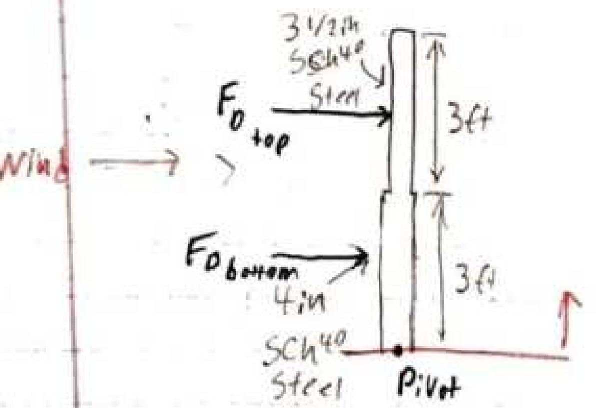
Test 3

Problem 1

Jacob Leonard

Purpose:
To compute the moment at the base of a vertical pole due to a 80 mi/h wind

Drawing:



Design Considerations
The following must be assumed
1) Incompressible Fluid
2) Isothermal Process
3) Steady State

Source: Unit 3 Exam

Data and Variables
- $V = 80 \frac{\text{miles}}{\text{hour}}$ $\quad 80 \frac{\text{miles}}{\text{hour}} \cdot \frac{5280\text{ ft}}{1\text{ mile}} \cdot \frac{1\text{ hr}}{3600\text{ s}}$ $\quad$ • $V = 117.33 \frac{ft}{s}$

digit 3
- $L_{bottom} = 3ft$ • $L_{top} = 3ft$
- $D_{bottom} = 4.5in = 0.375ft$ • $D_{top} = 4 in = 0.333 ft$
- $T_{air} = 71°F$

Procedure
- To compute the moment at the base of the pole, I need to find the drag force on the top and bottom sections of the pole using the formula:

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

- To obtain the coefficient of drag for each section, I will need to calculate the Reynolds number using

$$Re = \frac{VD}{\nu}$$

- Where D is the outside diameter of each pipe
- After I find the Reynolds number, I will use figure 17.4 from the textbook to find the coefficient of drag.
- Then I can calculate the drag force for each section of pipe, top and bottom

- Next, with the drag force of each section I can calculate the moment at the base of the pole due to the wind
- The location of each drag force will be located at the middle of each section of pipe
  - This is important because I will need this to find the length of the moment arm of each in order to calculate the moment at the base

$$M = F_{D,bottom} \cdot d_{bottom} + F_{D,top} \cdot d_{top}$$

Calculations

$$R_{e,bottom} = \frac{V \cdot D_{bottom}}{\nu}$$

To obtain kinematic viscosity for the air temperature of 71°F, I need to interpolate the value since table E.2 only provides values at 60°F and 80°F

	T°F	ν
1	60	$1.58 \times 10^{-4}\ ft^2/s$
2	80	$1.69 \times 10^{-4}\ ft^2/s$

$$\frac{T_{air} - T_1}{T_2 - T_1} = \frac{\nu_{air} - \nu_1}{\nu_2 - \nu_1}$$

$$\left(\frac{T_{air} - T_1}{T_2 - T_1}\right)(\nu_2 - \nu_1) + \nu_1 = \nu_{air}$$

$$\frac{71°F - 60°F}{80°F - 60°F}\left(1.69 \times 10^{-4}\frac{ft^2}{s} - 1.58 \times 10^{-4}\frac{ft^2}{s}\right) + 1.58 \times 10^{-4}\frac{ft^2}{s} = 1.641 \times 10^{-4}\frac{ft^2}{s}$$

$$R_{e,bottom} = \frac{V \cdot D_{bottom}}{\nu} = \frac{117.33 \frac{ft}{s} \cdot 0.375 ft}{1.6405 \times 10^{-4} \frac{ft^2}{s}}$$

$$R_{e,bottom} = 268210.91 \quad 2.68 \times 10^5$$

From figure 17.4, I read $C_D \cong 0.9$

I will need the density of the air so, again, I must interpolate the value at 71°F between 60° and 80°F

