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MET 330
10/08/2022

Test 2 Reflection

1) Problem 1:
    a. What course objectives are being directly assessed?

    b. How are other course objectives being indirectly assessed?

2) Problem 1: I made numerous mistakes on this problem. A number of which were related to units, and others were due to a misunderstanding of the problem. I think one of my main problems was my labeling of the initial diagram, and not carrying that through to my free body diagram of the reaction forces. I was very confused when looking back over my work trying to figure out where I went wrong. I also made a mistake when determining stability and drag. I modeled the log with a square cross section as I did when determining the size but should have modeled as a cylinder. I also had an issue in the cavitation section where I must have written down the wrong equation and used the area instead of the velocity. I think I need to be more meticulous with labeling conventions going forward and convert to metric versus trying to solve the problems in U.S. Customary units to make it easier.

3) Based on the provided rubric, I think I should get full points for following the problem-solving rubric. For the remainder of the rubric:

Section	Graded	Available
1	2	2
2	1	3
3	1	2
4	1.5	2
5	0.5	2
6	1	3
7	0	2
8	0.5	1

10+(80/10)*(2/2+1/3+1/2+1.5/2+0.5/2+1/3+0/2+0.5/1) = 39.33

4) The main issue I encountered with the test was units and misunderstanding what the problem asked for. I should have reached out to clarify some of the questions I had. As for units, going forward I will be converting to metric at the beginning of the problems to avoid confusion especially related around lbm versus lbf. The steps I took for this test is similar to what I have done in thermodynamics, thermal applications, and heat transfer. I usually draw the diagrams for all problems and put down the design considerations and known variables. I like to do this as quickly as possible once the test is out to also give myself time to think about the problems and the methods to solve them. Then I proceed to solve the problems in order.

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Concepts learned throughout this section as well as on the test itself include mainly cavitation and forces from static and moving fluids. I'm sure these get used in any design of any fluid system. Even as simple as plumbing in a commercial building. In addition anytime a pump is used cavitation has to be taken into account to avoid at a minimum wear and tear on the pump. As I hope to go into HVAC and Refrigeration it is extremely likely that I would at lease be peripherally involved in fluid mechanics. All forms of HVAC that I am aware of have to deal with fluids, whether humidity, condensate, or moving coolant around. I actually feel like I did worse from the first test to the second test, I think the whole thing being one problem made me nervous, but I did take more time for the test this time. I spent roughly 5-6 hours on the test including the prework. I spread it out more than the last test, but I'm not sure that was overly helpful. The biggest takeaway is to reach out with questions.

Writing Rubric 10/10

39.33/90

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1	2/2
2	1/3
3	1/2
4	1.5/2
5	0.5/2
6	1/3
7	0/2
8	0.5/1

g) Forces acting upon the blind flange

$$F = pA$$

$$A_{Flange} = 0.01414 ft^2$$

$$p = \gamma h = \left(62.4 \frac{lb}{ft^3}\right)(3 ft) = 187.2 \frac{lb}{ft^2}$$

$$F = 187.2 \frac{lb}{ft^2}\left(0.01414 ft^2\right) = 26.47 lb \text{ at the center of the flange}$$

Summary:

The system designed above would be used to transport logs from the location of the system to a destination using gravity in an open channel. The maximum size of these logs was determined, a flow nozzle was also implemented. The drag forces acting upon a wedged log, and the force acting on the flange on the tank were also calculated.

Materials:

- Pressurized Storage Tank
- 300ft of 1.5 in Schedule 40 steel piping.
- 1 gate valve
- 1 90-degree elbow
- 1 blind flange
- An unfinished concrete channel
- Flow nozzle with a diameter ratio of 0.5

Analysis:

There were a few issues determined during the analysis of the system. There is a risk of cavitation if the valve were to be closed suddenly. This easiest way to mitigate this would be to slowly close the valve, but the pipe diameter could also be increased. Another issue was the stability of the logs, if the largest possible log were to be added to the channel it would not be stable, this could cause the log to wedge in the channel causing a large amount of drag force. This could be mitigated by limiting the size of the logs allowed to travel down the channel.

