MET 330

Test 1

9/25/24

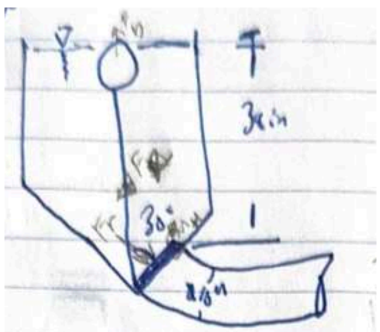
Elson Edmonds II

eedmo003@odu.edu

Purpose:

Determine the necessary size of the buoy required to open the hatch. The second purpose is to figure out the best angle of the latch so that the smallest buoy could be used.

Diagram:



Sources:

Applied Fluid Mechanics, 8th edition, 2021

Design Considerations:

Based on the description, I assumed:
1. The buoy was spherical
2. Incompressible fluid
3. Steady state

Data and Variables:

$$\gamma_{water} = 62.4 \frac{lb}{ft^3}$$

h = 38in

$\theta = 30°$

d = 10in

Materials:

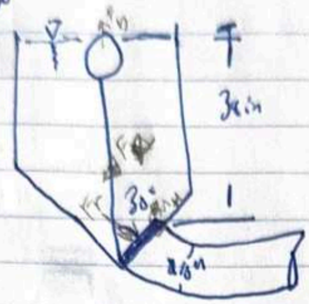
- Water
- Gate of unknown material
- Buoy
- String attached to the buoy

Procedure/Calculations:

Elson
Edmunds
Fluids
Test #1
9/23

h_2o @ 60°F $\gamma = 62.4\ lb/ft^3$, $\rho = 1.94\ slug/ft^3$

looking for Area



$h_c = 38 + y = 5\cos 30° = 42.33\ in$

$L_c = h_c / \cos 30 = 48.88\ in$

$F_R = \gamma h_c A = 62.4\ lb/ft^3\ (\pi(10in)^2/4)\left(\frac{1}{12^3 ft}\right)(42.33in) = 120.1\ lb$

$I_c = \frac{\pi D^4}{64} \Rightarrow \frac{\pi 10^4}{64} = 490.9 in^2$

hp is the y component of the center of pressure $h_p = h_c + \frac{I_c \sin^2\theta}{h_c A}$

$\frac{2}{3}(10) + 38 = 44.66in = h_p$

$(h_p - h_c)h_c = I_c \sin^2\theta / A$

$A = \frac{I_c \sin^2\theta}{(h_p-h_c)h_c}$, $\frac{F_r}{\gamma_c} = A$

$\frac{F_r}{\gamma_c} = \frac{I_c \sin^2\theta}{(h_p-h_c)h_c}$

$F_r = \frac{I_c \sin^2\theta\ \gamma_c}{(h_p-h_c)h_c} \Rightarrow \frac{490.9in(\sin^2 30)\ 62.4\ lb/ft^3}{(44.66in - 42.33in)\ 42.33in}\left(\frac{1 in^3}{12^3 ft^3}\right) = .0449\ lbs$

$52.67\left(\frac{62.4\ lb/ft^3}{42.33in}\right)\left(\frac{1}{12 ft^3}\right) = .0445\ lbs$

