Purpose:

a) Using the following diagram, what is the depth (y) of the water? $T = 2.309y$ + the slope is 0.1% of unfinished concrete

b) The pipe needs to be supported. Calculate the total total horizontal + vertical forces in the pipe-elbow system.

c) What is the largest hickory wood log the channel can support while just barely floating. The log has a square cross section + $\rho = 830\ kg/m^3$. Is the log stable?

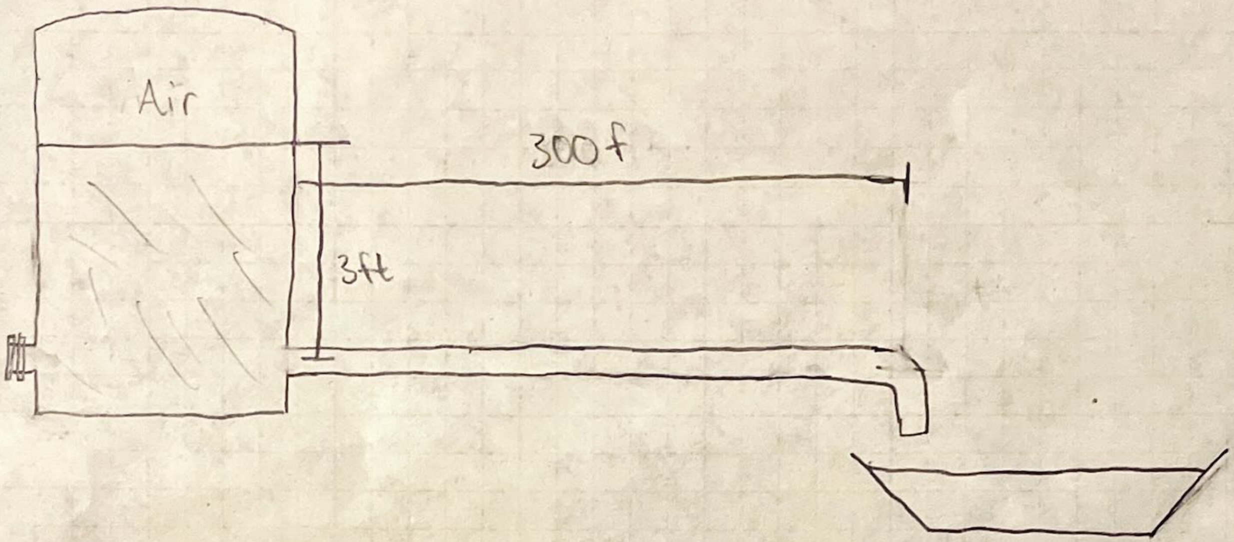
d) Use a flow nozzel with a diameter of half the the pipe diameter to measure the pressure drop across the nozzel.

e) If the valve was closed suddenly, what is the pressure increment of the sudden closing? Is there any cavitation in the system? Why?

f) Using a log with half the size of the largest log found in part c, what is the largest drag force it would experience if it got stuck at the bottom of the channel?

g) Compute the force acting on the blind flange on the left side of the tank. The diameter is the same as the pipe. Where is the force located?

Drawings + Diagrams:



Sources:

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

Design Considerations:

Constant Properties.

Constant Temperature

Incompressible Fluid

Data + Variables:

$Q = 75\ gpm$	$T = 60°F$	$E = 200\ GPa$	$\rho_{wood} = 830\ \frac{kg}{m^3}$		
$\gamma_{H_2O} = 9.81\ \frac{kN}{m^3}$	γ_{wood}	$1\frac{1}{2}$ in schedule 40 steel pipe			
$S = 0.001$	F_b	W	depth (y)	V_d	V_w
V	R_x	R_y	A_{pipe}	D_{pipe}	d_{nozzle}
MB	y_{cg}	y_{cb}	ΔP	$\rho_{H_2O} = 1000\ \frac{kg}{m^3}$	
C	N_R	F_D	C_D	h_L	$F = \frac{P}{A}$

Procedure:

a) First I will use the table 14.3 in book to find the specifications for the Channel. With that I can form my equation and get all my values on the right hand side in terms of y which I want to solve for. The left side of my equation is Q which is know, therefore I can iterate to solve for y.

b) First I will run bernoulli's to find the pressure at the start of the pipe. After that I can use my sum of forces equations in the x + y to get the reaction forces that are needed.

