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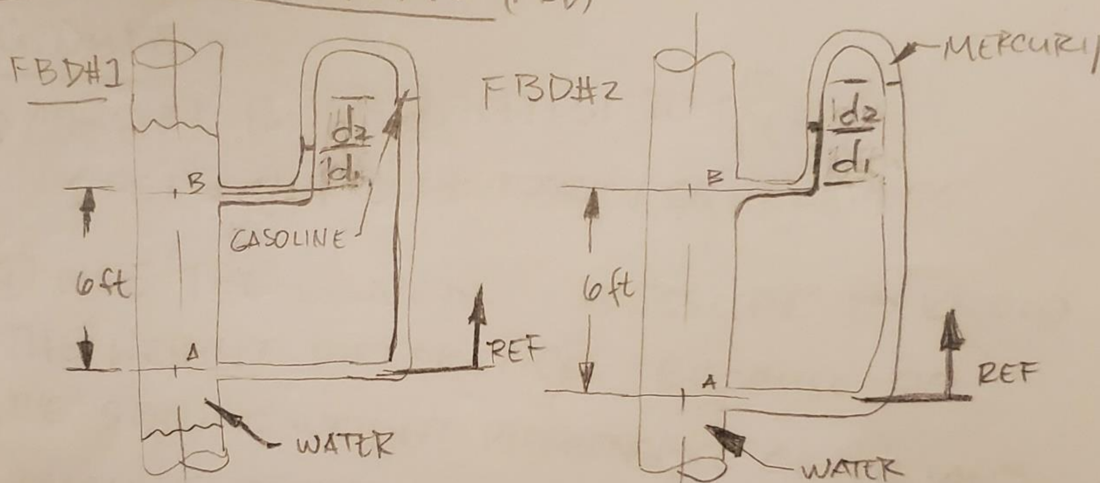
① PURPOSE

What is the minimum height of the manometer so the gasoline does not go into the system?

DRAWING & DIAGRAMS (FBD)



SOURCES

- Mott, R., Untener, J.A., "Applied Fluid Mechanics," 7th edition Pearson Education, In (2015)

DESIGN CONSIDERATION

CONSTANT TEMPERATURE
INCOMPESSIBLE
CONSTANT PROPERTIES OF WATER, GASOLINE, & MERCURY
CONSTANT PRESSURE

CALCULATION

FOR CASE 1: GASOLINE AS THE REPLACEMENT OF OIL INSIDE THE MANOMETER

$P_A - P_B = 2.7177$ PSI

$$\left(\frac{2.7177 \text{ PSI}}{1}\right)\left(\frac{144\left[\frac{lb}{ft^2}\right]}{1 \text{ PSI}}\right) = 391.3488 \left[\frac{lb}{ft^2}\right]$$

$$P_A - P_B = -\gamma_{WATER}(d_1) - \gamma_{GASOLINE}\, d_2 + \gamma_{WATER}(6 + d_2 + d_1)$$

$$391.3488\left[\frac{lb}{ft^2}\right] = \cancel{-62.4\left[\frac{lb}{ft^3}\right](d_1)} - 42.4\left[\frac{lb}{ft^3}\right] d_2 + 62.4\left[\frac{lb}{ft^3}\right](6 + d_2 + \cancel{d_1})$$

$$391.3488\left[\frac{lb}{ft^2}\right] = -42.4\left[\frac{lb}{ft^3}\right] d_2 + \cancel{62.4\left[\frac{lb}{ft^3}\right](6ft)} + 62.4\left[\frac{lb}{ft^3}\right] d_2$$

$$-374.4\left[\frac{lb}{ft^2}\right] \qquad \cancel{-374.4\left[\frac{lb}{ft^2}\right]}$$

$$\frac{16.9488\left[\frac{lb}{ft^2}\right]}{20\left[\frac{lb}{ft^3}\right]} = \frac{20\left[\frac{lb}{ft^3}\right] d_2}{20\left[\frac{lb}{ft^3}\right]}$$

$$\boxed{d_2 = .84744\ [ft] = .85\ [ft]}$$

$$d_1 = 5\ [ft] - .85\ [ft] = 4.15\ [ft]$$

$$\boxed{d_1 = 4.15\ [ft]}$$

FOR CASE 2: MERCURY AS A REPLACEMENT OF OIL IN THE MANOMETER

$P_A - P_B = 391.3488 \frac{lb}{ft^2}$

$P_A - P_B = -\gamma_{WATER}(d_2) - \gamma_{MERCURY}\, d_1 + \gamma_{WATER}(6 + d_2 + d_1)$