	T °F	ρ
1	60	2.37×10^{-3} slugs/ft³
2	80	2.28×10^{-3} slugs/ft³

$$\frac{T_{air} - T_1}{T_2 - T_1} = \frac{\rho_{air} - \rho_1}{\rho_2 - \rho_1}$$

$$\left(\frac{T_{air} - T_1}{T_2 - T_1}\right)(\rho_2 - \rho_1) + \rho_1 = \rho_{Air}$$

$$\left(\frac{71°F - 60°F}{80°F - 60°F}\right)\left(2.28 \times 10^{-3} \frac{slugs}{ft^3} - 2.37 \times 10^{-3} \frac{slugs}{ft^3}\right) + 2.37 \times 10^{-3} \frac{slugs}{ft^3} = \rho_{Air}$$

$$\rho_{Air} = 2.3205 \times 10^{-3} \; slugs/ft^3$$

$$F_{D,bottom} = C_{D,bottom} \left(\frac{\rho V^2}{2}\right) A_{Bottom}$$

$$F_{D,bottom} = 0.9 \cdot \left(\frac{2.3205 \times 10^{-3} \frac{slugs}{ft^3} \left(117.33 \frac{ft}{s}\right)^2}{2}\right)\left(0.375 ft \cdot 3 ft\right)$$

$$F_{D,bottom} = 16.173 \frac{slugs}{\cancel{ft^3}} \cdot \frac{ft^{\cancel{4}}}{s^2} \cdot \cancel{ft}$$

$$F_{D,bottom} = 16.173 \; slugs \cdot \frac{ft}{s^2}$$

$$\underline{F_{D,bottom} = 16.173 lb}$$

$$Re_{,top} = \frac{V \cdot D_{top}}{\nu} = \frac{117.33\ ft/s \cdot 0.333\ ft}{1.6405 \times 10^{-4}\ ft^2/s}$$

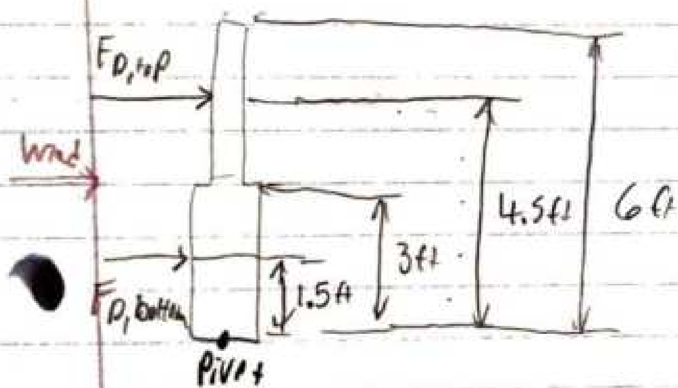
$$Re_{,top} = 238409 \quad 2.38 \times 10^5$$

From figure 17.4, I read $C_D \cong 0.95$

$$F_{D,top} = C_{D,top}\left(\frac{\rho V^2}{2}\right) \text{Area top}$$

$$F_{D,top} = 0.95\left(\frac{2.3205 \times 10^{-3}\ \frac{slugs}{ft^3}\left(117.33\ \frac{ft}{s}\right)^2}{2}\right)(0.333\ ft \cdot 3\ ft)$$

$$F_{D,top} = 15.175\ lb$$



$d_{top} = 4.5ft$

$d_{bottom} = 1.5ft$

$$M = F_{D,bottom} \cdot d_{bottom} + F_{D,top} \cdot d_{top}$$

$$M = 16.173 lb \cdot 1.5 ft + 15.175 lb \cdot 4.5 ft$$

$$M = 92.545\ ft \cdot lb$$

Summary

The moment at the base is 92.546 ft·lb due to the drag force on the pole from the 80mi/h wind

Materials

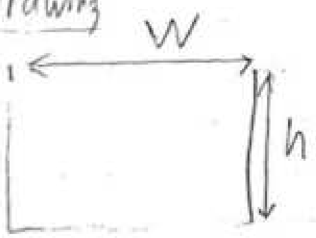
Air

Analysis - The moment due to the drag force of the upper portion of the pole is larger than the moment due to the drag force of the lower portion of the pole. This is due to the larger moment arm of the upper portion.

- The drag force on each section is similar, but the drag force on the lower section is higher due to the larger diameter which results in a larger area perpendicular to the wind direction.

