWER DELIVERED BY PUMP} = 3.0814\ HP}$$

8-33)



80°F

$Q = 2.50\ ft^3/s$

$D = 0.5054\ ft$

$$\overset{ATM}{\cancel{\frac{P_1}{\gamma}}} + \overset{\text{negligible}}{\cancel{\frac{V_1^2}{2g}}} + z_1 = \overset{ATM}{\cancel{\frac{P_2}{\gamma}}} + \frac{V_2^2}{2g} + \overset{\emptyset}{\cancel{z_2}} + h_L$$

$$h_L = f\frac{L}{D}\frac{V^2}{2g} \qquad Re = \frac{\rho V D}{\mu} = \frac{VD}{\nu} \qquad \text{Relative Roughness} = \frac{D}{\varepsilon}$$

$$z_1 = \frac{V_2^2}{2g} + h_L = \frac{V_2^2}{2g} + f\frac{L}{D}\frac{V^2}{2g}$$

$$z_1 = \frac{V_2^2}{2g}\left(1 + f\frac{L}{D}\right) \qquad Q = VA \qquad V_2 = \frac{Q}{A} = \frac{2.50\ ft^3/s}{\frac{\pi}{4}(0.5054\ ft)^2}$$

$$V_2 = 12.46\ \frac{ft}{s}$$

$$Re = \frac{\left(12.46\ \frac{ft}{s}\right)(0.5054\ ft)}{9.15\times10^{-6}\ \frac{ft^2}{s}} = 6.88\times10^5$$

$$\frac{D}{\varepsilon} = \frac{0.5054\ ft}{1.5\times10^{-4}\ ft} = 3369$$

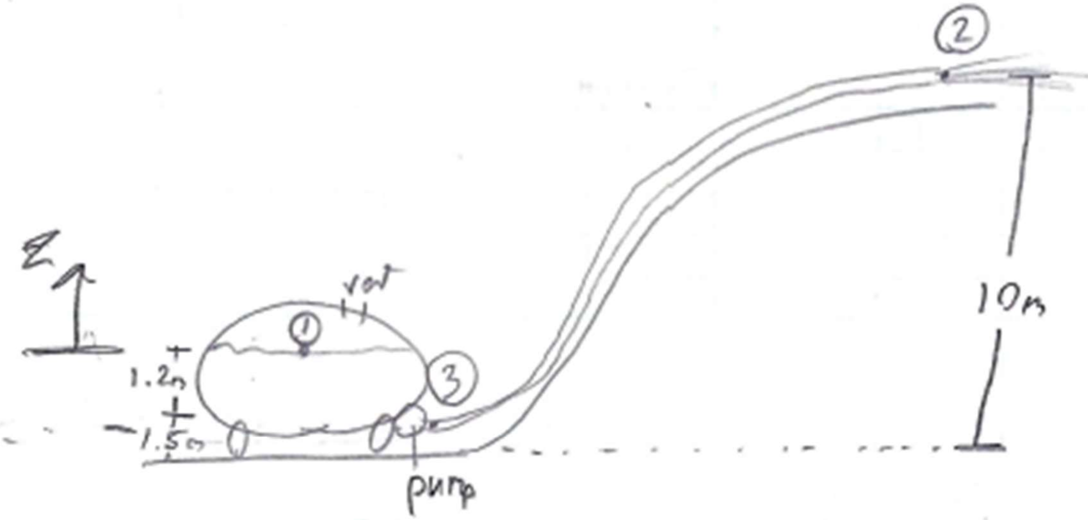
Re > 4000 ∴ flow is turbulent

$$f = \frac{0.25}{\left[\operatorname{Log}\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2} = 0.016$$

$$z_1 = \left(\frac{12.46^2}{2(32.2)}\right)\left(1 + 0.016\left(\frac{550}{0.5054}\right)\right) =$$

$$\boxed{z_1 = 44.39 \text{ ft}}$$

8-38)



$P_2 = 140\ kPa$

$\varepsilon = 3.0 \times 10^{-7} m$

$D_{Hose} = 0.025m$

$Q = VA$

$Sg_{fertilizer} = 1.10$

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

$L_{Hose} = 85m$

$Q = 95\ L/min$

$\eta = 2.0 \times 10^{-3}\ Pa \cdot s$

$Re = \frac{\rho V D}{\eta}$

$V = \frac{Q}{A} = \frac{(95\ L/min)\left(\frac{1 min}{60s}\right)\left(\frac{0.001 m^3}{1L}\right)}{\left(\frac{\pi}{4}\right)(0.025m)^2} = 3.23\ m/s$

