Old Dominion University

MET 330 Fluid Mechanic

Instructor: Professor Ayala

Test 2

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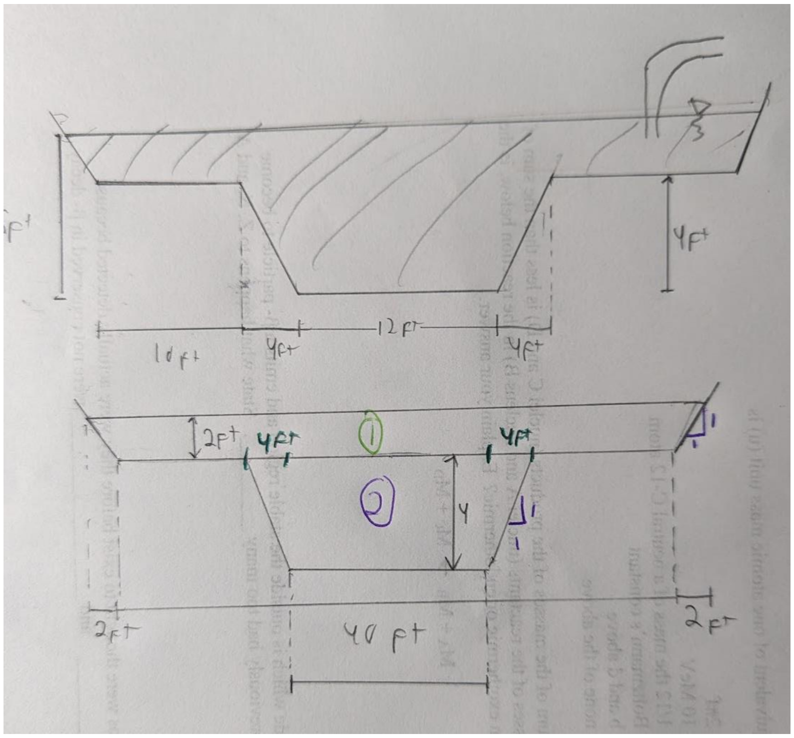
Section A

Purpose:

Determine whether the amount of pumped water is negligible compared to the flowing flow rate of lower open channel

Drawing/Diagrams of this section of calculation:



Lower open channel dimensions

Sources:

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

Design Considerations:

- Incompressible fluids
- Steady state
- Isothermal process
- Uniform steady natural channel with light brush(lower open channel)

Data and Variables

S = Lower open channel slope = 0.00015

T= 60°F

n= 0.050(table 14.1)

Q_1 = Water pumped from lower open channel to upper channel flow= $3.387\frac{ft^3}{s}$

Q_2 = Lower open channel flow = ?

Procedure:

This problem deal with fluid (water) flowing through an open channel, while some part of it is being pumped from an existing design, to determine whether the fluid being pumped is negligent, I must calculate the water flowing(Q_2) in the open channel against the water being pumped (Q_1):

First, I will calculate the cross sectional-area of the water flowing in the open channel, as it is a variable required to determine the water flowing to apply to the normal discharge equation. Then I will compute R, and then the flow rate of the open channel and compare it to the flow rate of water being pumped away from the open channel.

Calculations:

$$A_1 = \frac{a+b}{2}h = \frac{44+40}{2}2 = 84\,ft^2$$

$$A_2 = \frac{a+b}{2}h = \frac{(12+20)\,ft}{2}4\,ft = 64\,ft^2$$

$$A_{total} = 84+64 = 148\,ft^2$$

$$R = \frac{A}{WP} = \frac{148\,ft^2}{(2\sqrt{2^2+2^2}+10+2\sqrt{4^2+4^2}+12+10)\,ft} = 3.022\,ft$$

$$OpenChannelFlow = Q_2 = Av = \frac{1.49}{n}AR^{2/3}S^{1/2} = \frac{1.49}{0.050}148^2 * (3.022)^{2/3} * 0.00015^{1/2} = 112.91\frac{ft^3}{s}$$

$$\%different = \frac{Q_1}{Q_2} = \frac{3.387\frac{ft^3}{s}}{112.91\frac{ft^3}{s}} * 100 = 3.00\%$$

Materials:

Water at 60°f

Summary:

The water being pumped away from the lower open channel is 3.387 ft $\frac{ft^3}{s}$, and the calculation for water flowing in lower open channel is 112.91 $\frac{ft^3}{s}$, which indicates that the existing pipeline system design takes away approximately 3% of the natural water flowing through. This is a small amount of water being taken away from the channel and is negligible in my opinion, however, the employer should consider the local regulations into account when determining this factor.

Analysis:

The current calculation of water flow in open channel is based on given diagram, this value could fluctuate to a lower amount if the water from the lower open channel is experiencing less rainfall during drought season, and/or if the pumped water amount is increased, then the value of 3% being pumped away from the open channel could be much higher.

