Colby C. Burnam
MET 330
Fall 2022
Test 2

Purpose:

a) Determine the water depth (y) in the open channel.

b) Determine forces for support design.

c) Determine the largest hickory wood log the open channel can carry. prove stability.

d) Determine pressure drop across the nozzle.

e) Determine pressure increment after suddenly closing the valve. Determine if there is a chance of cavitation.

f) Determine drag force max on ½ log from "c)".

g) Determine force on the blind flange at left-hand-side of the tank. Determine force location.

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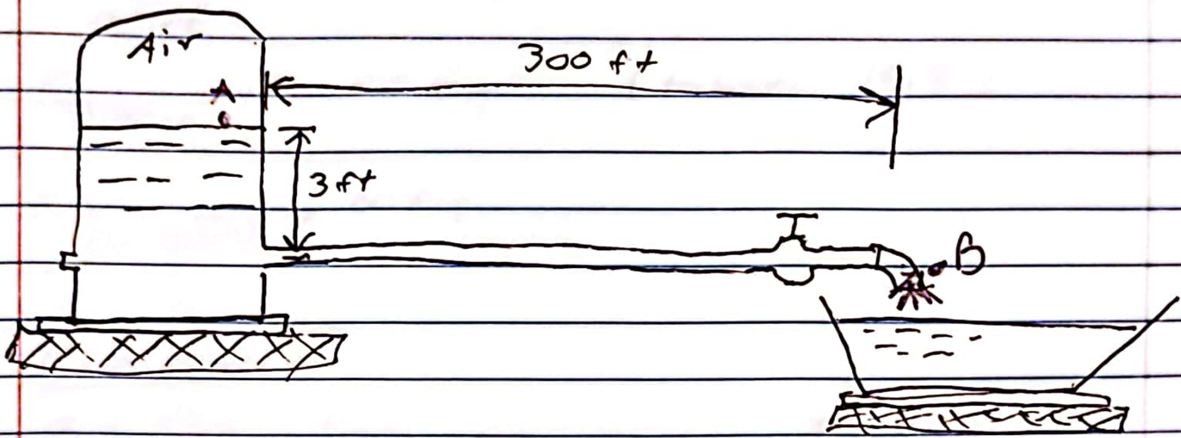
Drawings + Diagrams:



Sources:

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

Design Considerations

- Constant properties
- Incompressible fluid
- Constant temprature
- Steady State

Data & Variables

- 1½" Schedule 40

  $D = 1.610 \text{ in} = 0.13 \text{ ft}$ (Appendix F)

  $A = 2.03 \text{ in}^2$

- Water @ 60°F

$\rho = 1.94$ slugs/ft³

$\gamma = 61.0$ lb/ft³

$f_T = 0.020$ (table 10.5)

$K_{entrance} = 0.5$ (Per Fig. 10.14)

$K_{\text{valve full open}} = 8 f_T$ (table 10.4)

$K_{\text{elbow}} = 20 f_T$ (table 10.4)

$K_{\text{valve full closed}} = \infty f_T$

Procedure:

a) For this question, I will calculate the water depth

$y = \frac{w}{2.309}$ y = depth, γ = difference (Table 14.3)

b) For this question I will calculate the sum of the pressures to determine the forces.

c) For this question I will use the depth less 1/2" to set up a buoyancy equation. The proof of stability will be from determining if C_g is lower than C_b.

d) For this question I will use $\Delta p = P_d - P_0$ to determine pressure drop across the nozzle

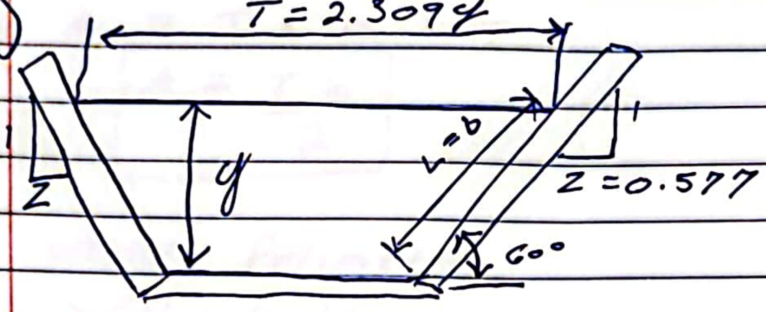
e) For this question I will use water hammer theory to solve for the ΔP and to prove it will cause cavitation

f) For this question I will drag force on a log 1/2 of the size found in "c)" and apply the friction factor of the unfinished concrete for the bottom of the open channel

g) For this question I will calculate the forces on the blind-flange using $\gamma \cdot h$ equation.