$\rho_{fert} = Sg(\rho_w @ 4°C) = (1.10)(1000\ kN/m^3)$

$Re = \frac{(1.100\ kN/m^3)(3.23\ m/s)(0.025m)}{(2.0 \times 10^{-3}\ \frac{N}{m^2} \cdot s)}$ 44.41

$Re < 2100$ ∴ Laminar Flow

$f = 64/Re = 1.44$

$$h_A = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g} = 1.44 \cdot \frac{85m}{0.025m} \cdot \frac{3.23^2}{2(32.2)} = \boxed{793.16 \frac{m \cdot kg}{kg}}$$ A

$$h_A + \cancel{\frac{P_1}{\gamma}}^{ATM} + \cancel{\frac{V_1^2}{2g}}^{Ng} + \cancel{z_1}^{\emptyset} = \cancel{\frac{P_2}{\gamma}}^{ATM} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$h_L = h_A - \frac{V_2^2}{2g} - z_2$$

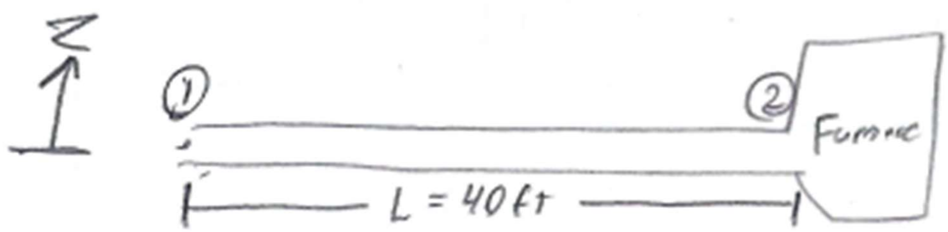
$$h_L = 793.16m - \left(\frac{3.23^2 m/s}{2(32.2 m/s^2)}\right) - 7.3m$$

$$\boxed{h_L = 785.698}$$

8-44) $Sg_{oil} = 0.94$ $\quad Q = 60\,gal/min$

$T_{oil} = 85°F$

1/2 Schedule 40 steel pipe



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

$Q = VA$ $\quad Q_1 = Q_2$ & $A_1 = A_2$

$\therefore V_1 = V_2$

$P_1 - P_2 = \gamma h_L \longrightarrow \Delta P = \gamma h_L$

$$h_L = f\,\frac{L}{D}\cdot\frac{V^2}{2g} \qquad V = \frac{Q}{A} = \frac{(60\,gal/min)\left(\frac{0.1337\,ft^3}{gal}\right)\left(\frac{1}{60}\right)}{\frac{\pi}{4}(0.0518\,ft)^2}$$

$V = 63.4\,ft/s$

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

From B-1 $= 2.24\times10^{-3} = \eta$

$Re = \frac{\rho V D}{\eta} = \frac{VD}{\nu}$

$\nu = 1.27\times10^{-3}\,ft^2/s$

$$Re = \frac{(63.4\,ft/s)(0.0518\,ft)}{1.27\times10^{-3}\,ft^2/s} = 2585.92 > 2100 \therefore$$

turbulent

$$f = \frac{2.5}{\left[\log\left(\frac{1}{3.7(0.518/1.5\times10^{-4})} + \frac{5.74}{2585.92^{0.9}}\right)\right]^2}$$

$f = 0.01485$

!!