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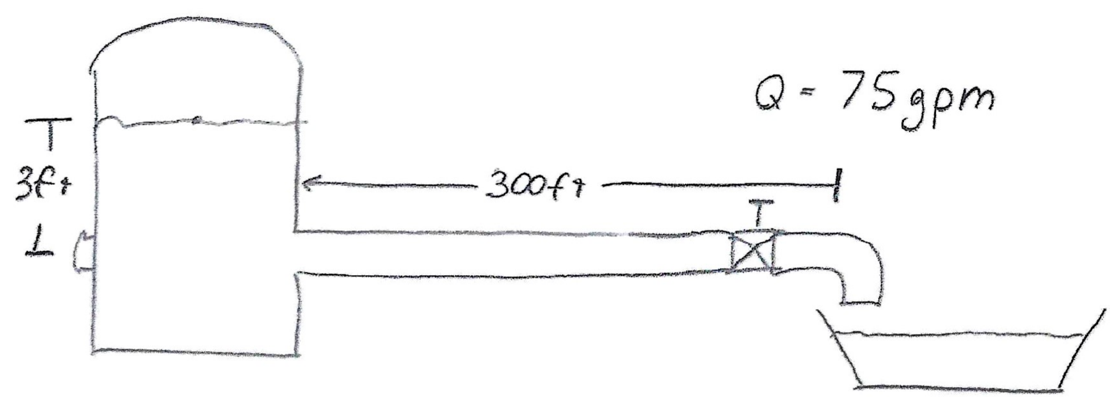
Problem 1

Purpose:

a. Determine the depth of the open channel.
b. Determine all relevant forces in the x and y directions.
c. Determine the largest log of a square cross section that could be carried by the open channel.
d. Determine the pressure drop across a flow nozzle with diameter ratio of 0.5
e. Determine the risk of cavitation along with pressure increment if the valve was closed suddenly
f. Determine the drag force on a log half the size of the one determined in part c if it was stuck in the open channel
g. Determine the force acting on the blind flange in the storage tank.

Drawings and Diagrams:

System Drawing



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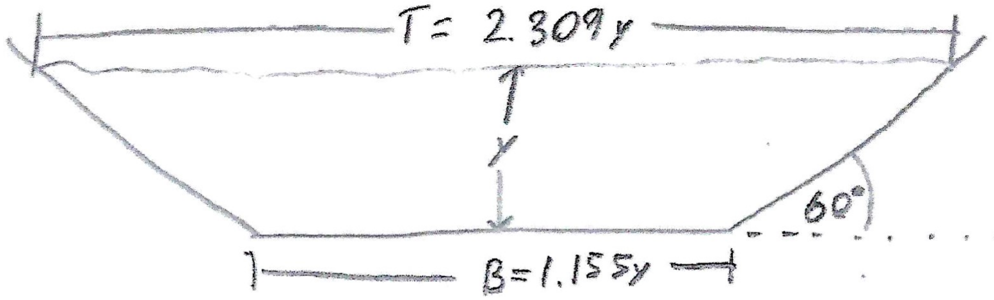
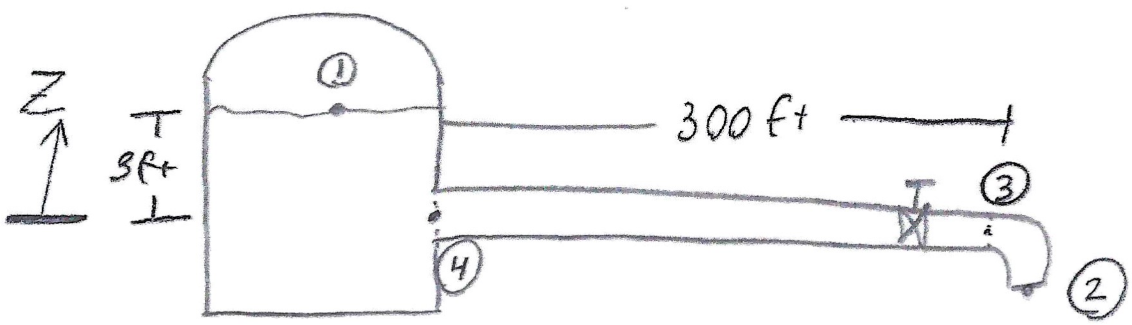
Channel Drawing



