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MET 330

Test #2

Purpose: The purpose of this problem is to find the water depth in the open channel. Then find the horizontal and vertical forces acting on the whole pipe system from the tank to the channel. Then determine what the biggest log the channel can carry and then prove if it is stable or not. After that find the pressure drop across the nozzle if you have a ratio of 0.5. After this find the pressure increment in the pipe if the valve was closed suddenly and determine if cavitation could occur. Then find the largest drag force a log would experience if it was at the botton of the channel and was half the size of the log computed in part C. Finally find the force acting on the blind flange on left side of the tank and determine it's location.

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

Design Considerations:

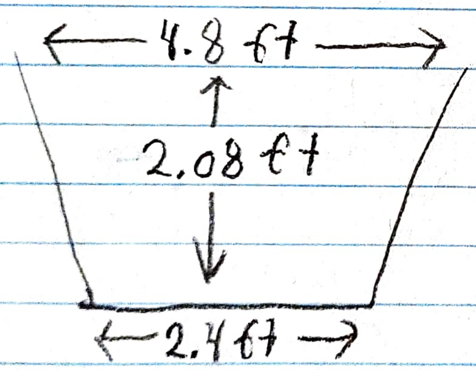
Incompressible fluid
Density of the wood

Data & variables:

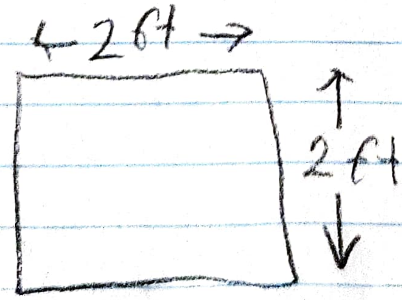
All variables are listed with each part of the problem.

Drawings & diagrams:

a.



c.



and it is 2 ft long

Procedure:

For the first part of this problem I used the equation for Q, I then figured out all of my variables except Y and then I plugged it all into excel and began entering different values for Y until I got a Q equal to 75 gpm. I started at 5 and ended up finding that 2.08 ft was the golden number. For the second part I calculated the weight of the pipe for 1 ft. Then I found the weight of the whole pipe. Then I found the weight of the whole pipe filled with water. There is nothing pushing on the pipe so the horizontal part is zero. For the third part I found the largest log that would fit and still have a tad bit of room was 2 ft X 2 ft, I then computed the specific weight of the log and the water and compared the two. The log was lighter so it is stable. For the fourth part I used the equation for V and then I subtracted P_2 from P_1 to find the pressure drop. For part e I used the equation for ΔP and I also found there would be no cavitation. For part f I just used the equation for F_D and solved after I found all the variables. For part G I used the equation for F_R and then I added 20 psi in the tank to what I got for Pavg.

Calculations:

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

$Q = 75$ gpm
$S = \frac{1}{10}$
$R = \frac{Y}{2}$
$A = 1.73\, Y^2$
$n = 0.017$
$Wp = 3.46\, Y$

$T = 2.309(2.08) = 4.8$ ft
$b = 1.155(2.08) = 2.4$ ft

$$75 = \left(\frac{1.49}{0.017}\right)(1.73\, y^2)\left(\frac{y}{2}\right)^{\frac{2}{3}}\left(\frac{1}{10}\right)^{\frac{1}{2}}$$

$$75 = 87.64(1.73\, y^2)\left(\frac{y}{2}\right)^{\frac{2}{3}}(0.3162)$$

using excel I found 2.08 ft was very close to 75 gpm.

