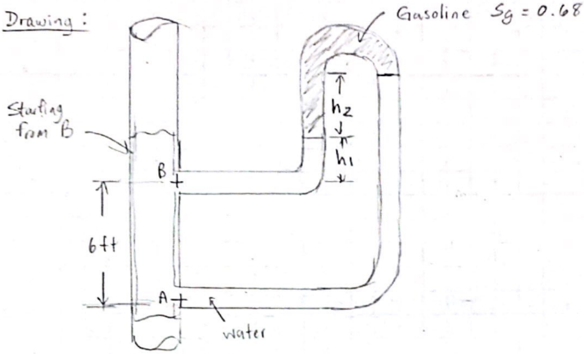
Problem 1.

Purpose: Determine the minimum height of the manometer so the gasoline does not go into the system.

Drawing:



Sources:

Mott R. and Untener J. Applied Fluid Mechanics 7th Edition. Peason 2014.

Design Consideration:

1 Incompressible fluid
2. Isothermal process

Data and Variables:

$P_A - P_B = 2.7177 \text{ psi} = 2.7177 \text{ lb/in}^2 \left(\frac{144 \text{ in}^2}{1 \text{ft}}\right) = 391.35 \text{ lb/ft}^2$

$\gamma_{water} = 62.4 \text{ lb/ft}^2$

$Sg_{gasoline} = 0.68$

$\gamma_{gasoline} = Sg_{gasoline} \times \gamma_{water}$

Procedure:

Problem can be solved using $\Delta p = \gamma h$

In this case pressure difference is already given $= 2.7177 \text{ psi}$

Therefore, equation is as follow:

$$P_A = P_B - \cancel{\gamma_w (h_1)} - \gamma_g (h_2) + \gamma_W (6\text{ft} + \cancel{h_1} + h_2)$$

$$P_A - P_B = \gamma_W (6) + h_2(\gamma_W - \gamma_g)$$

$$h_2 = \frac{P_A - P_B - \gamma_W (6)}{\gamma_W - \gamma_g}$$

Calculation:

$$h_2 = \frac{(P_A - P_B) - \gamma_W(6ft)}{\gamma_W - \gamma_g}$$

$$h_2 = \frac{(391.35\ lb/ft^2) - (62.4\ lb/ft^2 \times 6ft)}{62.4\ lb/ft^2 - (0.68 \times 62.4\ lb/ft^2)}$$

$$\boxed{h_2 = 0.848\ ft}$$

Summary:

The deflection in the manometer is 0.848ft.

Meaning the minimum height of the manometer on the left has to be 0.848ft or higher. The right side need to be 6.848ft or higher for the gasoline not to get into the system.

Material:

water
gasoline

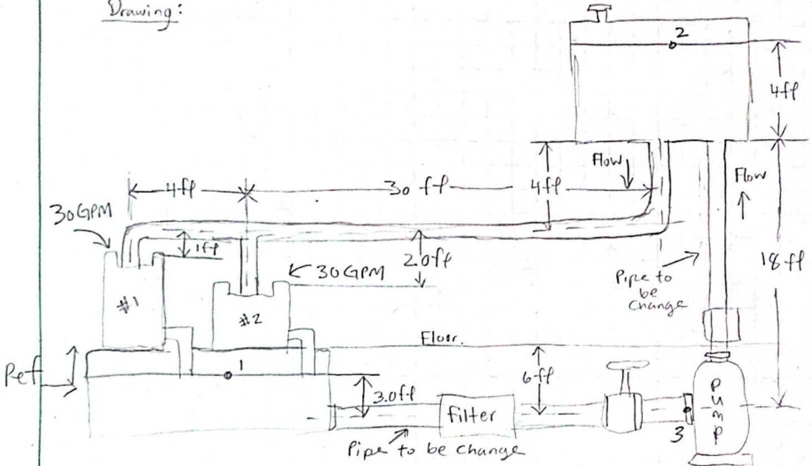
Analysis:

When running the equation in excel using the specific gravity of mercury instead of gasoline I noticed the number got smaller. I believe its because mercury has a lower viscosity than gasoline allowing it to flow through the manometer easier.

