## ① PURPOSE

A

a) Make sure that when the elevated tank is full, the gravity driven system only delivers gasoline. Find how large should the buoy be so when the gas level reaches a depth of 0.9*h, the buoy opens the gate. Prove the buoy is stable when it starts to pull the gate.

b) Find the the horizontal/vertical forces due to the moving fluid in the discharge pipe-elbow-valve system

c) Find the pressure drop across the nozzle based on a nozzle diameter to pipe diameter of 0.5.

D) (use trapezoid cross section). Find how deep (y) should the open channel be to handle a spillage of 400 gpm given that the lateral wall is 60°. The width at the top of the water: T = 2.309*y. Channel slope: S 0.1% (made from unfinished concrete)

e) Find the pressure increment after the sudden closing. determine if the pipe would fail. Determine if cavitation could occur.

f) Find the maximum weight to allow the fluid flow drags along the bottom surface

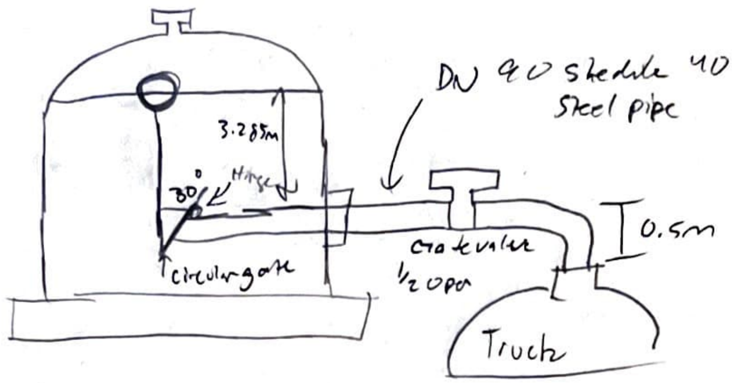
A) After looking through the exam, course objectives: Buoyancy/stability, pipes/fittings, open channel flow, forces in pipes, how fluid-machinery work, cavitation

B) for fluid-machinery, I need to know the concepts on how it works to apply it to the drawing.

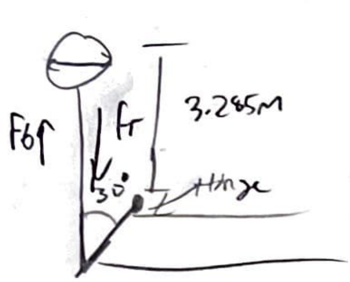
For Pre-test

## DRAWINGS AND DIAGRAMS

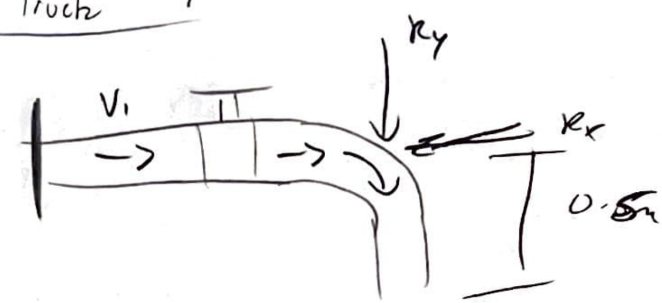
General Drawing:



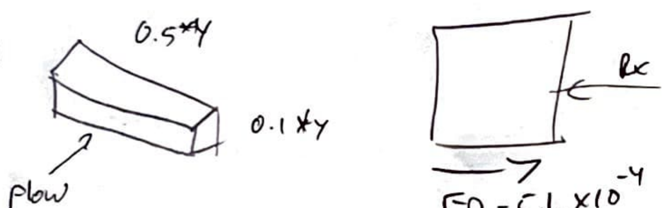

a)




b)




F)




## SOURCES:


- ODU Canvas Lecture Slides
- MATT, R, Untes, TA, "Applied Fluid Mechanics," 7th Edition Pearson Education Inc. (2015)


## DESIGN CONSIDERATIONS

- Isothermal Conditions at @ 25°C
- Gasoline
- Hinge/Gate
- Buoy is halfway up
- The 30° Angle at the gate

## DATA AND VARIABLES

- All distances and values in drawing
- 400 gpm = $0.0252 \frac{m^3}{s}$
- $\gamma_{gas} = 6.67 \frac{kN}{m^3}$ (TABLE B.1)
- DN 90 sch. 40 steel pipe diameter: 0.082m from table 4.1, Thickness: 5.74mm
- $C_D = 1.6$ from table pg. 438
- $\rho = 680 \frac{kN}{m^3}$ (TABLE B.1)