c) For something to barely float the F_b must equal W, therefore, the $\gamma_f \cdot V_d$ should equal $\gamma_{object} \cdot V_{object}$. From this relationship, I can get everything in terms of known and one unknown. The one unknown is the max height of the log which is found based off of the max y depth. Then to find if the log is stable, I will have to find the metacenter and compare it to the y_{cg}.

d) To find the change in pressure using a flow nozzle, I will use the flow nozzle equation. All the variables in the equation will be known or solved for using properties in the book. I then will isolate for ΔP and solve.

e) I will use the water hammer equation. All values for the equation can be found using the book, therefore I can just solve.

f) I will use the log size found in part C and half it. This will give me my log size for this part. With this log siz and dimensions, I can compute the drag force F_D using the F_D equation. The drag coefficient C_D can be obtained from Table 17.1 in the book along with the other properties needed. Then I can solve for the F_D.

g) To compute the force on the flange, I will first use Bernoulli's to calculate the unknown pressure at the top of the tank. This will give me the pressure of the pressureized air. Then I can do the γh equation to find the pressure of the stagganate fluid. I will sum them together to get my total pressure. I will use the force equation to get the force acting on the area of the flange. Then to locate where that force is acting I will use the radius of the pipe.

Calculations:

a)

$$Q = \left(\frac{1.00}{n}\right) A R^{2/3} S^{1/2}$$

$n = 0.017$
$A = 1.73 y^2$
$R = \frac{y}{2}$
$S = 0.001$
$Q = 75$ gpm

$$75 \text{ gpm} \left| \frac{1 \text{ m}^3/\text{s}}{15850 \text{ gpm}} \right.$$

$$Q = 0.00473 \text{ m}^3/\text{s}$$

$$0.00473 \frac{m^3}{s} = \left(\frac{1.00}{0.017}\right)(1.73y^2)\left(\frac{y}{2}\right)^{2/3}(0.001)^{1/2}$$

using a calculator

$$\boxed{y = 0.1030 \text{m}}$$

b) $Q = 0.00473 \frac{m^3}{s}$ $A = 0.001314 m^2$ $V = \frac{Q}{A}$ $V = \frac{0.00473 \frac{m^3}{s}}{0.001314 m^2}$

$V = 3.6 m/s$

$$\frac{P_1}{\gamma_{H_2O}} + \frac{V_1^2}{2g} + z_1 = \cancel{\frac{P_2}{\gamma_{H_2O}}} + \cancel{\frac{V_2^2}{2g}} + z_2 + h_L$$

$$h_L = f_T \frac{L}{D} \frac{V^2}{2g} + 8 f_T \frac{V^2}{2g} + 30 f_T \frac{V^2}{2g}$$

$$h_L = 0.02\left(\frac{300 ft}{3.281 ft} / 0.0409 m\right)\left(\frac{(3.6 m/s)^2}{2 \cdot 9.81 m/s^2}\right) + 0.2(8)\left(\frac{(3.6 m/s)^2}{2 \cdot 9.81 m/s^2}\right) + 0.2(30)\left(\frac{(3.6 m/s)^2}{2 \cdot 9.81 m/s^2}\right)$$

$$h_L = 30.0 m$$

$$P_1 = (30.0 m)\, 9.81 \frac{kN}{m^3}$$

$$P_1 = 294.3 \text{ kPa}$$

$$\Sigma F_x = \rho Q (V_{2x} - V_{1x}) + P_1 A - R_x = 0$$

$$R_x = \left(1000 \frac{kg}{m^3}\right)\left(0.00473 \frac{m^3}{s}\right)\left(0 - 3.6 \frac{m}{s}\right) + (294.3 kPa \cdot 0.001314 m^2)$$

$R_x = -16.6$ kN or $\boxed{16.6 \text{ kN} \leftarrow}$

$$\Sigma F_y = \rho Q (V_{2y} - V_{1y}) - R_y = 0$$

$$R_y = \left(1000 \frac{kg}{m^3}\right)\left(0.00473 \frac{m^3}{s}\right)\left(3.6 \frac{m}{s}\right)$$

$$\boxed{R_y = 362.2 \text{ kN}}$$

c)

$F_b = W$

$F_b = \gamma_f V_d = W = \gamma_w V_w$

$\gamma_{H_2O} V_d = \gamma_{wood} V_w$

$V_d = l \cdot x \cdot y$ $\qquad$ $V_w = l \cdot x \cdot x$

$\gamma_{H_2O} = 9.81 \frac{kN}{m^3}$ $\qquad$ $\gamma_{wood} = \rho_{wood} \cdot g$

