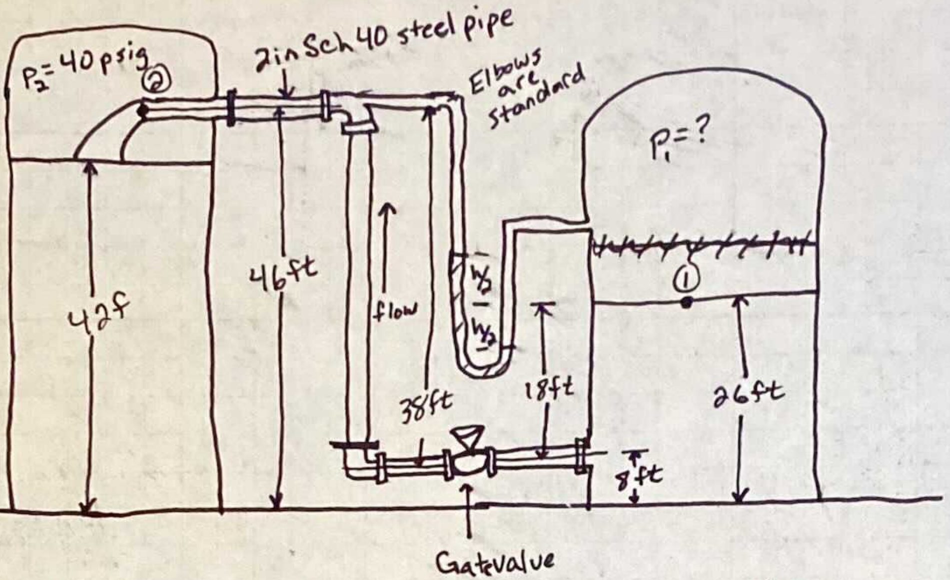
Purpose: Determine required air pressure on right tank to deliver 250gpm of ethyl alcohol. Determine the air pressure at which the flow stops. What will the manometer read when there is no flow. Use excel to determine flow rate at 75psi. Plot pressure vs flow rate.

Diagram:



Sources: Mott & Untener. Applied Fluid Mechanics. 7th Edition. Pearson. 2015

Design consideration: Assume following based on description;

1. Incompressible fluid
2. Temp is 77°F
3. Ethyl alcohol and mercury do not mix.
4. Length of pipe for each horizontal section is 36ft
5. manometric fluid is mercury

Data & variables:

$Q = 250$ gpm
$p_2 = 40$ psi
$z_1 = 26$ ft
$z_2 = 46$ ft

$\gamma_{ethyl\ alcohol} = 49.01\ lb/ft^3$
$\gamma_{HG} = 844.9\ lb/ft^3$
$\epsilon_{steel} = 1.5 \times 10^{-4}$ ft
$\nu = 1.37 \times 10^{-5}\ ft^3/s$

Pipe - 2-in Sch40 steel pipe
$D = 0.1723$ ft
$A = 0.02333\ ft^2$
$L = 36 + 38 + 36 = 110$ ft

Materials: Ethyl Alcohol, Mercury

Procedure: Apply Bernoulli's Equation to determine p_1. Solve for Reynold's Number(N_R) and relative roughness $\left(\frac{D}{\epsilon}\right)$ to determine head loss(h_L) in pipe.

$$\text{Bernoulli's: } \frac{p_1}{\gamma}+z_1+\frac{\cancel{v_1^2}^{\,0}}{2g}-h_L=\frac{p_2}{\gamma}+z_2+\frac{v_2^2}{2g}$$

$$\text{Reynold's }(N_R)\text{: } N_R=\frac{\nu D}{V} \qquad \nu=\frac{Q}{A}$$

Roughness(ϵ) of steel pipe: $\epsilon = 1.5\times10^{-4}$ ft

Use Relative Roughness and Reynolds number to determine friction factor (f) of Moody chart.

Determine head loss(h_L) of pipe using Darcy's Equation

$$h_L=(f)\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

Use these solutions to solve for p_1.

<u>Calculations:</u>

① $Q=\left(250\ \frac{gal}{min}\right)\left(\frac{1\,ft^3/s}{449\ \frac{gal}{min}}\right)=0.5568\ ft^3/s$

$$N_R=\frac{\nu D}{V}=\frac{(23.87\,ft/s)(0.1723\,ft)}{1.37\times10^{-5}\,ft^2/s}=300204=3.00\times10^5$$

From Moody chart

$$\frac{D}{\epsilon}=\frac{0.1723}{1.5\times10^{-4}}=1148.67\rightarrow f\approx0.0205$$

$$h_L=(f)\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)=(0.0205)\left(\frac{110\,ft}{0.1723\,ft}\right)\left(\frac{(23.87\,ft/s)^2}{2\times32.2\,ft/s^2}\right)$$

$$h_L=115.79\ ft$$

① Bernoulli's @ $Q = 250\,\text{gal/min}$

$$\frac{p_1}{\gamma} + z_1 + \cancelto{0}{\frac{v_1^2}{2g}} - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$p_1 = \gamma\left[\frac{p_2}{\gamma} + z_2 - z_1 + \frac{v^2}{2g} + h_L\right]$$

