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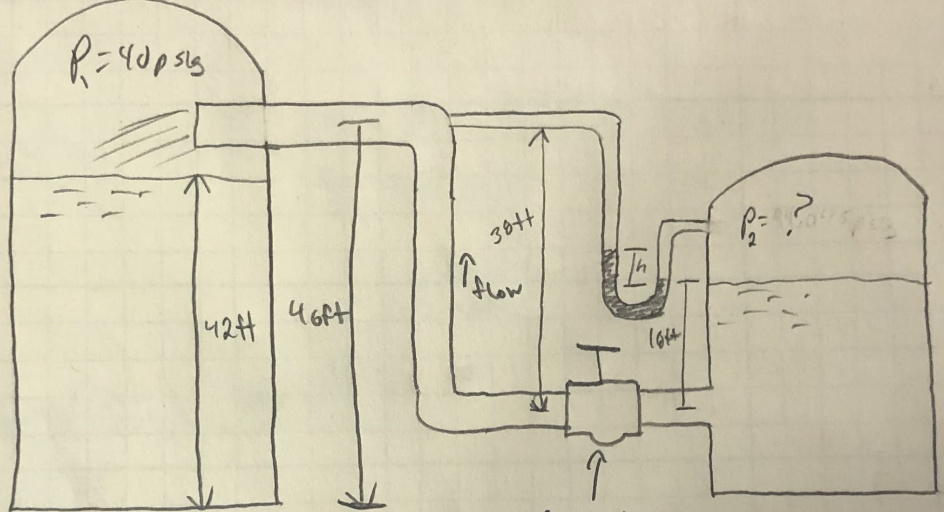
Purpose: Part A) 1. Determine the force magnitude on the blind flange in the system.

2. Determine the forces in the X & Y directions of the system.

3. Determine the pressure drop across the nozzle.

4. Compare the thickness of pipe to actual pipe thickness & verify there is no cavitation in the system.

Drawings & Diagrams:



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

Design Considerations: Incompressible fluids

Pressure in right tank must be higher

Data & Variables: $P_1 = 40$ psig

$P_2 =$ To find.

$d/D = 0.5$

$\rho_{ethyl} = 1.53$ slugs/ft^3

Blind Flange Diameter: 2in

Flow of ethyl alcohol $= 150$ gpm $= 0.334$ ft^3/s

$E_{steel} = 200$ GPa

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Procedure:

$Q = 150\,gpm = 0.334\,ft^3/s$

1) First we find the pressure in the right tank.

$$P_1 = P_2 + \gamma_{alc}\left((z_2 - z_1) + \frac{V_2^2}{2g} + h_{L\,1\text{-}2}\right)$$

$$V_2 = \frac{4Q}{\pi D^2}$$

$$= \frac{4(0.334\,ft^3/s)}{\pi\,(0.1723\,ft)^2}$$

$$V_2 = 14.32\,ft/s$$

$$h_{L_{pipe}} = f\,\frac{L}{D}\left(\frac{V_2^2}{2g}\right)\ ; \quad f < \begin{cases} Re = \frac{VD}{\nu} = \frac{14.32(0.1723)}{1.37\times10^{-5}} = 1.8\times10^5 \\ \frac{D}{\varepsilon} = 1148.67 \end{cases}$$

$$f = 0.0194$$
$$f_T = 0.01899$$

$$h_{L_{pipe}} = (0.0194)\left(\frac{110\,ft}{0.1723}\right)\left(\frac{(14.32\,ft/s)^2}{2(32.2\,ft/s^2)}\right)$$

$$h_{L_{pipe}} = 39.44\,ft$$

$$h_{L_{ent}} = K_{ent}\left(\frac{v^2}{2g}\right) = 0.5\left(\frac{14.32^2}{2(32.2)}\right)$$

$$h_{L_{ent}} = 1.59\,ft$$

$$h_{L_{elbows}} = 2\,k_{elbow}\left(\frac{v^2}{2g}\right) = 2(30)(0.01899)\left(\frac{14.32^2}{2(32.2)}\right)$$