Bernoulli's Equation Drawing



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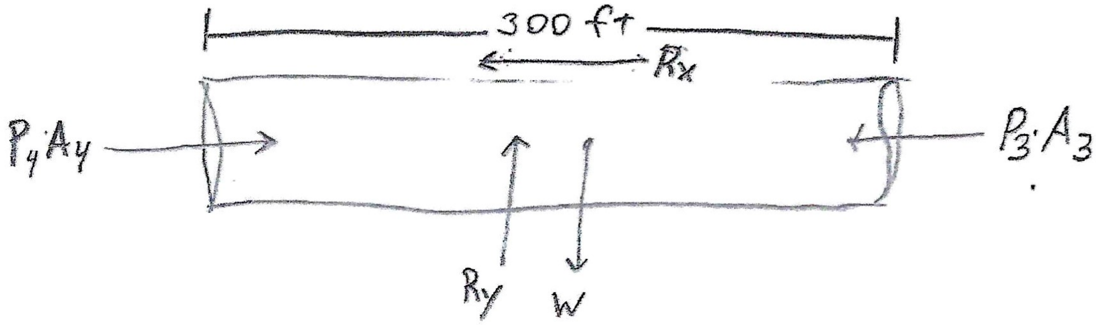
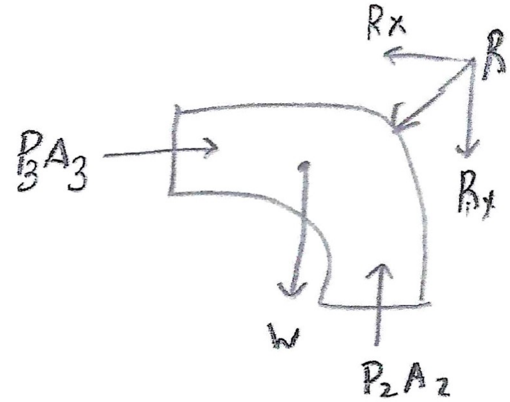
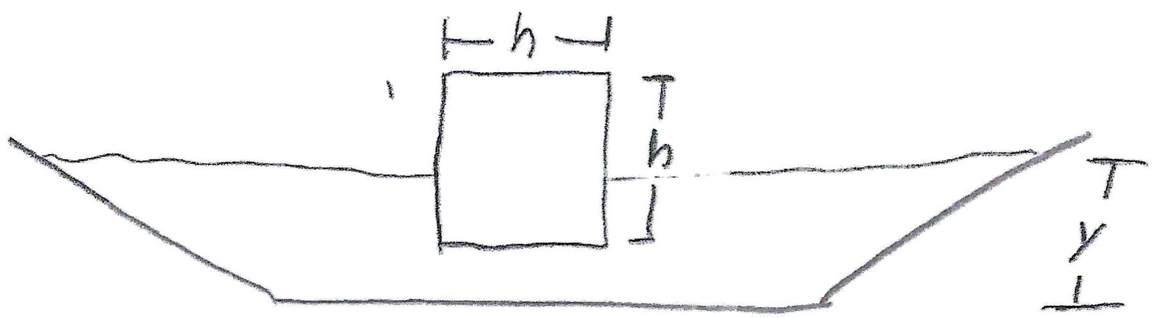
Forces Drawing