Problem 2: Purpose: To compute the liquid height of an open channel and to determine if the flow is super critical or subcritical

Drawing



Sources: Unit 3 Exam

Design Considerations

The following must be assumed
1) Incompressible fluid
2) Isothermal process
3) Steady state

Data and Variables

$S = 0.001$ Cement $n = 0.015$

Digit 7 $W = 18\,ft$ $Q = 150\,ft^3/s$

Procedure

- To find the fluid depth of the channel, I will Manning's equation to find the flow rate of an open channel and solve for the height

$$Q = \frac{1.49}{n} A S^{\frac{1}{2}} R^{\frac{2}{3}}$$

- In order to do this, I will need to find the area, wetted perimeter, and hydraulic radius
- However, the equations I just mentioned will require the fluid height which will involve an iterative process

- Area = W·h
- Wp = W + 2h
- $R = \frac{A}{Wp} = \frac{W \cdot h}{W + 2h}$

- After I find the fluid height, I can calculate the Froude Number

$$F_r = \frac{V}{\sqrt{g \cdot y_h}}$$

- y_h is the hydraulic depth and is calculated by:

$$y_h = \frac{A}{T}$$

- Where T is the width of the free surface at the top of the channel
- For this problem, T is equal to W

$$y_h = \frac{A}{W}$$

- Once I calculate the Froude Number, I can determine if the flow is subcritical or supercritical
  - If Fr<1, then it is subcritical flow
  - If Fr>1, then it is supercritical flow

<u>Calculations</u>

$$Q = \frac{1.49}{n} A S^{\frac{1}{2}} R^{\frac{2}{3}} \xrightarrow{\text{move all terms to the right side that I know}} AR^{2/3} = \frac{nQ}{1.49 S^{1/2}}$$

$$AR^{\frac{2}{3}} = \frac{0.015 \cdot 150 \frac{ft^3}{s}}{1.49 (0.001)^{\frac{1}{2}}}, \quad AR^{\frac{2}{3}} = 47.753.$$

$$W \cdot h \left(\frac{W \cdot h}{W + 2h}\right)^{2/3} = 47.753$$

At this point, I must iterate in excel to find h

To find h

1. Pick a value of h
2. Calculate left hand side of equation
3. Compare left hand side to right hand side, If they are the "same", meaning % error < 1%, then I will stop. If the values are not the same than I must choose a new value for h and repeat the process

After iterating in excel, I find $h = 1.9417\ ft$

- Now, I can calculate the Froude number
- First I need to calculate the velocity

$$V = \frac{Q}{A} = \frac{Q}{w \cdot h} = \frac{150\ ft^3/s}{18ft \cdot 1.9417ft} = 4.292\ ft/s$$

$$r_h = \frac{A}{W} = \frac{W \cdot h}{W} = h = 1.9417\ ft$$

$$Fr = \frac{V}{\sqrt{g \cdot r_h}} = \frac{V}{\sqrt{g \cdot h}} = \frac{4.292\ ft/s}{\sqrt{32.2\ ft/s^2 \cdot 1.9147 ft}}$$

$$Fr = 0.543$$

$$Fr = 0.543 < 1$$

This flow is subcritical

Summary

- The required fluid depth for the channel to flow $150 ft^3/s$ is 1.9417 ft
- The Froude number is less than 1, therefore the flow is sub-critical

Materials

- Cement

Analysis

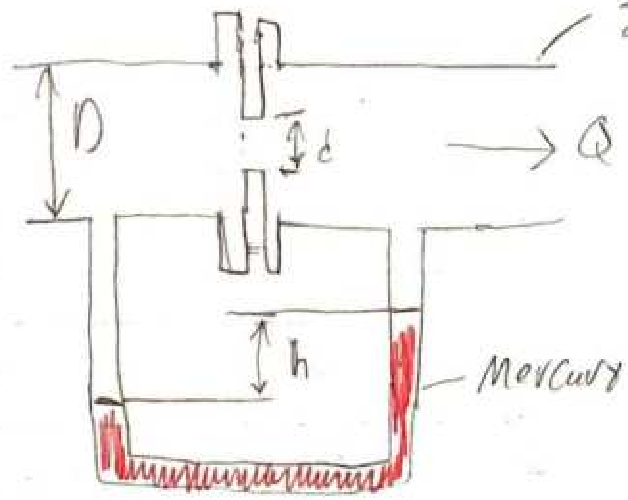
- The channel width chosen was important for the problem because if it were wider, the fluid depth may be too small and the flow could become supercritical.
  - This made the fluid depth high enough that the flow wouldn't be supercritical.
    - Also in this case, because the flow is wide and not very deep, this minimizes the wetted perimeter for the given area. A channel 18ft tall and 1.9417ft wide would have the same area of $34.9506 ft^2$, but the wetted perimeter would be 37.9417 ft versus the wetted perimeter of the configuration I calculated was 21.8834 ft. This makes for a more efficient channel flow