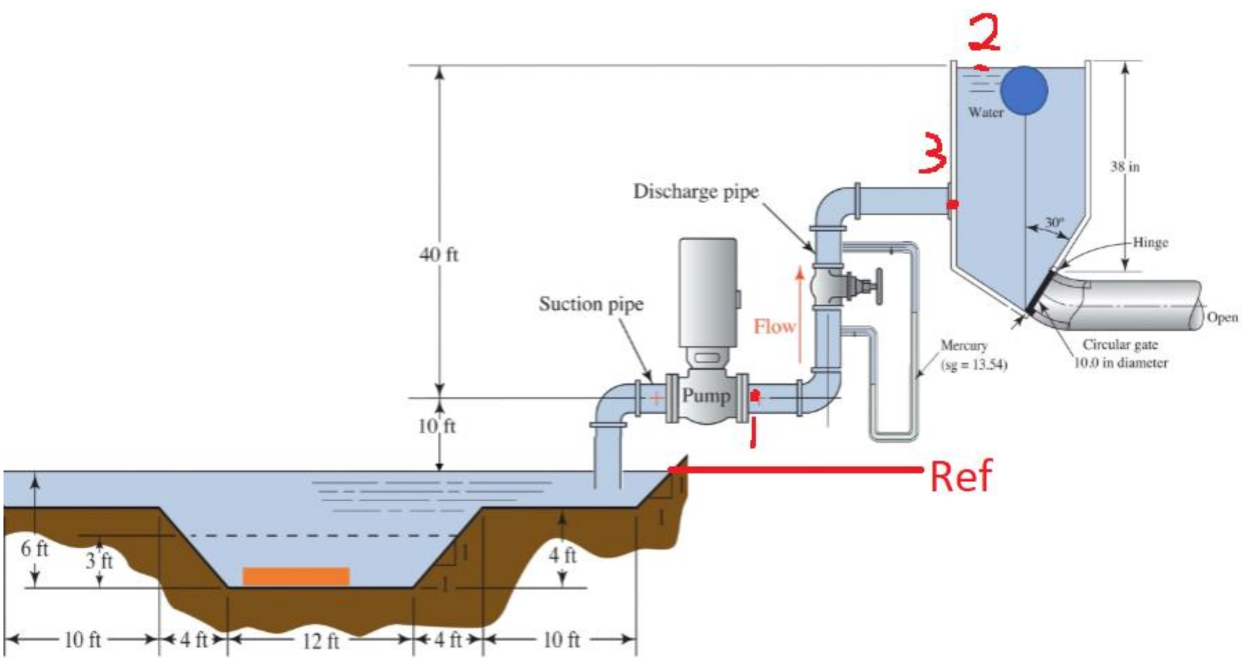
Therefore, I'd recommend the employer to set the end of suction pipe at the point where they don't want water level of the lower open channel to be lowered further. Thus, the system won't draw any water if the water dipped below the suction level; and I'd also recommend to install a detection system in this case for the pump to be turned off automatically, preventing the pump from running dry and potentially causing overheating issues.

Section B

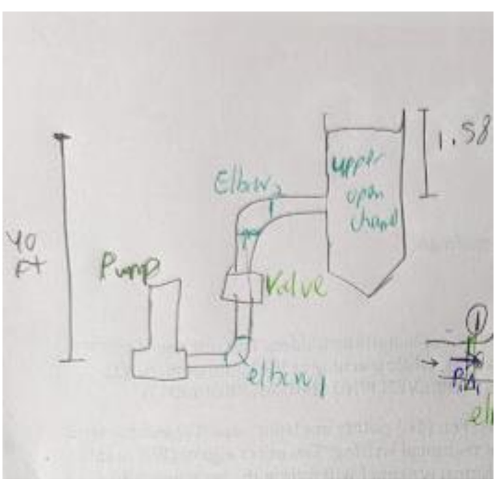
Purpose:

Calculating the forces of water inflicting on the discharge pipe, in order to design a supporting structure from these forces

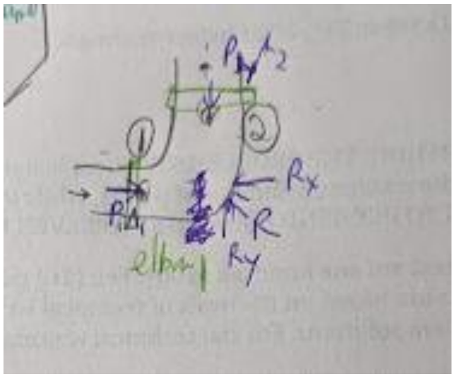
Drawing/Diagrams of this section of calculation:



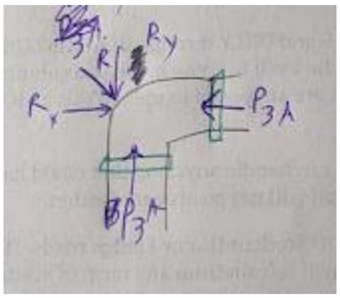
Bernoulli's reference



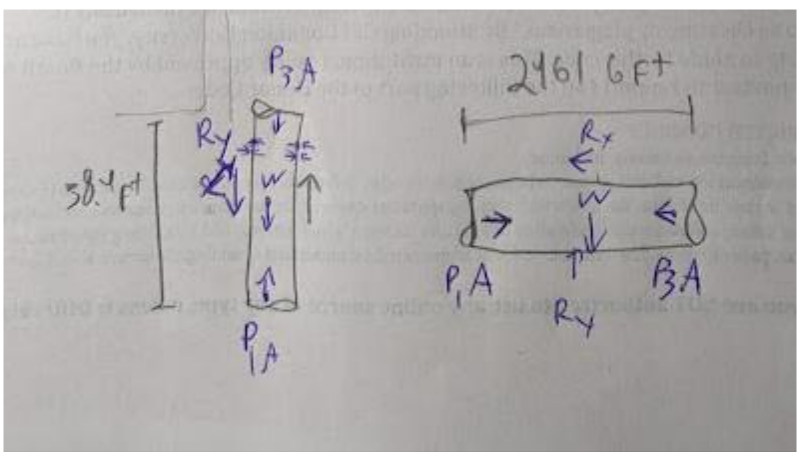
Preliminary drawing



Elbow 1



Elbow 2



Vertical and Horizontal section of discharge pipe

Sources:

