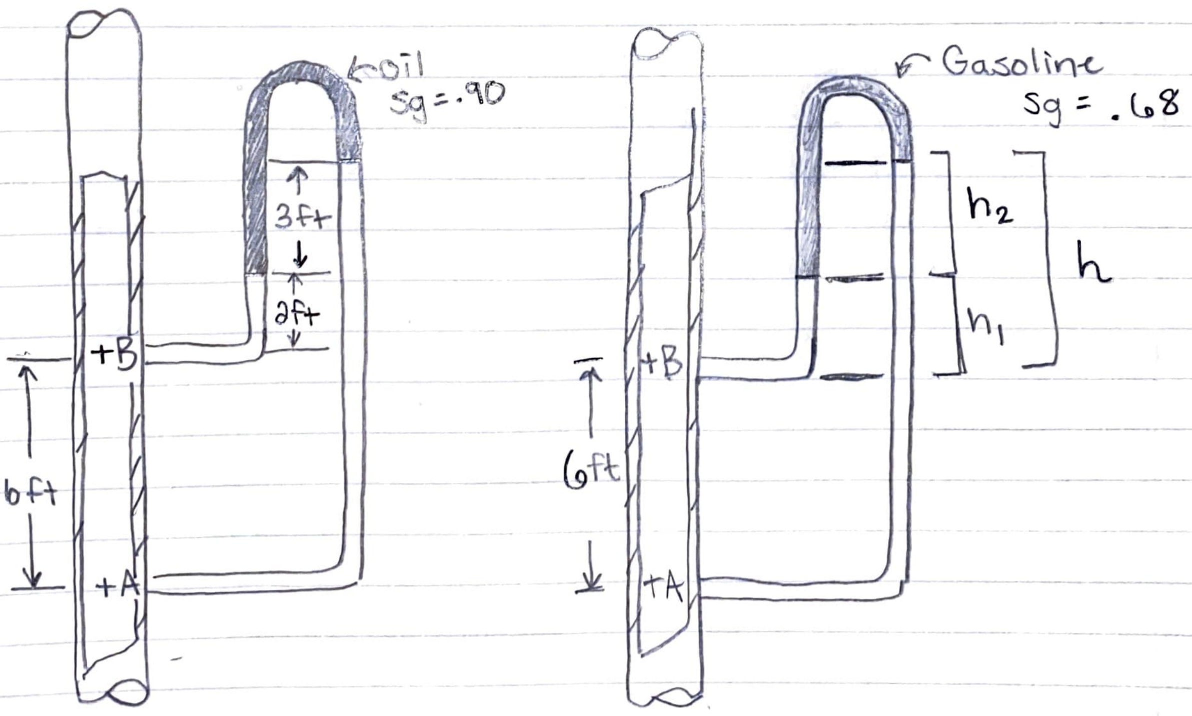
Curtis Domingues Test 1 Feb 15

Problem 1:

1 **Purpose:** Find the deflection in the monometer if using gasoline instead of oil. Next, determine the minimum height of the manometer, while preventing gasoline to enter system. Finally, determine deflection if using Mercury as manometric fluid.

Drawings & Diagrams:



$P_B - P_A = 2.7177$ psi $\qquad$ $P_B - P_A = 2.7177$ psi

Sources: "Mott, R., Utener, J.A., "Applied Fluid Mechanics", 7th Edition.
Pearson Education, INS (2015)

Design Considerations:

- Incompressible Fluids
- Isothermal process
- Constant System pressure

Data and Variables:

- $\gamma_{water} = 62.4\ lb/ft^3$ • $\gamma_{Gasoline} = 42.40\ lb/ft^3$ Table B.2 Pg. 491
- Conversion: $2.7177\ psi = 391.3488\ lb/ft^2$

Procedure: I will begin this problem by using the Gamma·h Equation to solve for h_2 (see figure 2). Next, I will use the calculated deflection (h_2) to determine the minimum manometer size capable of sustaining the gasoline. It's important to note the rise of 'h_2' will equal the fall of 'h_1'. Finally, on excel I will rerun calculations to determine the deflection of Hg.

