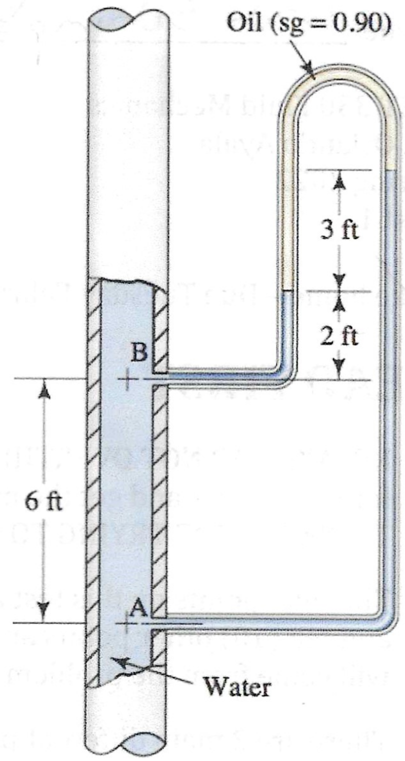
1) For the manometer shown in the figure, the pressure difference between point A and B was calculated and it was found to be 2.7177psi. What would be the deflection in the manometer if instead of using oil with sg=0.90 you use gasoline? What is the minimum height of the manometer so the gasoline does not go into the system?

Using an excel spreadsheet, run the calculations again. Then determine the deflection for the case of using mercury as the manometric fluid.

Please, look at the results you got and make comments about them in the "analysis" section of your solution. Why do they make sense?



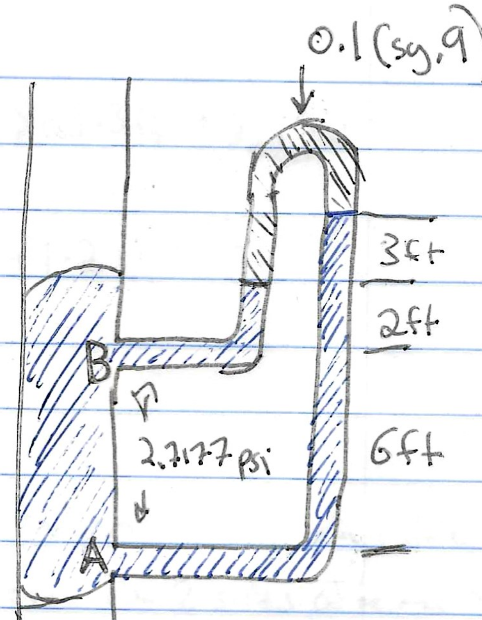
2) The system shown in the figure was designed to handle a total of 30 gpm of coolant. The owners of the company realized that the coolant needed for Machines #1 and #2 are different to what they had estimated initially. Instead of 20 gpm and 10 gpm, they actually need 30 gpm for each machine exactly. Thus, they need a new pump to deliver the new total flow rate of coolant. The coolant then flows back to the machines as needed, by gravity. The coolant has a specific gravity of 0.92 and a dynamic viscosity of 3.6×10^{-5} lb.s/ft^2. The filter has a resistance coefficient (K) of 1.85 based on the velocity head in the suction line.

You are hired to redesign for now only the pumped system, but we do not know what the best pipe size would be for this new flow rate. Here it is what you need to do:

a. Pick a commercial steel pipe Schedule 40 that will give you a mean flow velocity of about 3m/s with the new total flow rate (do not forget there are two machines in the upper system and one pipe in the pumped system).
b. With the selected pipe, compute the pump head and the power delivered by the pump to the coolant. Also, compute the pressure at the inlet of the pump.
c. Using an excel spreadsheet, run the calculations again.
d. Using an excel spreadsheet, run the calculations again using different steel pipe Schedule 40 sizes. Pick two pipe sizes smaller than the one you selected on part a, and two pipe sizes larger than the one you selected on part a. Keep in mind that the fluid velocity will change for every pipe size while the flow rate is the same for all cases.
e. For each of the pipe sizes, estimate the cost of installation using the pipe cost list below and consider than labor, transportation, and pump costs ammount for about 40% of the pipe cost. Include a 15% extra for unforseen costs. Make a table of the installation costs in excel.