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

Design Considerations:

- Incompressible fluids
- Steady state flowing
- Isothermal process
- Neglecting the weight of pipes

Data and Variables

Q= 3.387 $\frac{ft^3}{s}$

A = 0.3472 ft^2

p = 1.94 $\frac{slug}{ft^3}$

V = 9.755 $\frac{ft}{s}$

g = 32.2 ft $\frac{ft}{s^2}$

γ = 62.4 $\frac{lb}{ft^3}$

h_{Lelbow}=1.86ft(3 elbows)

h_{Lvalve}=7.83ft

Procedure:

For this section, I will need to calculate the force happening in the pipe to determine how much force that the structure need to be supported for the discharged pipe. The forces happening will be computed for elbows, the pipes, and valves.

First off, I know that the reaction will require pressure, thus I will apply Bernoulli equation as it is moving fluid to determine pressure after pump (point 1).

For point 3 pressure at the inlet, due to lack of information of height referencing from bottom(diagram above), I will assume it is around the middle of the upper open channel), and thus, about 19 inches, or ~1.58 ft off the top of the upper open channel.

Then I will compute for the forces acting at each elbow using impulse theorem, along with the mass conservation. The same thing apply for the whole pipeline system that I will compute below as well.

Calculation:

Setting up bernoullie's equation, and some variables cancelled out (P_2 for atmosphere, V_2~0, no h_A)

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^{\ 2}}{2g} + Z_2 + h_{L_{1-2}}$$

$$P_1 = (Z_2 + h_{L_{1-2}} - \frac{V_1^2}{2g} - Z_1)\gamma = [50\,ft - 10\,ft + (\frac{1.86\,ft}{3} * 2 + 7.83\,ft) - \frac{(9.755\frac{ft}{s})^2}{2*32.2\frac{ft}{s^2}}] * 62.4\frac{lb}{ft^3} = 2969.8\,psf$$

$$h_A + \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + Z_3 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L_{3-2}}$$

$$P_3 = (Z_2 - \frac{V_3^2}{2g} - Z_3)\gamma = (50\,ft - \frac{(9.755\frac{ft}{s})^2}{2*32.2\frac{ft}{s^2}} - (50\,ft - 1.58\,ft))*62.4\frac{lb}{ft^3} = 6.39\,psf$$

Forces acting on Elbow 1:

$$R_x = P_1A_1 + pQV_1 = (2969.8\frac{lbf}{ft^2}*0.3472\,ft^2) + 121.06\frac{lbm}{ft^3}*3.387\frac{ft^3}{s}*9.755\frac{ft}{s} = 3095.1lbf$$

Since the size of the elbows are quite small and are energy loss also minimal(0.62ft per elbow), and also because the size of inlet=outlet, I'll equate P_{1y} to P_1 as well inside elbow diagram

$$R_y = PQV_2 + P_1A_1 = R_x = 3095.1lbf$$

Forces acting on Elbow 2:

I'll also apply the same logic from Elbow 1 to Elbow 2, and thus P_3 will be the same in both x and y direction at elbow 2

$$-P_3A + R_x = pQV$$

$$R_x = pQV + P_3A = 62.47\frac{lbm}{ft^3}*3.387\frac{ft^3}{s}*9.755\frac{ft}{s} + 6.39\frac{lbf}{ft^2}*0.3472\,ft^2 = 2066.2lbf$$

$$R_y = R_x = 2066.2lbf$$

Forces acting at Valve:

There is no horizontal force component as the fluid is moving directly upward.

And the vertical force will not be taking into consideration at the valve, since the support structure of the piping and elbow will also supporting the force at/near the valve.

Forces acting on the pipeline system:

Based on the diagram, the vertical component of the discharge pipe should be around ~38.4 ft(according to the previous assumption of where the exit to upper open channel is), and since I know that the discharge pipe is 2,500 ft. Subtracting that the vertical length from total length give me the horizontal length of 2,461.6 ft

For the horizontal section of the discharge pipe:

$$Rx = \frac{P_1 - P_3}{A} = \frac{2969.8\,psf - 6.39\,psf}{0.3472\,ft^2} = 8535.2lbs$$

$$Ry = W = pAL = 1.94\frac{slug}{ft^3} * 0.3472\,ft^2 * 2461.6\,ft * \frac{32.2lb}{1slug} = 53389.4lbs$$

For the vertical section of the discharge pipe:

Rx = 0

$$P_1A - W - R_y - P_3A = PQ(V_{3y} - V_3y)$$

$$Ry = (P_1 - P_3)A - W - = (2969.8 - 6.39)\frac{lb}{ft^2} * 0.3472\,ft^2 - (62.4\frac{lb}{ft^3} * 0.3472\,ft^2 * 38.4\,ft) = 196.9lbs$$

