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MET 350

Dr. Ayala

October 1, 2021

Exam 1

1.

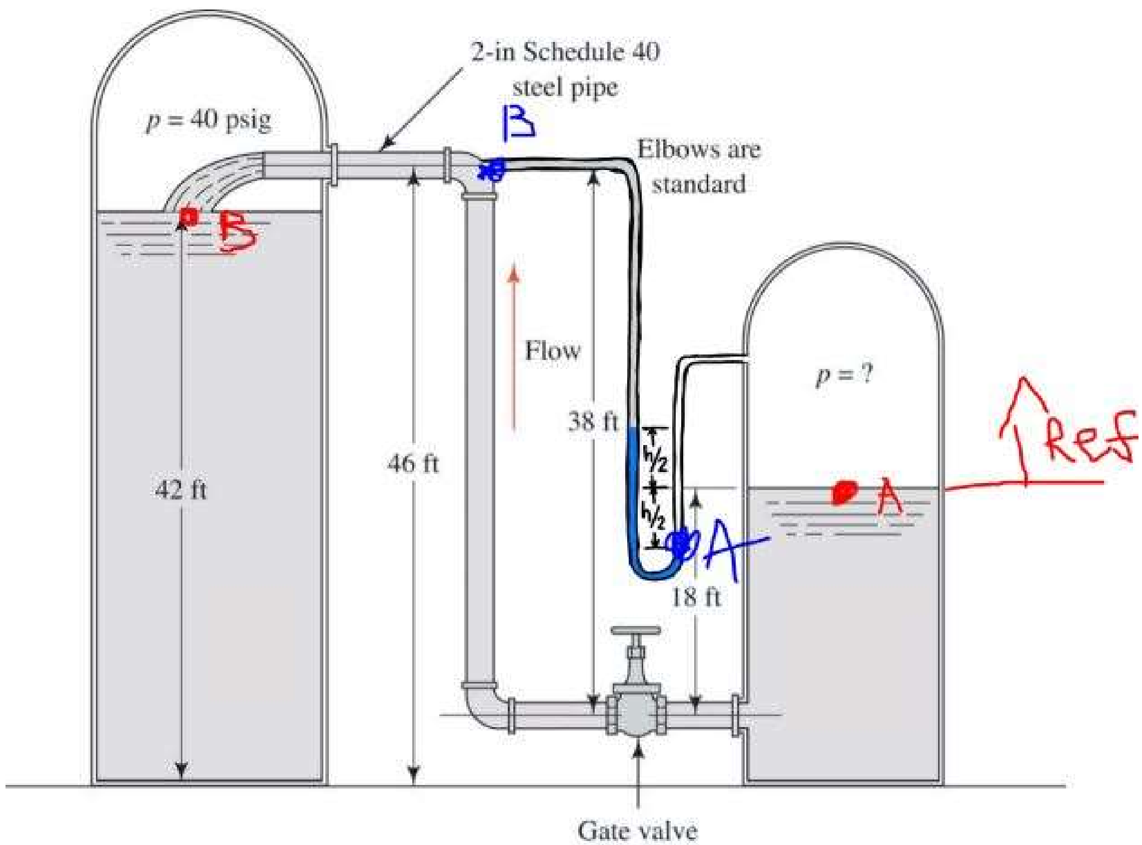
Purpose:

Determine the air pressure in the tank on the right based on a flow rate of 250 gpm. Also, determine the manometer reading and make an excel spreadsheet with the solution.

Drawings and Diagrams:

Points for solving pressure of tank

Points for solving manometer



Sources:

Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)

Design Considerations:

- Constant Properties
- Incompressible Fluids
- Ethyl Alcohol @ 77˚F

Data and Variables:

- γ_{Hg} = 844.9 lb/ft^3
- γ_{ea} = 49.01 lb/ft^3
- I_D = 0.1723 ft
- A = 0.0233 ft^2
- Q = 250 gpm
- N = 6.91 X 10^{-4}

Materials:

- Ethyl alcohol
- Mercury

Procedure and Calculations:

Rearrange Bernoulli's to solve for the pressure at point A using the given flow rate. Find the h_L of the standard elbow and multiply it by 2. Find the h_L of the piping. Find the h_L of the gate valve. Add all of the h_L and plug it into to Bernoulli's to solve for the pressure at Point A.

