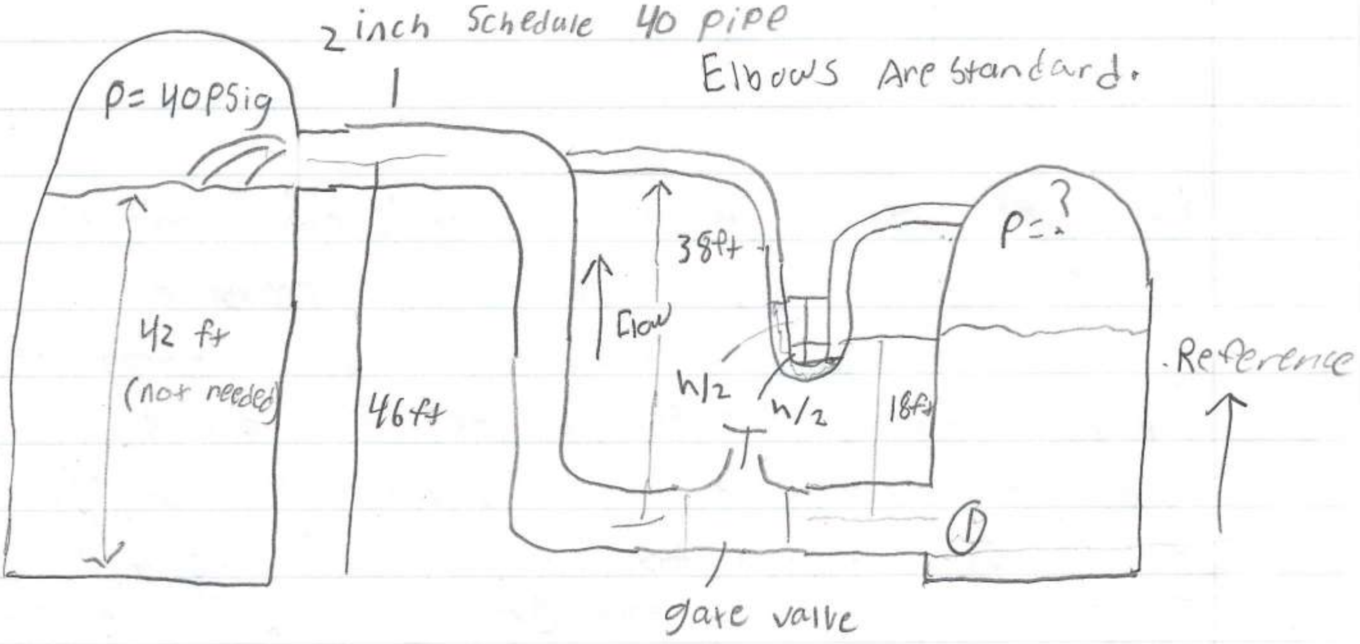
Fluid Mechanics Test 1 Ben Smithson

Question 1.

Purpose: The purpose of this problem is to determine the air pressure in the small tank that is required in order to push 250 gallons of ethyl alcohol through the system per minute. This task requires considerations for mercury, energy loss (pipe, valve, elbow), as well as Bernoulli's equation.

Drawing / Diagram:



Sources: Applied Fluid Mechanics 7th edition, Robert L Mott & Joseph Untener

Design considerations: 1. Incompressible Fluids (mercury, ethyl Alcohol)

2. Water & alcohol don't mix
3. Pressure problem with $P_2 = 40$ PSIG
4. Temp $= 77°F$

Data & Variables:

P_2 tank $= 40$ PSIG

$T = 77°F$

h fluid from gate $= 18$ ft

2 in Schedule 40 pipe diameter $= 2.067$ in

Procedure: first write out Bernoulli's equation to find pressure at P_1. In order to find pressure we must first find the velocity of liquid through the pipe, as well as the energy loss through the pipe, gate valve, and elbows. Next, we must use the pressure found to find the manometer height. This is found using the Δp equation. For the second part of the problem, using the bernoulli's equation without velocity, or energy loss, we are able to find the pressure in the tank. Using this pressure, we are able to find the measurment of mercury in the manometer using Δp equation. Then finally in the last part of the problem, we use excel to find multiple pressures & flow rates using the equations found by hand.

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Problem 1. continued.