Problem 3

Purpose:

To Compute the liquid height of a mercury manometer when an orifice plate of $\beta = 0.5$ is used to measure a water flow rate

Drawing



Source: Unit 3 Exam

Design Considerations

The following must be

1) Incompressible fluid
2) Isothermal Process
3) Steady state

Data and Variables

- $\beta = 0.5$
- $D = 1.886$ ft
- $Q = 6000$ gpm $= 13.36 \ ft^3/s$
- $\gamma_{water} = 62.4 \ lb/ft^3$
- $Sg_{mercury} = 13.54$
- $\nu = 1.21 \times 10^{-5} \ ft^2/s$

Digit 7

$$6000 \frac{Gal}{min} \cdot \frac{1 \ ft^3/s}{449 \ gal/min} = 13.36 \frac{ft^3}{s}$$

Assuming a water temperature of $60°F$

Procedure

- To find the fluid height of the mercury manometer, I will use the following equation which is used to find flow rate with an orifice plate meter

$$Q = A_1 \cdot C \cdot \sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w} - 1\right)}{\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}}$$

- I will solve this equation for h
  - I will need to find Area of the inside of the pipe and the area of the orifice plate bore

$$A = \frac{\pi}{4} \cdot D^2$$

- To find the bore diameter, I will use the Beta β and inner pipe diameter

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

- To find the correction factor, C, I will calculate the Reynold's number and use diameter ratio β to find the correction factor from figure 15.7 from the book

Calculations

$$Q = A_1 \cdot C \sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w}-1\right)}{\left[\left(\frac{A_1}{A_2}\right)^2-1\right]}} \rightarrow \frac{Q}{A_1 \cdot C} \sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w}-1\right)}{\left[\left(\frac{A_1}{A_2}\right)^2-1\right]}}$$

$$\left(\frac{Q}{A_1 \cdot C}\right)^2 = \frac{2gh\left(\frac{\gamma_m}{\gamma_w}-1\right)}{\left[\left(\frac{A_1}{A_2}\right)^2-1\right]} \longrightarrow \left(\frac{Q}{A_1 \cdot C}\right)^2\left[\left(\frac{A_1}{A_2}\right)^2-1\right] = 2gh\left(\frac{\gamma_m}{\gamma_w}-1\right)$$

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

$$d = \beta \cdot D = 0.5 \cdot 1.886\,ft = 0.943\,ft$$

$$A_1 = \frac{\pi}{4}(1.886\,ft)^2 \quad A_1 = 2.794\,ft^2$$

$$A_2 = \frac{\pi}{4}(0.943\,ft)^2 \quad A_2 = 0.698\,ft^2$$

$$V = \frac{Q}{A_1} = \frac{13.36\,ft^3/s}{2.794\,ft^2} = 4.78\,ft/s$$

$$Re = \frac{VD}{\nu} = \frac{4.78\,ft/s \cdot 1.886\,ft}{1.21 \times 10^{-5}\,ft^2/s} = 745569.27$$

$$\beta = 0.5 \qquad Re = 7.46 \times 10^5$$

$$C = 0.601$$

$$h = \frac{\left(\frac{13.36\frac{ft^3}{s}}{2.794ft^2 \cdot 0.661}\right)^2 \left[\left(\frac{2.794ft^2}{0.698ft^2}\right)^2 - 1\right]}{2 \cdot 32.2\frac{ft}{s^2}\left(\frac{844.896\,lb/ft^3}{62.4\,lb/ft^3} - 1\right)}$$

$\gamma_m = 13.54 \cdot 62.4\frac{lb}{ft^3}$

$\gamma_m = 844.896\frac{lb}{ft^3}$

$$h = 1.177\,ft$$

Summary:

- The liquid height of the mercury manometer is 1.177ft or 14.12in for a flow rate of 6000 gpm.

