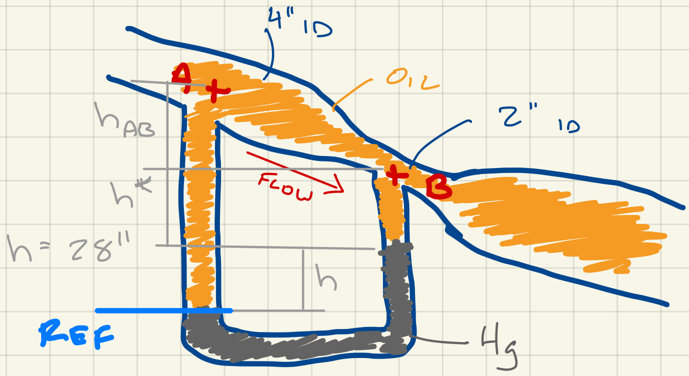
6-79 **Given:**

Oil is flowing downward through a venturi meter.

$Sg_{oil} = 0.90$ $\quad Sg_{Hg} = 13.54$



Required:

Calculate the volume flow rate of the oil (Q)

Solution:

- Steady flow, use Bernoulli's equation, simplified for this specific case:

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

- Because the goal is to calculate flow rate, the flow rate equation is necessary:

$$Q = V \cdot A \quad \therefore \quad V = Q/A$$

- Combining Bernoulli's and the flow rate equation:

$$\frac{p_1}{\gamma} + \frac{(Q/A_A)^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{(Q/A_B)^2}{2g} + z_2$$

- Simplifying and solving for Q:

$$\frac{Q^2}{2gA_A^2} - \frac{Q^2}{2g\,A_B^2} = \frac{p_2 - p_1}{\gamma} + (z_2 - z_1)$$

$$\therefore$$

$$\frac{Q^2}{2g}\left(\frac{1}{A_A^2} - \frac{1}{A_B^2}\right) = \frac{\Delta p}{\gamma} + (z_2 - z_1)$$

6-79 CONT

$$Q = \sqrt{\frac{2g\left(\frac{\Delta p}{\gamma_{OIL}} + (z_B - z_A)\right)}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}} \quad (1)$$

- THE Δp CAN BE FOUND BY USING THE MANOMETER, w/ THE Δp EQUATION FOR STAGNANT FLUIDS:

$$\Delta p = \gamma \cdot h$$

$$p_A + \gamma_{OIL}(\Delta z + \cancel{h^*} + h) - \gamma_{Hg} h - \cancel{\gamma_{OIL} h^*} = p_B$$

$$\therefore$$

$$\Delta p = \gamma_{OIL}(\Delta z + h) - \gamma_{Hg} h \quad (2)$$

- COMBINE (1) AND (2), SOLVE FOR Q:

$$Q = \sqrt{\frac{2g\left(\frac{\cancel{\gamma_{OIL}}(\cancel{\Delta z} + h) - \gamma_{Hg} h}{\gamma_{OIL}}\right) + \cancel{(z_B - z_A)}}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}$$

- $\Delta z = z_A - z_B$

$$\therefore$$

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

- $\frac{\gamma_{Hg}}{\gamma_{OIL}} = \frac{Sg_{Hg}}{Sg_{OIL}}$
- $A_A = \frac{\pi (1/3')^2}{4} = 0.0873 \text{ ft}^2$
- $A_B = \frac{\pi (1/6')^2}{4} = 0.0218 \text{ ft}^2$