$$h_{L_{elbows}} = 3.63\,ft$$

$$h_{L_{valve}} = K_{valve}\,\frac{v^2}{2g} = 8(0.01899)\left(\frac{14.32^2}{2(32.2)}\right)$$

$$h_{L_{valve}} = 0.48\,ft$$

$$h_{L_{total}} = 39.44 + 1.59 + 3.63 + 0.48$$

$$h_{L\,total} = 45.14\,ft \rightarrow \quad P_1 = 40\,\frac{lb}{in^2} + 49.296\,\frac{lb}{ft^3}\left(20ft + \frac{(14.32\,ft/s)^2}{2(32.2\,ft/s^2)} + 45.14ft\right)\left(\frac{1\,ft^2}{144\,in^2}\right)$$

$$P_1 = 63.39\,psig$$

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Procedure:

1) I am going to find the pressure in the tank with air and ethyl alcohol.

$P = P_{air} + \gamma_{ethyl}(h_{ethyl})(sg_{ethyl})$

$\gamma_{ethyl} = sg_{ethyl}(\gamma_{water})$

$\gamma_{ethyl} = (0.79)(62.4\ lb/ft^3)$

$\gamma_{ethyl} = 49.296\ lb/ft^3$

$P = 63.39\ psig + (49.296)(26ft)(0.79)$

$P = 63.39\ psig + 1012.53984\ lb/ft^2 / 144\ lb/ft^2$

$P = 63.39\ psig + 7.031\ psig$

$\underline{P = 70.421\ psig}$

Then find the force in the tank that will be put on the flange

$F = P(A)$

$F = 70.4216\ psig\ (\pi D^2/4)$

$F = 70.421\ psig\ (\pi(2in)^2/4)$

$F = 70.421\ psig\ (3.14159\ in^2)$

$\boxed{F = 221.23\ lb}$

Then we find the location of the force/pressure on the flange since opposite inlet

$L_p = \bar{y} + \frac{I_c}{\bar{y}A}$

$I_c = \frac{\pi D^4}{64} = \frac{\pi(2in)^4}{64} = 0.785\ in^4$

$L_p = 216.5755 + \frac{0.785}{216.5755(3.14159)}$

$\bar{y} = 216in + (r - \frac{4r}{3\pi})$

$= 216in + (1in - \frac{4(1)}{3\pi})$

$\bar{y} = 216.5755\ in$

$L_p = 216.576$

$\boxed{L_p = 18.04\ ft \text{ from alcohol top}}$

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Procedure)

2) We need to find the horizontal & vertical forces

$$\Sigma F_x = \rho Q (V_2 - V_1) \qquad \Sigma F_y = \rho Q (V_2 - V_1)$$

$Q = Av$

$0.334\ ft^3/s = A(v)$ $\qquad A = \frac{\pi d^2}{4} = \frac{\pi (0.1723 ft)^2}{4} = 0.0233 ft^2$

$0.334\ ft^3/s = (0.0233 ft^2)(v)$

$V = 14.33\ ft/s$

$\Sigma F_x = 1.53\ slug/ft^3 (0.334\ ft^3/s)(14.33 - 0)$

$\boxed{\Sigma F_x = 7.32\ lb}$

$\Sigma F_y = 1.53\ slug/ft^3 (0.334\ ft^3/s)(14.33 - 0)$

$\boxed{\Sigma F_y = 7.32\ lb}$

Procedure:

3) $V_1 = C\sqrt{\dfrac{2g(p_1-p_2)/\gamma}{(A_1/A_2)^2-1}}$

$0.5 = \dfrac{d}{D}$

$d = 1.0335\text{ ft} = 0.0857\text{ in}$

$$(p_1-p_2) = \left(\frac{V_1}{C}\right)^2 \frac{\gamma[(A_1/A_2)^2-1]}{2g}$$

$A_1 = 0.02333\text{ ft}^2$

$A_2 = \dfrac{\pi(0.0857)^2}{4} = 0.0057\text{ft}^2$

$C = 0.9975 - 6.53\sqrt{\beta/N_R}$

$= 0.9975 - 6.53\sqrt{0.5/1.5\times10^5}$

$C = 0.9866$

$\downarrow$

$$(p_1-p_2) = \left(\frac{14.32}{0.9866}\right)^2\left(\frac{(49.296)[(0.02333/0.0057)^2-1]}{2(32.2)}\right)$$

$= 210.67(12.06)$

$= 3347.55\text{ lb/ft}^2/(144\text{ in}^2)$

$\boxed{\text{Pressure Drop} = 17.64\text{ psi}}$

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Procedure:

4) Find the pressure increment after the sudden closing of the valve, and would the pipe fail.