$F_r = \gamma_c A$

$.0449 lb = 62.4\ lb/ft^3\ A$

$F_r \leq F_b$ in order for gate to open

$M_H = FD \Rightarrow F_r(d)$

$\Sigma F_y = 0 = F_b + F_g - F_R + M_H$

buoy is a sphere

$M_H\ 120.1\ lb(10)$

$M_H = 1201$

$F_b = M_H - F_r$

$F_b = 1201\ lb - 120$

$F_b = 1080\ lb/in\left(\frac{1in}{12ft}\right)$

$F_b = 90.1$

$F_b = \gamma_F V_d$

$90.1 = 62.4\ lb/ft\left(\frac{4}{3}\right)\pi r^3$

$.3449\ ft^3 = r^3 = .701 ft^3 = 8.4 in^3$

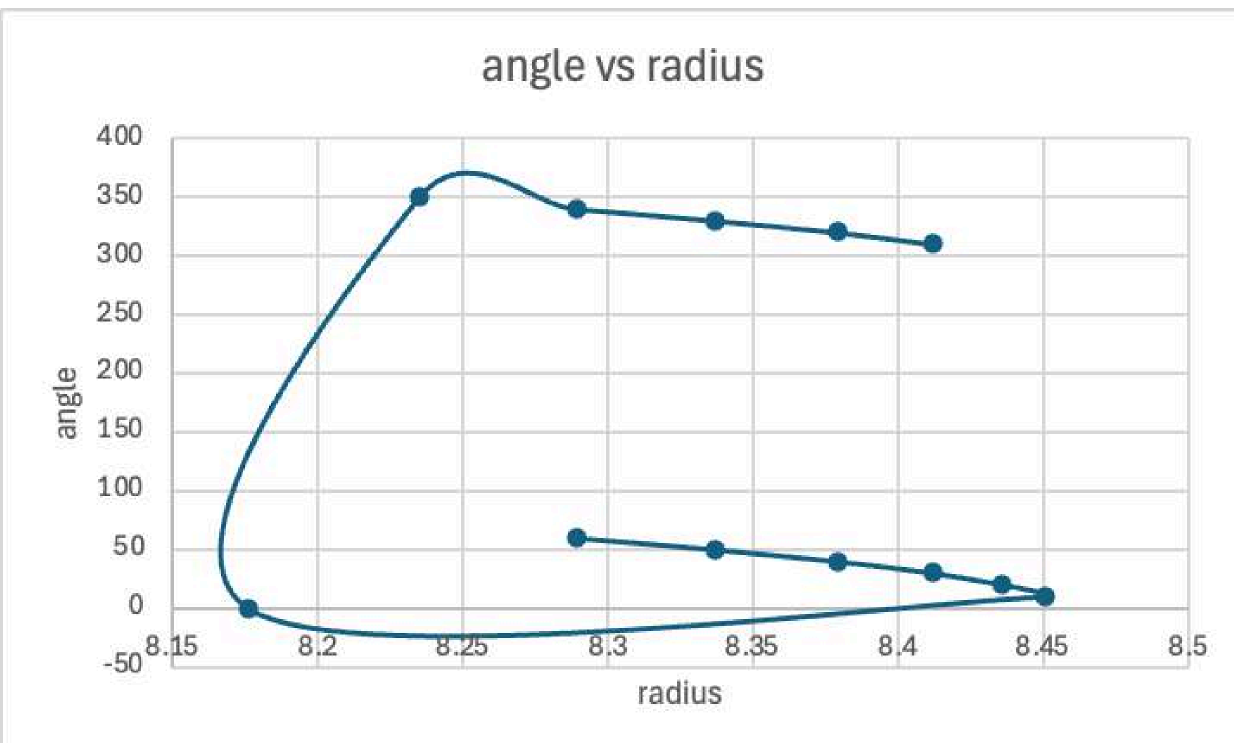
$r = .701 ft^3$ or $8.4 in^3$

No, the buoy is not stable because it is still rising to the top of the container instead of just floating on top, still.

these results make sense because they fit within the frame of the tank and look right

0° would be the smallest buoy due to my calculations. This makes sense because the buoy would only have to pull in one direction opposed to a gate with an angle that would "waste" force on the x-axis

angle	rads	radius (in)
310	5.41052068	8.412
320	5.58505361	8.379
330	5.75958653	8.337
340	5.93411946	8.289
350	6.10865238	8.235
0	0	8.176
10	0.17453293	8.451
20	0.34906585	8.436
30	0.52359878	8.412
40	0.6981317	8.379
50	0.87266463	8.337
60	1.04719755	8.289



Summary:

The necessary size of the buoy required to open the hatch at the bottom of the tank is .701 ft or 8.4in.

The smallest size that the buoy could be that would still open the hatch is at 0°, the radius would then be 8.176in.

The buoy is not stable because it is still rising to the top of the container instead of just floating still on top, still, where it would be stable.

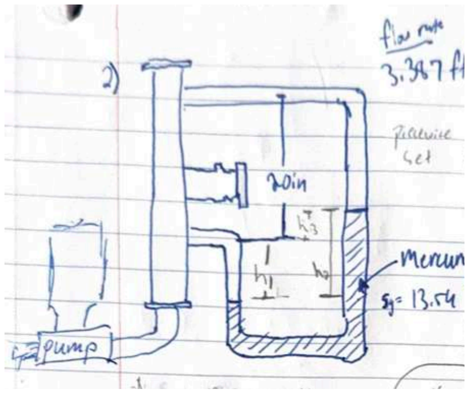
Analysis:

At 0° would be the smallest buoy size that would still open the gate, according to my calculations. This makes sense because the buoy would only have to pull in one direction opposed to a gate with an angle that would “waste” force on the x-axis.

Purpose:

Determine the U-tube manometer reading in the pipe.
Determine the pressure difference between the two taps if there is no flow.

