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MET 330

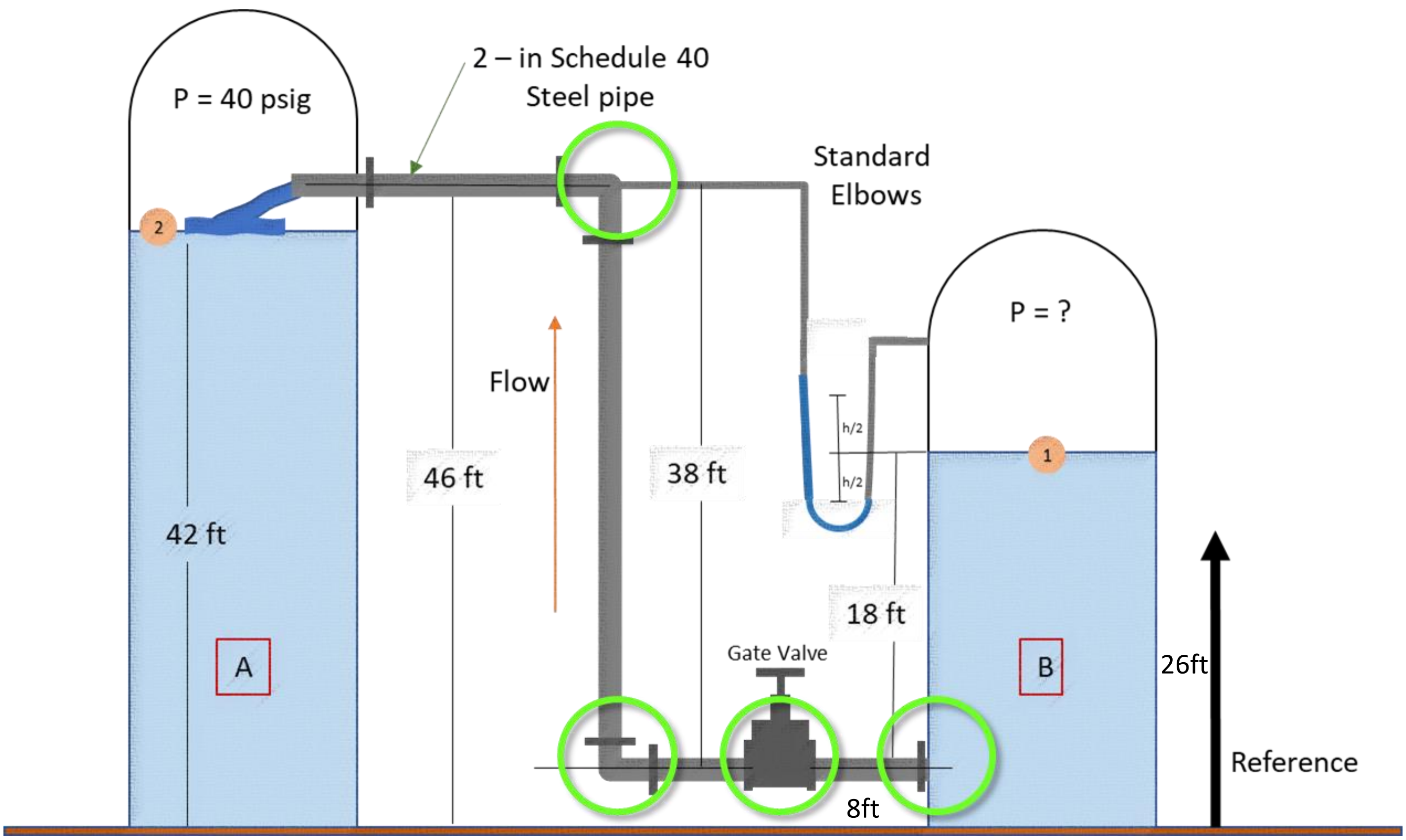
Fluid Mechanics

Test 1

Purpose

Determine the amount of air pressure required by the tank on the right (B) needed to deliver 250 gal/min of ethyl alcohol. Once the air pressure in tank B begins to drop, determine at what air pressure the flow of the ethyl alcohol comes to a stop. Lastly determine the flow rate when the air pressure reaches 75 psi.