$\Delta P = \rho C V \qquad P_{max} = P_{op} + \Delta P$

$$C = \frac{\sqrt{\frac{E_o}{\rho}}}{\sqrt{1 + \frac{E_o D}{E \delta}}}$$

$\rightarrow$
$D = 2.375$ in
$\delta = 0.218$ in
$E = 200$ GPa
$\rho = 1.53$ slug/ft³
$E_o = 130000$ psi

$$C = \frac{\sqrt{\frac{(130000)}{1.53}}}{\sqrt{1 + \frac{(130000)(2.375)}{(200)(0.218)}}}$$

$C = 3.46$

$\Delta P = \rho C V$

$= (1.53)(3.46)(14.32)$

$\boxed{\Delta P = 75.88 \text{ psi}}$

$P_{max} = P_{op} + \Delta P$

$= 63.39 + 75.88$

$\boxed{P_{max} = 139.27 \text{ psi}}$

Then find the thickness of the pipe

$$t = \frac{pD}{2(SE + pY)}$$

$p = 63.39$ psig
$D = 2.375$ in
$S = 20$ ksi ← used carbon steel valve
$E = 1.00$
$Y = 0.40$

$$t = \frac{(63.39)(2.375)}{2(20(1) + (63.39)(0.40))}$$

$$t = \frac{150.55}{90.712}$$

$\boxed{t = 1.659 \text{ in}}$

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Procedure:

4) Then verify there is no cavitation

$P_{suction} > P_{saturation\ of\ ethyl\ alcohol}$

The lowest pressure in the tank is 40 psig at the outlet of the ethyl alcohol.

The pressure of saturated ethyl alcohol at 77°F is 1.17 psig

Thus... 40 psig > 1.17 psig, so there is no cavitation in the system.

Summary: 1) The force magnitude on the blind flange is 221.23 lb and the location is 18.04 ft from the top of the ethyl alcohol in tank on the right.

2) The total horizontal force is 7.32 lb and the total vertical forces is 7.32 lb for the system.

3) The pressure drop across the nozzle is 17.64 psi in the system.

4) The pressure increment for the water hammer is 139.27 psi and thickness is 1.659 in, as well as there is no cavitation.

Analysis: After finding the new pressure for the right tank, I believe I went about most of the problems the right way. Once I understood how large or small values should be especially related to pressure, I have started to understand the real life implications behind everything.

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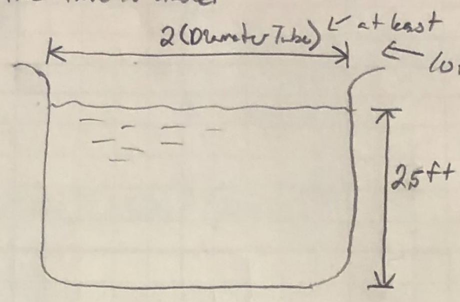
Purpose: Part B) 5. Determine the water flow rate required for the lazy river.

6. Determine the drag a 4-year old kid would experience in the lazy river.

7. Determine how deep into the water the tube will go, and make sure the tube is stable.

Drawings & Diagrams:



Sources: Holt, R, Untener, J.A. "Applied Fluid Mechanics", 7th Edition, Pearson Education Inc (2015)

Design Considerations: Water to such a 4-year old can stand in it.
Slope = 0.1%
Fit 2 lazy river tubes side by side.

Data & Variable: Tube diameter = 96 cm = 3.14 ft
Tube weight = 1.9 kg
Slope = 0.1%
Height of 4 year old = 40 in = 3.33 ft
D = 18 in = 1.5 ft
Specific weight water @ 80°F = 62.2 lb/ft^3

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Procedure: We must find the flow rate of the river for a constant water level.