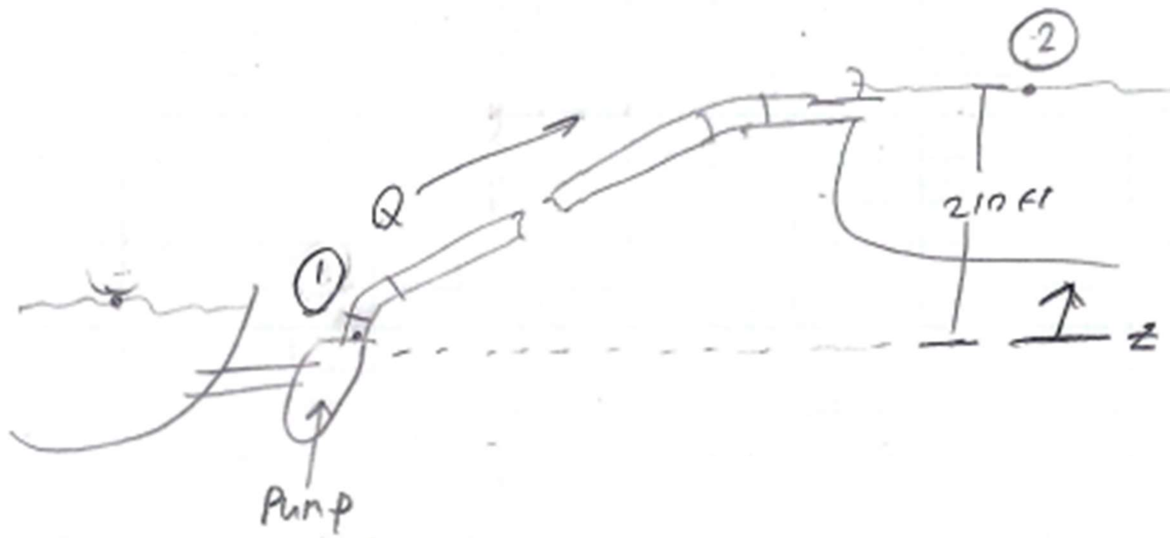
$$h_L = f\ \frac{L}{D} \cdot \frac{V^2}{2g} = 0.01485 \left(\frac{40\,ft}{0.518\,ft}\right)\left(\frac{63.4\,ft/s^2}{2(32.2\,ft/s^2}\right)$$

$$h_L = 1.13\ \frac{ft-lb}{lb}$$

$$\Delta P = \gamma h_L = (0.94)(62.2\ lb/ft^3)(1.13\,ft)$$

$$\Delta P = 66.07\ lb/ft^2 = \boxed{0.459\ psig}$$

8-46)



$T_{water} = 60°F$ $\quad D = 0.6651\,ft$

8in Schedule 40 steel pipe $\quad \epsilon = 1.5\times10^{4}$

$L = 2500\,ft$

$Q = 4\,ft^3/s$

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

$$Re = \frac{VD}{\nu} \qquad V = \frac{Q}{A} = \frac{4\,ft^3/s}{\frac{\pi}{4}(0.6651)^2} = 11.51\,ft/s$$

$$Re = \frac{(11.51\,ft/s)(0.6651\,ft)}{1.21\times10^{-5}\,ft^2/s} \qquad \nu = 1.21\times10^{-5}\,ft^2/s$$

$Re = 637{,}942$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(0.6651/1.5\times10^{4})} + \left(\frac{5.74}{637{,}942^{0.9}}\right)\right)\right]^2} = 0.0155$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + h_L$$