Calculations

section

a) 

(Table 14.3)

Area $A=1.73y^2$

Wetted perimeter $WP=3.46y$

Hydraulic Radius $R=y/2$

$Q=75$ Gal/min $= 0.167\ ft^3/sec$

$S=0.01$

$n=0.017$ (unfinished concrete)

$$Q=\frac{1.49}{n}AS^{1/2}R^{2/3}$$

$$AR^{2/3}=\frac{nQ}{1.49S^{1/2}}$$

$$AR^{2/3}=\frac{0.017\times 0.167\ ft^3/sec}{1.49(0.\cancel{0}1)^{1/2}}$$

0.1

$$AR^{2/3}=\frac{0.002839}{\cancel{0.024566}}$$

0.2456 595

$$AR^{2/3}=\frac{\cancel{0.X}16}{0.012}$$

a) $A = T \times h \times \frac{1}{2}$

$$\boxed{A = \frac{Th}{2}}$$

wetted Perimeter

$WP = h + h$

Using Pythagoras theorem, the L variable can be obtained as a function of the unknown h:

$L = \sqrt{1+h^2}$

Thus, the hydraulic radius is

$$R = \frac{A}{WP} = \frac{h/2}{h+\sqrt{1+h^2}}$$

$$R = \frac{\boxed{A = \frac{Th}{2}}}{\boxed{WP = h+\sqrt{1+h^2}}}$$

$A \cdot R^{2/3} = 0.116$

$$\frac{h}{2}\left(\frac{1}{2_h}\frac{h}{+\sqrt{1+h^2}}\right)^{2/3} = 0.0635$$

$\boxed{h = 0.15\ ft}$

* Assume h and Itterate in excell $\boxed{h = 0.\cancel{18}\ ft}$

~~B)~~ $h = 0.15\,ft$

a) $A = T \times 0.15\,ft \times \frac{1}{2}$

$=$

$T = 2.309y$

$y_h = A/T$

T = width of the free surface of the fluid at the top of the channel

$y_h = \cancel{2.309y} \cdot 0.15\,ft \cdot \frac{1}{2} \,/\, \cancel{2.309y}$

$y_h = 0.15\,ft \cdot \frac{1}{2}$

$y_h = 0.075\,ft$

$\boxed{y_h = 0.89\,in}$ Hydraulic depth

? This is not going to allow for a very large "log" to be ~~sta~~ ~~floating~~ "barely floating"

b. $P = F/A$

$\boxed{P \cdot A = F}$ at elbow

Sum of pressures

$P = \gamma h +$ tank pressure

Tank surface (Ref A)

$V_{surf} = \emptyset$

$P =$ tank pressure

When calculating the forces we will need to calculate

* Friction Factor using L/D

+ Fr · L

b)

Use General Energy Equation to solve for total system pressure, then solve for Force

$$\frac{P_1}{\gamma} + z_1 + \cancel{\frac{v_1^2}{2g}} + \cancel{h_A} - \cancel{h_R} - h_L = \frac{P_2}{\gamma} + \overset{0}{\cancel{z_2}} + \frac{v_2^2}{2g}$$

P_1 = Tank press

$\gamma = 61.0 \ lb/ft^3$

$z_1 = +3ft$

$v_1 = 0 \ ft/sec$ (large tank)