Drawings & Diagrams



Drawing Created in "One Note"

Sources

Mott, R., Untener, J.A. “Applied Fluid Mechanics”, 7^{th} edition Pearson Education, Inc, (2015)

Design Considerations

-2 in Schedule 40 Steel Pipe

-Temperature 77°F

-System Fluid = Ethyl alcohol

-Horizontal Pipe section 36ft

-Manometer Fluid = Mercury

Data Variables:

-Tank A, pressure = 40 lb/in^2

-Volume Flow Rate Q= 250gal/min = 0.557 ft^3/s

-Pipe Roughness E = $1.5x10^{-4}$

-Ethyl Alcohol @ 77°F pg. 490 | SG = .787 | γ = 49.01 lb/ft^3 | Ꝓ = 1.53lb $slug/ft^3$ | Dynamic Viscosity η = $2.10x10^{-5}$ | Kinematic Viscosity = $1.37x10^{-5}$

-2in Schedule Pipe 40 pg. 500 | OD = 2.375in | Wall Thickness = 0.154in | ID = .1723ft, 2.067in | Flow Area = 0.02333 ft^2

Procedure:

I would reference my sketch / drawing for the known variables, as I am to solve for pressure within tank B (right). I would then use the given heights to find the total distance from the reference to the height of the fluid (ethyl alcohol) within tank B. Utilizing Bernoulli’s equation I would solve using the known values to provide a value for the pressure within tank B. After establishing my equation for pressure needed in tank B, I would identify any energy added, energy removed and energy loss within the system. After solving for the pressure within tank B, I would then utilize the needed equations to establish the readings displayed within the monometer portion of the system. I would then utilize calculations to proceed with calculating new manometer reading, along with flow rates as required.

Calculations:

Part 1

~~Solve for p1 At tank B~~

Calculations

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_{L\,\text{gate valve}} + h_{L\,\text{Pipe Bend 1}} + h_{L\,\text{pipe Bend 2}} + h_{L\,\text{overall Pipe}} + h_{L\,\text{going in pipe}}$$

$$p_1 = p_2 + \gamma\left(\frac{v_2^2 - v_1^2}{2g} + z_2 - z_1 + h_{L\,total}\right)$$

pg 491 Alcohol ethyl at 77°F

$\gamma = 49.01\ lb/ft^3$

- $\gamma = 49.01$
- $V_1 = 0$
- $z_2 = 42$ ft
- $z_1 = 26$ ft
- $g = 32.2\ ft/s$
- $V_2 = ?$
- $h_L = ?$
- $p_1 = 40\ lb/in^2$

z_1 = pipe $46 - 38 = 8$, $18 + 8 = 26$

$z_1 = 26$ ft

- Now I would Solve for Values Q, V, A = given pg 500

$A = .02333\ ft^2$

$Q = A V_2$

- $Q = \frac{250\ gal/min}{449} = .557\ \frac{ft^3}{sec}$
- $\frac{V_2^2}{2g} = \frac{23.87^2}{2(32.2)} = 8.85$
- $V_2 = \frac{.557\ ft/s}{.02333\ ft^2} = V_2 = 23.87$

- Now I would Solve for All Energy loss h_L = gate Valve + Pipe Bend 1 + pipe Bend 2 + pipe 144 ft friction + h_L Entrance

- I need to Solve for Roughness of Pipe = pg 185 equation + moody Diagram

$$\frac{D}{\varepsilon} = \frac{.1723}{1.5\times10^{-4}} = 1148.67$$

$\varepsilon = 1.5\times10^{-4}$

- I need to Solve for Flow through pipe = pg 183 equation

$$N_R = \frac{v D \rho}{\eta} = \frac{(23.87)(.1723)(1.53)}{2.10\times10^{-5}} = 299646.9$$

f_T = .020 (Calculated)
f_T = .019 * (Table 10.5)

* Need to find friction factor of overall pipe
f = pg 185 Chart

- I need to Solve for Energy loss of Both pipe Bend - 90°

pg 241 + 242

$$2h_{L\,Bend} = k\left(\frac{V_2^2}{2g}\right) = .57(8.85) = 2(5.044) = \boxed{h_L = 10.08\ ft}$$

$\frac{Le}{D} = 30$
Standard 90°

$$k = f_T \frac{Le}{D} = .019(30) = .57$$

- I need to solve for Energy loss at gate valve pg 239

$$h_{L\,\text{gate valve}} = K\left(\frac{v_3^2}{2g}\right) = (.152)(8.85) = \boxed{h_L = 1.3452\text{ft}}$$

gate valve fully open

$$\frac{L_e}{D} = 8$$

$$k = f_t \frac{L_e}{D} = .019(8) = .152$$

- I need to solve for Energy loss In overall 110 ft of pipe

$$h_{L\,\text{overall pipe}} = f \cdot \frac{L}{D} \times \frac{v^2}{2g} = (.019)\left(\frac{110}{.1723}\right)(8.85) = \boxed{h_L = 107.34\text{ft}}$$

pg 183 equation

L = 110 ft

D = .1723 ft pg 500

- I Dont know if I have to solve for Entrance Loss of fluid going into pipe, I believe so   pg 237 equation "Entrance loss"

$$h_L = K\frac{v_2^2}{2g} = (.5)(8.85) = \boxed{h_L = 4.425\text{ ft}}$$

g = 32.2 ft/s

k = .5

"Square edge inlet"