$391.3488\left[\frac{lb}{ft^2}\right] = -62.4\left[\frac{lb}{ft^3}\right](d_1) - 844.9\left[\frac{lb}{ft^3}\right] d_2 + 62.4\left[\frac{lb}{ft^3}\right](6 + d_2 + d_1)$

$391.3488\left[\frac{lb}{ft^2}\right] = -844.9\left[\frac{lb}{ft^3}\right] d_2 + 374.4\left[\frac{lb}{ft^3}\right] + 62.4\, d_2$

$-374.4\left(\frac{lb}{ft^3}\right) \qquad -374.4\left[\frac{lb}{ft^3}\right]$

$$\frac{16.9488\left[\frac{lb}{ft^2}\right]}{-782.5\left[\frac{lb}{ft^3}\right]} = \frac{-782.5\left[\frac{lb}{ft^3}\right] d_2}{-782.5\left[\frac{lb}{ft^3}\right]}$$

$d_2 = -.0217\,ft \approx -.02\,ft$

$\boxed{d_2 = -.02\,ft}$

$d_1 = 5\,[ft] - -.02 = 5.02$

$\boxed{d_1 = 5.02}$

SUMMARY

REPLACE OIL TO GASOLINE AND THEN RUN THE CALCULATION TO GET THE HEIGHT DIFFERERENCE. THE SPECIFIC GRAVITY OF THE TWO LIQUID WILL BE THE REASON WHY THE LIQUID'S MOVE FROM IT'S ORIGINAL POSITION. REPEAT THE SAME STEP BUT REPLACE THE GASOLINE TO MERCURY.

DATA & VARIABLES

$\gamma_{WATER} = 62.4 [\frac{lb}{ft^3}]$

$\gamma_{GASOLINE} = 42.4 [\frac{lb}{ft^3}]$

$\gamma_{MERCURY} = 844.9 [\frac{lb}{ft^3}]$

$P_A - P_B = 2.7177 psi$

PROCEDURE

① CONVERT $P_A - P_B = 2.7177$ PSI TO $\frac{lb}{ft^2}$

1 PSI = 144 POUND-FORCE / SQUARE FOOT

② USE THE GIVEN PRESSURE TO KNOW THE HEIGHT DIFFERENCE BECAUSE OF THE SPECIFIC WEIGHT DIFFERENCE OF OIL AND GASOLINE. REPEAT THE SAME PROCESS BUT INSTEAD OF THE GASOLINE, USE THE SPECIFIC WEIGHT OF MERCURY.