$h_L = K f_T + K_{ent} + K_{valve \ open} + K_{elb}$ ~~K valve~~

$P_2 = 1 \ Atm$

$z_2 = 0 \ ft$

$v_2 = 11.93 \ ft/sec$

$$\boxed{\frac{\text{Tank press}}{61.0 \ lb/ft^3} + 3ft - \overset{h_L}{\cancel{0.020}}\ 1.08 = \frac{1 \ Atm}{61.0 \ lb/ft^3} + \frac{v_2^2}{2g}}$$

$$h_L = \underset{f_T}{0.020} + \underset{K_{ent}}{0.5} + \underset{\text{full open}}{\overset{K_{valve \ \text{full open}}}{\cancel{K_{valve}}}} + 20 f_T$$

$h_L = 0.52 + 8(0.020) + 20(0.020)$

$h_L = 0.52 + 0.16 + 0.4$

$\boxed{h_L = 1.08 ft}$

Atm press = 14.696 psi

= 2116 lbf/ft^2

b) $\frac{\text{Tank press}}{61.0\ lb/ft^3} + 3ft - 1.08ft = \frac{2116.224psf}{61.0\ lb/ft^3} + \frac{V_2^2}{2g}$

$\frac{\text{Tank press}}{61.0\ lb/ft^3} + 1.92ft = 34.69ft + \frac{V_2^2}{2g}$

$\text{Tank press} = \left(32.77ft + \frac{V_2^2}{2g}\right)\left(61.0\ lb/ft^3\right)$

$Q = 0.167\ ft^3/sec$ $\quad V = Q/A$
$A = \pi r^2$
$A = 2.03\ in^2$
$A = 0.014\ ft^2$

$\text{velocity} = \frac{0.167\ ft^3/sec}{0.014\ ft^2}$

$\boxed{\text{Velocity} = 11.93\ ft/sec}$

$\text{Tank press} = \left(32.77ft + \frac{(11.93\ ft/sec)^2}{2 \cdot 32.2\ ft/sec}\right)\left(61.0\ lb/ft^3\right)$

$\text{Tank press} = \left(32.77ft + \frac{142.32\ ft^2/sec}{64.4\ ft/sec}\right)\left(61.0\ lb/ft^3\right)$

b) Tank press $= (32.77\,ft + 2.21\,ft)(61.0\,lb/ft^3)$

Tank press $= (34.98\,ft)(61.0\,lb/ft^3)$

$\boxed{\text{Tank press} = 2{,}133.78\ lb/ft^2}$

$P \cdot A = F$

$2{,}133.78\ lb/ft^2 \cdot 0.014\,ft^2 = F$

$\boxed{29.87\ lbf = F_x}$

The support should be located at the elbow and should be able to support 29.87 lbf of Force

$\rho Q V = F_x$

$\rho = 1.94\ slugs/ft^3$

$Q = 0.167\ ft^3/sec$

$V = 11.93\ ft/sec$

$\boxed{F_x = 3.87\ lbf}$

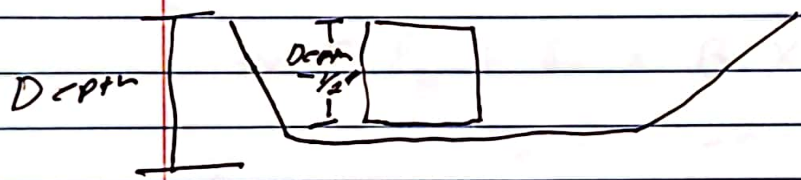
$F_{total} = F_x + F_y$

$\boxed{33.74\ lbf} = 3.87\ lbf + 29.87\ lbf$

C. To solve, use the depth of the channel to indicate ~~Diameter~~ width of ~~log~~ square cross timber, less ½"

*The point of it being square is so that we can prove it does not rotate and has a stable buoyancy

prove stability with equations.