Total Rx = 13,696.5 lbs

Total Ry = 58,747.3 lbs

Materials:

Water at 60^{o}f

Steel pipe

Summary:

Force acting at elbow 1 = 3095.1 at both x/y direction

Force acting at elbow 2 = 2066.2 lbs at both x/y direction

Force acting at valve is neglect and is calculated along with the vertical section of discharge pipe

Force acting on the horizontal (2461.6ft) discharge pipe are:

Fx= 8,535.1 lbs

Fy = 53,389.4 lbs

Force acting on the vertical discharge pipe are:

Fx = 0

Fy = 196.9 lbs

Total Rx = 13,696.5 lbs

Total Ry= 58,747.3 lbs

These calculation doesn't include the weight of the pipe, but only including the weight of water

Analysis:

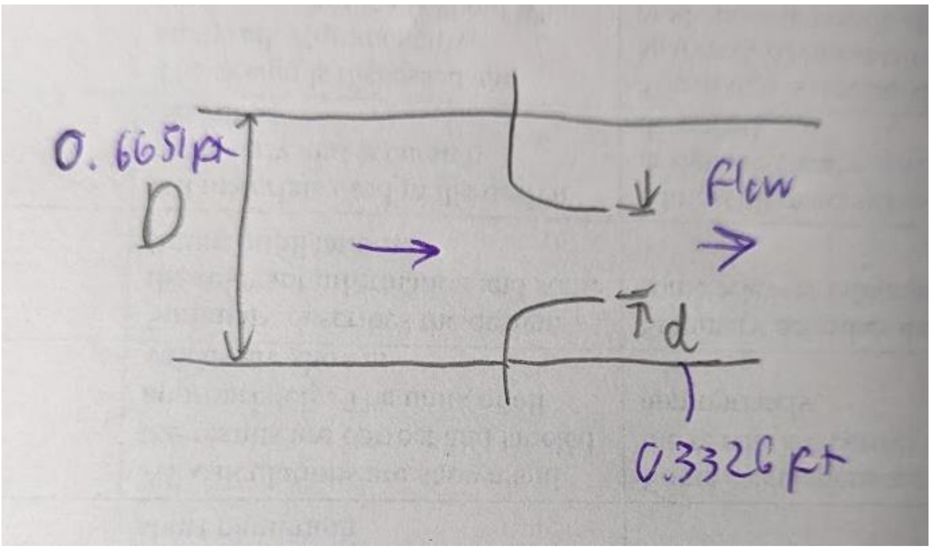
The force acting at elbow 1 is higher than elbow 2 due to the pressure different at the two locations. Also due to the total length of the discharge pipe, there are quite a lot of fluid moving through, and thus the structure will have a lot of water weight and needed proper support along the whole pipeline system. I recommend having the support structure to not spaced out too far from each other to prevent high amount of moment. The diagram also doesn't indicate how far the discharge pipe go out before it is connected with elbow 1 and elevated 90 degree to the vertical discharge pipe, but I would delay having the vertical discharge to as near the exit as possible to save on costs of building support structures. As raising the discharge pipe too early would mean the pipeline system of 2400 ft would have to be supported at a higher level, which increase the materials needed.

Section C

Purpose:

Client proposed an idea of using nozzle to measure the flow. Find out the pressure drop across the nozzle, and also calculate the energy loss to take that into account that is needed for the pump power to increase.

Drawing/Diagrams of this section of calculation:



Flow nozzle inside piping system

Sources:

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

Design Considerations:

- Incompressible fluids
- Steady state flowing
- Isothermal process

Data and Variables

Q= 3.387 $\frac{ft^3}{s}$

β = d:D = 0.5

D = 0.6651 ft

d = 0.3326 ft

A_1 = 0.3472 ft^2

$A_2 = 0.0869\ ft^2$

$V = 9.755\ \frac{ft}{s}$

$g = 32.2\ \frac{ft}{s^2}$

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

$\eta = 2.35E\text{-}5\ \frac{lb-s}{ft^2}$

v

Pump motor efficiency= 0.6

Procedure:

I know the pipe diameter, pipe area, and the ratio of nuzzle to pipe diameter, thus I can use that to find the actual diameter of nuzzle, area of after, and also Reynold number. I also know that I need to set up a few equations with complex arithmetic variables, so I'll write every equations that I might need to use down in Calculation first, then simplified it down to the variable that I want, which is the pressure different (Delta P).

From there, I will use delta P to plot into a Bernoulli's equation to find energy loss from the nozzle and the pump power % increased after.