Log Cross Section



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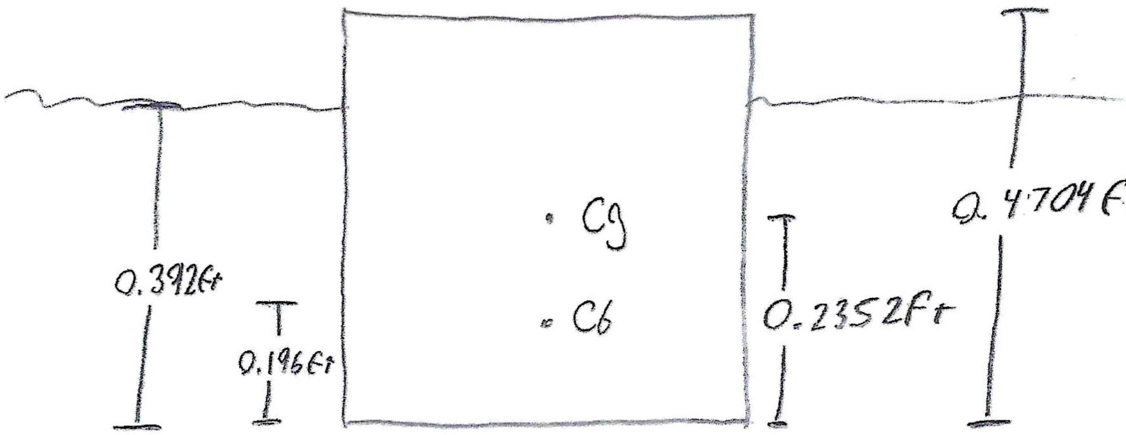
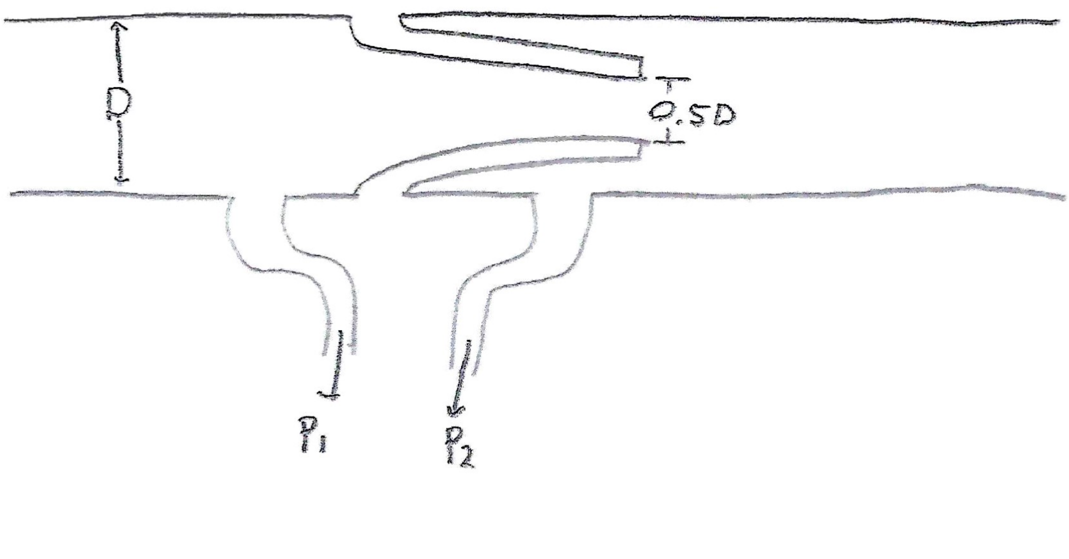
Log Stability