Materials:

- Water
- Mercury

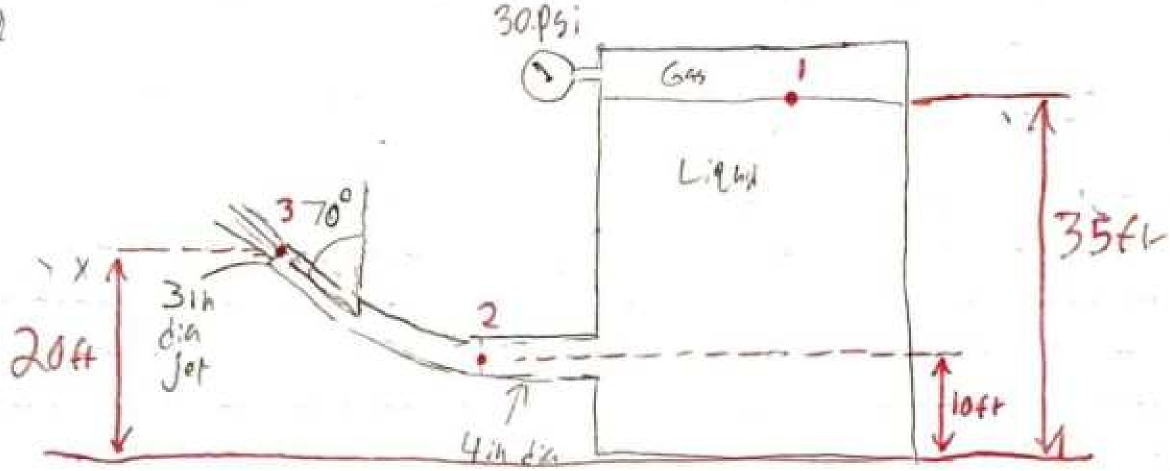
Analysis:

The fluid level height differential in the manometer is due to the increase velocity after the orifice plate. This causes the pressure to decrease and is less than the pressure before the plate which has a lower velocity.

Problem 4:

Purpose: To compute the force on the curved pipe section and direction of the force

Drawing



Source: Unit 3 Exam

Design Considerations

The following must be assumed

1) Incompressible fluid
2) Isothermal Process
3) Steady State
4) Neglect energy losses

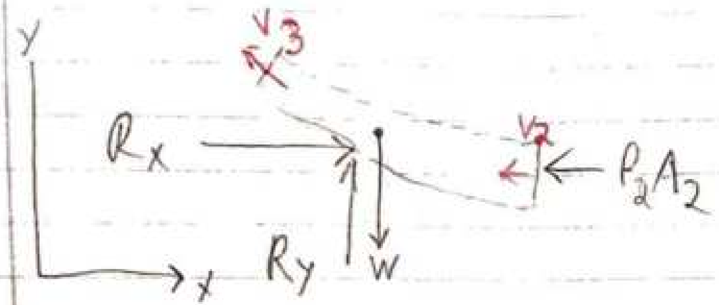
Data and Variables

- All dimensions are in drawing
- $\gamma = 55 \ lb/ft^3$
- $L_{curved} = 30 ft$

Digit

Procedure

- To find the magnitude and direction of the force on the curved section of pipe, I will apply a control volume to this section



- Next, I will apply a free body diagram to this curved section to find the forces acting on it in the x and y directions.

$$F_x = \rho Q \Delta V_x = \rho Q(V_{3x} - V_{2x})$$

$$R_x - P_2 A_2 = \rho Q(-V_{3x} - (-V_{2x}))$$

$$R_x = P_2 A_2 + \rho Q(-V_3 \cdot \sin\theta + V_2)$$

$$F_y = \rho Q \Delta V_y = \rho Q(V_{3y} - V_{2y})$$

$$R_y - W = \rho Q(V_{3y} - 0)$$

$$R_y = W + \rho Q(V_3 \cdot \cos\theta)$$

- Once I have found the x and y components, I can calculate the magnitude of the force using Pythagorean Theorem

$$R_x^2 + R_y^2 = R^2$$

$$R = \sqrt{R_x^2 + R_y^2}$$

- Using R_x and R_y, I can also calculate the direction of the force.

$$\tan\alpha = \frac{R_y}{R_x} \quad \alpha = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

- Before I can calculate the reaction forces, I need to find the flow rate of the pipe and pressure 2 which is at point 2 that I have labeled on the drawing.