PROCEDURE

C

a) To determine the diameter of buoy I have to apply the sum of the moments. before doing that I have to apply the force equation for buoyancy and force for flow from pg. 70-71. After that I have to use the buoyancy formula and solve for Diameter. When I get the first values, I will be able to prove the buoy is stable

b) First I will be applying the $\Sigma F = \rho Q \Delta$ formula and adjust it to solve for Horizontal and vertical force. The FBD will demonstrate the direction of the forces

c) with the proposal being a flow nozzle (flow meter), and the diameter ratio 0.5, I have to utilize the formula: $V_1 = C\sqrt{\frac{2g(P_1 - P_2)/\gamma}{(A_1/A_2)^2 - 1}}$ and rearrange it to equal $(P_1 - P_2)$ so I can solve for the pressure drop

d) Since the client proposes a trapezoidal cross section, I will use the shape from figure 14-1 as reference. After finding $AR^{2/3}$ after using the open channel equation, I have to do trial and error on excel to find the depth that matches the $AR^{2/3}$.

e) To find the pressure increment in case of cavitation/water hammer, I will use the formula $C = \frac{\sqrt{E_0/\rho}}{\sqrt{1 + \frac{E_0 D}{E \delta}}}$ and use this to plug in the pressure formula $\Delta p = c \rho$. to see if the pipe would fail, after solving for the value using the formula $t = \frac{pD}{2(SE + pY)}$, I will compare it to the actual thickness of the pipe.

f) To find the max weight, I will utilize the drag force equation and use the sum of moments to solve for the weight.

# CALCULATIONS

(D)

a) $F_b = \gamma_{fg} V_d$ $\quad \gamma_g = 6.67 \frac{kN}{m^3}$

$0.9(3.65m)$
$= 3.285m$

DN 90 schedule 40 steel pipe
diameter: 0.269ft = 0.082m ← gate diameter

$V_d = Ax = \frac{\pi D^2}{4}(x)$ from pg. 106 from TB

$F_R = \gamma h_c A$ ← Using this formula because the gate is at an incline pg 70-71

$$F_R = (6.67 \tfrac{kN}{m^3})(3.285m)\left(\frac{\pi(0.082m)^2}{4}\right)$$
$$= (6.67 \tfrac{kN}{m^3})(3.205m)(0.0053m^2)$$
$$F_R = 0.116kN$$

$$F_b = (6.67 \tfrac{kN}{m^3})\left(\frac{\pi D^2}{4}\right)(3.285m)$$
$$F_b = 17.2\ kN\ D^2$$

$$\Sigma m = F_b(3.285m) - F_R(3.285m \cos 30°)$$
$$= 17.2 \tfrac{kN}{m^2} D^2 - 0.116kN(2.845m)$$
$$= D^2 17.2\ kNm - 0.33002\ kNm$$
$$D^2 = \frac{0.33002\ kNm}{17.2\ kNm}$$
$$D^2 = 0.01919$$

**ANS: D = 0.14m**

$$F_b = (6.67 \tfrac{kN}{m^3})\left(\frac{\pi(0.14m)^2}{4}\right)(3.285m)$$

Explanation on why it's stable in summary *

E

b) $\Sigma F = \rho Q \Delta$

$F_x = \rho Q \Delta v_x = \rho Q (v_{2x} - v_{1x})$
$F_y = \rho Q \Delta v_y = \rho Q (v_{2y} - v_{1y})$ ← Pg. 421

$V = 400\ gpm = 0.0252\ m^3/s$

$R_x = \rho Q v_1$
$= 0.116 kN (6.381 \times 10^{-3} m^2)(0.0252\ m^3/s)$

↑ from a ↑ Pg. 500 table F.1

$R_x = 1.865 \times 10^{-5} \frac{kN\ m^5}{s}$

$R_y = 0.116 kN (6.381 \times 10^{-3} m^2)(-0.0252\ m^3/s)$
$= -1.865 \times 10^{-5} \frac{kN\ m^5}{s}$

c) Flow Nozzle
$v_1 = C \sqrt{\frac{2g(P_1 - P_2)/\gamma}{(A_1/A_2)^2 - 1}}$
$C = 0.9975 - 6.53\sqrt{\beta / N_R}$
$\beta = d/D$

$\gamma_j = 6.67 \frac{kN}{m^3}$

< Lecture 10-30-2014 pdf

$N_R = \frac{v_1 D}{\nu}$ (Pg. 401) $= N_R = \frac{(0.0252\ m^3/s)(0.2957 ft)}{4.22 \times 10^{-7}}$ (0.0901 m; Table B.1)
$= 17657.9$

$\beta = \frac{0.082 m = 0.2690 ft}{0.2957 ft} = 0.91$ (table F.1)