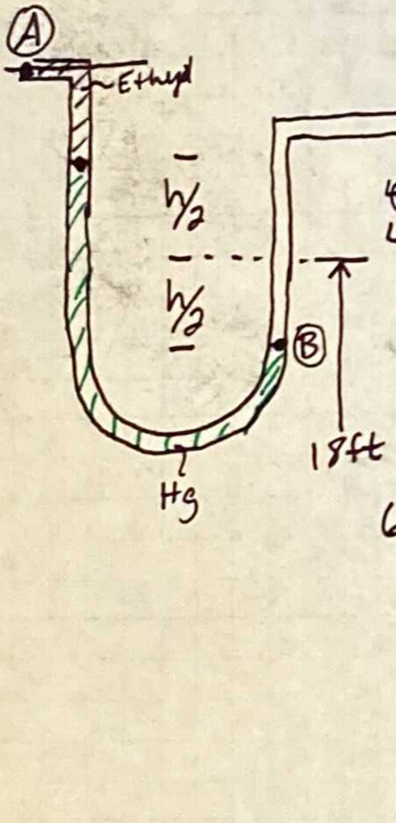
$$p_1 = 49.01\,\text{lb/ft}^3\left[\frac{40\,\text{psi}}{49.01\,\text{lb/ft}^3} + 20\,\text{ft} + \underbrace{\frac{(23.87\,\text{ft/s})^2}{2(32.2\,\text{ft/s}^2)}}_{8.847\,\text{ft}} + 115.79\,\text{ft}\right]$$

$$40\,\text{psi} + 49.01\,\text{lb/ft}^3\,(144.64\,\text{ft})\left(\frac{1\,\text{psi}}{144\,\text{lb/ft}^2}\right)$$

$$40\,\text{psi} + 49.22\,\text{pss}$$

$$p_1 = 89.22\,\text{psi}$$

Manometer:



$$P_A + \gamma_{Ethyl}h + \gamma_{Hg}h = P_B$$

$$P_A + \gamma_{Ethyl}(18 + h/2) + \gamma_{Hg}h = P_B$$

~~40psi+49.01~~

$$40\,\text{psi} + \underline{49.01}\,\text{lb/ft}^3(18\,\text{ft}) + 49.01\,\text{lb/ft}^3(h/2) + 844.9\,\text{lb/ft}^3(h) = 89.22$$

$$882.18\,\text{lb/ft}^2\left(\frac{1\,\text{psi}}{144\,\text{lb/ft}^2}\right) + 49.01\,\text{lb/ft}^3\left(\frac{h}{2}\right) + 844.9h = 49.22$$

$$6.13\,\text{psi} + (24.505 + 844.9)(h) = 49.22\,\text{psi}$$

$$h = \frac{6204.96\,\text{lb/ft}^2}{869.405\,\text{lb/ft}^3}$$

$$\underline{h = 7.14\,\text{ft}}$$

② Pressure when $v = 0 \, ft/s$

p_2 constant at 40 psi

Energy losses = 0 due to no movement

$$\frac{p_1}{\gamma} + z_1 + \overset{0}{\cancel{\frac{v_1^2}{2g}}} - \overset{0}{\cancel{h_L}} = \frac{p_2}{\gamma} + z_2 + \overset{0}{\cancel{\frac{v_2^2}{2g}}}$$

$$p_1 = \gamma \left[\frac{p_2}{\gamma} + z_2 - z_1 \right]$$

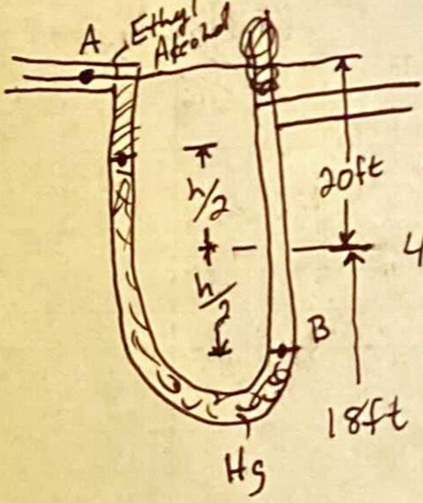
$$p_1 = 49.01 \, lb/ft^3 \left[\frac{40 \, psi}{49.01 \, lb/ft^3} + 20 ft \right]$$

$$p_1 = 40 \, psi + (49.01 \, lb/ft^2)(20 \, ft)\left(\frac{psi}{144 \, lb/ft^2}\right)$$