$\gamma_{wood} = 0.830 \frac{kg}{m^3} \cdot 9.81 \, m/s^2 \to \frac{kN}{m^3}$

$\gamma_{wood} = 8.142 \frac{kN}{m^3}$

$$\frac{(\gamma_{H_2O})(\cancel{l}\cancel{x}y)}{\gamma_{wood}\,\cancel{lx}} = \frac{(\gamma_{wood})(lxx)}{\gamma_{wood}\,lx}$$

$$\frac{\gamma_{H_2O}}{\gamma_{wood}} y = x$$

$y = 0.103 m$

$$x = \frac{9.81 \frac{kN}{m^3}}{8.142 \frac{kN}{m^3}} 0.103 m$$

$$\boxed{x = 0.124 \, m}$$

Stability:

$y_{cg} = \frac{1}{2} \, 0.124 m = 0.062 m$

$y_{cb} = \frac{1}{2} \, 0.103 m = 0.0515 m$

assume any l

$l = 0.5 m$

$$MB = I/V_d = \frac{\left(\frac{(0.124 m)(0.124 m)^3}{12}\right)}{(0.5 m)(0.103 m)(0.124 m)}$$

$MB = 0.00309 m$

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

$y_{mc} = 0.00309 m + 0.0515 m$

$y_{mc} = 0.0546 m$

$0.062 m > 0.0546 m$

$$\boxed{\text{not stable since } mc \not> cb}$$

d)

$D = 0.0409\,m$ $A = 0.001314\,m^2$

$d = \frac{1}{2}\,0.0409\,m$ $A_2 = 0.00033\,m^2$
$= 0.0205\,m$
$V = 3.6\,m/s$ $\nu = 1.15\times10^{-6}\,m^2/s$

$$N_R = \frac{VD}{\nu} = \frac{3.6\,m/s \cdot 0.0409\,m}{1.15\times10^{-6}\,m^2/s}$$

$N_R = 128035$

From chart
$C = 0.985$

$$V = C\sqrt{\frac{2g\,\Delta P/\gamma_{H_2O}}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

$$\Delta P = \frac{\left(\frac{V}{C}\right)^2\left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]\gamma_{H_2O}}{2g}$$

$$\Delta P = \frac{\left(\frac{3.6\,m/s}{0.985}\right)^2\left[\left(\frac{0.001314\,m^2}{0.00033\,m^2}\right)^2 - 1\right]9.81\,\frac{kN}{m^3}}{2\cdot 9.81\,m/s^2}$$

$$\frac{\cancel{m^2}/\cancel{s^2}\cdot\frac{kg\,m}{s^2}\cdot\frac{1}{\cancel{m^3}}}{\cancel{m}/\cancel{s^2}} \quad \frac{kN}{m^2}$$

$\frac{kN}{m^2}$

$$\boxed{\Delta P = 99.2\ KPa}$$

e)

$\Delta p = \rho C V$ $C = \sqrt{\frac{E_0/\rho}{1 + \frac{E_0 D}{E\,\delta}}}$

$E_0 = 2179\ MPa$ $\rho = 1000\,\frac{kg}{m^3}$
$D = 0.0409\,m$
$E = 200\ GPa$
$\delta =$ Pipe thickness
$= 0.00368\,m$

$$C = \sqrt{\frac{2179\times10^6\,Pa/1000\,kg/m^3}{1 + \left[\frac{(2179\times10^6\,\cancel{Pa})(0.0409\,\cancel{m})}{(200\times10^9\,\cancel{Pa})(0.00368\,\cancel{m})}\right]}}$$

$Pa = \frac{N}{m^2}$
$N = \frac{kg\,m}{s^2}$

$$\boxed{\frac{\frac{\cancel{kg}\,m}{s^2}}{m^2}}\cdot\frac{m^3}{\cancel{kg}} = \frac{\frac{m^4}{s^2}}{m^2}\quad \frac{1}{\cancel{m^2}}$$

$\frac{kg}{m^3}$

$\sqrt{\frac{m^2}{s^2}}$ m/s

$C = 1394\ m/s$

$\Delta P = \rho C V$

$\Delta P = (1000\,\frac{kg}{m^3})(1394\,m/s)(3.6\,m/s)$ $\frac{N}{m^2}$

$$\boxed{\Delta P = 4.86\ MPa}$$

Micujah Paynter

f)