Ch. 5 pg. 104 - 105
Buoyancy and Stability

Equation of Equilibrium

$$\sum F_v = 0 = F_b - w$$

$$w = F_b$$

Submerged Volume

$$V_d = B \times L \times X$$

Buoyant Force

$$F_b = \gamma_f V_d = \gamma_f \times B \times L \times X$$

Then, we have

$$w = F_b = \gamma_f \times B \times L \times X$$

$$X = \frac{w}{B \times L \times \gamma_f} \leftarrow w = \text{weight}$$

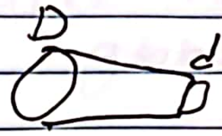
For our ~~question~~ problem, the log is to be "barely floating", which means we can set our $X = 0.001$ in

c) The depth of the channel is
$y_n = 0.89$ in

The log is not stable and ~~top~~ "rolls" with a everchanging C_B due to the angle ~~w~~ rotating ~~the~~ around the C_g

diameter ratio

d. Flow nozzle



$D/d = 0.5$

$P_d = P_D \cdot \underset{0.5}{\text{diameter ratio}}$

$P_D = 2{,}133.78\ lb/ft^2$

$\boxed{\rho h + \text{tank pressure}}$

water @ 60°F

Pressure drop across Nozzle

$\Delta p = P_D - P_d$

$h = 3\,ft$

$P_D = 2{,}133.78\ \frac{lb}{ft^2} \times 0.5$

$\cancel{P_d = 1{,}066}$

$$\boxed{P_d = 1{,}066.89\ \frac{lb}{ft^2}}$$

$\Delta p = \overset{P_D}{2{,}133.78\ \frac{lb}{ft^2}} - \overset{P_d}{1{,}066.89\ \frac{lb}{ft^2}}$

press incr

$$\boxed{\Delta p = 1{,}066.89\ \frac{lb}{ft^2}}$$

e.) Δp after water hammer effect at globe valve

Yes it will cavitate if our velocity is high enough.

The rapid change in velocity to Ø results in a rapid change in pressure. The pressure ~~drop~~ increases while the velocity decreases to Ø, then the Force is distributed to the surrounding molecules wich water, steel The responds by moving in the way of least resistace which ils up stream, when it does that, velocity is increased and pressure decreased which results in a boiling of water which is the definition of cavitation, the liquid changing states.

e) Water hammer equation for Δp. ~~[illegible]~~ ~~[illegible]~~

$$\Delta p = \rho v c$$

ρ = density of water at 60°F = $\boxed{1.94 \text{ slugs/ft}^3}$
V = Velocity = $\boxed{11.93 \text{ ft/sec}}$

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

(rate of increase of wave velocity)

(Table 1.3) E_o = bulk modulus of water @ 60°F = 316,000 psi
E = elastic modulus of schedule 40 steel pipe
δ = pipe thickness = 0.145 in

$E_o = 316{,}000/12 =$

$E_o = 26{,}333.3$ psf

$D = 1.610 \text{ in} = 0.13 \text{ ft}$

$\delta = 0.145 \text{ in} = 0.012 \text{ ft}$

$$C = \frac{\sqrt{E_o / 1.94 \text{ slugs/ft}^3}}{\sqrt{1 + \frac{E_o \; 1.610 \text{ in}}{E \; (0.145 \text{ in})}}}$$

$$C = \frac{\sqrt{13{,}573.88}}{\sqrt{1 + \frac{(26{,}333.3 \text{ psf}) \cancel{4.6} (0.13 \text{ ft})}{E \; (0.145 \text{ in})}}}$$

$$C = \frac{\sqrt{13{,}573.88}}{\sqrt{1 + \frac{3{,}423.29}{E \; \cancel{0.145} \; 0.012 \text{ ft}}}}$$

Elastic modulus of steel

$E = 29{,}000{,}000 \text{ psi}$

$E = 2{,}416{,}666.67 \text{ psf}$

e) $C = \dfrac{116.51}{\sqrt{1 + \dfrac{3.423.29}{E(0.012 \text{ ft})}}}$

$C = \dfrac{116.51}{\sqrt{1 + \dfrac{3.423.29}{29{,}000}}}$

$C = \dfrac{116.51}{\sqrt{1.00}}$

$\boxed{C = 116.51}$

$\Delta P = \left(1.94 \dfrac{\text{slugs}}{\text{ft}^3}\right)\left(11.93 \dfrac{\text{ft}}{\text{sec}}\right)\left(116.51 \cancel{\text{psi}}\right) \text{lb/in}$