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

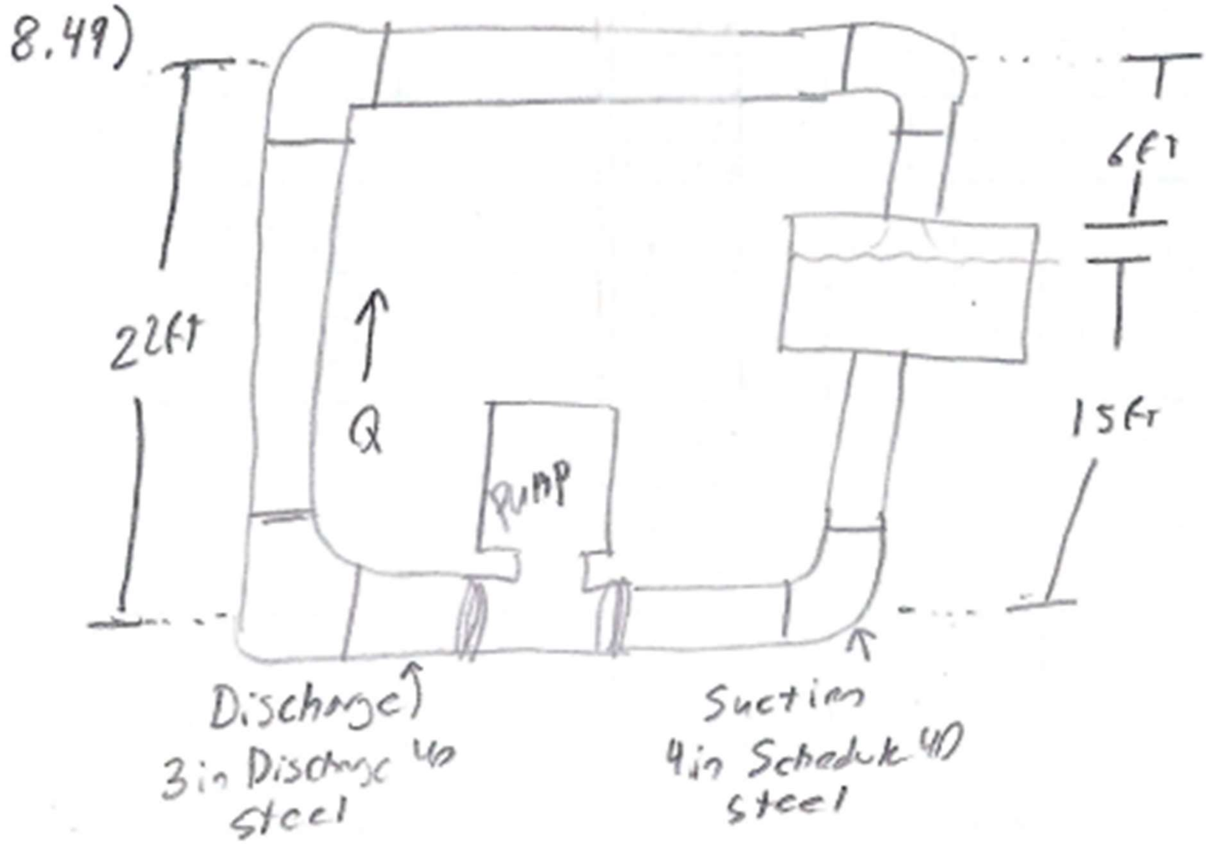
$$P_1 = \gamma\left[z_2 + f\frac{L}{D}\frac{V_1^2}{2g} - \frac{V_1^2}{2g}\right]$$

$$P_1 = (62.4\ \mathrm{lb/ft^3})\left[210\ \mathrm{ft} + 0.0155\left(\frac{2500\ \mathrm{ft}}{0.6651\ \mathrm{ft}}\right)\frac{(11.51\ \mathrm{ft/s})^2}{2(32.2\ \mathrm{ft/s^2})} - \frac{(11.51\ \mathrm{ft/s})^2}{2(32.2\ \mathrm{ft/s^2})}\right]$$

$$P_1 = (62.4\ \mathrm{lb/ft^3})\left[210\ \mathrm{ft} + 58.262(2.05714\ \mathrm{ft}) - 2.05714\ \mathrm{ft}\right]$$

$$P_1 = 20454.5\ \mathrm{lb/ft^2} = \boxed{11.837\ \mathrm{psi}}$$

8.49)



$Q = 300 gal/min = 0.668\ ft^3/s$

$T = 104°F$ $\quad\quad$ $\varepsilon = 1.5 \times 10^{-4} ft$

$L_{4in} = 25ft$ $\quad\quad$ $D_{4in} = 0.3355 ft$

$L_{3in} = 75ft$ $\quad\quad$ $D_{3in} = 0.2557 ft$

$\nu = 2.15 \times 10^{-3} ft^2/s$ @ $104°F$ $\quad\quad$ $Sg = 0.890$

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

8-62) $T = 77°F = 25°C$

6 in Schedule 40 steel pipe

$V = 12\,ft/s = 3.6576\,m/s$

Heavy fuel oil

$$Re = \frac{VD}{\nu} \qquad \nu = 1.18\times10^{-4}\,m^2/s$$

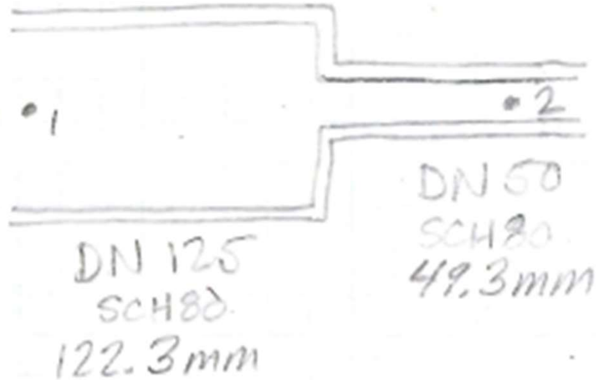
$$D = 0.1541\,m$$

$$Re = \frac{(3.658\,m/s)(0.1541\,m)}{1.18\times10^{-4}\,m^2/s} = 4777.1 \quad \therefore \text{Turbulent}$$