Calculation:

$$\beta = \frac{d}{D} = 0.5$$

$$\mathrm{Re} = \frac{VD}{v} = \frac{9.755\frac{ft}{s} * 0.6651\,ft}{1.21E-5\frac{ft^2}{s}} = 536202$$

$$C = 0.9975 - 6.532\sqrt{\frac{\beta}{\mathrm{Re}}} = 0.9975 - 6.532\sqrt{\frac{0.5}{536202}} = 0.991$$

$$Q = CA_1 \sqrt{\frac{2g(P_1 - P_2)/\gamma}{(\frac{A_1}{A_2})^2 - 1}}$$

$$(\frac{Q}{CA_1})^2 = \frac{2g(P_1 - P_2)}{(\frac{A_1}{A_2})^2 - 1}$$

$$(\frac{Q}{CA_1})^2 * [(\frac{A_1}{A_2})^2 - 1] = \frac{2g(P_1 - P_2)}{\gamma}$$

$$\frac{\{(\frac{Q}{CA_1})^2 * [(\frac{A_1}{A_2})^2 - 1]\}\gamma}{2g} = \Delta P$$

$$\Delta P = \frac{\{(\frac{3.387\frac{ft^3}{s}}{0.991 * 0.3472\,ft^2})^2 * [(\frac{0.3472\,ft^2}{0.0869\,ft^2})^2 - 1]\}62.4\frac{lb}{ft^3}}{2 * (32.2)\frac{ft}{s^2}} = 1404.9\,psf$$

Using Bernoulli, a head loss can be derived to:

$$\frac{\Delta P}{\gamma} = h_L = \frac{1404.9\frac{lbs}{ft^2}}{62.4\frac{lb}{ft^3}} = 22.5\,ft$$

New power requirements:

$$P = \frac{\gamma Q h_A}{\eta} = \frac{62.4 * 3.387 * (147.53 + 22.5)}{0.6} = 59892.7\frac{lb * ft}{s} = 110.41 HP$$

%different:

$$PowerDifferent = 110.41 - 94.48 = 15.93 HP$$

$\% = \frac{15.93}{94.48} * 100 = 16.86\% increase$ in pump power needed

Materials:

Steel pipe

Water

Flow nozzle

Summary:

The pressure different was calculated to be 1404.9 pound per square feet, and that is equated to 22.5 ft of energy loss. And the pump power needed to be increase up to 110.41 H.P to keep up with the new head loss, which is 16.86% increase in pump power from the previous state.

Analysis:

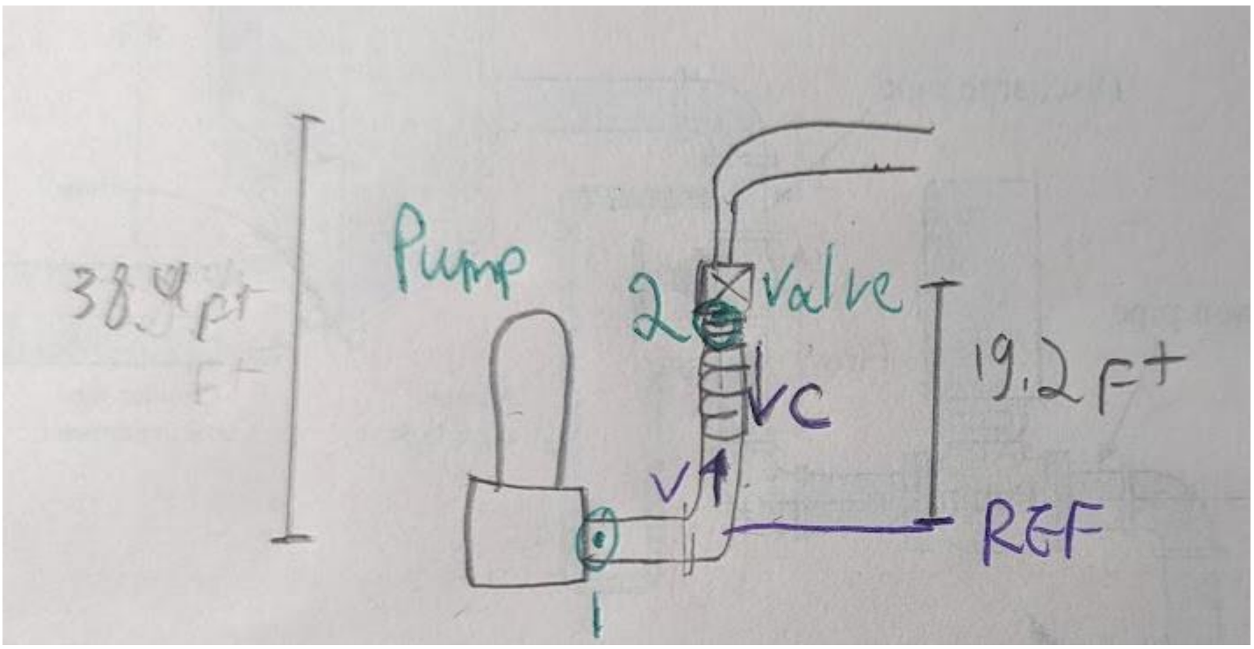
The new proposed nozzle by client with the diameter ratio of 0.5 has an energy loss of 22.5 ft, which is significant as it requires the previously designed pump to be replaced something that is almost 120% the current pump design. The calculation is there so if the client wish to switch to a different nozzle with different diameter ratio, it can be done quickly, as the equation is already set up and just needed to replace the diameter ratio to calculate the new pump head.