Diagram:



Sources:

Applied Fluid Mechanics, 8th edition, 2021

Design Considerations:

Based on the description, I assumed:

1. Water @ 60°F
2. Incompressible fluid
3. Steady state

Data and Variables:

Flow rate = 3.38 ft^3/s
Change in pressure = 3.393 psi = 488.59 lb/f^2
Gravity = 32.1 ft/s^2
Distance between the two pumps = 20in
$\gamma_{mercury} = 13.54$

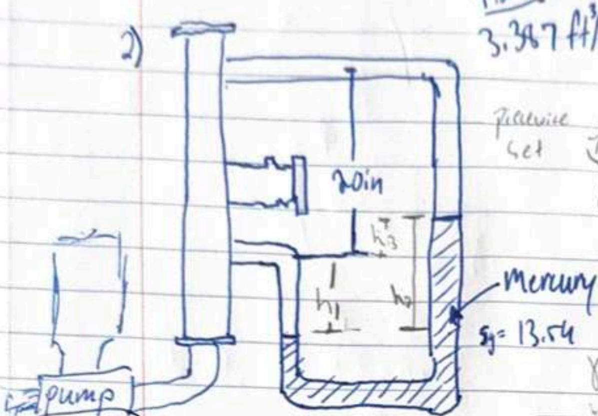
Materials:

- Water
- Mercury
- Pump
- U-Tube Manometer
- pipes

Procedure/Calculations:

γ_w @60°F = 68.4 lb/ft³

2)



flow rate
3.387 ft³/s

ΔP
3.393psi = 488.593 psf (looked up conversion)

$\Delta P = \rho g h_2 \Rightarrow h_2 = \frac{\Delta P}{\rho g}$

piecewise set
$h_2 = h_1 + h_3 \Rightarrow h_1 = h_2 - h_3$
$p_2 - p_1 = 3.393\,psi = \Delta p$

$p_1 + \gamma_w(h_1) - \gamma_{Hg}(h_2) - \gamma_w(20in - h_3) = P_2$

$\gamma_w(h_1) - \gamma_{Hg}(h_2) - \gamma_w(20in - h_3) = \Delta P$

$\gamma_w h_2(-\gamma_w h_3) - \gamma_{Hg} h_2 - \gamma_w 20in(\gamma_w h_3) = \Delta P$

$\gamma_w h_2(-\gamma_w h_3) - \gamma_w 20in(\gamma_w h_3) = \Delta p + \gamma_{Hg} h_2$

$\gamma_w h_3(-\gamma_w h_2 - \gamma_w 20in) = \Delta p + \gamma_{Hg} h_2$

$\gamma_w h_3\left(-\gamma_w\left(\frac{\Delta p}{\rho g}\right) - \gamma_w 20in\right) = \Delta p + \gamma_{hg}\left(\frac{\Delta p}{\rho g}\right)$

$h_3 = \frac{\Delta p \gamma_{hg}\left(\frac{\Delta p}{\rho g}\right)}{\left(-\gamma_w\left(\frac{\Delta p}{\rho g}\right) - \gamma_w 20in\right)}\left(\frac{1}{\gamma_w}\right)$

$h_3 = \frac{488.593\,psf\,(1.21\,lb/ft^3)\,15.2\,lbf/s^2}{-68.4\,lb/ft\,(15.2\,lb/s^2 + 1.6ft)}\left(\frac{1}{68.4\,lb/ft^3}\right)$

$\frac{\gamma_{Hg}}{\gamma_{60°F}} \Rightarrow \frac{13.5}{64.4\,lb/ft^3} = .21\,lb/ft^3$

$g = 9.81\,m/s^2$
$g = 32.2\,ft/s^2$

$\frac{\Delta p}{g} \Rightarrow \frac{488.59\,psf}{32.1\,ft/s^2} = 15.2\,lb/s^2$

20in = 1.6ft

$\frac{155.1}{1149.2}\left(\frac{1}{684}\right) \Rightarrow .00197\,ft$
$h_3 = .02\,ft$

$\gamma_w h_3(-\gamma_w h_2 - \gamma_w(1.6ft)) = \Delta p + \gamma_{Hg} h_2$

$68.4\,lb/ft\,(.02\,ft)(-68.4\,lb/ft\,(h_2 - 1.6ft)) = 488.59\,lb/ft^2(.21\,lb/ft^3)h_2$