Test 1

Problem 1



- Through visual inspection, P_A is greater than P_B, because the water on the manometer is higher on the A side.

$$P_A = 2.7177 + P_B$$

first, I will find P_A and P_B

$$P_A = P_B - \gamma_{water} \cdot 2ft \cdot - \gamma_{0.1} \cdot 3ft \cdot \frac{12in}{1ft} + \gamma_{water} \cdot 11ft \cdot \frac{12in}{1}$$

$2.7177_{psi} = (P_A - P_B)$ ~~B~~

Finding pressure isn't necessary, the Delta is enough data

According to apendix, Sg of gasoline = 0.68

Sg of mercury = 13.54

With gasoline, Since the Sg is less than oils, the height will have to be much taller so that

SO I will assume pressure at B to be 0 - therefore pressure @ A is 2.7177 psi

for gasoline in the manometer

$$2.7177_{psi} = 0 - (1 \cdot 0.1ft) - (.68 \cdot x \cdot 12 + (x + 6 \cdot 12 \cdot 1)$$

.68

$-8.16x + 12x + 72$

-69.2823 $\quad 3.84x \quad x = 18.04 ft$

Incorrect

Pressure @ A and B

$P_A - P_B = 2.7177_{psi} = P_A - \gamma_w \cdot 11ft + \gamma_{0.1} \cdot 3ft + \gamma_{water} \cdot 2ft$

$2.7177 = P_A - 1 \cdot 11 + 0.9 \cdot 3 + 1 \cdot 2$

$P_A = 9.0177 psi$

$P_B = 6.3 psi$

↓

SO, since P_A and P_B are known i will calculate for the height, x, between the 2 sides of the manometer using

$P_B = P_A - (\gamma_{water} \cdot (6' + 2' + x')) + (\gamma_{gas} \cdot x) + (\gamma_{water} \cdot 2')$

$6.3_{psi} = 9.0177 - (1 \cdot 6' + 1 \cdot 2' + 1 \cdot x') + 0.68 \cdot x' + 1 \cdot 2'$

$6.3 = 3.0177 - x + .68x$

$-29.1178 = x$ → ?

I realized this is a mathematical error my excell spits out 10.25' which i believe to be correct

With Mercury,

$6.3_{psi} = 9.0177 - (1 \cdot 8' + 1 \cdot x') + 13.54 \cdot x' + 1 \cdot 2'$

$-x + 13.54x$

$.2617' = x$

Analysis: as stated before, since the Sg of gasoline is less than water, far more of it is required to transmit the pressure. Alternatively, if instead of oil mercury is much higher, allowing for much less of it to be used and for a much less deflection distance →

Analysis Cont.

When Starting the problem, I had some issues conceptually finding a way to calculate the pressures. of the total 2hours this problem took me, roughly an hour and a half was just trying to figure out how to set up the problem. What ultimately aided me were the notes I took in class, where the Δp, 2.7177, was $P_A \cdot P_B$, and that was equal to the equation stated previously. for the gasoline, I got a negative number for the height, which I assumed means, as, the gasoline would spill into the pipe, so to prevent against that the minimum height would just be the absolute value of that number.

Problem 2

Sg of coolant = .92, Dynamic Viscosity at 3.6×10^{-5} lb s/ft²

@ first, find the pipe diameter that will give **3 m/s flow Velocity** given is all in feet, so

$V = 3\ m/s = 9.84\ ft/s$ via google

30 gal/min through 2 pumps, so total flow rate is **60 gal/min** → convert to feet³/sec