Flow Nozzle



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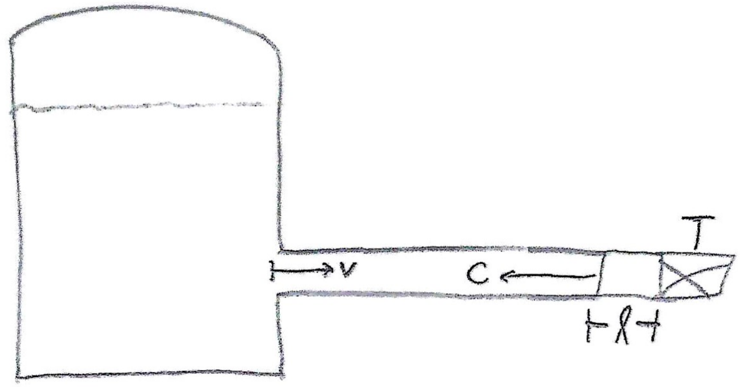
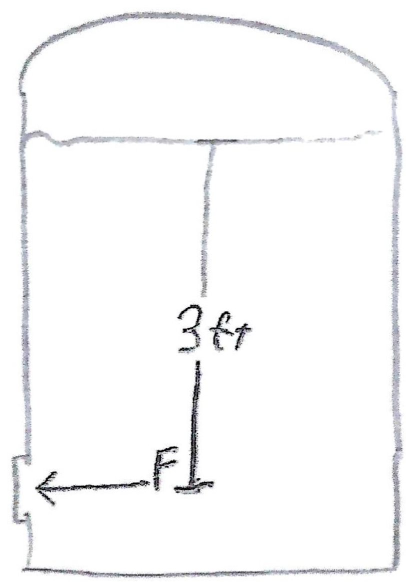
Cavitation



Blind Flange



Sources:

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

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Design Considerations:

- Constant Properties
- Incompressible Fluids
- Isothermal

Data and Variables:

$Temp = 60°F$

$Q = 75GPM$

$L_{pipe} = 300ft$

1.5in Schedule 40 Steel Pipe

Modulus of Elasticity of Steel $= 200GPa$

$\rho_{hickory} = 830kg/m^3$

$S = 0.001$

$T = 2.309y$

Procedure:

h. Draw a sketch of the channel, the given information is used to determine that this is efficient trapezoid and table 14.3 can be used. Since the material is provided, unfinished concrete, the Manning number can also be determined. Using Manning's equation, and the values A and R from table 14.3 the value for the depth of the water, y can be determined.

i. Draw a free body diagram for the straight section of the pipe as well as the 90 deg elbow. The force equation can be used with statics to determine the reaction force values. Add the horizontal and vertical sections from each section to determine the overall vertical and horizontal forces. Bernoulli's equation will be used to determine the pressure at all locations, with the tank being the other reference point.

j. Draw a cross sectional sketch of the log. The value for the depth of the water was determined in part a. For the log to barely be floating the log cannot have a width higher than the depth of the water. The density is provided and can be used to determine the specific weight. Set the buoyant force equal to the weight and this creates a ratio of the volume displaced to the total volume, this can be used to determine the width of the cross sections. The center of gravity is easily determined because of the square cross section. I'm not sure how to determine the length since it doesn't seem to be needed for determining the maximum size? I selected an arbitrary length. The center of buoyancy is determined using the depth that is submerged and the metacenter is found

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using the equation of the moment of inertia/volume. The stability will then be determined based on whether the metacenter is above or below the center of gravity

k. A sketch of the flow nozzle was drawn. Since we know both diameters, beta can be determined. The Reynolds number can be calculated and then the value for the discharge coefficient can be found. $P_1 - P_2 = h(\gamma_m - \gamma_f)$ will be used but h needs to be determined. This equation will be used $h = \frac{\left(\frac{Q}{A_1 \times C}\right)^2 \times \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)}$. Once that is complete the pressure drop can be found.

l. For this section since the valve closed suddenly this equation can be used $\Delta P = \rho A C$ to find the pressure increment. To determine the value of C this equation can be used: $C = \frac{\sqrt{\frac{E_o}{\rho}}}{\sqrt{1 + \frac{E_o D}{E \delta}}}$ The values for δ,ρ,D,E_o can be found in tables in the textbook, while E was given in the problem statement. Once C is determined the pressure change can be determined. To decide if cavitation is an issue the pressure will have to be compared to the saturation pressure at the temperature given in the problem. If the pressure is greater than there are no issues but if it is lower cavitation will be a problem.

m. Assuming that the log has the same square cross section, the projected area can be determined. We know the velocity of the fluid and the density. Since this is a square projected area, the C_D=1.16. $F_D = C_D \frac{\rho V^2}{2} A$ can be used to determine the drag force.

n. The force can be determined by the pressure times the area. The pressure will be determined by the gamma h equation, and the area is the same as the pipe.