$\varepsilon = 4.6\times10^{-5}\,m$

$$f = \frac{0.25}{\left[\operatorname{Log}\left(3.7\left(\frac{0.1541\,m}{4.6\times10^{-5}\,m}\right) + \left(\frac{5.74}{4777.1^{0.9}}\right)\right)\right]^2} = \boxed{0.0149}$$

10.20



$h_L = K\frac{v^2}{2g}$ TABLE 10.3A FIND K

NEED RATIO $D_1 : D_2$ $\frac{122.3\,mm}{49.3\,mm} = 2.48$

NEED V_2 $V_2 = \frac{Q}{A_2} = \frac{500\ L/min}{1.905E{-3}\,m^2}$

$V_2 = 2.625E5\ L\cdot m^2/min$

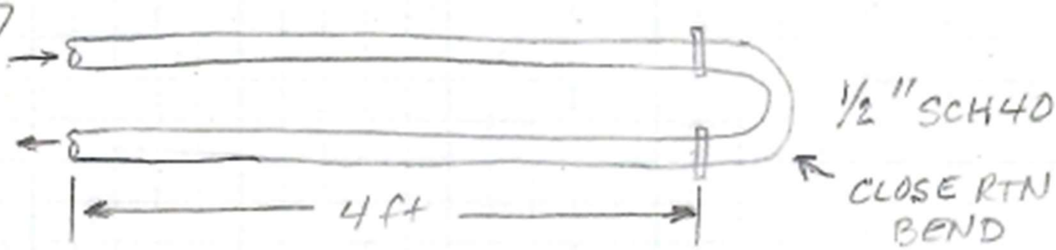
$1\,m^3 = 1{,}000\,L$ $1\,min = 60\,sec$

$\frac{2.625E5}{60{,}000\,L/min} = 4.37\,m/s$

$K = 0.38$

$h_L = 3.8\left(\frac{4.37^2}{2\cdot 9.81}\right) = \boxed{0.356\,m}$

10.37



Q = 12.5 gal/min Ethylene Glycol @ 77°F

TABLE 10.5 – 1/2" SCH40 ⇒ $f_T = 0.026$

TABLE 10.4 – CLOSE RTN BEND ⇒ $Le/D = 50$

TABLE F.1 SCH40 – 1/2" NPS ⇒ A= $0.00211\,ft^2$, I.D = 0.0518 ft

$V = \frac{Q}{A} = \frac{12.5\,gal/min}{0.00211\,ft^2} = \frac{5{,}924\ gal\cdot ft^2/min}{448.8} = 13.20\ ft^3/sec$

$$h_{L_B} = f\left(\frac{L_e}{D}\right)\left(\frac{v^2}{2g}\right) = 0.026 \cdot 50\left(\frac{13.20^2}{2 \cdot 32.2}\right) = 3.52 \text{ ft}$$

4 ft pipe ×2 $\quad \frac{D}{\varepsilon} = \frac{0.0518 \text{ ft}}{1.5E-4} = 345$

$$h_{L_P} = f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right) = 0.04\left(\frac{8 \text{ ft}}{0.0518}\right)\left(\frac{13.20^2}{2 \cdot 32.2}\right) = 16.71 \text{ ft}$$

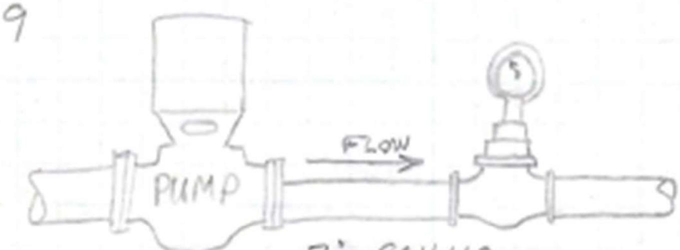
TABLE B.2

$\gamma_{ETH.GL} = 68.47 \text{ lb/ft}^3$ $\qquad h_{L_T} = 3.52 \text{ ft} + 16.71 \text{ ft} = 20.23 \text{ ft}$