Calculations:

For the case of Gasoline: $P = \gamma h$

$$-2.7177\ psi\left(\frac{144\ lb/ft^2}{1\ psi}\right) = -391.3488\ lb/ft^2 = P_A - P_B$$

$$P_A - P_B = -6\ ft(\gamma_{water}) - (h_1 + h_2)(\gamma_{water}) + h_2(\gamma_{Gasoline}) + h_1(\gamma_{water})$$

$$-391.3488\ lb/ft^2 = -6\ ft(62.4\ lb/ft^3) - (h_1 + h_2)(62.4\ lb/ft^3) + h_2(42.40\ lb/ft^3) + h_1(62.4\ lb/ft^3)$$

$$-391.3488\ lb/ft^2 = -374.4\ lb/ft^2 - \cancel{h_1(62.4\ lb/ft^3)} - h_2(62.4\ lb/ft^3) + h_2(42.40\ lb/ft^3) + \cancel{h_1(62.4\ lb/ft^3)}$$

$$-16.9388\ lb/ft^2 = -h_2(62.4\ lb/ft^3) + h_2(42.40\ lb/ft^3)$$

> Continued

$$-16.9388 \text{ lb/ft}^2 = h_2\left(-62.4 \text{ lb/ft}^3 + 42.40 \text{ lb/ft}^3\right)$$

$$-16.9388 \text{ lb/ft}^2 = h_2\left(-20 \text{ lb/ft}^3\right)$$

$$h_2 = -16.9388 \text{ lb/ft}^2 \cdot \left(\frac{\text{ft}^3}{-20 \text{ lb}}\right) = \boxed{.84744 \text{ ft}}$$

↑ ANS ↑

Note: Rise of Gasoline is equal to Fall of water
∴ New 'h' ($h_1 + h_2$) is .84744 (2) = $\boxed{1.69488 \text{ ft}}$

Part 2.

Minimum size of Monometer to prevent gasoline from entering system.

Current size of monometer using oil = roughly 3 ft on Left Leg
roughly 12 ft on right leg

New monometer using gas (deflected) = roughly 2 ft 2 inches on left leg
roughly 12 ft 10 inches on right leg.

Thus the minimum height of the gasoline manometer to ensure gasoline does not enter system is

$\boxed{154.17 \text{ inches or } 12.85 \text{ ft.}}$ ANS

> See excel spread sheet for solution to part 3 (Mercury Deflection)

Summary:

The deflection due to using gasoline instead of oil is the total change in height (h_2) which is the rise of water and the fall of gasoline. So the answer is $\boxed{h_1 = h_2 = .84744 \text{ ft}}$

The minimum height of the manometer is the shortest possible height which still prevents gasoline from entering the system. Thus, due to the deflection caused in part 1, the shortest possible height is $\boxed{12.85 \text{ ft}}$ roughly.

Materials:

- Water
- Gasoline
- Mercury

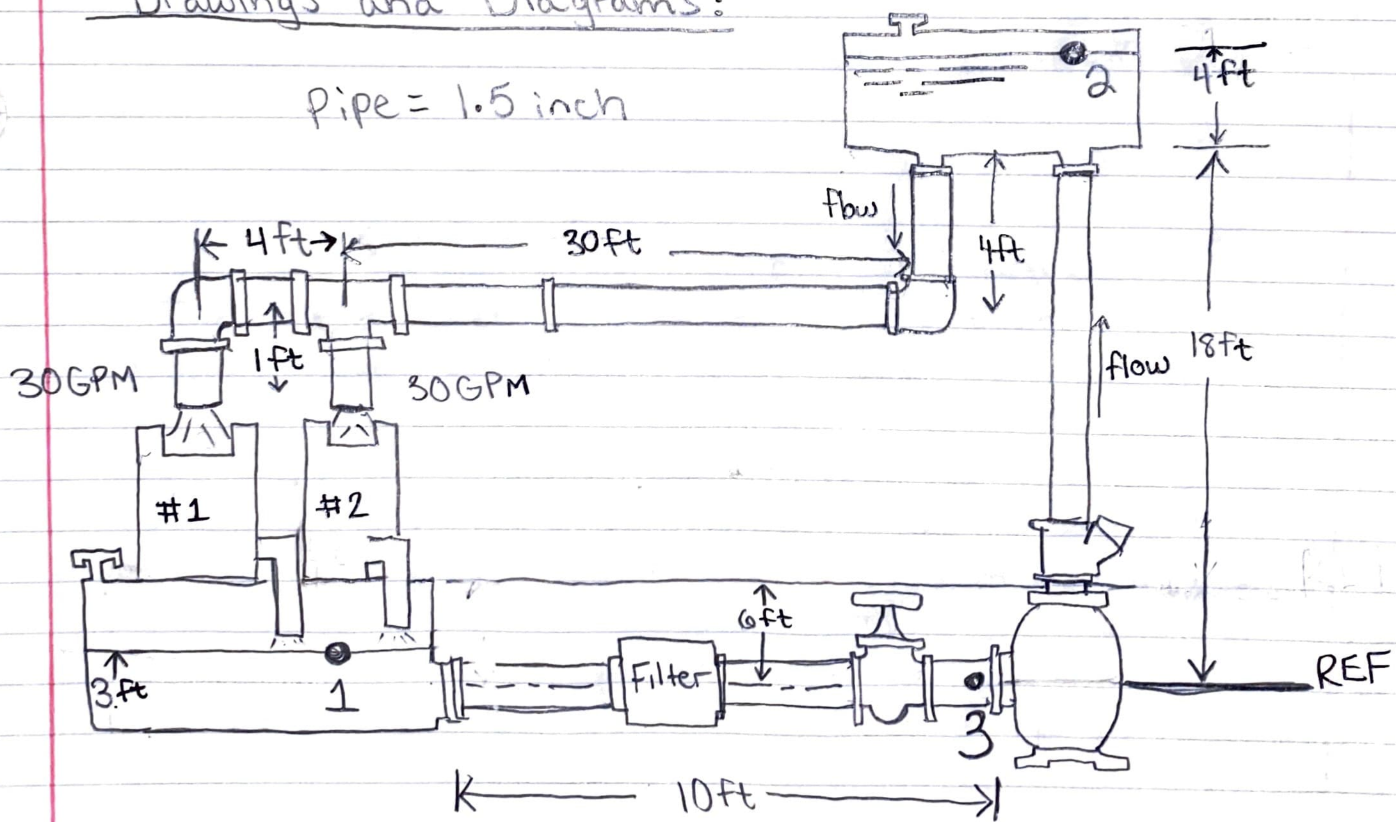
Analysis:

The key of this problem was to recognize the constant pressure difference between points A and B. Due to this, the deflection caused by changing manometric fluids would directly correspond to change of specific gravity. Furthermore, it was essential to realize the change in height of one fluid would be equal and opposite to the change of the respective fluid. Finally, when determining the minimum manometer height, it was simply a matter of accounting for the measured deflection and adjusting height accordingly. My excel spreadsheet displayed proof of accurate arythmatic which makes sense because since gas is a lighter fluid than oil, it makes sense that it would deflect the way it did. In addition, Mercury is much heavier, hence why it's deflection was negative.

Problem 2:

Purpose: Redesign pump system to accomadate the new required flow rate of machines 1 and 2. Accomplish this by: determining new size of commercial steel pipe (schedule 40) that will produce a new total flow rate of 3 m/s. Using selected pipe size, calculate both the pump head (hA), and the power delivered the pump to the coolant. Finally, determine the pressure at the pump inlet.

Drawings and Diagrams:



Sources: • Mott, R., Untener, J.A., "Applied Fluid Mechanics", 7th editions pearson Education, Inc. (2015)

Design Considerations:

- Constant Velocity (in system)
- Constant pipe size
- Constant properties
- Incompressible fluid
- Pump and pipe size require mean flow velocity of 3 m/s
- Machines require a total volumetric flow rate of 60 GPM

Data and Variables:

- $\gamma_{water} = 62.4\ lb/ft^3$
- $sg_{coolant} = .92$
- $\gamma_{coolant} = 57.408\ lb/ft^3$
- Dynamic Viscosity $= 3.6 \times 10^{-5}\ lb \cdot s/ft^2$
- Filter resistance Coeficient $= K = 1.85$
- $Q = VA$

For schedule 40 Commercial steel pipe $1\frac{1}{2}$ inch:

- Inner Diameter = 1.61 inches = .1342 feet.
- $\varepsilon = 1.5 \times 10^{-4}$
- Flow area = $.01414\ ft^2$

Procedure: To begin the problem requires selecting the proper pipe size to achieve desired functions. This will be done by recognizing that flow rate and volumetric flow rate are constants. Thus, by manipulating the volumetric flow rate equation to solve for area. Doing so will determine the desired pipe size which will correspond to the area calculated. Next, to determine both pump head and power delivered to pump, the systems total loss due to friction (h_L) will be computed using the length, size, and constant values of the selected pipe, along with concidering the friction loss due to fittings, entry, exit, filter, and valves.