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Calculations:

a) Water Channel Depth

$A = 1.73y^2$ ✓

$WP = 3.46y$

$R = y/2$ ✓

$S = 0.001$ ✓

The material is unfinished concrete $\therefore$ n=0.017 ✓

$$AR^{2/3} = \frac{nQ}{S^{1/2}} \longrightarrow (1.73y^2)\left(\frac{y}{2}\right)^{2/3} = \frac{(0.017)(0.167\,ft^3/s)}{0.001^{1/2}}$$

$$(1.73y^2)\left(\frac{y}{2}\right)^{2/3} = 0.0898$$

Using Excel:

y	A	R	RHS	LHS	% diff
1	1.73	0.5	0.089777	1.089832	-1114%
2	6.92	1	0.089777	6.92	-7608%
0.5	0.4325	0.25	0.089777	0.171638	-91%
0.4	0.2768	0.2	0.089777	0.094664	-5%
0.39	0.263133	0.195	0.089777	0.088484	1%
0.392	0.265839	0.196	0.089777	0.089699	0%

$\boxed{y = 0.392\,ft}$ ✓

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b) Applying Bernoulli's equation to determine unknown pressures

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+h_L$$

$$\frac{p_1}{\gamma}+\frac{\cancel{V_1^2}}{2g}+z_1=\frac{\cancel{p_2}}{\gamma}+\frac{V_2^2}{2g}+\cancel{z_2}+h_L$$

$$\frac{p_1}{\gamma}+z_1=\frac{V_2^2}{2g}+h_L$$

$$Q=VA\longrightarrow V=Q/A$$

$$\frac{p_1}{\gamma}+z_1=\frac{(Q/A)^2}{2g}+h_L$$

$$p_1=\gamma\left(\frac{(Q/A)^2}{2g}+h_L-z_1\right)$$

Energy Losses

$$h_L=h_{L,inlet}+h_{L,valve}+h_{L,elbow}$$

$$h_L=K_{inlet}\left(\frac{V^2}{2g}\right)+K_{valve}\left(\frac{V^2}{2g}\right)+K_{elbow}\left(\frac{V^2}{2g}\right)+f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

$$K_{inlet}=0.5$$

$$K_{valve}=340f$$

$$K_{elbow}=30f$$

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Reynolds Number

$$V = Q/A = \left(0.167\frac{ft^3}{s}\right)/\left(0.01414ft^2\right) = 11.8104ft/s$$

$$\text{Re} = \frac{\rho V D}{\eta} = \frac{\left(1.94\frac{slugs}{ft^3}\right)(11.8104ft/s)(0.1342ft)}{2.34\times10^{-5}\frac{lb-s}{ft^2}}$$

$$\text{Re} = 131,402.3085 \therefore \text{flow is turbulent}$$

Friction Factor

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

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{\text{Re}^{0.9}}\right)\right]^2} = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.1342ft}{1.5\times10^{-4}ft}\right)} + \frac{5.74}{131,402.3085^{0.9}}\right)\right]^2}$$

$$f = 0.0203$$

Energy Losses Continued:

$$h_L = K_{inlet}\left(\frac{V^2}{2g}\right) + K_{valve}\left(\frac{V^2}{2g}\right) + K_{elbow}\left(\frac{V^2}{2g}\right) + f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

$$h_L = \left(\frac{V^2}{2g}\right)\left(K_{inlet} + K_{valve} + K_{elbow} + f\left(\frac{L}{D}\right)\right)$$

$$h_L = \left(\frac{V^2}{2g}\right)\left(0.5 + 340f + 30f + f\left(\frac{L}{D}\right)\right)$$

$$h_L = \left(\frac{11.8104ft/s^2}{2(32.2ft/s^2)}\right)\left(0.5 + 340(0.0203) + 30(0.0203) + (0.0203)\left(\frac{300ft}{0.1342ft}\right)\right)$$