③ CALCULATE FOR d_2 & d_1

MATERIAL

- WATER
- MERCURY
- GASOLINE

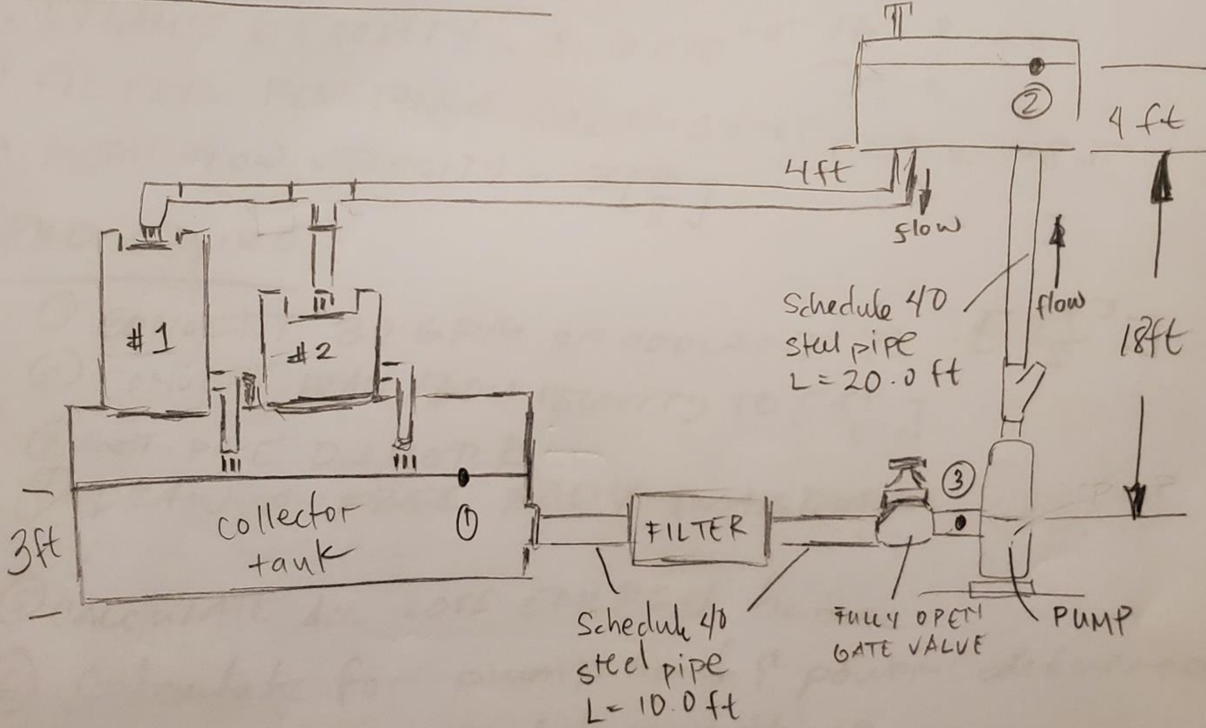
ANALYSIS

BECAUSE OF THE CHANGE OF LIQUID, THE SPECIFIC GRAVITY IS CHANGE, MOVING THE LIQUID POSITION.

PURPOSE

- Pick a commercial steel pipe schedule 40
- compute the pump head and the power delivered by the pump to the coolant.

Drawing & Diagrams



SOURCES

- Mott, R. Untener, J A. "Applied Fluid Mechanics," 7th edition Person Education, In (2015)

DESIGN CONSIDIRATION:

CONSTANT TEMPERATURE
INCOMPRESSIBLE
CONSTANT PROPERTIES

DATA & VARIABLES:

- 30 GPM OF COOLANT
- COOLANT SPECIFIC GRAVITY = 0.92
- DYNAMIC VISCOSITY = $3.6 \times 10^{-5} \frac{lb \cdot s}{ft^2}$
- FILTER RESISTANCE COEFFICIENT (K) = 1.85
- MEAN FLOW VELOCITY = $3 [\frac{m}{s}]$

PROCEDURE:

1. CONVERT 30 GPM OF COOLANT TO $[\frac{ft^3}{s}]$
2. CONVERT MEAN FLOW VELOCITY TO $[\frac{ft}{s}]$
3. GET PIPE DIAMETER
4. DRAW A FREE BODY DIAGRAM.
5. CALCULATE ALL LOSS ENERGY $h_{L TOTAL}$
6. Calculate for pump head & power delivered
7. Use excel to calculate everything
8. Use excel to run the calculation with different steel pipe schedule
9. estimate the cost
10. Make a table of the operation cost in excel
11. Add both cost
12. Make an analysis

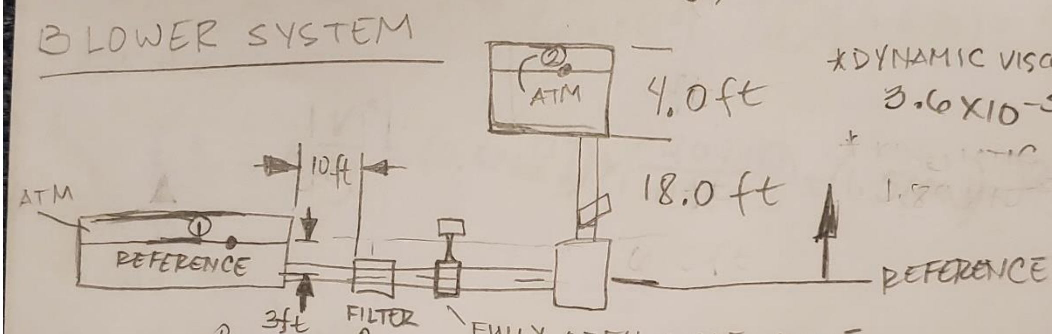
CALCULATION:

(A) $Q = \left(\frac{30\,[\frac{Gal}{min}]}{1}\right)\left(\frac{1\,[\frac{ft^3}{s}]}{449\,[\frac{Gal}{min}]}\right) = .0668\,[\frac{ft^3}{s}]$

$V = 3\,[\frac{m}{s}] = 9.84252\,[\frac{ft}{s}]$

* Pipe $\phi = \sqrt{\frac{4Q}{\pi V}} = \sqrt{\frac{4(.0668\,[\frac{ft^3}{s}])}{\pi(9.84252\,[\frac{ft}{s}])}} = .093\,[ft]$