Problem 2

Purpose: Determine the new pipe size best for the new flow rate. Using the selected pipe to calculate for pump head, power delivered by the pump to coolant and the pressure at the inlet of the pump.

Drawing:



Sources:

Matt R. and Untener J. Applied fluid Mechanics 7th Edition. Peason 2014.

Design Consideration:

Incompressible fluid
Isothermal process
Steady state.

Data and variables:

$Q = 30\,gal/min \times 2 = 60\,gal/min = 0.0038\,m^3/s \left(\frac{35.3\,ft^3}{1\,m^3}\right) = 0.13414\,ft^3/s$

$Sg\,(coolant) = 0.92$

dynamic viscosity $= \eta = 3.6\times10^{-5}\ lb\cdot s/ft^2$

filter resistance coeff. $(K) = 1.85$

Procedure: Pick references : show on Drawing.

Use the Bernoulli's equation with energy losses and pump head.

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L12}$$

For power deliverd by the pump can be determine by using

$$P = \gamma Q h_a$$

For energy losses use $h_L = f\frac{LV^2}{D2g}$ or $h_L = K\frac{V^2}{2g}$

Calculation:

Choosing the pipe. using $V = \frac{Q}{A}$ pipe need to give about 3 m/s velocity

We Know that $Q = 0.0038\, m^3/s$

Pipe 1-1/2"
flow Area = $1.314 \times 10^{-3}\, m^2$ $V = \frac{0.0038\, m^3/s}{1.314 \times 10^{-3}\, m^2} = 2.89\, m/s$ or $9.48\, ft/s$

Pipe 1-1/4"
flow Area = $9.653 \times 10^{-4}\, m^2$ $V = \frac{0.0038\, m^3/s}{9.653 \times 10^{-4}\, m^2} = 3.94\, m/s$ or $12.92\, ft/s$

Since the pipe need to give about 3 m/s velocity flow
I would say pipe 1-1/2" is the closest to 3 m/s.

Solving for ha using 1-1/2" pipe.

$$h_a + \cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + \cancel{Z_1} = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + Z_2 + h_{L12}$$

$$h_a = Z_2 + h_{L12}$$

Now we need to find energy losses h_{L12} there total of 8

$$h_L = h_1 + h_2 + h_3 + h_4 + h_5 + h_6 + h_7 + h_8$$

h_1 = entrance loss @ New 1-1/2" pipe $h_1 = K\left(\frac{V^2}{2g}\right) = 0.5\left(\frac{(9.48\, ft/s)^2}{2(32.2\, ft/s)}\right) = 0.698\, ft$

h_2 = filter loss $h_2 = K_{FH}\left(\frac{V^2}{2g}\right) = 1.85\left(\frac{(9.48\, ft/s)^2}{2(32.2\, ft/s)}\right) = 2.582\, ft$

$h_3 =$ open gate Valve $=$ $h_3 = f\frac{LV^2}{D2g} = 0.012(8)\left(\frac{(9.48\ ft/s)^2}{2(32.2\ ft/s^2)}\right) = 0.134\ ft$
gate valve $= 8 = \frac{L}{D}$

$h_4 =$ Suction line : $h_4 = f\frac{L}{D}\frac{V^2}{2g} = 0.012\left(\frac{10ft}{0.1342}\right)\left(\frac{(9.48ft/s)^2}{2(32.2ft/s^2)}\right) = 1.248\ ft$

$h_5 =$ check valve $=$ at New pipe 1-1/2" $h_5 = K\frac{V^2}{2g} = 1.10\left(\frac{(9.48ft/s)^2}{2(32.2ft/s^2)}\right) = 1.535\ ft$

$h_6 =$ discharge line at pipe 1-1/2" : $h_6 = f\frac{LV^2}{D2g} = 0.012\left(\frac{20ft\ (9.48ft/s)^2}{0.1342\ ft\ (2(32.2ft/s^2))}\right) = 2.496\ ft$