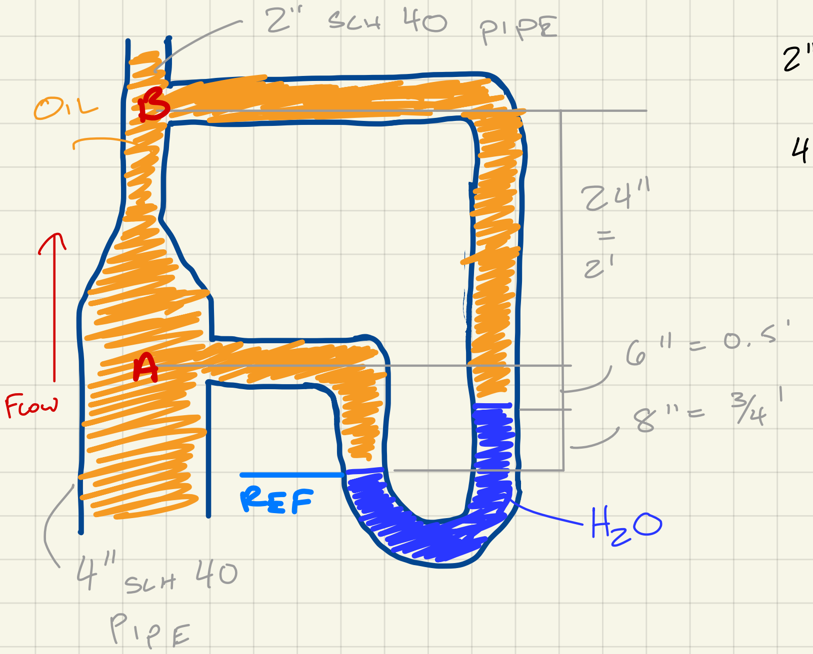
$$Q = \sqrt{\frac{2(32.2 \text{ ft/s}^2)\left(7/3' - \left(\frac{13.54}{0.90} \cdot 7/3'\right)\right)}{\frac{1}{(0.0873 \text{ ft}^2)^2} - \frac{1}{(0.0218 \text{ ft}^2)^2}}}$$

$$= \boxed{1.03 \text{ ft}^3/\text{s}}$$

6-82 **GIVEN:**

OIL FLOWS THROUGH A SYSTEM.

$\gamma_{OIL} = 55 \text{ lb/ft}^3$



2" SCH 40 ID = 2.067"

4" SCH 40 ID = 4.026"

REQUIRED:

CALCULATE VOLUME FLOW RATE (Q)

SOLUTION:

- SAME PROCEDURE AS PREVIOUS PROBLEM
  - USE A COMBINATION OF FLOW RATE EQUATION AND BERNOULLI'S EQUATION, ALONG W/ Δp IN STAGNANT FLUID TO FIND Q

$$Q = V \cdot A$$

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

$$\therefore$$

$$Q = \sqrt{\frac{2g\left(\frac{p_B - p_A}{\gamma_{OIL}}\right) + (z_B - z_A)}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}} \quad (1)$$

- FOR Δp:

$$\Delta p = \gamma \cdot h$$

6-82 CONT

$$p_A + \gamma_{oil}(6'' + 8'') - \gamma_{H_2O}(8'') - \gamma_{oil}(6'' + 24'') = p_B$$

$$\therefore$$

$$p_B - p_A = (55\ lb/ft^3)(7/6\ ') - (62.4\ lb/ft^3)(2/3\ ') - (55\ lb/ft^3)(5/2\ ')$$

$$= \boxed{-114.9\ lb/ft^2}$$

- SOLVE FOR A_A AND A_B:

$$A_A = \frac{\pi\left(\frac{4.026''}{12''}\right)^2}{4} = 0.0884\ ft^2$$

$$A_B = \frac{\pi\left(\frac{2.067''}{12''}\right)^2}{4} = 0.0233\ ft^2$$

- INSERT VALUES INTO (1), SOLVE FOR Q:

$$Q = \sqrt{\frac{2(32.2\ ft/s^2)\left(\frac{(-114.9\ lb/ft^2)}{(55\ lb/ft^3)} + (2')\right)}{\frac{1}{(0.0884\ ft^2)^2} - \frac{1}{(0.0233\ ft^2)^2}}}$$

$$= \boxed{0.278\ ft^3/s}$$

7-11 **GIVEN:**

A SUBMERSIBLE PUMP DELIVERS WATER THROUGH A PIPING SYSTEM.