B LOWER SYSTEM



*DYNAMIC VISCOSITY: $3.6\times10^{-5}\ \frac{lb\cdot s}{ft^2}$

$h_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L2} + h_{R/2}$

* FRICTION

$N_R = \frac{VD}{\nu} = \frac{(9.84\,[\frac{ft}{s}])(.093\,[ft])}{3.6\times10^{-5}\,[ft^2/s]} = \frac{.91512\,[\frac{ft^2}{s}]}{3.6\times10^{-5}\,[\frac{ft^2}{s}]} = 25418.1$

$D/\varepsilon = \frac{.093\,[ft]}{1.5\times10^{-4}\,[ft]} = 620$

$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(\frac{D}{\varepsilon})} + \frac{5.74}{N_R^{0.9}}\right)\right]^2} = \frac{.25}{\left[\log\left(\left(\frac{1}{3.7(620)}\right) + \left(\frac{5.74}{25418^{0.9}}\right)\right)\right]^2} = .028$

* ENTRANCE LOSS (SQUARE-EDGED INLET USE $K = 0.5$)

$h_{L_1} = K\left(\frac{V_2^2}{2g}\right) = (0.5)\left(\frac{(9.84252\,[\frac{ft}{s}])^2}{2(32.2\,[\frac{ft}{s}])}\right) = .75\,[ft]$

* FULLY OPEN GATE VALVE

$h_{L_2} = K\left(\frac{V_2^2}{2g}\right) = (.028)8\left(1.5\,[\frac{ft}{s}]\right) = .34\ [ft]$

* SWING CHECK VALVE

$hL_3 = K\left(\frac{V_2^2}{2g}\right) = (100(.028))\left(1.5\,[\frac{ft}{s}]\right) = 4.3\,[ft]$

* Filter

$$h_{L_4} = k\left(\frac{V_L^2}{2g}\right) = (1.85)\left(1.5\left(\left[\frac{ft}{s}\right]\right)\right) = 2.78\ [ft]$$

* Pipe #1

$$h_{L_5} = f \times \frac{L}{D} \times \frac{V^2}{2g} = \left(0.028\left[\frac{1}{s}\right]\right) \times \left(\frac{10\ [ft]}{.09\ [ft]}\right) \times (1.5\ ft) = 4.67\ [ft]$$

* Pipe #2

$$h_{L_6} = f \times \frac{L}{D} \times \frac{V^2}{2g} = \left(0.026\left[\frac{1}{s}\right]\right) \times \left(\frac{20\ [ft]}{.09\ [ft]}\right) \times (1.5\ [ft]) = 9.14\ [ft]$$

* Exit loss

$$h_{L_7} = (1.0)\left(\frac{V^2}{2g}\right) = (1)(1.5\ [ft]) = 1.5\ [ft]$$

$$h_{L_{TOTAL}} = h_{L_1} + h_{L_2} + h_{L_3} + h_{L_4} + h_{L_5} + h_{L_6} + h_{L_7}$$

$$h_1 = 18\ [ft] + 4\ [ft] - 3\ [ft] + h_{L_{TOTAL}}$$

$h_1 + z_1 = z_2 + h_{L2}$

$h_1 + 3\,[ft] = (18\,[ft] + 4\,[ft]) + h_L$

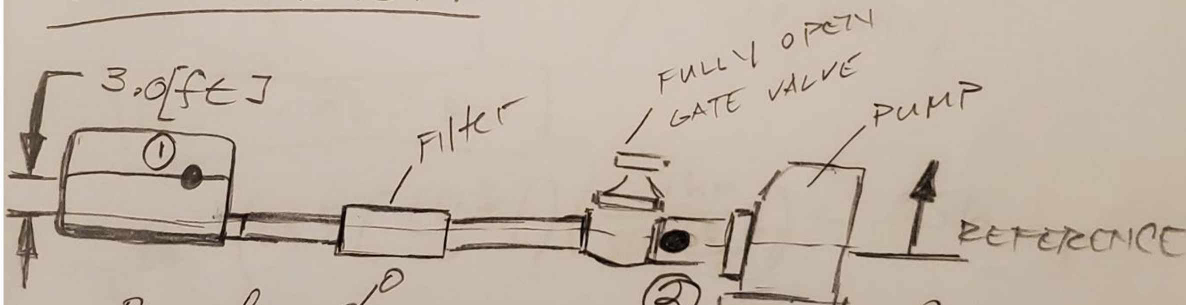
$h_1 = 18\,[ft] + 4\,[ft] - 3\,[ft] + h_L$