$\boxed{y = 2.08 \text{ ft}}$

b. $1\frac{1}{2}$ in pipe weighs 2.721 lb/ft
300 ft of this pipe = 816.3 lb
The pipe filled with water = 1081 lb

$\boxed{\begin{array}{l}\text{horizontal force} = 0 \\ \text{vertical force} = 1081 \text{ lbf}\end{array}}$

c. The largest log that could fit comfortably is 2 ft X 2 ft.
$\rho_{log} = 51.81$ lb/ft^3
$\rho_{water} = 62.241$ lb/ft^3
$g = 32.174$ ft/s

$\gamma_{log} = 51.81(32.174) = 1666.93(2) = 3333.86$ lb/ft^3
$\gamma_{water} = 62.241(32.174) = 2002.54(2) = 4005.08$ lb/ft^3

$3333.86 \text{ lb/ft}^3 < 4005.08 \text{ lb/ft}^3$

yes it is stable

length does not matter

$\boxed{\text{largest log} = 2 \text{ ft} \times 2 \text{ ft}}$

Calculations con't:

d. $V_1 = C\sqrt{\frac{2g(P_1 - P_2)/\gamma}{(A_1/A_2)^2 - 1}}$

$C = 0.5$
$P_1 = 20\ lb/in^2$
$P_2 = 14.7\ lb/in^2$
$\gamma = 0.04\ lb/in^3$
$A_1 = 1.767\ in^2$
$A_2 = 3.543\ in^2$

$V_1 = 0.5\sqrt{\frac{2(32.2)(81-14.7)/0.04}{(1.767/3.543)^2 - 1}}$

$V_1 = 0.5\sqrt{\frac{106743}{0.751}} = 0.5(377.007) = 188.503\ in/s^2$

$20\,psi - 14.7\,psi = \boxed{5.3\ psi}$

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

$\rho = 62.4\ lb/ft^3$
$V = 13.62\ ft/s$
$C = 0.097$
$E_0 = 2.1\,gpa$
$D = 1.5\ in$
$E = 200\ gpa$
$\delta = 0.15\ in$

$C = \frac{\sqrt{E_0/E}}{\sqrt{1 + \frac{E_0(D)}{E(\delta)}}}$

$C = \frac{\sqrt{2.1/200}}{\sqrt{1 + \frac{2.1(1.5)}{200(0.15)}}} = \frac{0.1024}{1.0511}$

$\Delta P = 62.4(0.097)(13.62) = \boxed{82.43\ psi}$

No cavitation will happen because the pressure will not go low enough to reach water vapor.

f. half the size from part C would be 1X1

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

$\gamma = 1666.93\ lb/ft^3$
$\rho = 51.81\ lb/ft^3$
$C_D = 1.16$ ← from table 17.1
$V = 12.5$
$A = 6\ ft^2$

$Q = AV$
$V = \frac{Q}{A} = \frac{75\ gpm}{6\ ft^2} = 12.5$

$C_D = \frac{a}{b} = \frac{1}{1} = 1 \rightarrow 1.16$ from table 17.1

$$F_D = 1.16\left(\frac{51.81\,(12.5)^2}{2}\right)(6) = 28171.68 = \boxed{6333.24\ lbf}$$

G. $F_R = P_{avg} \times A$

$\gamma = 62.241\ lb/ft^3$
$h = 3\ ft$
$A = 1.77\ in^2$

$P_{avg} = \gamma(h/2)$
$P_{avg} = 62.241(3/2) = 93.36 + 20 = 113.36\ psi$

$$F_R = 113.36\,(1.77) = \boxed{200.65\ lbf}$$

The force is located at the center of the flange.

Summary:

For this problem I found the depth of the channel was 2.08 ft. I also found that the largest log it could handle was 2 ft X 2 ft and it was stable. I found that the pressure drop across the nozzle was 5.3 psi. I found that the pressure increment was 82.43 psi if the valve was closed suddenly and that cavitation would not occur. I also found that the drag force would be 6333.24 lbf on a log at the bottom of the channel. Finally I found that the force acting on the blind flange was 200.65 lbf and the location was at the center of the flange.

Analysis:

I believe that most of this information makes sense. If I could change anything about this design I would make the channel deeper so you would have less chances of a log getting stuck. Other than that this seems like a very good design.