$1.3686(-68\,lb/ft(h_2 - 1.6)) = 102.6\,ft\,h_2$

$-93.02h_2 + 148.84 = 102.6\,ft\,h_2$

If there was no flow, there would be no difference between the two taps

$148.84 = 195.62h_2$

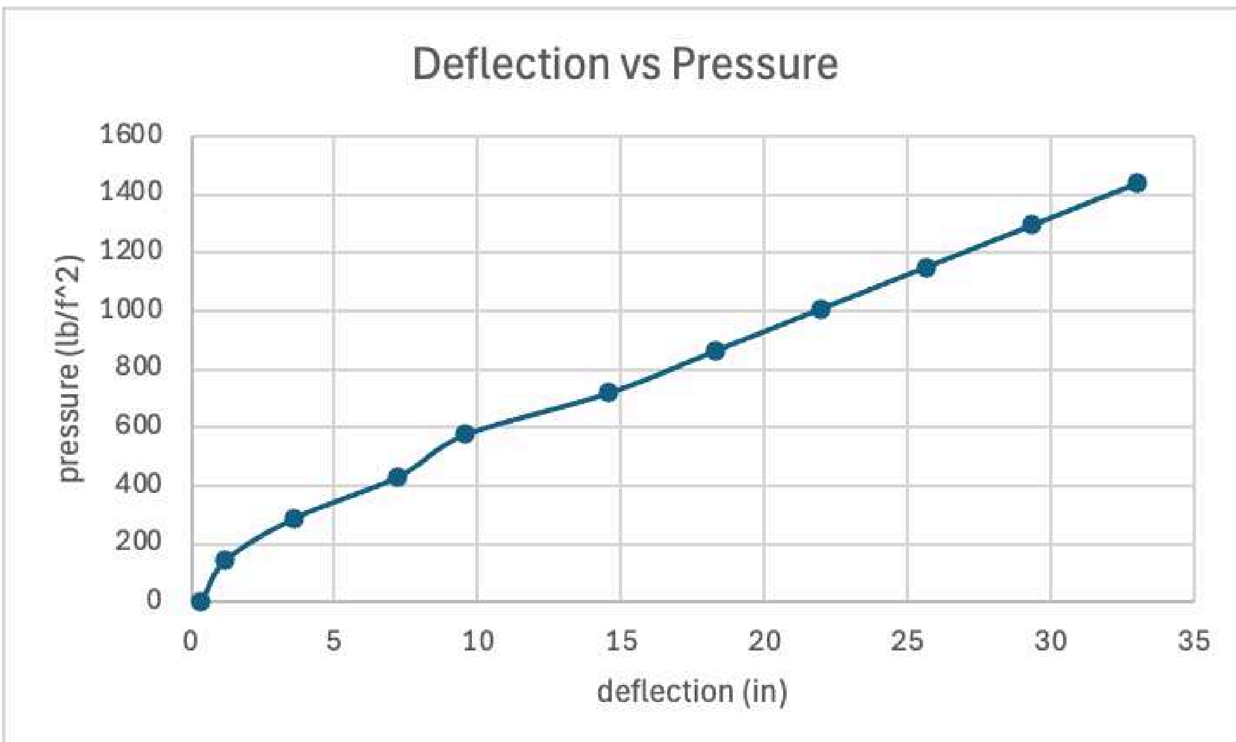
$.761ft = h_2 \Rightarrow 9.13\,in$

$-\gamma_w h_3 \gamma_w h_2 - \gamma_w h_3 \gamma_w 1.6ft = \Delta p + \gamma_{Hg} h_2$

$-\gamma_w h_3 \gamma_w 1.6ft - \Delta p = \gamma_{Hg} h_2 + \gamma_w h_3 \gamma_w h_2$

$\frac{-\gamma_w h_3 \gamma_w 1.6ft - \Delta p}{(\gamma_{Hg} + h_3 \gamma_w^2)} = h_2$; $h_2(\gamma_{Hg} + h_3\gamma_w^2)$

pressure psi	pressure lb/ft^2	deflection (ft)	deflection (in)
0	0	0.03	0.36
1	144	0.1	1.2
2	288	0.298	3.576
3	432	0.602	7.224
4	576	0.798	9.576
5	720	1.216	14.592
6	864	1.523	18.276
7	1008	1.83	21.96
8	1152	2.137	25.644
9	1296	2.445	29.34
10	1440	2.751	33.012



Summary:

The deflection of the mercury is .761 ft or 9.13in.

If there was no flow, there would be no difference between the two taps.

Analysis:

The deflection of the mercury makes sense because it fits within the length of the tube, as well as makes sense within the scope of the question and picture.