$p_1 - p_2 = \gamma(h_{L_B} + h_{L_P})$ $\qquad \text{psi} = \frac{\text{psf}}{144}$

$$p_1 - p_2 = 68.47 \text{ lb/ft}^3\left(\frac{20.23 \text{ ft}}{144}\right) = \boxed{9.62 \text{ psi}}$$

10.39



3in NPS $\quad A = 0.05132 \text{ ft}^2$

$f_T = 0.017$

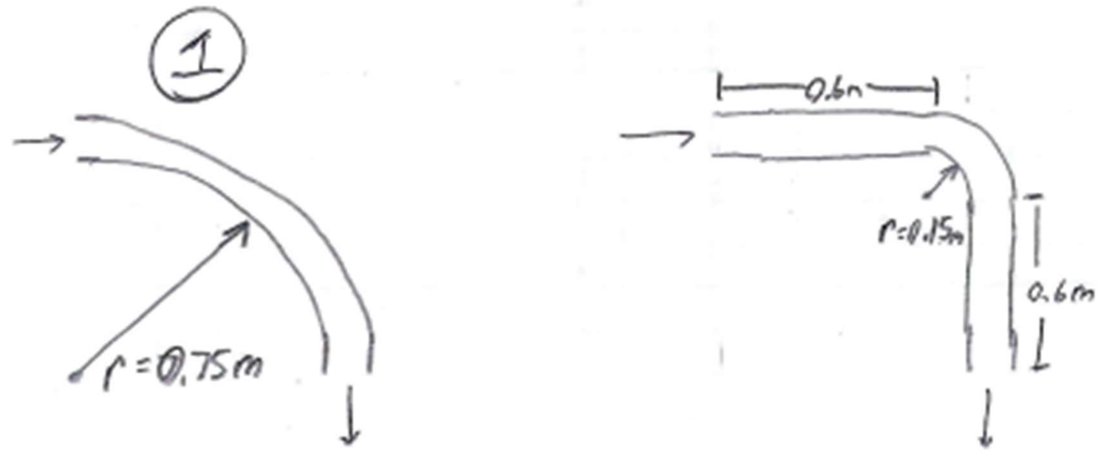
WATER = 0.40 ft³/s @ 50°F

$$v = \frac{Q}{A} = \frac{0.40 \text{ ft}^3/\text{s}}{0.05132 \text{ ft}^2} = 7.79 \text{ ft/s}$$

TABLE 10.4 Std. Tee w/FLOW THRU ⇒ $L_e/D = 20$

$$h_L = f\left(\frac{L_e}{D}\right)\left(\frac{v^2}{2g}\right) = 0.017 \cdot 20\left(\frac{7.79^2}{2 \cdot 32.2}\right) = \boxed{0.320 \text{ ft}}$$

10- 43)



$D = 50mm - 2(2mm) = 0.046\ m$

copper tubing

$Q = 750\ L/min = 0.0125\ m^3/s$

$\gamma = 7.87\ kN/m^3 \qquad \nu = 2.39\times10^{-6}\ m^2/s$

$\varepsilon = 1.5\times10^{-6}m \qquad A = \frac{\pi}{4}D^2 = \frac{\pi}{4}(0.046^2) = 0.001662\ m^2$

$$V = \frac{Q}{A} = \frac{0.0125 m^3/s}{0.001662 m^2} = 7.52\ m/s$$

$$Re = \frac{VD}{\nu} = \frac{(7.52m/s)(0.046m)}{2.39\times10^{-6}\ m^2/s} = 144{,}736.40$$

Case 1

$$r = R_i + \frac{D_o}{2} = 0.75m + \frac{0.05m}{2} = 0.775m$$

$$\frac{r}{D} = \frac{0.775m}{0.046\ m} = 16.85 \quad \therefore \quad \frac{L_e}{D} = 40$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.046m}{1.5\times10^{-6}m}\right)} + \left(\frac{5.74}{144{,}736.40^{0.9}}\right)\right)\right]^2}$$