$h_1 = 19\,[ft] + h_L$

$= 19\,[ft] + .75\,[ft] + 4.6\,[ft] + 2.78\,[ft] + 4.6\,[ft] + .34\,[ft] + 3.9\,[ft] + 9.1\,[ft] + 1.5\,[ft] = 46.9\,[ft]$

$$h_1 = 46.9\,[ft]$$

* LOWER SYSTEM



$$h_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + h_{L2} + h_{R3}$$

$$0 = -3\,[ft] + \frac{P_3}{(0.92)(62.4\,[\frac{lb}{ft^3}])} + \frac{(9.8\,[\frac{ft}{s}])^2}{2(32.2\,[\frac{ft}{s^2}])} + h_{L2}$$

$$-\frac{P_3}{57.408\,\frac{lb}{ft^3}} = -1.5\,[ft] + .75\,[ft] + 4.6\,[ft] + 2.78\,[ft] + 4.6\,[ft] + .34\,[ft]$$

$$P_3 = (11.572\,[ft])(-57.408\,[\tfrac{lb}{ft^3}]) = -664.2\,[\tfrac{lb}{ft^2}]$$

$$P_3 = -664.2\,[\tfrac{lb}{ft^2}]$$

$$P_A = h_1 \gamma_w Q = (46.9\,(ft))\left(62.4\,\frac{lb}{ft^3}\right)\left(.0668\left[\frac{ft^3}{s}\right]\right)$$

$$\boxed{P_A = 195\left[\frac{ft\text{-}lb}{s}\right]}$$

$$\left(195\left[\frac{ft\text{-}lb}{s}\right]\right)\left(\frac{1.356\,W}{1\ \frac{lb\text{-}ft}{s}}\right) = 265.19\,Watts$$

$$\left(\frac{265.19\,Watts}{1}\right)\left(\frac{1\ kW}{1000\ Watts}\right) = .265\,kW$$

$$\boxed{P_A = .265\ kW}$$

$$P_A = \left(195\left[\frac{ft\cdot lb}{s}\right]\right)\left(\frac{1\,hp}{550\left[\frac{ft\cdot lb}{s}\right]}\right) = .356\ hp$$

SUMMARY

FIRST, WE PICK THE SIZE OF THE PIPE AND THEN CALCULATE FOR THE POWER. SECOND IS TO CALCULATE COST OF INSTALLATION AND COST OF OPERATION. LASTLY, FIND THE SUMMATION OF ALL OF THE COST. DO THIS PROCESS WITH MULTIPLE PIPE. THE COST VERY DEPENDING ON THE PIPE SIZE.

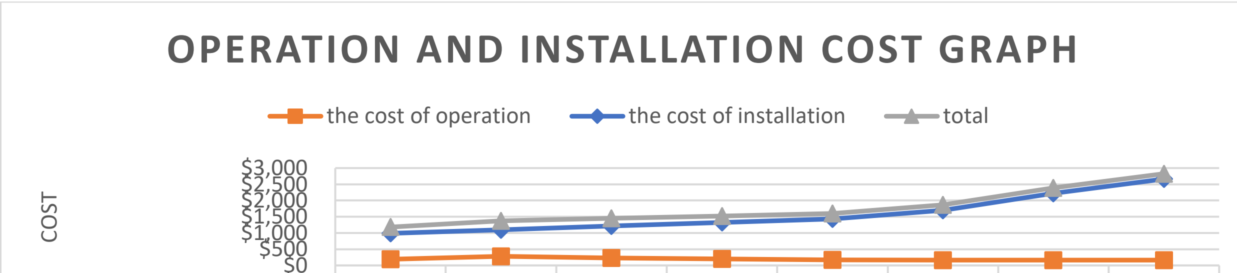
MATERIAL

COOLANT

PIPE = DN 25 Schedule 40 (Pipe nominal size = 1in

ANALYSIS

THE CALCULATION WAS MADE WITH DIFFERENT SIZE OF PIPES AND DEPENDING OF THE SIZE OF THE PIPE, THE COST OF INSTALLING AND MAINTAING THE COST OF OPERATION IN TWO YEAR ARE ALL DIFFERENT. THE BIGGER THE PIPE, THE BIGGER THE COST.



	1/2	3/4	1	1 4/16	1 1/2	2	2 1/2	3
the cost of operation	$194	$282	$231	$200	$175	$164	$164	$164
the cost of installation	$988.64	$1,093.29	$1,218.87	$1,323.52	$1,428.17	$1,700.26	$2,223.51	$2,663.04
total	$1,182.23	$1,375.01	$1,449.84	$1,523.62	$1,602.84	$1,864.00	$2,387.25	$2,826.78

PIPE NOMINAL SIZE (IN)