- To obtain the flow rate in the pipe, I will apply Bernoulli's equation between point 1 and point 3

$$\frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_3}{\gamma}} + \frac{V_3^2}{2g} + z_3$$

- Velocity is zero for point 1 since the system is steady state.
- Pressure at point 3 is zero since it is open to the atmosphere.

$$\frac{V_3^2}{2g} = \frac{P_1}{\gamma} + z_1 - z_3$$

- I will substitute in $V = \frac{Q}{A} = \frac{4Q}{\pi \cdot D^2}$

$$\frac{16Q^2}{\pi^2 \cdot D_3^4 \cdot 2g} = \frac{P_1}{\gamma} + z_1 - z_3 \longrightarrow \frac{8Q^2}{\pi^2 \cdot D_3^4 \cdot g} = \frac{P_1}{\gamma} + z_1 - z_3$$

$$8Q^2 = \pi^2 \cdot D_3^4 \cdot g\left(\frac{P_1}{\gamma} + z_1 - z_3\right) \qquad Q^2 = \frac{\pi \cdot D_3^2 \cdot g\left(\frac{P_1}{\gamma} + z_1 - z_3\right)}{8}$$

$$Q = \sqrt{\frac{\pi \cdot D_3^2 \cdot g\left(\frac{P_1}{\gamma} + z_1 - z_3\right)}{8}}$$

- With the flow rate, I can apply Bernoulli's equation between points 1 and 2 to find the pressure at point 2

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

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + z_1 - z_2 - \frac{V_2^2}{2g} \qquad P_2 = \gamma\left(\frac{P_1}{\gamma} + z_1 - z_2 - \frac{V_2^2}{2g}\right)$$

- To find the weight of the water, I will need to find the volume of the curved section of pipe.
  - Since diameter at the beginning of the curved section of pipe is 4 inch and the end is 3 inch, I will have to make an approximation for the diameter to find the volume. To do this, I will take an average of the two diameters.

$$\text{Volume} = A \cdot L_{curved}$$

$$\text{Volume} = \left(\frac{\pi}{4} \cdot D^2\right)(L_{curved})$$

$$\text{Volume} = \left(\frac{\pi}{4} \cdot \left(\frac{D_2 + D_3}{2}\right)^2\right)(L_{curved})$$

- With the volume and specific weight of the fluid, I can calculate the weight of the water

$$W = \text{Volume} \cdot \gamma = V \cdot \frac{W}{V}$$

Calculations

$$Q = \sqrt{\frac{\pi^2 \cdot D_3^4 \, 4g\left(\frac{P_1}{\gamma} + z_1 - z_3\right)}{8}}$$

$$P_1 = 30\,\frac{lb}{in^2} \cdot \frac{144\,in^2}{1\,ft^2} = 4320\,\frac{lb}{ft^2}$$

$$Q = \sqrt{\frac{\pi^2 \cdot \left(3in \cdot \frac{1ft}{12in}\right)^4 \cdot 32.2\,\frac{ft}{s^2}\left(\frac{4320\frac{lb}{ft^2}}{55\frac{lb}{ft^3}} + 35ft - 20ft\right)}{8}} \qquad \sqrt{ft^4 \cdot \frac{ft}{s^2} \cdot ft} \quad \sqrt{\frac{ft^6}{s^2}}$$

$$\frac{ft^3}{s}$$

$$Q = \underline{3.809\ ft^3/s}$$

$$V_3 = \frac{Q}{A_3} = \frac{3.809\,ft^3/s}{\frac{\pi}{4} \cdot \left(3in\left(\frac{1ft}{12in}\right)\right)^2} = \underline{77.62\,\frac{ft}{s}}$$