$$h_L = 115.64ft$$

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$$p_1 = 62.4 lb/ft^3 \left(\frac{\left(0.167 \frac{ft^3}{s} / 0.01414 ft^2\right)^2}{2(32.2 ft/s^2)} + 115.64 ft - 3 ft \right)$$

$$\boxed{p_1 = 247.79 lb/ft^2}$$

$$\frac{p_3}{\gamma} + \frac{\cancel{V_3}^2}{2g} + \cancel{z_1} = \frac{\cancel{p_2}}{\gamma} + \frac{\cancel{V_3}^2}{2g} + \cancel{z_2} + h_L$$

$$p_3 = \frac{h_L}{\gamma} = \frac{30f\left(\frac{V^2}{2g}\right)}{\gamma} = \frac{30(0.0203)\left(\frac{(11.8104 ft/s)^2}{2(32.2 ft/s^2)}\right)}{62.4 lb/ft^3}$$

$$\boxed{p_3 = 0.02113 lb/ft^2}$$

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Forces in the Straight Section of the Pipe

$F_x = \rho Q(V_{2x} - V_{1x}) = P_4A_4 - P_3A_3 - R_x$

$R_x = P_4A_4 - P_3A_3 - \rho Q(V_{2x} - \not{V}_{1x})$

$R_x = \left(434.99\frac{lb}{ft^2}\right)(0.01414ft^2) - (0.02113lb/ft^2)(0.01414ft^2)$

$\boxed{R_x = 6.15lb}$

$F_y = \rho Q(V_{2y} - V_{1y}) = R_y - W$

$R_y = \rho Q(\not{V}_{2y} - \not{V}_{1y}) + W$

$\boxed{R_y = W}$

Forces in the Elbow of the Pipe

$F_x = \rho Q(V_{2x} - V_{1x}) = P_3A_3 - R_x$

$R_x = P_3A_3 - \rho Q(\not{V}_{2x} - V_{1x})$

$R_x = (0.02113lb/ft^2)(0.01414ft^2) - 1.94\frac{slugs}{ft^3}\left(0.167\frac{ft^3}{s}\right)(-11.8104ft/s)$

$\boxed{R_x = 3.827lb}$

$F_y = \rho Q(V_{2y} - V_{1y}) = -P_2A_2 - W + R_y$

$R_y = \rho Q(V_{2y} - \not{V}_{1y}) + \not{P}_2A_2 + W$

$R_y = \rho Q(V_{2y}) + W$

$R_y = 1.94\frac{slugs}{ft^3}\left(0.167\frac{ft^3}{s}\right)(11.8104ft/s) + W$

$\boxed{R_y = 3.83lb + W}$

Total Forces:

$\boxed{\text{Horizontal: 9.97lb}}$

$\boxed{Vertical: 3.83lb + 2W}$

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c) Determining the largest log the channel can support

$$\gamma_{\log} = \rho g = 830 kg/m^3 \cdot 9.81 m/s^2 = 8142.3 \frac{kg}{m^2 \cdot s^2}$$

$$F_b = \gamma_{water} V_d$$

$$F_b = W$$ ✓

$$W = \gamma_{\log} V_{\log}$$

$$\gamma_{\log} V_{\log} = \gamma_{water} V_d$$

$$V_{\log} = \frac{\gamma_{water}}{\gamma_{\log}} V_d = \frac{9810 \frac{kg}{m^2 \cdot s^2}}{8142.3 \frac{kg}{m^2 \cdot s^2}} V_d = 1.2 V_d$$

The log will be 80% submerged in the fluid based on the determined ratio.