Using the pressure found in the tank. Rearrange $\Delta P = \gamma \Delta h$ Use the pressure and specific weights of the fluids in the manometer to solve for the missing height.

$$\cancel{h_A} + \frac{P_A}{\gamma} + \cancel{\frac{V_A^2}{2g}} + z_A = \frac{P_B}{\gamma} + \cancel{\frac{V_B^2}{2g}} + z_B + \cancel{h_R} + h_L$$

Solving for P_A $\rightarrow$ $P_A = \gamma\left(\frac{P_B}{\gamma} + (z_B - z_A) + h_L\right)$

$$P_A = 49.01\ lb/ft^3 \left(\frac{5760\ psf}{49.01\ lb/ft^3} + (38 - (-14)\ ft) + 137.77\right) / 144$$

$$\boxed{P_A = 165.95\ psi}$$

Energy Losses $\rightarrow$ $h_L = f_t \frac{L}{D}\frac{V^2}{2g} = 0.002\left(\frac{110\ ft}{0.1723}\right)\left(\frac{623.41\ ft/s}{64.4\ ft/s^2}\right)$

h_L of straight pipes $= 124.51$

k for 90° Bends $= 30(f_t) = 30(0.02) = 0.60$

$h_L = k\left(\frac{v^2}{2g}\right) = 0.60\left(\frac{623.41\ ft/s}{64.4\ ft/s^2}\right) \times 2 = 11.70$

k for gate valve $= 8(f_t) = 8(0.02) = 1.56$

h_L total $= h_{L_{straight}} + h_{L_{90}} + h_{L_{gv}} = 137.77$

$$R_e = \frac{\rho V D}{\eta} = \frac{(1.535\ slugs/ft^3 \cdot 24.97\ ft/s \cdot 0.1723\ ft)}{2.10 \times 10^{-5}\ lb\text{-}s/ft^2} = 313434.1$$

$R_e > 4000$ so flow is turbulent.

$$f_t = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}\right) + \frac{5.74}{R_e^{0.9}}\right]} = \frac{0.25}{\left[\log\left(\frac{1}{3.7 \cdot 1148.667}\right) + \frac{5.74}{313434.1^{0.9}}\right]} = 0.02$$

$$\gamma_{ea}(h_{ea}) + \gamma_{hg}(h) = P_a - P_B$$

$$0.0284\,lb/in^3(456\,in - 214\,in - h/2) + 0.4884\,h\,lb/in^3 = 105.95\,psi - 40$$

$$6.816\,lb/in^2 - 0.142\,h\,lb/in^3 + 0.4884\,h\,lb/in^3$$

$$6.816\,lb/in^2 + 0.4742\,lb/in^3\,h = 65.95\,psi$$

$$-6.816 \qquad -6.816$$

$$\frac{0.4742\,lb/in^3\,h}{0.4742} = \frac{59.134\,lb/in^2}{0.4742\,lb/in^3}$$

$$h = 124.7\,in / 12\,in$$

$$h = 10.39\,ft$$

Summary:

The pressure in the tank on the right is **105.95 psi at a flow rate of 250 GPM.** The manometer reads **10.39 ft** for these conditions.

Analysis:

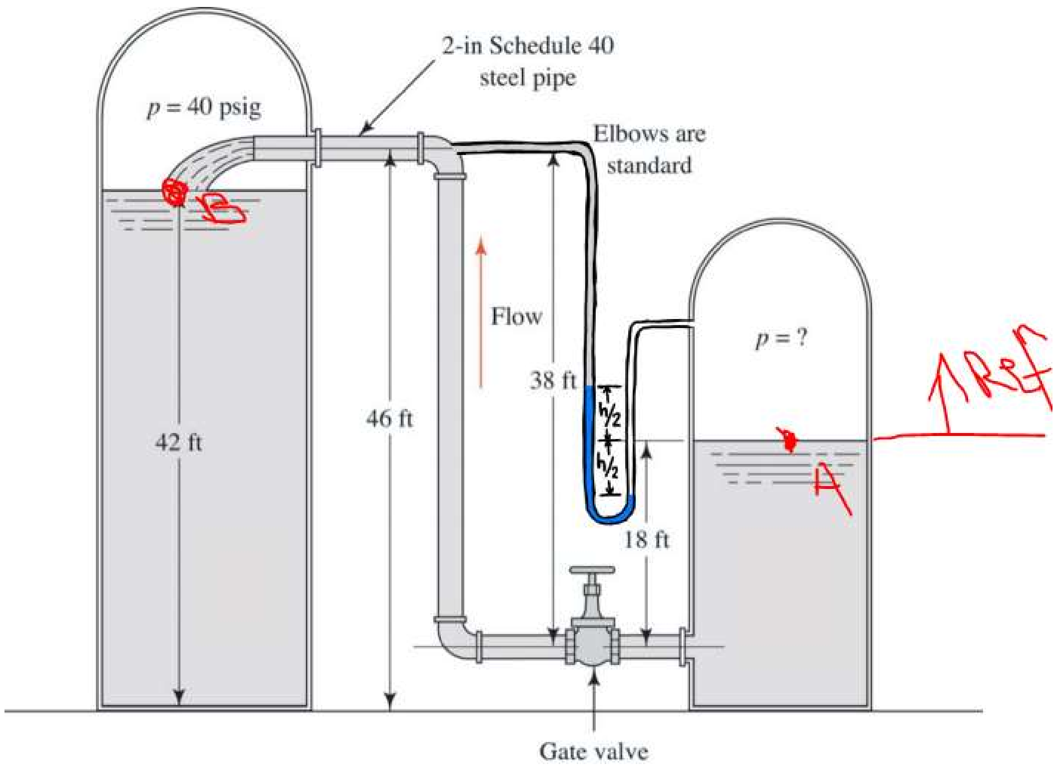
Heat added and heat removed were removed from Bernoulli's equation because the system has no pumps or turbines. Because the points were placed at the surface, velocities of the fluids were assumed to be zero. Pipe bends were assumed to be short radius and the gate valve was assumed fully open. The fluid was found to be turbulent based on a Reynold's number greater than 4000.

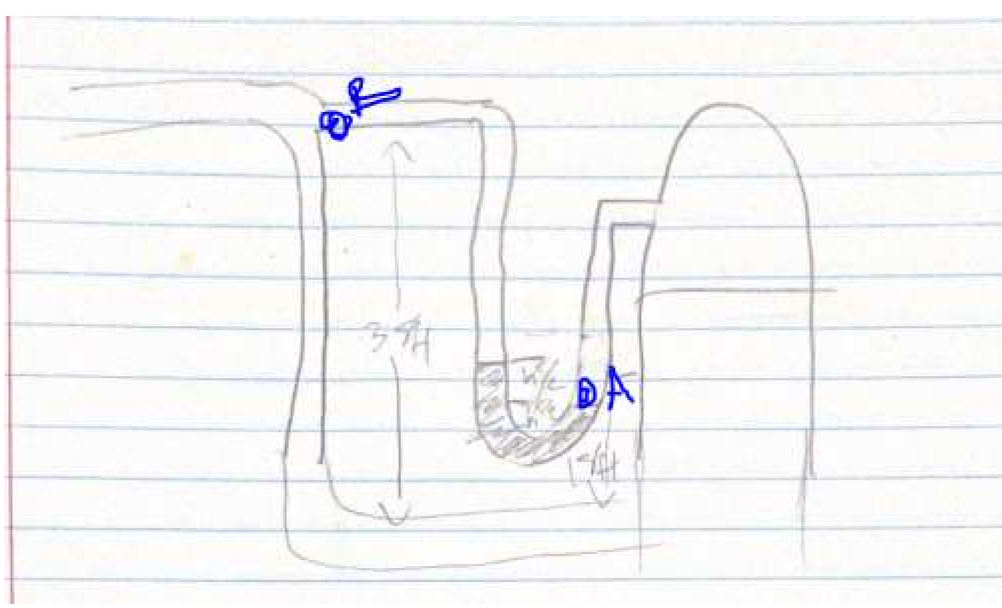
2.

Purpose:

Determine the pressure that stops flow of the system.