$$V_2 = \frac{Q}{A_4} = \frac{3.809\,ft^3/s}{\frac{\pi}{4} \cdot \left(4\left(\frac{1ft}{12in}\right)\right)^2} = \underline{43.66\,\frac{ft}{s}}$$

$$P_2 = \gamma\left(\frac{P_1}{\gamma} + z_1 - z_2 - \frac{V_2^2}{2g}\right)$$

$$P_2 = 55\,\frac{lb}{ft^3}\left(\frac{4320\,\frac{lb}{ft^2}}{55\,\frac{lb}{ft^3}} + 35ft - 10ft - \frac{\left(43.66\,\frac{ft}{s}\right)^2}{2 \cdot 32.2\,\frac{ft}{s^2}}\right)$$

$$P_2 = \underline{4067.09\ lb/ft^2}$$

$$Volume = \left(\frac{\pi}{4} \cdot \left(\frac{D_2 + D_3}{2}\right)^2\right)(L_{curved})$$

$$Volume = \left(\frac{\pi}{4} \cdot \left[\frac{\left(4in \cdot \frac{1ft}{12in}\right) + \left(3in \cdot \frac{1ft}{12in}\right)}{2}\right]^2\right)(30ft)$$

$$Volume = 2.004\ ft^3$$

$$Weight = Volume \cdot \gamma$$

$$= 2.004\ ft^3 \cdot 55 \frac{lb}{ft^3}$$

$$Weight = 110.24lb$$

$$\gamma = \rho g$$

$$\rho = \frac{\gamma}{g}$$

$$R_x = P_2 A_2 + \rho Q(-V_3 \cdot \sin\theta + V_2)$$

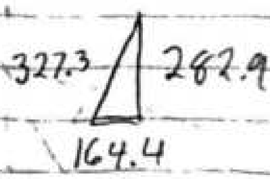
$$R_x = \left(4067.09 \frac{lb}{ft^2}\right)\left(\frac{\pi}{4}\left(4in \cdot \frac{1ft}{12in}\right)^2\right) + \frac{55 \frac{lb}{ft^3}}{32.2 \frac{ft}{s^2}} \cdot 3.809 \frac{ft^3}{s}\left(-77.62 \frac{ft}{s} \cdot \sin 70 + 43.66 \frac{ft}{s}\right)$$

$$R_x = 164.397lb$$

$$R_y = W + \rho Q(V_3 \cdot \cos\theta)$$

$$R_y = 110.24lb + \frac{55 \frac{lb}{ft^3}}{32.2 \frac{ft}{s^2}} \cdot 3.809 \frac{ft^3}{s}\left(77.62 \frac{ft}{s} \cdot \cos 70\right)$$

$$R_y = 282.4996\ lb$$



$$R = \sqrt{R_x^2 + R_y^2}$$

$$R = \sqrt{164.397lb^2 + 282.4996lb^2}$$

$$R = 327.28lb$$

$$\alpha = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

$$\alpha = \tan^{-1}\left(\frac{282.4996\ lb}{164.397lb}\right)$$

$$\alpha = 59.85°$$

Summary:

The force on the pipe is 327.28 lb and is at an angle of 59.85° for a pipe 30ft long.