$60\ gal/min = .1336\ ft^3/sec = Q$

from notes, $V = Q/A$, so $A = Q/V$

* Black pen ran out ink

$$A = \frac{.1336}{9.84} = 0.01357\ ft^2$$

Choose pipe with area of 0.01357

$$A = \frac{1}{4}\pi d^2, \quad \sqrt{\frac{0.01357 \cdot 4}{\pi}} = d \qquad d = .1314\ ft \cdot \frac{12\ in}{1\ ft}$$

1.57" d

So, since the next step up is 2" pipe, which would have increased flow and less pressure, the best fitting pipe would be the 1½" schedule 40

→

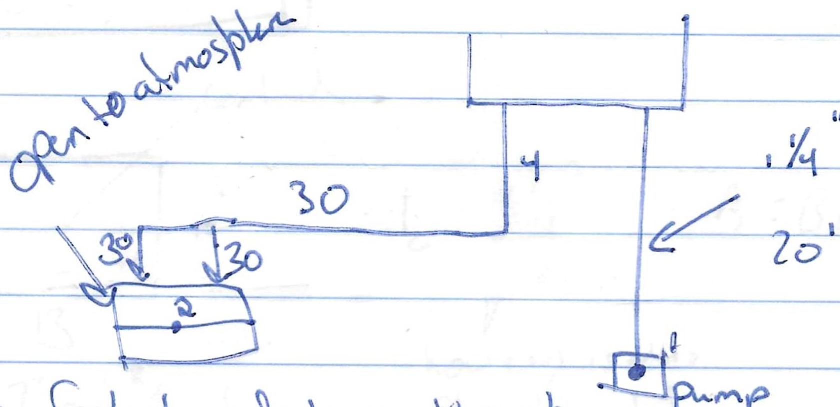
(b)

with the pipe, compute pump head, h_A

SO, $Q_{in} = Q_{Out}$, or $V_{in} A_{in} = V_{out} A_{out}$

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

friction factor for 1½" pipe = 0.02 as per table 10.5



*Since Coolant needs to go through the pump, and end up getting deposited in the collector tank, I will put my 2 points there. @the collector tank, there is no pressure @ the surface since it is open to atmospheric pressure

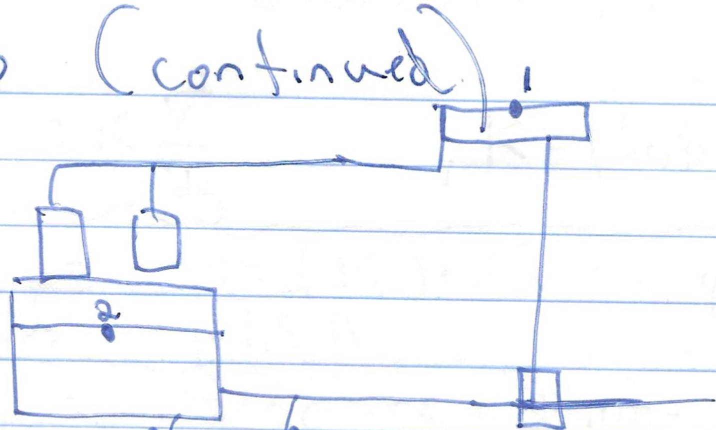
*SO

no z

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

Not enough is known of the pump, therefore, I will put the second point on the upper tank

6 (continued)



$$h_A + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_R + h_L$$

pumphead, no pressure, no velocity, no pressure, no velocity, no turbine

$$h_A + z_1 = z_2 + h_L$$ ← losses due to friction

height from baseline → use base line on given drawing. less room for error with simple math

Calculate h_L

$h_L = \sum h_{1-n}$ → What is known: on pg 242
There is a table with friction losses

as per pg 241, $K = (L_e/D) f_T$ filter has a K value of 1.85

$L_e = KD/f_T$

System has
- 2 90° bends 1
- 1 T joint 2
- 1 filter 3
- 1 swing check 4.
- 1 gate valve 5
- Straight pipe 6 →
- entrance/exit 7

Pipe Length	Diameter
30+4+1+4 ft	1 1/2" (calc)
18 ft	1 1/4"
10 ft	2"