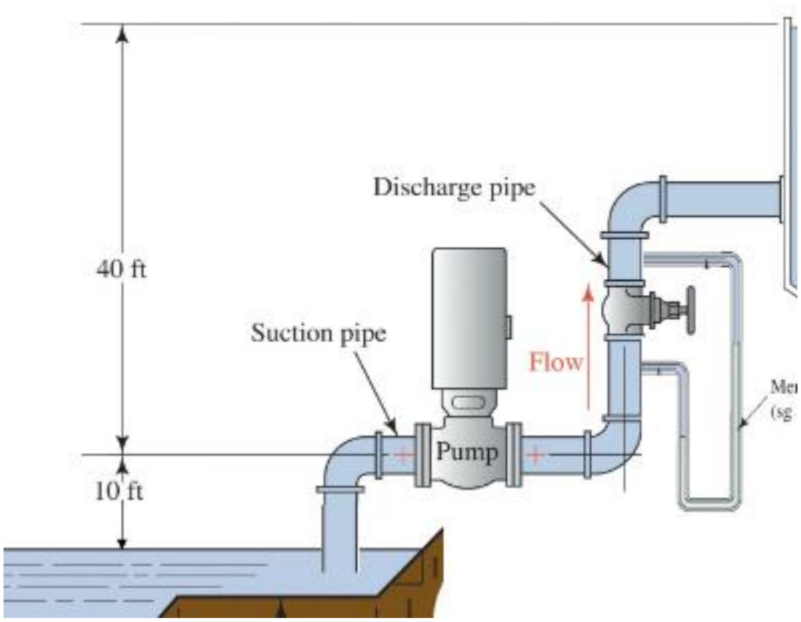
Section D

Purpose:

Verify the existing pipeline system for any occurrence of water hammer, and cavitation. Also check for pressure increment when valve is suddenly closed, and whether the pipe would fail with the provided modulus of elasticity.

Drawing/Diagrams of this section of calculation:





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Sources:

Mott, R., Untener, "Applied Fluid mechanics", 7^{th} edition, Pearson Education, Inc. (2015)

Design Considerations:

- When valve is closed and water started compressing and sending a fluctuation wave back
- Incompressible fluid when valve is fully opened and in operation
- Calculating as if the valve closing speed is very fast to prepare for worst case scenario
- Isothermal process.

Data and Variables:

$\varepsilon_{pipe} = 200GPa = 2E11Pa =$ 4177086757.6742psf

$\varepsilon_{w} = 316\ 000\,psi = 2.1787E9Pa = 45504000psf$

$\rho = 1.94\dfrac{slug}{ft^3} = 62.5\dfrac{lb}{ft^3} = 1000\dfrac{kg}{m^3}$

$\partial = 0.322in = 0.2683\,ft = 0.00818m = \ pipethickness$

D= pipe diameter =7.981in = 0.665 ft =.2027m

D_{OD}= pipe outside diameter = 8.625 in = 0.7188

V=9.755 $\dfrac{ft}{s}$= 2.97 $\dfrac{m}{s}$

γ = 62.4 $\dfrac{lb}{ft^3}$

g = 32.2 $\dfrac{ft}{s^2}$

P_1= $2969.8\,psf$

h_L elbow= 0.62ft

$h_{Ltotaldischargepipe}$ = 86.36ft

$P_{saturation}$= 0.25638 psi @ 60ºF

Procedure:

Treat the design system as if the valve suddenly closed very fast and water hammer started occurring, the wave of the fluid will be sending back while velocity is heading to slam toward the valve.

I know that the $P_{\max} = P_{op} + P_{\Delta}$ and, from the F = ma equation in class that derived to $P_{\Delta} = pcV$. So from these two equations, I need to find out the wave speed to find out the pressure increment.

Then I will also find the operating pressure by applying Bernoulli equation, and add it to the pressure increment to compute maximum pressure in the pipe as the result of water hammering. Once I have that value, I will compare it to provided modulus of elasticity in the summary section. Along with comparing the lowest pressure point obtained from previous test to pressure at the saturation point.

I also then need to calculate the minimum thickness required from eq 11-9

Calculation:

$$c = \frac{\sqrt{\frac{E_w}{\rho}}}{\sqrt{1+\frac{E_w D}{E_p \partial}}} = \frac{\sqrt{\frac{2.1787E9Pa}{1000\frac{kg}{m^3}}}}{\sqrt{1+\frac{21787E9Pa*0.2027m}{2E11Pa*0.00818m}}} = 1309.8\frac{m}{s} = 4297.2\frac{ft}{s}$$

$$P_{\Delta} = pcV = 1000*1309.8*2.97 = 3890106Pa = 81,247\,psf$$

For the calculation of Operating pressure at the valve, I'll make guesses of where the valve is based on provided drawing due to lack of information. I'll place it halfway up the discharge pipe (refer to drawing section for dimensions). Using Bernoulli:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L$$

Velocity is the same at both point(same area cross-section and Q), Z_1 is at reference line, so both will cancel out.

$$(\frac{P_1}{\gamma} - Z_2 - h_L)\gamma = P_2$$

Knowing energy loss from elbow, the friction loss from discharge pipe upto the valve(half of discharge pipe – 1250ft) also needs to be taken into account:

$$h_{Lpipe} = \frac{86.36}{2} = 43.18\,ft$$

Compute for P_2(Operating pressure of the fluid right before valve):

$$P_{op} = (\frac{P_1}{\gamma} - Z_2 - h_L)\gamma = P_2 = [\frac{2969.8\frac{lb}{ft^2}}{62.4\frac{lb}{ft^3}} - 19.2\,ft - (43.18\,ft + 0.62\,ft)]*\frac{62.4lb}{ft^3} = -961.4\,psf$$

$$P_{\max} = P_{op} + \Delta P = -961.4\frac{lb}{ft^2} + 81247\frac{lb}{ft^2} = 80285.6\,psf = 3{,}844{,}062\text{Pa} = 0.003844\text{GPa}$$