$f = 0.0168$

$$h_L = K\frac{V^2}{2g} = \left(f\frac{L_e}{D}\right)\left(\frac{V^2}{2g}\right) = 0.0168(40)\frac{(7.52m/s)^2}{2(9.81m/s^2)}$$

$$\boxed{h_L = 1.94m}$$

CASE 2

$h_L = h_{L,Bend} + h_{L,f}$

$r = r_i + \frac{D_o}{2} = 0.15m + \frac{0.05}{2} = 0.175m$

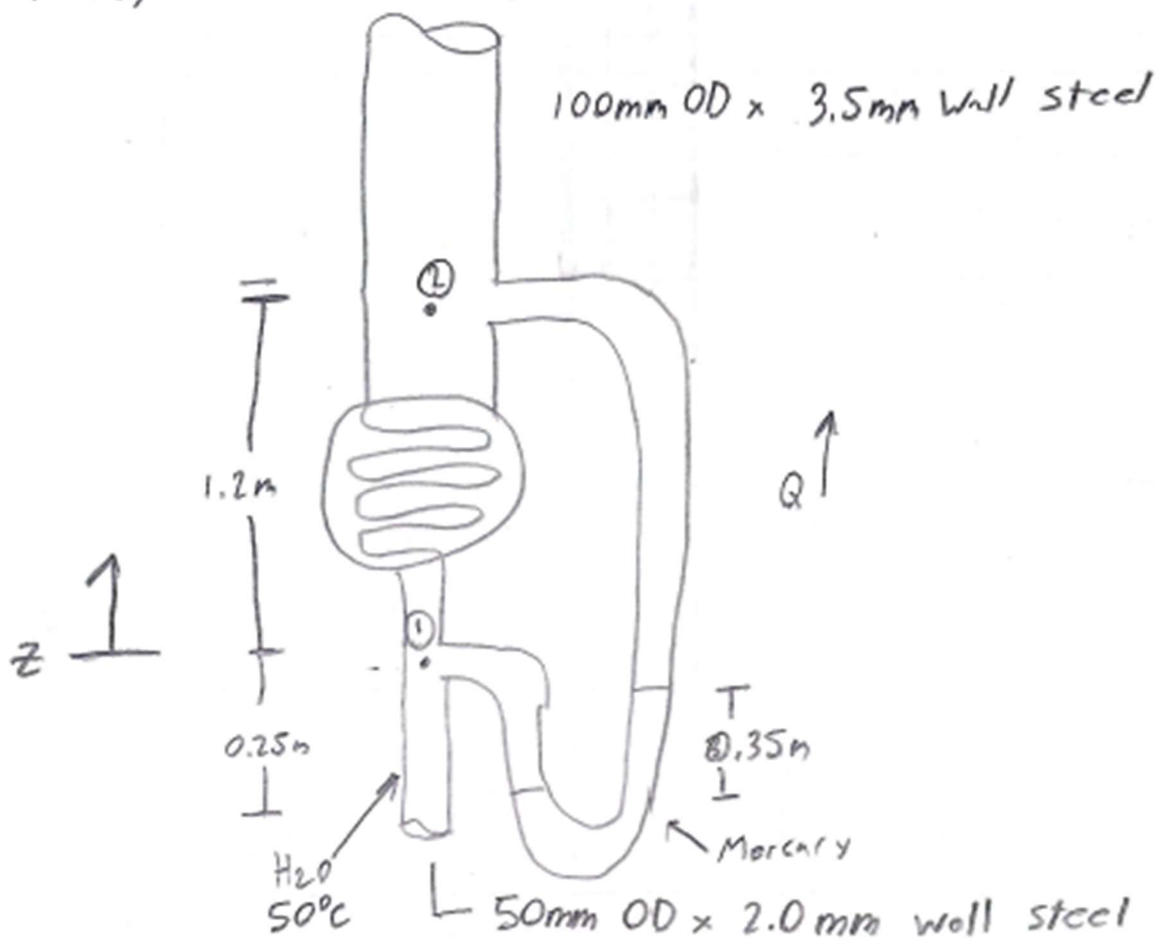
$\frac{r}{D} = \frac{0.175m}{0.046m} = 3.8 \qquad \frac{L_e}{D} = 13$

$$h_{L,Bend} = K\frac{V^2}{2g} = f\left(\frac{L_e}{D}\right)\frac{V^2}{2g} = 0.0168(13)\frac{(7.52)^2}{2(9.81)} = 0.6295m$$

$$h_{L,f} = f\left(\frac{L}{D}\right)\cdot\frac{V^2}{2g} = 0.0168\left(\frac{1.2m}{0.046m}\right)\frac{7.52^2}{2(9.81)} = 1.263m$$

$$\boxed{h_L = 1.8927m}$$

10-46)