Since y=0.392ft, $h = 0.392 \cdot 1.2 = \boxed{0.4704 ft \times 0.4704 ft}$ Determined cross section not Length

Stability Determination:

Assuming the same square cross section:

$$L_{cg} = \frac{h}{2} = \frac{0.4704 ft}{2} = 0.2352 ft$$ ✓

$$L_{cb} = \frac{y}{2} = \frac{0.392 ft}{2} = 0.196 ft$$ ✓

$$MB = \frac{I}{V_d}$$ ✓

$$I = \frac{h^4}{12} = \frac{(0.4704 ft)^4}{12} = 0.00408 ft^4$$ ✗ Should have modeled as cylinder.

$$MB = \frac{I}{V_d} = \frac{0.00408 ft^4}{2h \cdot L} = \frac{0.00408 ft^4}{2(0.4704 ft) \cdot L}$$

Assuming L=1ft

$$MB = 0.004336 ft$$ ✗

$$L_{mc} = L_{cb} + MB = 0.196 ft + 0.004336 ft = 0.20 ft$$

$$\boxed{L_{mc} < L_{cg} \therefore \text{Log is not stable}}$$

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d) Determining the pressure drop due to flow nozzle

$$Re = 131402.31$$ ✓

$$\beta = d / D = 0.5$$ ✓

$$C = 0.9975 - 6.53\sqrt{\frac{\beta}{Re}} = 0.9975 - 6.53\sqrt{\frac{0.5}{131402.31}} = 0.9848$$ ✓

$$h = \frac{\left(\frac{Q}{A_1 C}\right)^2 \bullet \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)}$$

$$A_1 = 0.01414 ft^2$$

$$A_2 = \frac{\pi}{4}D^2 = \frac{\pi}{4}\left(\frac{0.1342 ft}{2}\right)^2 = 0.00354 ft^2$$

Using Mercury as the manometric fluid   No manometer

$$\gamma_m = 844.9\frac{lb}{ft^3}$$

$$\gamma_w = 62.4\frac{lb}{ft^3}$$

$$h = \frac{\left(\frac{0.167\frac{ft^3}{s}}{(0.01414 ft^2)0.9848}\right)^2 \bullet \left[\left(\frac{(0.01414 ft^2)}{0.00354 ft^2}\right)^2 - 1\right]}{2g\left(\frac{844.9\frac{lb}{ft^3}}{62.4\frac{lb}{ft^3}} - 1\right)} = 0.0266 ft$$ Wrong equation used

$$P_1 - P_2 = h(\gamma_m - \gamma_w) = 0.0266 ft(844.9\frac{lb}{ft^3} - 62.4\frac{lb}{ft^3}) = \boxed{23.5\frac{lb}{ft^2}}$$

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e) Cavitation Calculations

$$E_o = 4.49\times10^7 \frac{lb}{ft^2}$$

$$E = 200GPa = 4.177\times10^9 \frac{lb}{ft^2}$$

$$\delta = 0.0118ft$$

$$C = \frac{\sqrt{\frac{E_o}{\rho}}}{\sqrt{1+\frac{E_oD}{E\delta}}} = \frac{\sqrt{\frac{4.49\times10^7 \frac{lb}{ft^2}}{1.94\frac{slugs}{ft^3}}}}{\sqrt{1+\frac{\left(4.49\times10^7 \frac{lb}{ft^2}\right)(0.1342ft)}{\left(4.177\times10^9 \frac{lb}{ft^2}\right)(0.0118ft)}}} = \boxed{4541.27ft/s}$$

In solution posted E & E_o are flipped

$$\Delta P = \rho AC = \left(1.94\frac{slugs}{ft^3}\right)\left(0.01414ft^2\right)\left(4541.27ft/s\right) = \boxed{124.57\frac{lb}{ft^2}}$$

f) Drag Calculations

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

$$V = \frac{1.0}{\eta}S^{1/2}R^{2/3} = \frac{1.0}{1.15\times10^{-3}}(0.001)^{1/2}\frac{0.119m}{2}^{2/3} = 4.19m/s = 13.746ft/s$$

$A =$ Projected Area of the log $= \frac{h}{2}\cdot\frac{h}{2} = 0.05532ft^2$ Carried forward incorrect

Since the projected area is a square $C_D = 1.16$

$$F_D = 1.16\left(\frac{\left(62.4\frac{lb}{ft^3}\right)\left(13.746ft/s\frac{ft}{s}\right)^2}{2}\right)0.05532ft^2$$

$$\boxed{F_D = 378.31lb}$$