The lowest point of pressure would be right before the pump. According to data from previous test , the pressure at suction point before the pump was calculated to be around -742psf, which is around -5.2psi, and the saturation pressure from the book is at 0.25638 psi.

$$t = \frac{pD}{2(SE + pY)} = \frac{557.5psig * 8.625in}{2(2.901E7 * 1.0 + 557.5psig * 0.40)} = 8.2903E - 4in = 0.000829in$$

Materials:

Water

Steel pipe

Summary:

The pressure increment was calculated to be 82,247 psf, and maximum pressure from water hammering when valve is closed very fast would be 3,844,062 Pa, which is 0.003844 GPa, and that is well under the modulus of elasticity provided (200GPa). So water hammering wouldn't be a problem for this piping system.

The lowest pressure before the pump was determined to be -5.2 psi (with the 95 horsepower system), and it shouldn't change to much if the employer decide to switch to 110 H.P pump to accommodating the nuzzle in Part C, thus cavitation should not be a problem as the operating pressure is nowhere near 0.25638psi(P_{sat})

Minimum thickness calculated to be 8.29E-4 in

Analysis:

The current pipeline system was analyzed and computed under the worst condition of water hammer, by using equation 11-9, the minimum thickness calculated to be 8.29 E-4, which the current piping thickness of .322 in can handle.

The same thing applies to cavitation as well, since the saturation pressure point is well away from the operating pressure (-5.2 psi versus 0.25638 psi).

If the employer wishes to ensure to minimize the potential of the issues, they could instruct their employer to close the valve slowly to decrease the potential increment in pressure. They could also inject air into the pipe as well.

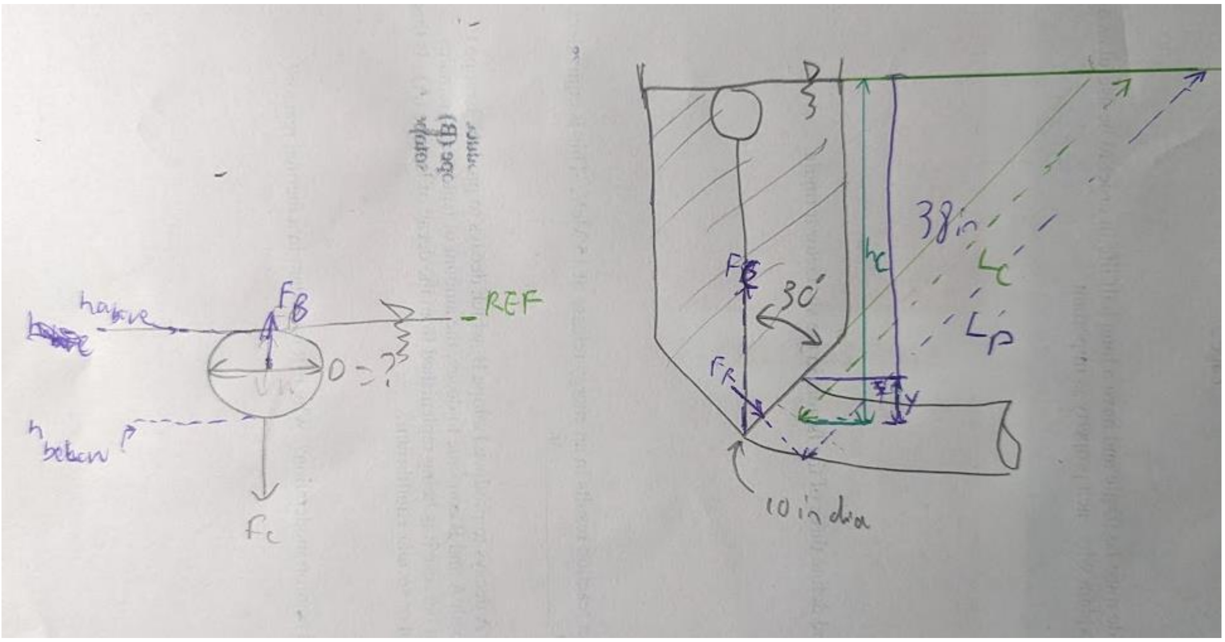
For cavitation, employer could check for sound of bubble collapsing in the pipe, specifically near the pump as it is where the lowest pressure point located at. If there is significant sound at this location, cavitation is an issue and need to be proper examined.

Section E

Purpose:

Determine how large the spherical buoy need to be, for it to lift the gate when the water level reaches 38 inches. And also, whether the buoy is stable when this happening.

Drawing/Diagrams of this section of calculation:



Free body diagram of buoy on left, and drawing of upper open channel on the right

Sources:

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

Design Considerations:

- Incompressible fluid
- Steady state
- Isothermal process.
- Neglecting the weight of circular gate and buoy

Data and Variables:

$$\rho = 1.94\frac{slug}{ft^3} = 62.5\frac{lb}{ft^3} = 1000\frac{kg}{m^3}$$

Dgate = 10 in

$\gamma = 62.4 \ \dfrac{lb}{ft^3}$

$g = 32.2 \ \dfrac{ft}{s^2}$

Procedure:

For this particular problem, the spherical buoy need to exert a buoyancy force that will lift the spherical itself, along with the circular gate at the bottom.