Calculations:

Bernoulli's equation : $\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L\,12}$

Appendix B:

Ethyl Alcohol : $sg = 0.787$ $\gamma = 49.01\ lb/ft^3$

Mercury : $sg = 13.54$ $\gamma = 844.9\ lb/ft^3$

$\nu = 1.37 \cdot 10^{-5}$ $\nu = 1.22 \cdot 10^{-6}$

h_L Energy loss

$h_L\ pipes = \overset{?}{f}\ \frac{L}{D}\ \frac{V^2}{2g}$ $= \frac{36ft}{2.067in = 0.172ft}$ · $\frac{V^2}{2g}$? (need velocity) $g = 32.2$

$Q = V \cdot A$ $Q = 250$ gal per min $= 0.557\ ft^3/sec$

$V = \frac{Q}{A}$

$A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.172)^2 = 0.0232\ ft^2$

$V = \frac{0.557}{0.0232} = 24\ ft/s$

back to energy loss

h_L pipes now that we have velocity

$Re = \frac{\rho V D}{\mu} = \frac{VD}{\nu}$ Appendix

$$Re = \frac{24\,ft/s \cdot 0.172\,ft}{1.37 \cdot 10^{-5}} = 301313.86 = 3.013 \times 10^5$$

$\frac{D}{\epsilon}$ = ϵ steel = 1.5×10^{-4} (Table 8.2 Pipe roughness) pg 183

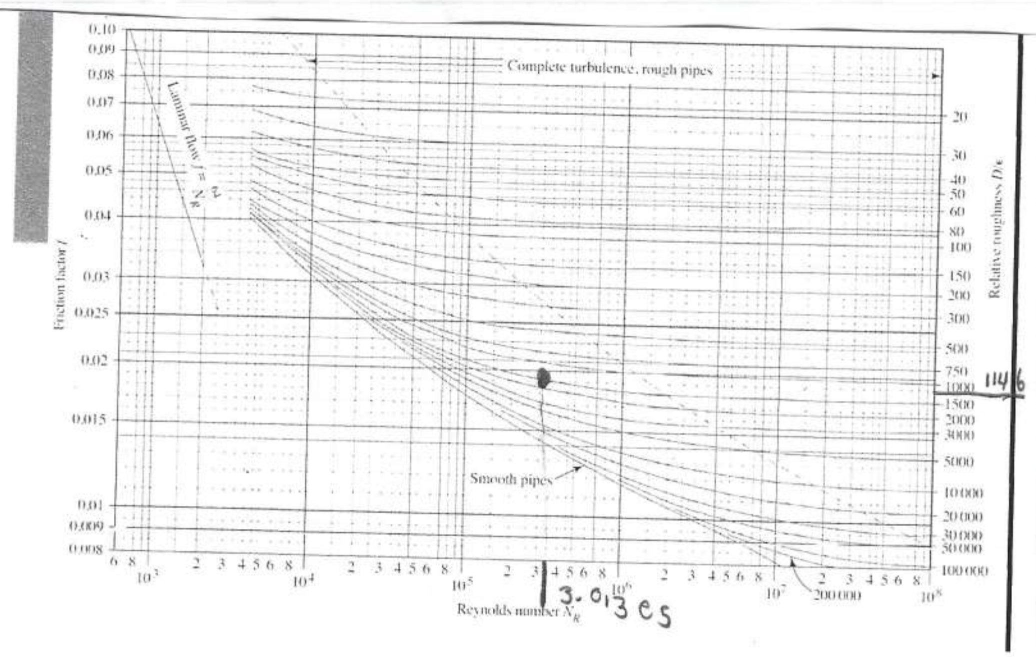
$$\frac{0.172}{1.5 \cdot 10^{-4}} = 1.146\,E{-5} = 1146$$

Mood's chart

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7D/\epsilon}\right) + \left(\frac{5.74}{N_R^{0.9}}\right)\right]^2}$$

$$f = \frac{0.25}{\left[\log\frac{1}{(1146)} + \left(\frac{5.74}{(3.013 \cdot 10^5)^{0.9}}\right)\right]^2} = 0.020$$

$F_T = 0.020$



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h_L pipes $= f \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$ major loss

$g = 32.2$

$L = 36 + 36 + 38 = 110$

h_L pipe $= 0.020 \cdot \frac{110ft}{0.172ft} \cdot \frac{(24 ft)^2}{2 \cdot 32.2} = 114.4$

minor loss

h elbow $= K \frac{V_2}{2g}$ $K = 20 \,(Ft) = 20\,(0.020)$

h elbow $= 20\,(0.020) \frac{24ft^2}{2 \cdot 32.2} = 3.57$.