• After Solving all h_L Apply Bernoullis for P1 tank B

$$p1 = p2\ \gamma\left(\frac{v^2 - v^1}{2g} + z_2 - z_1 + h_{L\,\text{total}}\right)$$

$$\boxed{h_L \text{ total} = 124 \text{ ft}}$$

$$p1 = 5760 + 49.01\left(\frac{23.87^2 - 0^2}{2(32.2)} + 42 - 26 + 124\right)$$

$$p1 = 5760 + 49.01(8.85 + 16 + 124) = \frac{13055.14 \text{ lb/ft}^2}{144}$$

$$\boxed{p1 = 90.609 \text{ lb/in}^2 \text{ or } 90.609 \text{ Psig}}$$

- h_L = 1.3452 ft gate valve
- h_L = 10.88 ft Both pipe Bends
- h_L = 107.34 ft 110 ft overall
- h_L = 4.425 ft Entrance
- 40 lb/in² = 5760 lb/ft²

Menometer reading (deflection shown)

$h = h_1 + h_2$

- $p1 = 90.340\ lb/in^2$
- $p1 = 13008.96\ lb/ft^2$

- $p2 = 40\ lb/in^2$
- $p2 = 5760\ lb/ft^2$

pg 491 mercury $\gamma = 844.9\ lb/ft^3$

S.G. = 13.54

- $\Delta p = \gamma h$
- $p2 - p1 = \gamma h$
- $\frac{p2 - p1}{\gamma} = h$

$\frac{5760 - 13008.96}{844.9}$

- pg 41 equation Chpt 3

* Solving off of provided feed back but I belive I might have missed something....

Menometer Deflection = h total

$\boxed{8.58\ ft \text{ or } 102.96\ in}$

$\frac{h}{2} = \boxed{4.29\ ft \quad 51.48\ in}$

Part 2 At what pressure does flow stop

$P_1 = ?$
$\gamma = 49.01$
$V_1^2 = 0$
$2g = 64.4\ ft/s^2$
$z_1 = 26ft$

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

$$\frac{P_1}{49.01} + \frac{0}{64.4} + 26 = \frac{5760}{49.01} + \frac{23.87^2}{64.4} + 42$$

$P_2 = 40 lb/in^2 = 5760\ lb/ft^2$
$\gamma = 49.01$
$V_2^2 = 23.87$
$2g = 64.4$
$z_2 = 42ft$

$$\frac{6978}{49.01} + \frac{0}{64.4} + 26 = 168.5$$

$$168.4\ lb/ft^2 = 168.5\ lb/ft^2$$

If $P_1 = 48.45 lb/in^2$ the equation is balanced
I belive this means No Flow

* My initial thought Is to use Bernoulli's equation to find what pressure value for tank B to equalize the equation. If there is No Flow Both sides must be equal, But I can be wrong

* Work is done in excel but once pressure was at the value of 48.449 lb/in² the equation was balanced meaning what I believe To be No Flow

New Manometer Deflection

$P_1 = 6978\ lb/ft^2$
$P_2 = 5760\ lb/ft^2$
$\gamma = 844.9\ lb/ft^3$
$h = ?$

$$\Delta p = \gamma h$$

$$= P_2 - P_1 = \gamma h$$

$$= \frac{5760 - 6978}{844.9} = h$$

New manometer Deflection

$h = 1.44\ ft$ or $17.28\ in$

$h/2 = .72\ ft$ or $8.64\ in$

Part 3

Graph and Calculations were Conducted in Excel

- When the pressure is a 75 psi, the Flow Rate is at approximately 205 gal/min or $.457\ ft^3/s$

Summary:

The required air pressure needed for tank B (right) to deliver 250 gal/min of ethyl alcohol as required was derived to be 90 psig. There were several areas of friction loss throughout the system. The identified areas included: two pipe bends, inlet loss from tank B to pipe, gate valve at 100% “open” and the overall 110ft of pipe. The manometer deflection reading originally depicted by the system was at a value of “h” at 8.5ft. As the pressure in tank B was established at 90psig, manometer deflection reading resulted in a dropped height. The flow rate calculated at the range of 75 psig was approximated at 205 gal/min.

Materials:

-Ethyl alcohol

-Overall system components, 2-in Schedule 40 steel pipe (tanks, piping sections, valve and fittings)

-Manometer apparatus

Analysis:

-The required pressure needed to deliver 250 gal/min is 90 psig.

-No energy was added or removed within the system.

-Friction energy was loss thought the entire system (valve, overall pipe friction, two pipe bends, tank square inlet) $h_L = h_{L\ \text{gate valve}} + h_{L\ \text{pipe bend 1}} + h_{L\ \text{pipe bend 2}} + h_{L\ \text{pipe friction loss}} + h_{L\ \text{tank inlet}}$.