* All factors here are grabbed from the tables on 241/2/3

$$h_L = K\frac{V^2}{2g} \quad , K = (L_e/D) f_t$$

h_{L1} elbows = $K = (30) \cdot .02 = .6 \cdot \left(\frac{9.84^2}{2 \cdot 32.2}\right) = .902$

$= 1.80$ ft

h_{L2} = $K = (20) \cdot .02 + (60 \cdot .02) = 1.6$

flow through run   flow through branch

T branch

$1.6 \cdot \left(\frac{9.84^2}{2 \cdot 32.2}\right) = 2.405$ ft

h_{L3} filter with K of $1.85 \cdot \left(\frac{9.84^2}{32.2 \cdot 2}\right) = 2.78$ ft

1.5035

h_{L4} $K = (100) \cdot .02 = 2 \cdot 1.5035 = 3.007$ ft

Swingcheck

h_{L5} $K = (8) \cdot .02 = .16 \times 1.5035 = .24056$ ft

Gate Valve

h_{L6} Straight pipe

Diameter	f_t	Length	K	H_L
1 1/4"	0.021	20'	.42	.63147
1 1/2"	0.02	4+30+4+1'	.78	1.17273 = Σ 2.0898'
2"	0.019	10'	.19	.285665

h_{L7} Entrance / Exit, $\frac{V^2}{2g} = 1.5035 \cdot 2$

one for entrance, one for exit

3.007 ft

$\sum h_{L\,1-7} = 15.329$ ft

→

b Continued

SO:

$h_A + z_1 = h_L + z_2$

$h_A + 3ft = 15.329ft + 22ft$

$\boxed{h_A = 33.329\ ft}$ ← Pump Head

Now, calculate Hp delivered by the pump
As per page 162 in the book,

$P_A = h_A \gamma \cdot Q$

$P_A = 33.329_{ft} \cdot \gamma \cdot .1336 ft^3/s = 33.329 \cdot 1.7848 \cdot .1336$

$\gamma = .92 \cdot 1.94\ slugs/ft^3 \cdot 32.2 ft/s^2$

$\frac{lbft}{s} \Rightarrow W = 255 lb/s \cdot 1.356 =$ | 255 lb/s

(B) $\boxed{P_A} = 346\ W$

Power delivered from pump into coolant

* Since pipe is open at the end, pressure is [atmospheric]

Analysis: After completing this problem, I feel very confident with my solution. I originally felt very confused and overwhelmed with this problem, but by breaking it down in digestable pieces it was far easier, albeit time consuming.

→

In my excell sheet, with the graph made, It is clearly shown that not only does the 1 1/2" pipe give you the closest velocity to the desired, but gains the lowest total cost between operation + Installation. It was interesting to see the cost of electricity required to pump fluids through a smaller pipe, I would not have predicted that to have the impact it did.

Alternatively, If i did choose the 2" pipe over the 1.5" pipe, the difference in cost would have been very close - only ~50$. This is interesting as both flow velocities would have been close to the desired, with the 1.5 just being a hair above it. If 3 m/s was a hard constraint, and there was no room for fluid moving quicker than that, the 2" pipe would have been a fine substitution.

Forgive my sloppy handwritting, I've put many hours into this, roughly 8 today (2.15) alone.

Thank you for your timely answers to my texts and questions!

Erich Schimpf

Pipe nominal size (in)	Cost per 6 ft
½	$12.95
¾	$17.95
1	$23.95
1 ¼	$28.95
1 ½	$33.95
2	$46.95
2 ½	$71.95
3	$92.95

f. For each of the pipe sizes, estimate the cost to maintain the system operating for 2 years knowing that the electricity cost is about $730 per kW constantly used during those 2 years. Make a table of the operation costs in excel.

g. Add both costs (operation and installation) and plot on the same graph the cost of installation, the cost of operation, and total cost as a function of nomical pipe diameter.

h. Please, look at the results you got and make comments about them in the "analysis" section of your solution. Why do they make sense? What do you think is the best pipe size to use in this system?