$\cancel{\boxed{\Delta P = 2{,}696.5 \dfrac{\text{slugs}}{\text{ft}^2}}}$

$\cancel{\boxed{\Delta = 2{,}696.5 \dfrac{\text{lb} \cdot \text{s}^2}{\text{ft}}}}$

$\Delta P = \underset{\rho}{\left(1.94 \dfrac{\text{lb} \cdot \text{s}^2}{\text{ft}}\right)} \underset{V}{\left(11.93 \dfrac{\text{ft}}{\text{sec}}\right)} \underset{C}{\left(9.71 \dfrac{\text{lb}}{\text{ft}}\right)}$

$\Delta P = 224.73 \dfrac{\text{lb} \cdot \text{s}^2}{\text{ft}^2}$

$\boxed{\Delta P = 224.73 \dfrac{\text{lb}}{\text{ft}^2}}$

CamScanner

f) $(\text{Depth} \cancel{\times 1/2''})/2 = \text{width}$

Calculating drag force, which is why we were told it has unfinished concrete and 0.1% slope

hickory wood

$\text{Depth} = 0.89\text{in}/2$

$1/2 \text{ depth} = 0.445 \text{ in}$

drag ~~area~~ diameter $= 0.445 \text{ in}$

$A = \pi r^2$

$= \pi (0.22)^2$

$\boxed{A = 0.155 \text{in}^2}$

$F_{drag} = P \times A$

$=$

$V = Q/A$

$V = 0.167 \text{ft}^3/\text{sec} \,/\, 0.155 \text{in}^2$

~~P = 1.08~~

$V = \dfrac{0.167 \text{ ft}^3/\text{sec}}{0.0129 \text{ ft}^2}$

$\boxed{V_{log} = 12.94 \text{ ft}/\text{sec}}$

f) Drag Force

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

? V = velocity (slope of open channel = 0.1% .29)

A = Area

$\rho V^2/2$ = dynamic pressure

C_D = drag coefficient

ρ = density of fluid

$\mu = 0.017$

$$C_D = \eta \cdot C_A$$

$F_D =$

9. The force will be equal to

$$P = \gamma h + \text{Tank Air pressure}$$

$$D = 1/2$$

$$P = F/A \qquad A = \pi r^2$$

$$A \cdot P = F \qquad r = \left(\frac{1}{2} D\right)$$

$$F = \left(\frac{\pi D}{2}\right)\left(\gamma h + \text{Tank Air pressure}\right)$$

$$F = (\pi r^2)(\gamma h + \text{Tank Air pressure})$$

$$P = (61.0\ lb/ft^3)(3ft) + 2{,}133.78\ \frac{lb}{ft^2}$$

$$P = \frac{183\ lb}{ft^3} + 2{,}133.78\ \frac{lb}{ft^2}$$

$$\boxed{P = 2{,}316.78\ lb/ft^2}$$

$$F = A \cdot 2{,}316.78\ \frac{lb}{ft^2} \qquad \boxed{F = 32.43\ lbf}$$

$$= 2.03 in^2 \cdot 2{,}316.78\ lb$$

$$= 0.014 ft^2 \cdot 2{,}316.78\ lb/ft^2 ft^2$$

Summary

a) The water depth ~~water~~ was determined to be shallower than expected. I have a suscipion about this because we used the physical properties of the trapazoid, but we did not apply the log requirements to float. Perhaps I should set up a integration excell table to find the log buoyancy requirements vs. trapazoid dimensions.

b) The forces were determined to be 3.87 lbf in the horizontal direction and 29.87 lbf in the vertical direction, with a net Force of 33.74 lbf. This can be supported with a metal brace rated for 33.74 lb.s/sec

c) The largest log the open channel can carry, is 0.89in in diameter.

d) Pressure drop across the nozzle was determined to be 1,066.89 lb/ft^2.

e) The pressure increment for the valve to be fully closed is 224.73 lb/ft^2

f) The drag force was determined to be

g) The force on the blind flange was determined to be 32.43 lbf.