5) $Q = \left(\frac{1.49}{n}\right) A R^{2/3} S^{1/2}$

$S = 0.001$

$A = (10ft)(2.5ft)$

$A = 25ft^2$

$R = \frac{A}{WP} = \frac{25}{2.5+2.5+10}$

$R = 1.67 ft$

$n = 0.015$ ← Constant for concrete Table 14.1

$Q = \left(\frac{1.49}{0.015}\right)(25ft^2)(1.67)^{2/3}(0.001)^{1/2}$

5.23
17.1
A.2

$\boxed{Q = 110.54\ ft^3/s}$

6) Find the drag force of a 4-year old in the river assuming they are a cylinder.

$F_D = C_D\left(\frac{\rho v^2}{2}\right)A$

Water at 82°F → $\nu = 9.15\times10^{-6}\ ft^2/s$

$N_R = \frac{vD}{\nu}$

$= \frac{4.42ft/s\,(1.5ft)}{9.15\times10^{-6}\ ft^2/s}$

$N_R = 7.2459\times10^{-5}$

$C_D = 1.04$

$Q = Av$

$110.54ft^3/s = 25ft^2(v)$

$v = 4.42ft/s$

$L/D = 2$

$A = (3.33)(1.5)$

$A = 4.995$

$F_D = 1.04\left(\frac{1.94\ slugs/ft^3\,(4.42ft/s)^2}{2}\right)(4.995\ ft^2)$

$\boxed{F_D = 22.24\ lb}$

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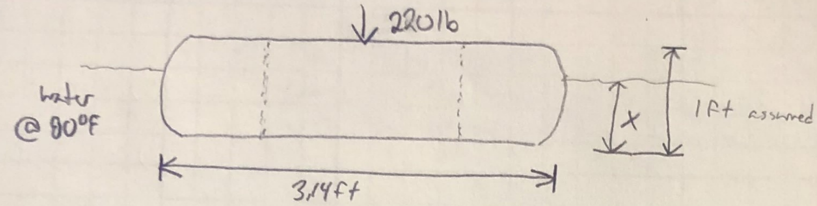
Procedure:

7) Find how deep into the water the tube goes and if its stable



$F_b = \gamma_f V_d$

$w = \gamma_c V_{cyl} = 4.19 lb$

$W_f = 220 lb$

$V_{cyl} = \frac{\pi}{4} D^2 h$

$= \frac{\pi}{4}(3.14)^2(1)$

$V_T = 7.74 ft^3$

$V_{displaced} = \frac{\pi}{4}(3.14)^2(x)$

$V_{displaced} = 7.74x \ ft^3$

$\Sigma F_y = 0$

$F_b - w - W_f = 0$

$\gamma_f V_d - w - W_f = 0$

$V_d = \frac{W_f + w}{\gamma_f}$

$7.74x \ ft^3 = \frac{220 + (4.19)}{62.2 lb/ft}$

$x = 0.465 ft$

$\boxed{x = 5.58 in}$

Then find the metacenter & center of bouyancy to see if stable.

$y_{cb} = \frac{x}{2}$

$y_{cb} = \frac{5.58}{2}$

$y_{cb} = 2.79 in$

$= 0.2325 ft$

$V_d = 7.74(0.465)$

$V_d = 3.59 ft^3$

$I = \frac{\pi D^4}{64}$

$= \frac{\pi(3.14)^4}{64}$

$I = 4.77 ft^4$

$MB = \frac{I}{V_d}$

$= \frac{4.77 ft^4}{3.59 ft^3}$

$MB = 1.33 ft$

$y_{mc} = y_{cb} + MB$

$= 0.2325 ft + 1.33 ft$

$\boxed{y_{mc} = 1.5625 ft}$ yes, it's stable with a person on it.

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Summary: 5) The water flow rate required for the lazy river is 110.54 ft^3/s.

6) The drag force a 4-year old would have in the lazy river is 22.24 lb.

7) The tube would have 5.58 in under the water, and the person in the tube would be stable as the meta center is in line with the middle of the tube with 220 lbs on it.

Analysis: After completing this, I think the key is to imagine the tube and river in your head as you would remember at a water park. This helped me to understand if the values I solved for made sense in my head.