$$p_1 = 40 \, psi + 6.81 \, psi$$

$$p_1 = \underline{46.81 \, psi}$$

Manometer



[illegible]

$$P_A + \gamma_{Ethyl}(18 + h/2) + \gamma_{Hg}(h) = P_B$$

$$40 psi + \underset{6.13 psi}{49.01 \, lb/ft^3 (18 ft)} + 49.01\left(\frac{h}{2}\right) + 844.9(h) = 46.81 psi$$

$$49.01 \, lb/ft^3 \left(\frac{h}{2}\right) + 844.9 \, \frac{lb}{ft^3}(h) = 0.68 \, psi \left(\frac{144 \, lb/ft^2}{1 psi}\right)$$

$$h(24.505 + 844.9) = 97.92 \, lb/ft^2$$

$$h = \frac{97.92 \, lb/ft^2}{869.405 \, lb/ft^3}$$

$$\underline{h = 0.11 ft}$$

Summary:

At $Q = 250 \frac{gal}{min}$ flow rate the pressure in the right tank $p_1 = 89.22 psi$.

The (h) reading for the manometer at $p_1 = 89.22 psi$ was $h = 7.14 ft$

At no flow rate after pressure dropped to $p_1 = 46.81 psi$

With no flow rate the manometer $h = 0.11 ft$

When the pressure $p_1 = 75 psi$, the flow rate was $Q = 202.85 \frac{gal}{min}$

Analysis:

The pressure requirement increases at a higher rate to increase the flow rate.

The pressure was required to obtain an accurate calculation on the height (h) on the manometer.

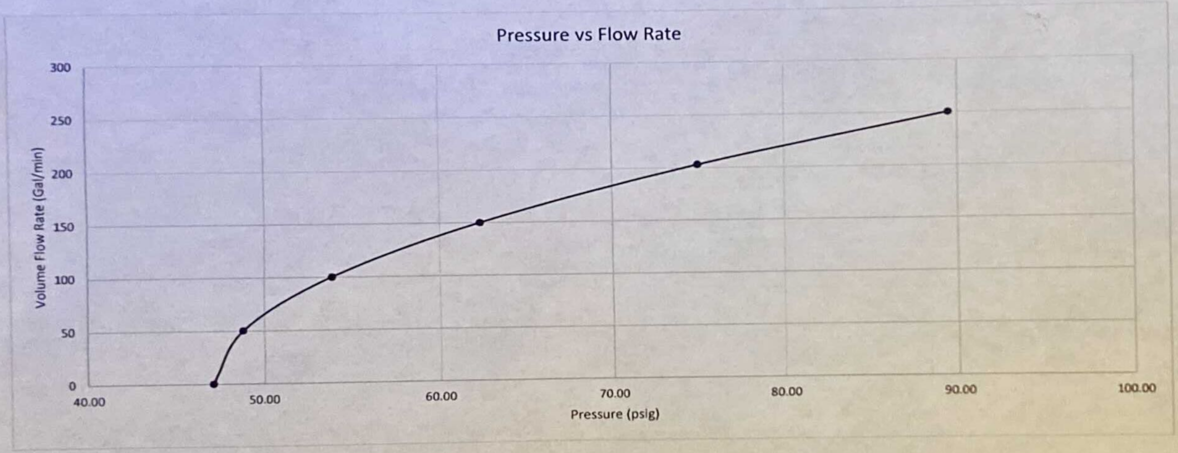
The pressure was higher in the right tank which caused the mercury to be pushed down on the right side.

At no flow rate the pressure was slightly higher which also showed a small height in the manometer. With no flow the Energy losses are also zero.

In conclusion, to obtain a higher flow rate, the pressure must increase at a higher rate.

* See attached graph for visual analysis.

Q	P1	p2	v1	v2	z1	z2	v	hL	A	γ	f	g	L	D	lb/ft^3 to psi
250	89.49	40.00	0.00	23.87	26.00	46.00	1.37E-05	115.75	0.02333	49.01	0.0205	32.2	110	0.1723	0.006944
202.85	75.00	40.00	0.00	19.36	26.00	46.00	1.37E-05	76.21	0.02333	49.01	0.0205	32.2	110	0.1723	0.006944
150	62.35	40.00	0.00	14.32	26.00	46.00	1.37E-05	41.67	0.02333	49.01	0.0205	32.2	110	0.1723	0.006944
100	53.87	40.00	0.00	9.55	26.00	46.00	1.37E-05	18.52	0.02333	49.01	0.0205	32.2	110	0.1723	0.006944
50	48.78	40.00	0.00	4.77	26.00	46.00	1.37E-05	4.63	0.02333	49.01	0.0205	32.2	110	0.1723	0.006944
0	47.08	40.00	0.00	0.00	26.00	46.00	1.37E-05	0.00	0.02333	49.01	0.0205	32.2	110	0.1723	0.006944



Flow Rate at 75 psig 202.85 gal/min