Drawings and Diagrams:





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Design Considerations:

- Constant Properties
- Incompressible Fluids
- Ethyl Alcohol @ 77˚F

Data and Variables:

- γ_{Hg} = 844.9 lb/ft^3
- γ_{ea} = 49.01 lb/ft^3
- I_D = 0.1723 ft
- A = 0.0233 ft^2
- Q = 0 gpm
- n = 6.91 X 10^{-4}

Materials:

- Ethyl alcohol
- Mercury

Procedure:

Using the same arrangement of Bernoulli’s equation used in problem one, solve for the pressure with a flow rate of zero. Because there is no flow, there are no energy losses. To find the new height of the mercury, redraw the manometer showing how the change in pressure moves the mercury and solve for the new height of mercury based on the new height of the alcohol.

$$P_A = \gamma\left(\frac{P_B}{\gamma} + (z_B - z_A)\right) = 49.01\left(\frac{5760\,psf}{49.01\,lb/ft^3} + (38-(-18))\right)$$

$$\boxed{P_A = 59.059\ psi\ @\ 0\ gpm}$$

$$P_A - P_B = \gamma_{ea}\left(38 - 18 - \frac{h^*}{2}\right) + \gamma_{hg}(h^*)$$

$$59.095\,psi - 40\,psi = 0.0284\,lb/in^3\left(456\,in - 216\,in - \frac{h^*}{2}\right) + 0.4884\,lb/in^3(h^*)$$

$$19.095 = 6.816 - 0.0142h^* + 0.4884h^*$$

$$-6.816$$

$$\frac{12.279}{0.4742} = \frac{0.4742h^*}{0.4742}$$

$$h^* = 25.89\,in / 12\,in$$

$$h^* = 2.15\,ft$$

Summary:

When the flow rate is 0 GPM there are no energy losses in the system, leaving a pressure of **59.059 psi.** When the pressure drops so does the height of the mercury, **resulting in a new height of 2.15 ft.**

Analysis:

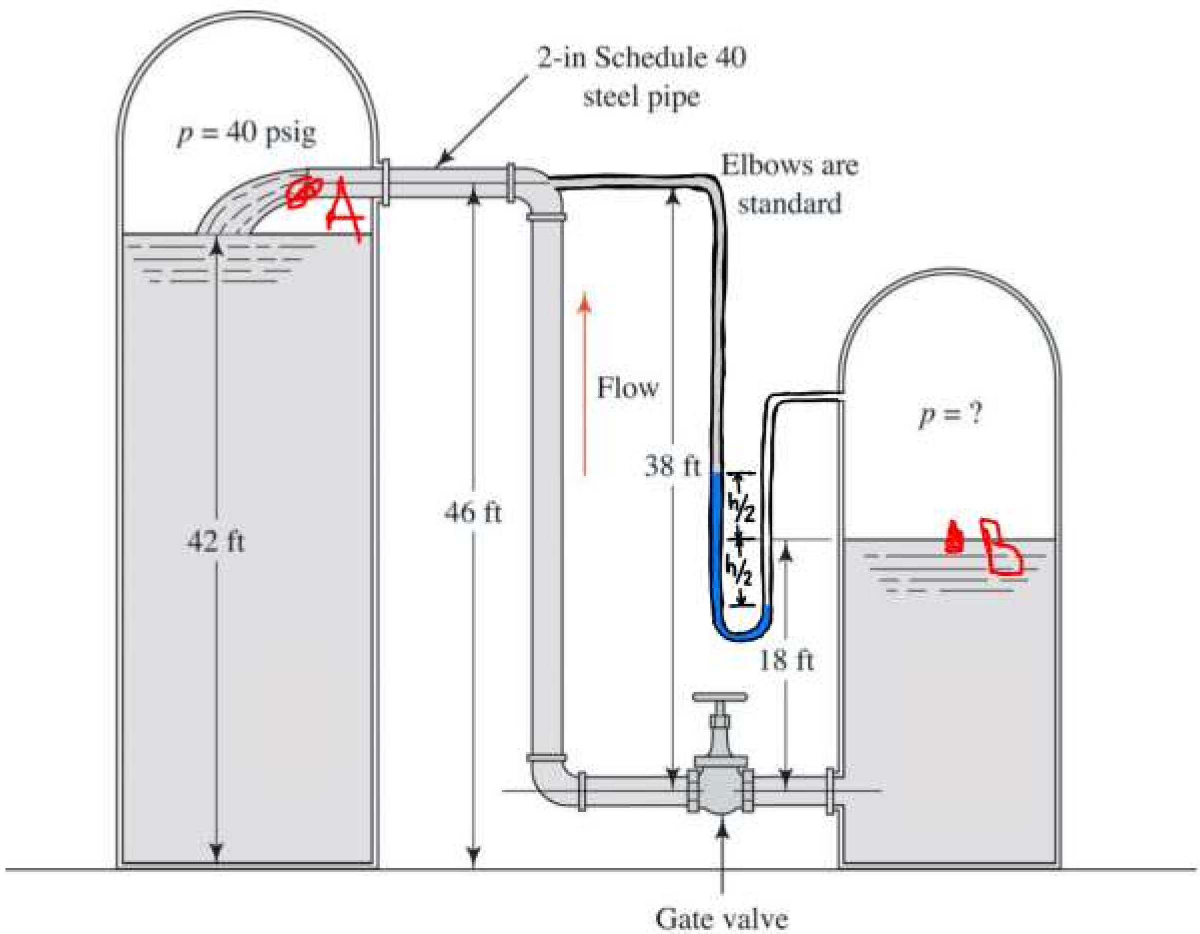
As flow rate decreases so does pressure. This is because the energy losses in the system also become zero with no flow rate. Note, both points were placed at the surface of the fluids to assume no velocity at either point. If the points were placed in places where they had velocities that did not cancel each other out this would change the pressure at which the flow rate becomes zero.