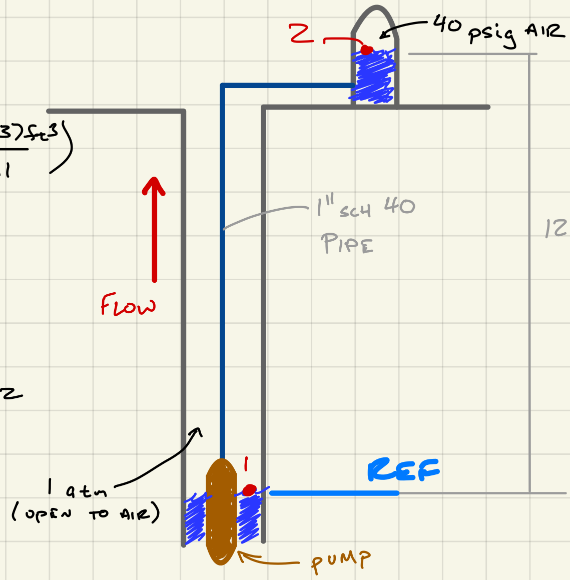
PIPE: 1" SCH 40

RATE: $745\ gal/h \left(\frac{1h}{3600s}\right)\left(\frac{0.1337ft^3}{1gal}\right)$

$= 0.0277\ ft^3/s$

ENERGY LOSS: 10.5 lb-ft/lb

$40\ psig \left(\frac{144\ si}{1\ sf}\right) = 5760\ lb/ft^2$



REQUIRED:

a) CALCULATE POWER DELIVERED BY PUMP

b) IF THE PUMP DRAWS 1 hp, CALCULATE THE EFFICIENCY

SOLUTION:

a) FOR PART a, WE CAN ASSUME 100% EFFICIENCY FOR THE PUMP. IT'S POWER CAN BE CALCULATED WITH:

$P = \gamma Q h_A$ WHERE h_A = PUMP HEAD.

- FIRST, h_A MUST BE CALCULATED USING BERNOULLI'S EQUATION W/ FACTORS FOR THE PUMP HEAD AND THE GIVEN ENERGY LOSS INCLUDED:

$$h_A + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$$ WHERE h_L IS ENERGY LOSS

- SOLVE FOR h_A:

$$h_A = \frac{p_2 - \overset{atm}{\cancel{p_1}}}{\gamma} + \frac{\overset{0}{\cancel{V_2^2}} - \overset{0}{\cancel{V_1^2}}}{2g} + (z_2 - \overset{0}{\cancel{z_1}}) + h_L$$

- USING POINT 1 AND POINT 2 MARKED IN DRAWING, MOST VARIABLES CAN BE CANCELLED.

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

$$h_A = \frac{(5760\ lb/ft^2)}{(62.4\ lb/ft^3)} + (120\ ft) + (10.5\ lb\,ft/lb) = \boxed{222.8\ ft}$$

7-11 cont

- Using the calculated h_A, find P:

$$P = (62.4\ ^{lb}/_{ft^3})(0.0277\ ^{ft^3}/_s)(222.8\ ft)$$

$$= 385.1\ ^{ft^3}/_s \left(\frac{1\ hp}{550\ ^{lbft}/_s}\right) = \boxed{0.70\ hp}$$

b) To find the efficiency of the pump if the power supplied is $1\,hp$:

$$\eta_p = \frac{P_{out}}{P_{in}} = \frac{(0.7\ hp)}{(1\ hp)} = 0.7 = \boxed{70\%}$$

7-16 **GIVEN:**

A pump system moves oil from an underground tank to a different storage tank.