-Manometer deflection was originally reflected 8.5ft = h, manometer deflection dropped as pressure was increased in tank B to approximately h = 1.4ft.

-Calculations reflect that as tank B was established to a pressure of 75 psig, the calculated flow would be approximately 205 gal/min.

Question 1

Variable	Value	Unit	Value	Unit
P_1	90.340	lb/in^2	13055.14	lb/ft^2
V_1	0.000	ft/s		
$V_1^2/2g$	0.000	ft/s		
Z_1	26.000	ft		
P_2	40.000	lb/in^2	5760	lb/ft^2
V_2	23.870	ft/s		
$V_2^2/2g$	8.850	ft/s		
Z_2	42.000	ft		
$h_{L\ \text{Gate Valve}}$	1.345	ft		
$h_{L\ \text{Pipe Bend 1}}$	5.045	ft		
$h_{L\ \text{Pipe Bend 2}}$	5.045	ft		
$h_{L\ \text{Overall Pipe}}$	107.351	ft		
$h_{L\ \text{Entrance Loss}}$	4.425	ft		
h_L Total	123.210	ft		
γ Ethyl	49.010	$slugs/ft^3$		
γ Ethyl	0.340	ft		
g	32.200	ft/s^2		
$Q_{\text{Flow Rate}}$	0.557	ft^3/s		
$Q_{\text{Flow Rate}}$	250.000	gal/min		
Area	0.023	ft^2		
$K_{\text{Pipe Bend}}$	0.570	_		
$K_{\text{Gate Valve}}$	0.152	_		
$K_{\text{Entrance Loss}}$	0.500	_		
Friction $_{\text{Factor}}$	0.019	_		
Length $_{\text{of Pipe}}$	110.000	ft		
Diameter $_{\text{of Pipe}}$	0.172	ft		

Variable	Equation	Value	Unit
Bernullis Equation	$P1/γ + V^2_1/2g + Z_1 = P2/γ + V^1_2/2g + Z_2$		_
Bernullis Equation for P1 =	$P2 + γ(V^2_1 - V^1_2 /2g + Z_2 - Z_1 + hL_{total})$	90.340	psig lb/in^2
$h_{L\ \text{Pipe Bend 1\&2}}$ $h_L = K_{\text{Pipe Bend}}(V2^2/2g)$	$K*(V2^2/2g)$	5.045	ft
$h_{L\ \text{Gate Valve}}$ $h_L = K_{\text{Gate Valve}}(V2^2/g)$	$K*(V2^2/2g)$	1.345	ft
$h_{L\ \text{Overall Pipe}}$ $h_L = f_f*(L/D)*(V2^2/2g)$	$h_L = f_f*(L/D)*(V2^2/2g)$	107.351	ft
$h_{L\ \text{Entrance Loss}}$ $h_L = K_{\text{Square Inlet}}(V2^2/2g)$	$h_L = K_{\text{Entrance Loss}}(V2^2/2g)$	4.425	ft
h_L Total Energy Loss	$(h_{L\ \text{Gate Valve}} + h_{L\ \text{Pipe Bend 1}} + h_{L\ \text{Pipe Bend 2}} + h_{L\ \text{Overall Pipe}} + h_{L\ \text{Tank Inlet}})$	123.210	ft

Question 2

Variable	Equation	Value	Unit	lb/in^2	lb/ft^2
Bernullis Equation Equalization P1	$P_1/γ + V^2_1/2g + Z_1$	168.355	_	48.45	6978
Bernullis Equation Equalization P2	$P_2/γ + V^2_2/2g + Z_2$	168.377	_		

Question 3									
Variable	Value								Units
Q Flow Rate	350	300	250	200	150	100	50	0	gal/min
Q Flow Rate	0.780	0.668	0.557	0.445	0.334	0.223	0.111	0.000	ft^3/s
V_1	33.455	28.676	23.897	19.117	14.338	9.559	4.779	0.000	ft/s
$h_{L\ Pipe\ Bend\ 1}$	9.907	7.278	5.054	3.235	1.820	0.809	0.202	0.000	ft
$h_{L\ Pipe\ Bend\ 2}$	9.907	7.278	5.054	3.235	1.820	0.809	0.202	0.000	ft
$h_{L\ Overall\ Pipe}$	210.818	154.886	107.560	68.838	38.722	17.210	4.302	0.000	ft
$h_{L\ Entrance\ Loss}$	8.690	6.384	4.434	2.838	1.596	0.709	0.177	0.000	ft
$h_{L\ Gate\ Valve}$	2.642	1.941	1.348	0.863	0.485	0.216	0.054	0.000	ft
h_L Total	241.962	177.768	123.450	79.008	44.442	19.752	4.938	0.000	ft
Pressure	133.616	110.223	90.428	74.232	61.636	52.638	47.240	45.440	lb/in^2