$h_7 =$ two 90° elbows at upper level pipe $L/D = 30$ $= h_7 = 2f\frac{L}{D}\frac{V^2}{2g} = (2)(0.018)(30)\left(\frac{(12.92ft/s)^2}{2(32.2ft/s^2)}\right) = 2.799\ ft$

$h_8 =$ exit loss $= h_8 = (1.00)\left(\frac{(12.92ft/s)^2}{2(32.2ft/s^2)}\right) = 2.592ft$

$h_L = (0.698\ ft) + (2.582\ ft) + (0.134\ ft) + (1.248\ ft) + (1.535\ ft) + (2.496\ ft) + (2.799\ ft) + (2.592\ ft)$

$h_L = 14.08\ ft$

Plug in Value

$$h_a = z_2 + h_{L12} = (9ft) + (14.08ft) = \boxed{23.08\ ft}$$

Now we can solve for power delivered by the pump

$P = \gamma Q h_a$ $\qquad \gamma_{coolant} = Sg(coolant)\gamma_{water}$

$$P = (0.92 \times 62.4\ lb/ft^3)(0.134 ft^3/s)(23.08 ft)$$

$$P = 177.57\ lb\text{-}ft/s\ \left(\frac{0.0018\ hp}{1\ lb\text{-}ft/s}\right)\left(\frac{0.746\ kW}{1\ hp}\right) = \boxed{0.24\ kW}$$

Next we need to find pressure at inlet of pump point 3.

$$\cancel{h_a} + \cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_1} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + h_{L13}$$

$$\frac{P_3}{\gamma} = \frac{V_3^2}{2g} - z_3 - h_{L13}$$

$$P_3 = (\gamma_{coolant})\left(\left(-\frac{V_3^2}{2g}\right) - z_3 - (h_1 + h_2 + h_3 + h_4)\right)$$

$$\gamma_{coolant} = 0.92\ (62.4\ lb/ft^3) = 57.41\ lb/ft^3$$

Plug in Valve

$$P_3 = (57.41 lb/ft^3)\left(\left(-\frac{(9.48 ft/s)^2}{2(32.2 ft/s^2)}\right) - 3ft - (0.698 ft + 2.582 ft + 0.134 ft + 1.248 ft)\right)$$

$$P_3 = -359.70 \text{ lb-ft/s} \left(\frac{1 \text{ psi}}{144 \text{ lb/ft s}}\right)$$

$$P_3 = \boxed{-2.49 \text{ psi}}$$

Summary :

The pump head is 23.08 ft, the power of the pump is 0.24 KW and the pressure at inlet pump is -2.49 psi

Material :

Coolant

Analysis :

From the calculation from excel and the graph shown that the larger the pipe the more expensive it is. It make sense because the cost of larger pipe is more. Larger pipe mean more labor due to its size. what i did notice that the operation cost seems to be cheaper when a larger pipe is used. I believe its because the larger pipe doesn't require the same amount of power.

In this case I think the best pipe would be the pipe size I choose 1-1/2" because the cost is some where in the middle, While the pipe still function correctly.

Pick 2 Smaller & 2 larger pipes $Q = 0.0038\ m^3/s$

1"
$$V = \frac{Q}{A} = \frac{0.0038\ m^3/s}{5.574 \times 10^{-4}\ m^2} = 6.817\ m/s \text{ or } 22.34\ ft/s$$

1-1/4"
$$V = \frac{Q}{A} = \frac{0.0038\ m^3/s}{9.653 \times 10^{-4}\ m^2} = 3.94\ m/s \text{ or } 12.92\ ft/s$$

2"
$$V = \frac{Q}{A} = \frac{0.0038\ m^3/s}{2.168 \times 10^{-3}\ m^2} = 1.753\ m/s \text{ or } 5.749\ ft/s$$

2-1/2"
$$V = \frac{Q}{A} = \frac{0.0038\ m^3/s}{3.090 \times 10^{-3}\ m^2} = 1.229\ m/s \text{ or } 4.031\ ft/s$$

1" ID : 0.874
1-1/4" : 0.1150

2" = 0.1723
2-1/2" = 0.2038