$Q = 6.0 \times 10^{-3}\ m^3/s$

$\gamma_{H_2O} = 9.69\ kN/m^3 \qquad \nu_{H_2O} = 5.48 \times 10^{-7}\ m^2/s$

$\gamma_{Hg} = 132.8\ kN/m^3 \qquad \nu_{Hg} = 1.13 \times 10^{-7}\ m^2/s$

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

$D_2 = 0.1m - 2(0.0035m) = 0.093\ m$

$D_1 = 0.05m - 2(0.002m) = 0.046\ m$

$A_2 = 0.00679\ m^2$

$A_1 = 0.00166\ m^2$

$V_2 = \frac{Q}{A_1} = \frac{6.0 \times 10^{-3}\ m^3/s}{0.00679\ m^2} = 0.884\ m/s$

$V_1 = \frac{Q}{A_2} = \frac{6.0 \times 10^{-3}\ m^3/s}{0.00166\ m^2} = 3.6\ m/s$

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

$$\Delta P = \gamma h$$

$$\Delta P = P_1 - P_2 = \gamma_{H_2O}(0.25m) - \gamma_{Hg}(0.35m) - \gamma_{H_2O}(1.2m)$$

$$\Delta P = -55.6855 \frac{kN}{m^2} = -55.68\, kPA$$

$$h_L = \frac{V^2}{2g} + \frac{P_1}{\gamma} - \frac{P_2}{\gamma} - \frac{V_2^2}{2g} - z_2 = \frac{V_1^2}{2g} + \frac{P_1 - P_2}{\gamma} - \frac{V_2^2}{2g} - z_2$$

$$h_L = \frac{0.884 m/s^2}{2(9.81 m/s^2)} + \frac{-55.68 kPa}{9.69 kN/m^3} - \frac{3.6 m/s}{2(9.81 m/s^2)} - 1.2m$$

$$\boxed{h_L = 4.96\ m}$$

$$h_{L,total} = h_{L,f} + h_{L,inter}$$

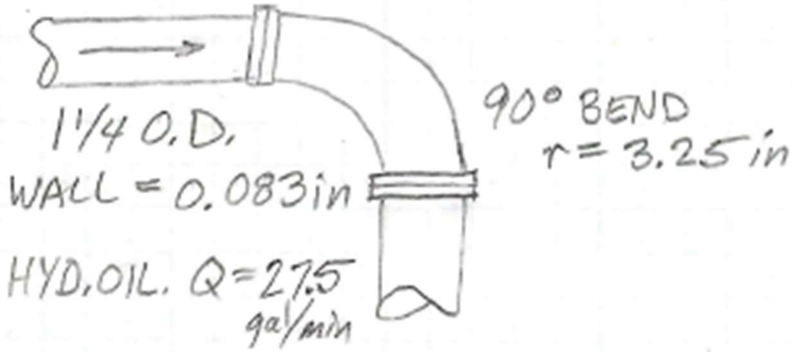
10.46 (CONT.)

$h_L = 4.96m$ $\quad V_1 = 3.058\ m/s$ $\quad V_2 = 0.804\ m/s$

$$h_L = K\left(\frac{V^2}{2g}\right) \quad \therefore \quad K = \frac{h_L \cdot 2g}{V^2}$$

$$K = \frac{4.96m \cdot 2 \cdot 9.81}{3.058^2} = \boxed{10.40}$$

10.48



$$\text{I.D.} = 1.25\text{in} - 2(0.083\text{in}) = 1.084'' = 0.090\text{ ft}$$

$$D/\varepsilon = (1.084/12)/1.5\text{E-}4 = 602.22$$

Fig 10.28 $\quad r/D = 3.25/1.084 = 3.00$

$$L_e/D \approx 13 \qquad K = f_T\,(L_e/D)$$

$$Q = 27.5\text{ gal/min} = 0.0613\text{ ft}^3/\text{sec}$$

Fig 8.7 MOODY @ $D/\varepsilon = 602 \Rightarrow f = 0.023$

$$K = 0.023(13) = 0.299$$

$$A = \pi\frac{d^2}{4} = \pi\frac{0.09^2}{4} = 0.00641\text{ ft}^2$$

$$v = \frac{0.0613\text{ ft}^3/\text{sec}}{0.00641\text{ ft}^2} = 9.563\text{ ft/sec}$$

$$h_L = K\left(\frac{v^2}{2g}\right) = 0.299\left(\frac{9.563^2}{2\cdot 32.2}\right) = \boxed{0.425\text{ ft}}$$