3.

Purpose:

Use excel to determine the pressure in the tank on the right for different flow rates and determine the flow rate for a pressure of 75 psi. Use that information to plot a graph showing the relationship of pressure and low rate.

Drawings and Diagrams:



Sources:

Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)

Design Considerations:

- Constant Properties
- Incompressible Fluids
- Ethyl Alcohol @ 77˚F

Data and Variables:

- γ_w = 62.4 lb/ft^3
- γ_{ea} = 49.01 lb/ft^3
- I_D = 0.1723 ft
- A = 0.0233 ft^2
- Q = ? gpm

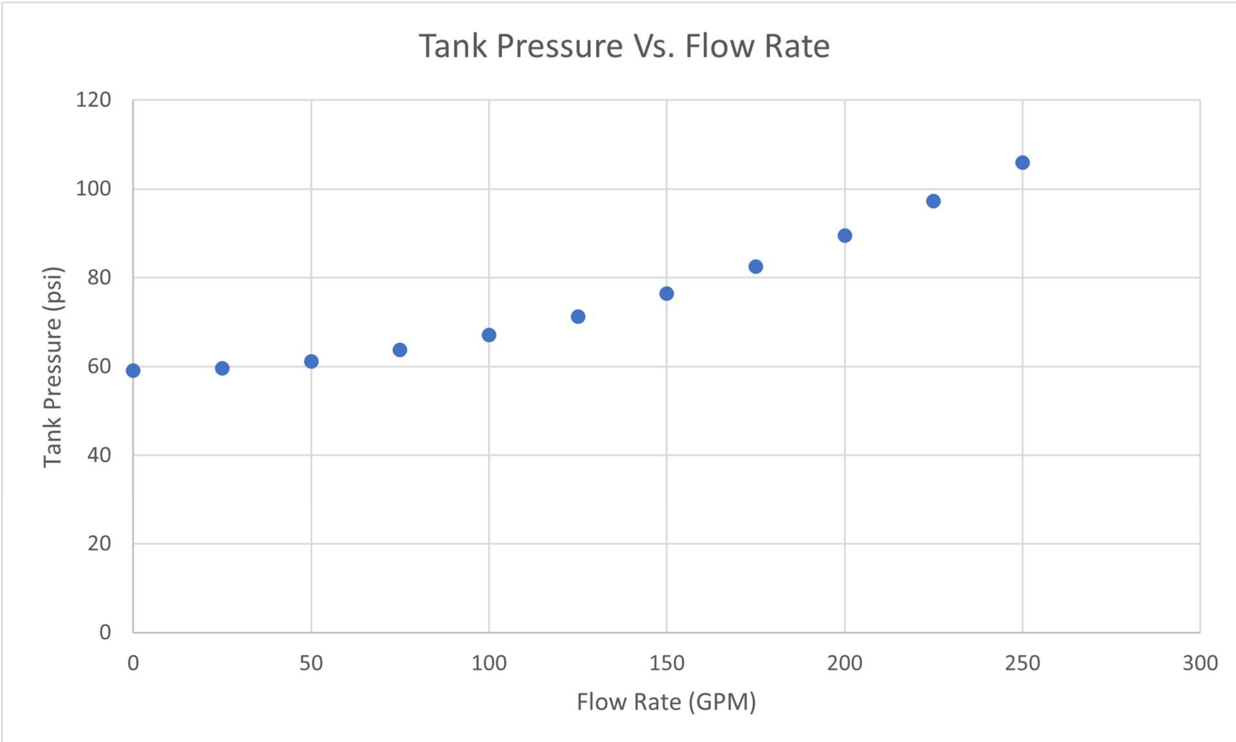
Materials:

- Ethyl alcohol
- Mercury

Procedure:

Use the spreadsheet made from the work done for problem one and make a chart with different flow rates and the pressures they equate to. Then create a graph showing the relationship of pressure and flow rate.

Figures and Charts:



Q GPM	Q Ft^3/s	PA	V^2	V	hL pipes	L/D	fT	D/E	inside LOG	p	D	n	Re	k 90	hl 90	GV k	hL GV	hl total
250	0.556793	105.9513	623.41552	24.96829	124.5142184	638.4214	0.020147	1148.667	0.000300211	1.53	0.1723	0.000021	313434.1	0.604423	11.70207	0.161179	1.560276	137.7766
225	0.501114	97.24196	504.96657	22.47146	101.3878523	638.4214	0.020254	1148.667	0.000306668	1.53	0.1723	0.000021	282090.7	0.607607	9.528615	0.162029	1.270482	112.1869
200	0.445434	89.42091	398.98593	19.97463	80.62024671	638.4214	0.020383	1148.667	0.00031465	1.53	0.1723	0.000021	250747.3	0.611486	7.576837	0.163063	1.010245	89.20733
175	0.389755	82.48878	305.4736	17.4778	62.2130308	638.4214	0.020544	1148.667	0.000324784	1.53	0.1723	0.000021	219403.9	0.616322	5.846894	0.164352	0.779586	68.83951
143.5	0.319599	75.02123	205.40045	14.3318	42.38409002	638.4214	0.020815	1148.667	0.000342284	1.53	0.1723	0.000021	179911.2	0.624455	3.983334	0.166521	0.531111	46.89854
125	0.278396	71.29486	155.85388	12.48415	32.48927243	638.4214	0.021028	1148.667	0.000356436	1.53	0.1723	0.000021	156717	0.630844	3.053401	0.168225	0.40712	35.94979
100	0.222717	67.03586	99.746483	9.987316	21.18016708	638.4214	0.02142	1148.667	0.000383381	1.53	0.1723	0.000021	125373.6	0.642586	1.990551	0.171356	0.265407	23.43612
75	0.167038	63.67208	56.107397	7.490487	12.2481374	638.4214	0.022021	1148.667	0.000427145	1.53	0.1723	0.000021	94030.22	0.660617	1.151102	0.176164	0.15348	13.55272
50	0.111359	61.20832	24.936621	4.993658	5.706019208	638.4214	0.023082	1148.667	0.000511637	1.53	0.1723	0.000021	62686.82	0.692461	0.536262	0.184656	0.071502	6.313783
25	0.055679	59.65551	6.2341552	2.496829	1.582749736	638.4214	0.02561	1148.667	0.00075097	1.53	0.1723	0.000021	31343.41	0.768306	0.14875	0.204882	0.019833	1.751333
0	0	59.05944	0	0	0	638.4214	0	1148.667	0	1.53	0.1723	0.000021	0	0	0	0	0	0

Summary:

The graph shows a parabolic relationship between flow rate and tank pressure. **At 145.3 GPM the tank pressure is approximately 75 psi.**

Analysis:

The change in flow rate varies with the pressure by affecting the energy losses in the components. At 0 GPM there is no flow so there are no energy losses, making the tank have the lowest pressure at 0 GPM. Close to the middle of our range from 0-250 GPM lies a tank pressure of 75 psi.