> Continued

Furthermore, using bernoulies equation in respect to chosen points and refrence (see figure 1) the equation will be manipulated to achieve desired values. Lastly, by chosing points 1 and 3 (see figure) the pump is essentially eliminated from the equation, which will allow for easy manipulation of bernoulies to determine the inlet pressure at the pump.

Calculations:

Determine pipe size:

$$Q = VA \rightarrow Q = 60 \text{ gpm} = (60\text{gpm})\left(\frac{1\text{ ft}^3/\text{min}}{7.48\text{gpm}}\right)\left(\frac{1\text{ minute}}{60\text{ sec}}\right)$$

$$Q = .1343\text{ ft}^3/\text{s}$$

$$V = 3\text{ m/s} = \left(\frac{3\text{m}}{\text{s}}\right)\left(\frac{3.281\text{ Ft/s}}{1\text{ m/s}}\right)$$

$$V = 9.845\text{ ft/s}$$

$$Q = VA,\quad A = \frac{Q}{V} = \frac{.1343\text{ Ft}^3/\text{s}}{9.845\text{ Ft/s}} = .01364\text{ feet}^2$$

∴ For a required Area, the best pipe size selection is $1\frac{1}{2}$ inch with a flow area of .01414

↳ Next page

$$\boxed{\text{Pipe Size} = 1\tfrac{1}{2}\text{ inch}}$$ ANS

> Calculations Continued:

Determine total Friction loss: Chapter 10 Table 10.4

Fittings / valves		L_e ID	Friction Factor (ft)
Swing:	1	100	For $1\frac{1}{2}$ inch
90° elbow:	2	30	Sched 40 commercial
T fitting:	1+1	20 (run) 60 (branch)	steel pipe:
Filter:	1	Given	$f_t = .020$
Gate:	1	8	(Chapter 10 Table 10.5)

For straight runs of pipe,
use Darcy's equation for energy loss (chapter 8 pg. 183)

$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g}$ where $f = .020$, $D = .1342$ ft, $v = 9.845$ ft/s and L = total length of flow stream.

↳ $L = 20\text{ ft} + 4\text{ ft} + 30\text{ ft} + 4\text{ ft} + 2\text{ ft} + 1\text{ ft} + 10\text{ ft}.$

$L = 71\text{ ft}$

$\therefore$ $h_L(\text{straight runs}) = (.020) \times \left(\frac{71\text{ ft}}{.1342\text{ ft}}\right) \times \left(\frac{9.845\text{ ft/s}^2}{2(32.2\text{ ft/s}^2)}\right)$

Pipe $h_L = \underline{15.93\text{ ft}}$ ★ $\frac{v^2}{2g} = 1.51$ ★

h_L Swing $= K = f_t(L_e ID) = .020(100)(1.51\text{ ft}) = \underline{3.02\text{ ft}}$

h_L 90° $= .020(30)(1.51\text{ ft}) = .906\text{ ft}(2) = \underline{1.812\text{ ft}}$

h_L T $= .020(20)(1.51\text{ ft}) + (.020)(60)(1.51\text{ ft}) = \underline{2.416\text{ ft}}$

h_L Filter $= K = 1.85$, $1.85(1.51\text{ ft}) = \underline{2.7331\text{ ft}}$

h_L Gate $= .020(8)(1.51\text{ ft}) = \underline{.2416\text{ ft}}$

Entry and Exit loss: (Chapter 10 pg. 231-237)

Entry Loss $= h_L = K\left(\frac{v^2}{2g}\right)$

For Square Edge pipe,

$K = .5$ $h_L = .5(1.51\text{ ft}) = .755(2) = \underline{1.51\text{ ft}}$

Exit loss $= h_L = 1\left(\frac{v^2}{2g}\right)$

$h_L = (1.51\text{ ft})(1)(3)$

$h_L = \underline{4.53\text{ ft}}$

> Calculations Continued

$$\text{Total } h_L = 15.93\,ft + 3.02\,ft + 1.812\,ft + 2.416\,ft + 2.7331\,ft + .2416\,ft + 4.53\,ft + 1.51\,ft$$

$$\text{Total } h_L = \underline{32.23\,ft}$$

Determine Pump head and Power delivered to coolant:
- Using points 1 and 2 (see figure)

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

* Since pressure and velocity are equal at points 1 and 2, equation can be rewritten as:

$$z_1 + h_A = z_2 + h_L$$

> To solve for pump head (h_A): $h_A = z_2 - z_1 + h_L$

So, $h_A = 22\,ft - 3\,ft + 32.23\,ft$ $\therefore$ $\boxed{h_A = 51.2\,ft}$ ANS

> To Solve for power delivered to coolant:

$P_A = h_A \gamma Q$ (Chapter 7 pg. 162)

$$P_A = (51.2\,ft)(57.408\,lb/ft^3)(.1343\,ft^3/s) \,/\, 550$$

OR $P_A = 394.7466\,lb\,ft/s \left(\frac{.0018\,HP}{1\,lb\,ft/s}\right)$

$$\boxed{P_A = .71\,HP}$$ ANS

> Calculations Continued

Find: Pressure at pump inlet between points 1 & 3 (see figure)

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

NOTE: hA is not used since points 1 and 3 have no pump between them. Z_3 is not used since point 3 is on ref.

$$\frac{P_3}{\gamma} = -\frac{V_3^2}{2g} + Z_1 - h_{L13}$$

OR

$$P_3 = \gamma\left(-\frac{V_3^2}{2g} + Z_1 - h_{L13}\right)$$

Before solving, find new h_L between points 1 & 3

$h_{L13} =$ Loss due to:
- entry: $K\left(\frac{V^2}{2g}\right) = .5(1.51\text{ft}) = \underline{.755\text{ft}}$
- filter: $1.85(1.51\text{ft}) = \underline{2.416\text{ ft}}$
- gate: $.020(8)(1.51\text{ft}) = \underline{.2416\text{ ft}}$
- pipe: $.020\left(\frac{10\text{ ft}}{.1342\text{ ft}}\right)(1.51\text{ft}) = \underline{2.25\text{ft}}$

Total $h_{L13} = 5.663$ ft

$$V_3 = \frac{Q}{A} = \frac{.1343\text{ ft}^3/\text{s}}{.01364\text{ ft}^2/\text{s}}$$

$V_3 = 9.845$ ft/s (same)

SO: $$P_3 = 57.408\ \frac{\text{lb}}{\text{ft}^3}\left(\left(-\frac{9.845\text{ ft/s}}{2(32.2\text{ ft/s}^2)}\right)^2 + 3\text{ ft} - 5.663\text{ ft}\right)$$

$$P_3 = 57.408\text{ lb/ft}^3\left(-1.51\text{ ft} - 2.663\text{ ft}\right)$$

$$P_3 = -239.56\text{ lb/ft}^2\left(\frac{1\text{ psi}}{144\text{ lb/ft}^2}\right) = \boxed{-1.66\text{ Psi}}$$

ANS

Summary:

In order for the system to operate as desired with a flow velocity of 3 m/s and a volumetric flow rate of 60 GPM, the most suitable pipe size is $1\frac{1}{2}$ inch pipe. Under the given circumstances with the pipe selected, the total friction loss in the system (h_L) will be 32.23 ft. Furthermore, (h_A), the pump head of the new system was measured to be 51.2 ft. Given the calculated pump head, the power delivered from the pump to the coolant was determined to be .71 Horse power. Lastly, the pressure at the inlet of the pump (using points 1 and 3) was calculated and found to be -1.66 psi.

Materials:

71 ft $1\frac{1}{2}$ inch pipe
1 pump
Coolant
fittings & Valves

Analysis:

The key of this problem was to recognize that volumetric flow rate and velocity were essentially constants, therefore solving for area yielded proper pipe dimensions. The next important step was to realize h_L consisted of multiple components of friction loss. When considering the values obtained through both calculations and the excel spreadsheet, almost all results were exceptionally close respectivley. This would imply that the performed math was done correctly assuming the procedure used was correct. The values obtained do seem to make very much sense. For example, it's clear that

Analysis Continued

the values obtained head (HA) directly correlated to both Horsepower and operation cost. The Uniform nature of the various pipe sizes seems to display the accuracy of the solutions provided. When considering the graph on excel, it seems the best pipe size to use (when considering both installation and operation) would infact be the chosen $1\frac{1}{2}$ inch pipe. This is because it is between the two extremes seen in 1 inch and 2.5 inch. The 1 inch pipe is much Cheaper to install, but extremely inefficient due to it's very high velocity, friction loss, and Horse power. Comparing the 2.5 inch pipe, it's high efficiency is greatly overshadowed by its high installation cost. The only two options worth considering are $1\frac{1}{2}$ inch and 2 inch pipe. However, Since the $1\frac{1}{2}$ inch pipe has a slightly lower total cost, it is the obvious choice and the solution to this design problem.