h elbow $= 3.57 \cdot 2$ (elbows) $= 7.155$

h gateV $= K \frac{V_2}{2g}$ $K = 8\,(Ft) = 8\,(0.020)$

h gateV $= 8(0.020) \frac{24ft^2}{2 \cdot 32.2} = 1.43$

h_{LB} = minor (elbows & gate valve) + major (pipes)

$h_{LB} = 114.4 + 7.155 + 1.43 = 122.98$

bernoullis equation:

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

$$P1 = P_2 + \gamma\left(z_1 - z_2 + \frac{V_2^2}{2g}\right) + h_L$$

$$P_1 = P_2 + \gamma \left(z_1 - z_2 + \frac{v_2^2}{2g} \right) + h_L$$

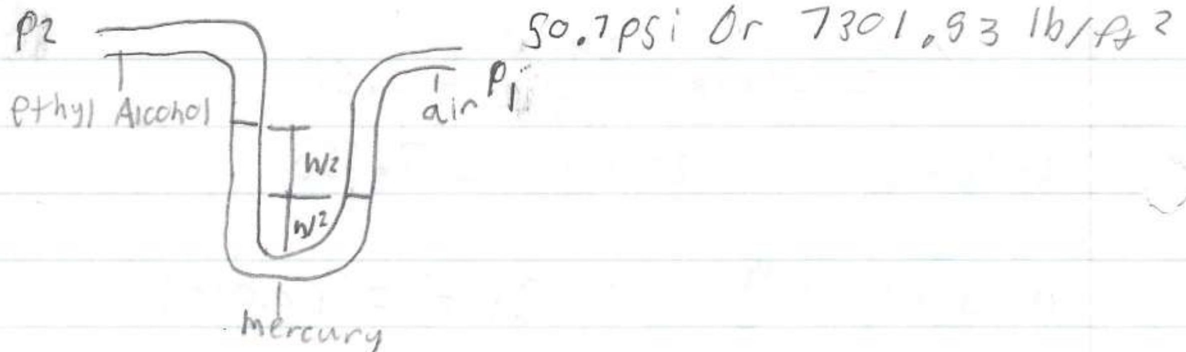
$P_2 = 40psig = 5760\ lb/ft^2$

$$P_1 = 5760 + 49.01\left(38 - 18 + \left(\frac{(24ft/s^2)^2}{2 \cdot 32.2}\right)\right) + 122.98$$

$$\boxed{P1 = 7301.53\ lb/ft^2 = 50.70\ psi}$$

manometer

$\Delta p = \gamma \cdot h$



$$h = \frac{P}{\gamma}$$

$$h = \frac{7301.53}{844.96} = \boxed{8.64\ ft}$$

Question 2.

Purpose: To find the air pressure in tank on the right, at which the flow of ethyl alcohol is zero with no energy losses and where the pipes remain full of alcohol.

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Bernoulli's equation:

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

no velocity or energy loss when flow is at zero

$$P_1 = P_2 + \gamma(Z_1 - Z_2)$$

$$P_1 = 5760 + 49.01(38-18)$$

$$\boxed{P_1 = 6740.2 \text{ lb/ft}^2 \text{ or } 46.8 \text{ psig}}$$

manometer reading at zero flow.

$$\Delta P = \gamma \cdot h$$

$$h = \frac{P}{\gamma}$$

$$h = \frac{6740.2}{844.96} = \boxed{7.97 \text{ ft}}$$

Question 3.

Purpose: To find the air pressure on the right tank for several flow rates using excel as a calculator. Then find the spicific flow rate when the pressure is at 75 psi.

Calcualations:

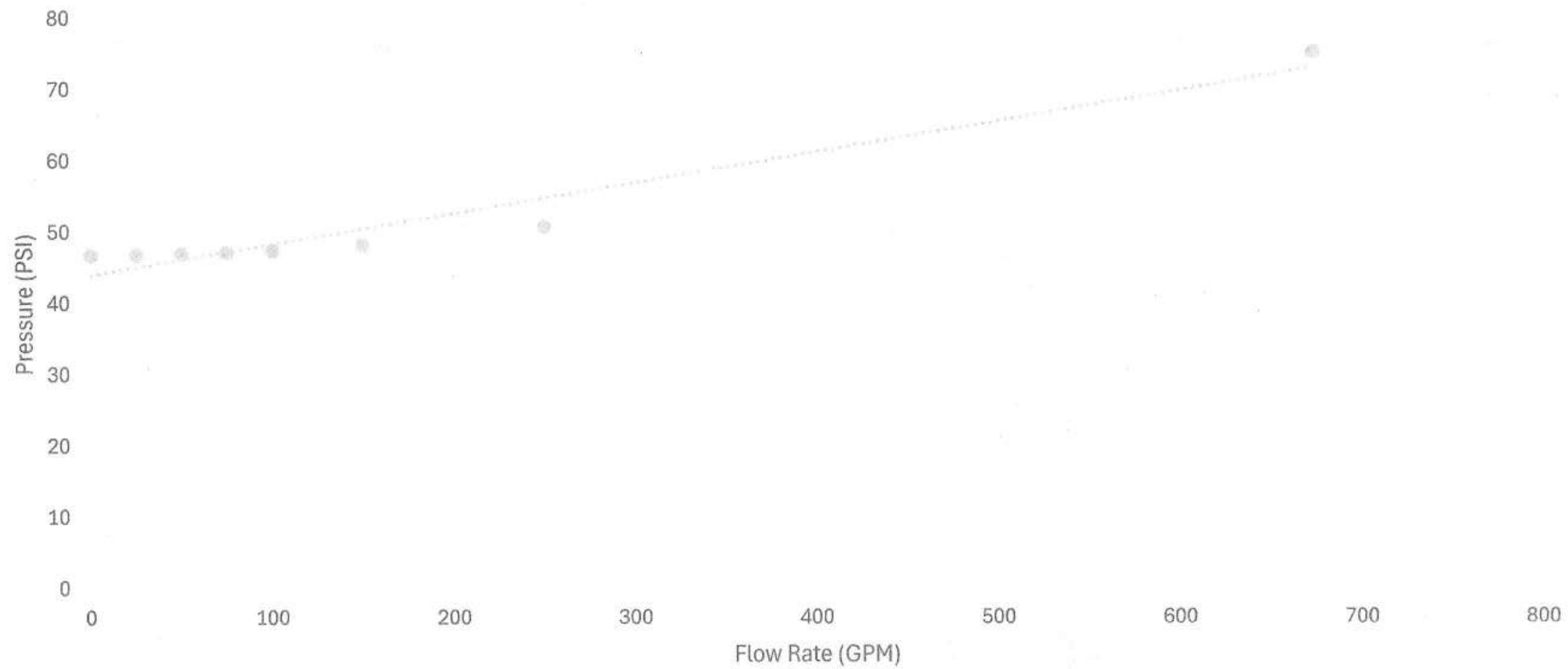
The air pressure in the right tank is at 75psi when the flow rate of the ethyl alcohol is 673.318 Gallons per minute.

Q3 : 673.318 GPM

see excel.

Pressure	Flow Rate	Velocity	Reyonalds Nun	Ft	Major Loss	Minor Loss	Minor Loss	hL
50.70796	250	24.01	301423.3479	0.020	114.4842	7.160464	1.432093	123.0767
48.21628	150	14.41	180854.0087	0.020	41.88025	2.619419	0.523884	45.02356
47.43589	100	9.60	120569.3392	0.021	18.95843	1.185764	0.237153	20.38135
47.16209	75	7.20	90427.00436	0.021	10.84698	0.678429	0.135686	11.6611
46.96592	50	4.80	60284.66958	0.022	4.972503	0.311007	0.062201	5.345712
75.00004	673.318	64.66	811815.063	0.020	816.542	51.07099	10.2142	877.8272
46.84743	25	2.40	30142.33479	0.023	1.342595	0.083973	0.016795	1.443363
46.80694	0	0.00	0	0.000	0	0	0	0

Pressure Vs Flow Rate Test 1 Ben Smithson



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Summary Q1 From these questions, this system has an air pressure in the right tank of 50.70 psi when the tank when the flow rate is 250 gallons per minute. The manometer reads 8.64 ft when this pressure and flow rate is present for problem 1.

Summary Q2: From this question, the system will be at 46.8 psi on the right tank when the flow of ethyl alcohol is 0 gpm. The manometer will read 7.97 ft when the flow is stagnent.

Summary Q3: when using excel, the flow rate of ethyl alcohol will be 673.318 when the pressure in the right tank is at 75 psi.

materials:

ethyl alcohol
mercury
Pressure tanks
manometer

Analysis: The key of this entire test through all the problems is to realize that for this pressure system, when the flow rate increases, then the pressure in the right tank will increase. This can be said vice versa as well, when pressure increases, the flow rate will as well. Also, we can learn that in this pressure system when the flow rate and pressure in the tank go down, then the manometer height will decrease as well.