I will first identify the required amount of force the cable attached to the ball.
First I need to determine the characteristic of cross section of the gate, such as moment of inertia, area, then I will find the different dimensions for Hc, Lc, etc to find centroid and reaction force.

Due to neglecting the weight of circular gate and buoy, the force in free body diagram at the buoy showed that $F_b = F_C$ in order for the buoy to stay submerged at the top, If Fb is slightly larger than Fc then the buoy will start floating and lift the circular gate as well. So whatever dimension that allow the buoy to have $F_b = F_C$ will be the required dimension.

Calculation:

$$I_c = \frac{\pi(10)^4}{64} = 490.9in^4$$

$$A_g = \frac{\pi}{4}(10)^2 = 78.54in^2$$

$$L_c = \frac{h_c}{\cos 30} = \frac{38 + 5\cos 30}{\cos 30} = 48.88in$$

$$h_c = 42.3in$$

$$F_r = \gamma h_c A = 62.4\frac{lb}{ft^3} * 42.3in\frac{1ft}{12in} * 78.54in^2(\frac{1ft}{12in})^2 = 120.0lb$$

Know:

$$L_p = L_c + \frac{I_c}{L_c * A}$$

$$L_p - L_c = \frac{I_c}{L_c * A}$$

$$L_p - L_c = \frac{I_c}{L_c * A} = \frac{490.9in^4}{48.88in * 78.54in^2} = 0.1279in$$

The force required to pull the cable using moment:

$$\sum M = 0 = F_R(5+(L_p - L_c)) - Fc*5$$

$$F_c = \frac{F_R(5.128)}{5} = \frac{120lb(5.128in)}{5in} = 123.1lb$$

Calculating for the buoy, knowing $F_b = F_C$

$$F_b = \left(\gamma h_{below} - \gamma h_{above}\right)A = \left(\gamma h_{below} - \gamma h_{above}\right)\frac{\pi}{4}h^2$$

$$\frac{F_b * \pi}{4} = \gamma(h)h^2$$

$$\sqrt[3]{\frac{F_b * \pi}{4\gamma}} = h = \sqrt[3]{\frac{123.1lb * \pi}{4(62.4)\frac{lb}{ft^3}}} = 1.16\,ft$$

Materials:

Water

Circular gate

Buoy

Summary:

The force required to lift the gate was determined to be 123.1 lb, and the minimum spherical buoy dimension diameter was calculated to be 1.16 ft

Analysis:

The buoy diameter dimension was calculated to be 1.16 ft, or 13.92 in. The buoy should be made of material that is not too heavy as this calculation does not taking the material and weight of the buoy into consideration, and thus not applicable unless the buoy density is less than water.

. This buoy also works if the employer decides to make the water level requirement for buoy activation lower, as long as the chain connecting to the ball is made shorter so that as water lift the buoy up, it also pull the chain along with it at the needed length.

Section F

Purpose:

Determine the maximum object weight at the bottom of the lower open channel in order for it to slide along the bottom surface.

Drawing/Diagrams of this section of calculation:

Sources:

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

Design Considerations:

- The object does not tumbles
- Incompressible fluid
- Isothermal process.
- Steady state
- The object sink completely at the bottom and does not float

Data and Variables:

$$\rho = 1.94 \frac{slug}{ft^3} = 62.5 \frac{lb}{ft^3}$$

Coefficient friction factor = μ = 0.6

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

$$g = 32.2 \ \frac{ft}{s^2}$$

L= 5ft

S = 1ft

$$V_{channel} = \frac{Q}{A_{total}} = \frac{112.91 \frac{ft^3}{s}}{148 \, ft^2} = 0.763 \frac{ft}{s} \text{ (From Section A)}$$

Procedure:

What determine whether the object slide along the bottom of the lower channel is the force of the water pushing onto the object is larger and overcame the static friction of the object against the ground. Thus, I need to determine the amount of force acting on the object using impulse theorem.

Calculation:

For object to move R_x need to be larger than F_f

$$F_f = \mu W$$

$$\sum F_x = pQ(V_{2x} - V_{1x})$$

$$R_x = pVA(0 - 0.763\frac{ft}{s}) = \frac{62.5lb}{ft^3} * (0.763\frac{ft}{s} * 5\,ft * 5\,ft) * (-0.763\frac{ft}{s}) = -909.64\frac{ft * lb}{s^2} = -125.8N$$

Plot Rx into F_f the weight equation to determine the weight.

$$W = \frac{F_f}{\mu} = \frac{909.64\frac{ft * lb}{s^2}}{0.60} = 1516.1\frac{ft * lbm}{s^2} * \frac{1lbf}{32.2\frac{ft * lbm}{s^2}} = 47.08lbf$$

Therefore W of the object < 47.08 lb

Materials:
Water

5x5x1ft Object

Summary:

The object need to weight less than 47.08 lb in order for the fluid in the open channel to slide it along the bottom of the channel.

Analysis:

The maximum weight of the box can be until it stop sliding is 47.08 lb, this is calculating with the previous known velocity of the channel from Section A, if the velocity increases, then the fluid will able to move heavier object with the same dimensions, and vice versa.