$C = 0.9975 - 6.53\sqrt{\frac{0.91}{17657.9}}$

$C = 0.956$

$A_1/A_2 = \frac{0.06868 ft^2}{0.0568 ft^2}$ ← Table F.1
$= 1.209$

$A_2 = \frac{(0.2690 ft)^2 \pi}{4} = 0.0568 ft^2$

$\left(\frac{v_1}{c}\right)^2 = \frac{2g(P_1 - P_2)/\gamma}{(A_1/A_2)^2 - 1}$

$7.036 \times 10^{-4} = \frac{19.62(P_1 - P_2)/6.67 \frac{kN}{m^3}}{1.209 - 1}$

$7.036 \times 10^{-4} = \frac{19.62(P_1 - P_2)/6.67 \frac{kN}{m^3}}{0.209}$

$9.808 \times 10^{-4} = 19.62(P_1 - P_2)$

$P_1 - P_2 = 5.0 \times 10^{-5}$

F

d)

400 gpm = $0.0252\ m^3/s$

Slope = 0.001

Unfinished Concrete = $n = 0.017$ ← Table 14.1

$A = 1.73y^2 \quad WP = 3.46y \quad R = y/2$

$R = \frac{A}{WP}$

$= \frac{1.173y^2}{3.46y} = 0.339y$

Open channel flow equation: $Q = \frac{1.49}{n} A s^{1/2} R^{2/3}$

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

$AR = \frac{(0.017)(0.0252\ m^3/s)}{(1.49)(0.001)^{1/2}}$

$= \frac{4.284 \times 10^{-4}\ m^3/s}{0.0471} = 0.0091\ m^3/s$

$AR^{2/3} = 0.0091\ m^3/s$

$1.73y^2(0.339y)^{2/3} = 0.0091\ m^3/s$

$Y = 0.371$

↑ from excel spread sheet

e)

Mod. of elas.: 200 Gpa → 200000 mpa

Act. thickness of the pipe = 0.226 in

= 0.00574 m

Bulk modulus of gas: 1303 mpa

$$C = \frac{\sqrt{E_0/\rho}}{\sqrt{1 + \frac{E_0 D}{E d}}} = \frac{\sqrt{\frac{1303\ Mpa}{680\ \frac{kN}{m^3}}}}{\sqrt{1 + \frac{(1303\ mpa)(0.082\ m)}{(200{,}000)(0.00574\ m)}}} = \frac{1.384}{1.0455} = 1.324$$

$\Delta P = (1.324)(680)$

$= 900.2$

$$t = \frac{(0.116)(0.00574\ m)}{2((20)(0.85) + (0.116)(0.4))}$$

$$= \frac{6.6584 \times 10^{-4}}{68.1856} = 9.765E{-}6$$

G7

F) Coeff friction: 0.6

$F_D = C_D \left(\frac{\rho v^2}{2}\right) A$ } from pg. 434

$C_D = 1.60$ from pg. 438

$$F_D = 1.60 \left(\frac{(680 \frac{kg}{m^3})(0.0252 \frac{m^3}{s})}{2}\right) 0.0069$$

$$= (1.60(0.0508)(0.0069)) = 5.6 \times 10^{-4}$$

$$A = (0.1855)(0.0371) = 0.0069$$

$F_D = 5.6 \times 10^{-4}$ $\quad M = \frac{5.6 \times 10^{-4}}{9.81} = 5.71 \times 10^{-5}$

$$W = 5.71 \times 10^{-5} (9.81)$$

$$= 5.6 \times 10^{-7}$$

## SUMMARY

After going through the require calculations, I was able to solve for the missing information. First of, to allow the buoy the raise and open the gate, it need to be a diameter of 0.14m, this is will be stable because it's not negative so it will always be pushing upwards hence bouyant. When I calculate the total hori/verti forces of the whole discharge pipes, I can assume the maximum pressure of the whole system is 0.116 kN. As a contingency plan for possible spillage, a trapezoid cross section depth would be 0.371. This will work because through the process of trial and error the y = 0.371 equaled to 0.0091 when I solved it for AR. When the pipe closes, the pressure increment will be 900.2 and the pipe will fail because after comparing the actual thickness to the solved pipe thickness, its ~~does~~ no where near equivalent. And cavitation could occur at 1.324 m of the pipe

## MATERIALS

- Buoy
- Gasoline
- Gate
- Flow nozzle

ANALYSIS

(H)

When determining the size of the buoy (0.14m). If the size is too large, the buoy will stay up the whole way because the bouyant force is too large. If the size is too small, The buoy will be fully submerged not allowing it to open the gate. The trapezoid depth needs to be 0.371m because any changes will either make it too big, using more money or redundant materials or too small causing a spillage from overfilling.