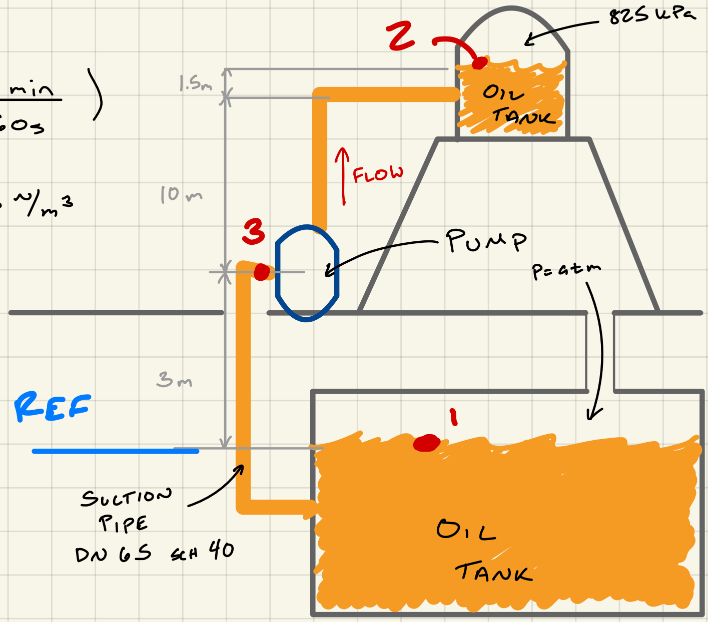
$$\text{Flow Rate} = 840\ ^L/_{min}\left(\frac{1\ m^3}{1000L}\right)\left(\frac{1 min}{60s}\right)$$

$$= 0.014\ ^{m^3}/_s$$

$$Sg_{OIL} = 0.85\,(9810\ ^N/_{m^3}) = 8338.5\ ^N/_{m^3}$$

h_L of system: $4.2\ ^{Nm}/_N$

h_L of suction pipe: $1.4\ ^{Nm}/_N$



REQUIRED:

a) Calculate power delivered by the pump using total energy loss

b) Calculate pressure at pump inlet w/ energy loss in suction pipe.

SOLUTION:

a) Use power equation along w/ Bernoulli's equation to find power delivered by pump.

- Investigating b/t points 1 and 2, w/ height of point 1 as the reference height.

(1) $P = \gamma Q h_a$ (2) $h_a + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$

7-16 cont

- SOLVE (2) FOR h_A:

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

$$\therefore h_A = \frac{P_2}{\gamma} + z_2 + h_L$$

$$= \frac{(825\ kPa)}{(8.34\ kN/m^3)} + (3m + 10m + 1.5m) + (4.2\ Nm/N)$$

$$= \boxed{117.6\ m}$$

- SOLVE (1):

$$P = (8.34\ kN/m^3)(0.014\ m^3/s)(117.6\ m)$$

$$= 13.73\ kNm/s = \boxed{13.73\ kW}$$

b) FIND THE PRESSURE AT THE PUMP INLET IF $h_L = 0.22\ Nm/N$

- CAN BE SOLVED BY INVESTIGATING POINTS 1 AND 3 W/ BERNOULLI'S EQUATION:

$$\frac{\cancel{P_1}^{0}}{\gamma} + \frac{\cancel{V_1^2}^{0}}{2g} + \cancel{z_1}^{0} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + h_L$$

- SOLVE FOR P_3:

$$(3)\quad P_3 = \left(-\frac{V_3^2}{2g} - z_3 - h_L\right)\gamma$$

- USE FLOW RATE EQUATION AND GIVEN FLOW RATE AND PIPE AREA TO SOLVE FOR V_3:

$$V_3 = \frac{Q}{A} = \frac{(0.014\ m^3/s)}{(3.09 \cdot 10^{-3}\ m^2)} = \boxed{4.531\ m/s}$$

- SOLVE (3):

$$P_3 = \left(\frac{-(4.531\ m/s)^2}{2(9.81\ m/s^2)} - (3m) - (1.4\ Nm/N)\right)(8.34\ kN/m^3)$$

$$= 45.42\ kN/m^2 = \boxed{45.42\ kPa}$$

Codes for Question Forms under HW assignment:

Link 1:

532571Higgins

Link 2:

581815Higgins