Materials

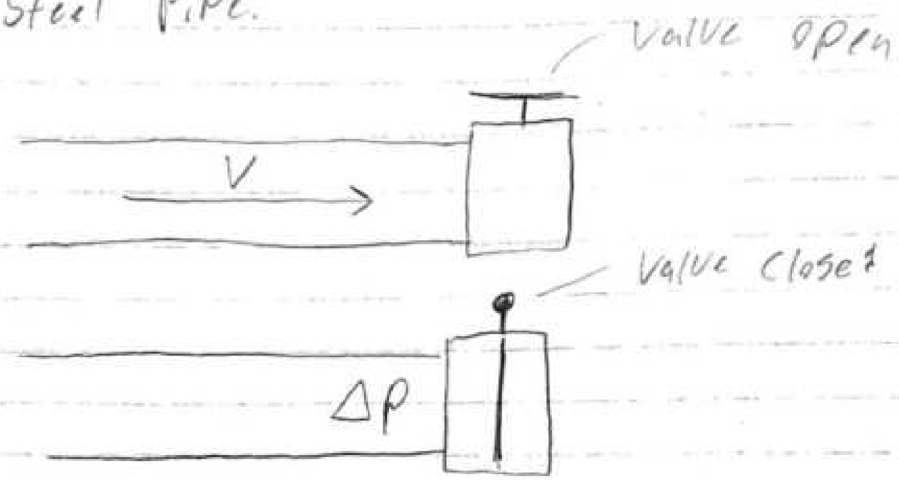
- Liquid With $\gamma = 55\ lb/ft^3$

Analysis

The reaction force in the Y is larger than the reaction force in the X due to the relatively low angle of the pipe. The Weight of the fluid also contributed to this. The pressure at point 2 contributed to most of the force in the Y direction. The pressure of the gas acting on the fluid and elevation created a large flow rate through the pipe which means it had a large velocity.

Problem 5

Purpose: Calculate the pressure increment when a valve is close suddenly at the end of a steel pipe.



Source: Unit 3 Exam

Design Considerations

The following must be assumed
1) Incompressible fluid
2) Isothermal process
3) Steady State

Data and Variables

- $E = 2 \times 10^7\ N/cm^2$
- $\delta = 10mm$
- $E_o = 2.03 \times 10^5\ N/cm^2$

Digit 4 - $D = 300mm$
- $V = 1.0\ m/s$
- $\rho = 1000\ Kg/m^3$ for $T = 10°c$

Procedure:

To calculate the pressure increment when the valve is closed, I will use the equation for water hammer.

$$\Delta P = \rho C V$$

-Where C is the velocity of the wave

$$C = \frac{\sqrt{\frac{E_0}{\rho}}}{\sqrt{1+\frac{E_0 D}{E\delta}}}$$

Calculations

$E = 2\times10^{7}\frac{N}{\cancel{cm^2}}\cdot\frac{100\cancel{cm}}{1m}\cdot\frac{100\cancel{cm}}{1m} = \quad E = 2\times10^{11}\frac{N}{m^2}$

$\delta = 10mm \quad \delta = 0.01m$

$E_0 = 2.03\times10^{5}\frac{N}{\cancel{cm^2}}\cdot\frac{100\cancel{cm}}{1m}\cdot\frac{100\cancel{cm}}{1m} \quad E_0 = 2.03\times10^{9}\frac{N}{m^2}$

$D = 300mm \quad D = 0.3m$

$V = 1.0 m/s$

$$C = \frac{\sqrt{\dfrac{2.03\times10^{9}\ N/m^2}{1000\ Kg/m^3}}}{\sqrt{1+\dfrac{2.03\times10^{9}\ N/m^2 \cdot 0.3m}{2\times10^{11}\ N/m^2 \cdot 0.01m}}}$$

$$C = 1247.46\ m/s$$

$$\Delta P = \rho C V$$

$$\Delta P = 1000\tfrac{Kg}{m^3} \cdot 1247.46\ m/s \cdot 1.0 m/s \qquad \frac{Kg}{m^{\cancel{3}}} \cdot \frac{\cancel{m}}{s} \cdot \frac{\cancel{m}}{s} = \frac{Kg \cdot \cancel{m^2}}{\cancel{m^3}\, s^2}$$

$$\Delta P = 1.25\times10^{6}\ \frac{Kg}{m \cdot s^2} \qquad Kg = \frac{N \cdot s^2}{m}$$

$$\Delta P = 1.25\times10^{6}\ \frac{\frac{N \cdot s^2}{m}}{m \cdot s^2} = \frac{N \cdot \cancel{s^2}}{m^2 \cdot \cancel{s^2}}$$

$$\Delta P = 1.25\times10^{6}\ \frac{N}{m^2}$$

Summary: The pressure increase in the pipe when the valve is suddenly closed is $1.25\times10^{6}\ N/m^2$ or 1.25×10^{6} pascals.

Materials: Water

Analysis: The pressure increase in the pipe is due to the inertial force of the water. The pressure increase due to water hammer is directly proportional to the fluid velocity. A larger velocity will result in a larger pressure increase.

I pledge to follow the Honor Code and to obey all rules for taking exams and performing homework assignments as specified by the course instructor.

Jacob Leonard

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7/16/23