$X = \frac{1}{2}\, 0.124\,m$

$X = 0.062\,m$

$A = (0.062\,m)^2$

$A = 0.00384\,m^2$

$A_c = 1.73\,y^2 = 1.73\,(0.103\,m)^2 = 0.0184\,m^2$

From table 17.1

$C_D = 1.16$

$V_c = \frac{Q}{A_c} = \frac{0.00473\,m/s}{0.0184\,m^2}$ $\quad V_c = 0.258\,m/s$

$F_D = C_D\,(\rho V_c^2/2)\,A$

$F_D = 1.16\,((1000\,\frac{kg}{\cancel{m^3}} \cdot 0.258\,m/s^2)\,/2)\,0.00384\,\cancel{m^2}$

$F_D = 0.148\,N$ $\quad \frac{kg\,m}{s^2} = N$

g)

$\frac{P_1}{\gamma} + z_1 = \frac{V_c^2}{2g} + h_{L_1}$

From part b $\quad h_L = 30.0\,m$

$h_{L_1} = 30.0\,m + 0.5\,\frac{V^2}{2g}$

$h_{L_1} = 30.0\,m + 0.5\left(\frac{(3.6\,m/s)^2}{2 \cdot 9.81\,m/s^2}\right)$

$h_{L_1} = 30.33\,m$

$P_1 = \left(\frac{(3.6\,m/s)^2}{2 \cdot 9.81\,m/s^2} + 30.33\,m - \frac{3\,ft}{3.281\,ft}\right) 9.81\,\frac{kN}{m^3}$

$P_1 = 295\,kPa$

$p' = \gamma h$

$p' = 9.81\,\frac{kN}{m^3} \cdot \frac{3\,\cancel{ft}}{3.281\,\cancel{ft}}$

$p' = 8.97\,kPa$

$P = 8.97\,kPa + 295\,kPa$

$P = 304\,kPa$

$F = \frac{P}{A} = \frac{304\,kPa}{0.001314\,m^2}$ $\quad \frac{kN}{\cancel{m^2}} \cdot \frac{\cancel{m^2}}{1}$ $\quad kN$

$F = 231354\,kN$

Force is acting on the center of the flange at $D/2 = 0.0205\,m$

Summary:

a) The depth Y of the channel is $\boxed{0.103\ m}$

b) The horozontal reaction force in the pipe is $\boxed{16.6\ KN}$ acting to the left. The vertical $\boxed{362.2}$ KN acting down.

c) Using the depth y as the max depth of immersion, the largest square cylinder log the channel can carry is $\boxed{0.124\ m}$ in hieght. The max log will not be stable based on the metacenter being below the center of buoyancy.

d) From the flow nozzle equation the pressure drop is $\boxed{99.2\ KPa.}$

e) If the valve was closed suddenly the pressure increment would be $\boxed{\Delta P = 4.86\ MPa.}$.

f) The drag force on a log at the bottom of the channel that is half the size of the max log would be $\boxed{0.148\ N}$

g) The force acting on the flange is $\boxed{231354\ KN}$ and it would act at the center of the flange or half its diameter.

Materials used:

Hickory wood logs   Water   1 ½ in Schedule 40 steel pipe

Analysis:

a) The channel depth was found since open channels have a specific relation when it comes to their dimensions. Therefore, the depth directly affects the length of the sides the width and the top width.

b) Since the majority of the forces in the x get canclled by opposing forces of $\rho Q \Delta V + P_1 A$ the R_x force was much lower than the R_y force.

c) Since the log would be barely floating only a small amount would be above the surface of the water. Using the y depth from part a as the depth of immersion I was able to find the max log size. Since F_b was equal to W, the $\gamma_{water} \cdot V_d$ was also equal to $\gamma_{wood} \cdot V_{wood}$. From this relationship the length and width cancle out leaving only the height of the log. Since the logs center of buoyancy was larger than the heigt of the mete center then the log cannot be stable

Micajah Paynter

d) The change in pressure found from the flow nozzle seems to be large. a large pressure drop doesn't make sense because the drop in area was only half of the pipe area.

e) My change in pressure due to water hammer was large. water hammer is due to a large increase in pressure so a large pressure makes sense. This increase in pressure could cause lots of damage to the system and things around it so rapid closing of the valve should be avoided, along with other safety measures. There was no cavitation from this. cavitation is from a drop in pressure, but from this there was an ~~in~~ increase in pressure.

f) If a log half the size of the max was subjected to drag of the channel the force could not be but so large since the area is small. I found drag force to be very small as suspected.

g) The force found from the pressurized air + the stagnant fluid on the center of the flange was strong. This makes sense because the area of the flange is very small so the pressure over area is very large.