10-27-19 | Test 1 | Yapmayan, Nathaniel | 1

Purpose

A company wants me to design a system with a specific amount of requirements. This system delivers 60°F water from an open channel to another elevated one. This requiring 30% of total fluid flowing in the lower open channel. This natural channel with light brush and it average being 0.00015. Each tasks have specific requirements.

(a) Determine the required pump power (in HP) with a pump efficiency of 60%. Ignore minor losses and only consider pipe losses. Afterwards determine a pipe diameter

(b) How large should the buoy be for a gate to open when it reaches 38 inches? Is it stable ?

(c) What would be the reading in U tube manometer.

(d) From pump outlet to elevated open channel inlet, calculate the total horizontal and vertical forces in the pipe - elbows - valve system. Find the pump outlet pressure and elevated channel inlet pressure.

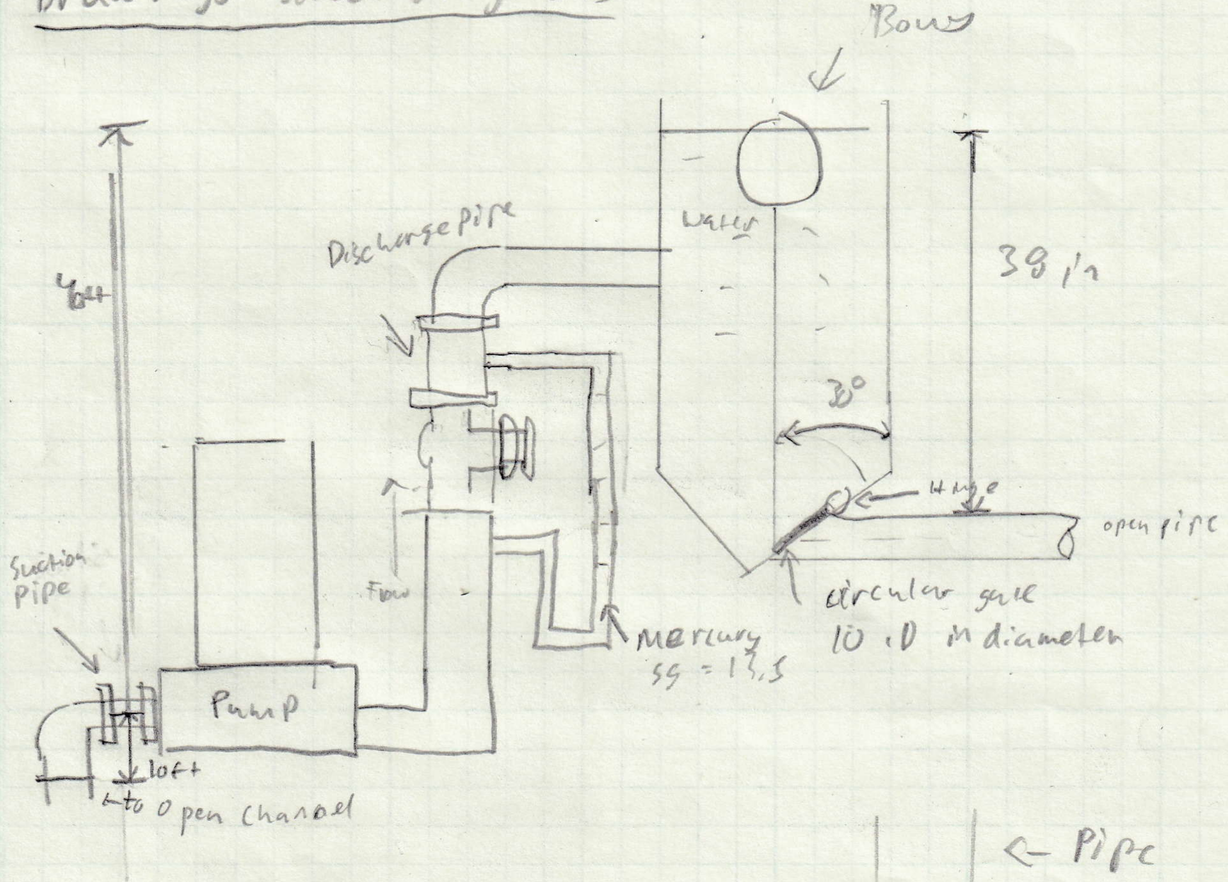
(e) What is the pressure drop across the nozzle

(f) Find the occurence of water hammer and/or cavitation What is the pressure increment after the sudden closing? Would this pipe fail?

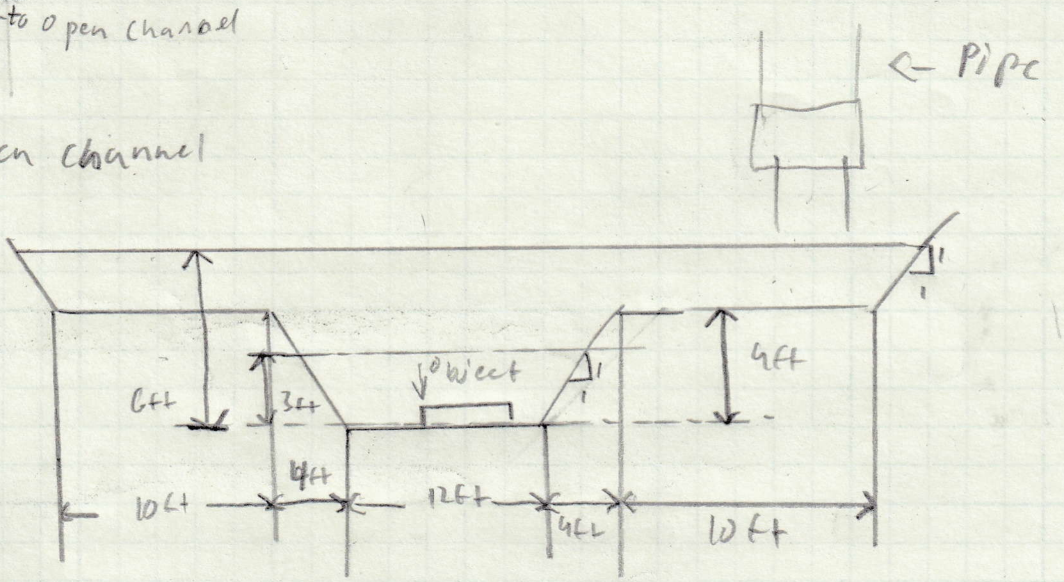
(g) What is the object maximum weight so the fluid flow around it slides it along the bottom surface? Object does not tumbles.

Test 7

Drawings and diagrams



Open channel



Sources

using the book

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

Design Consideration

- Deliver 3% of total fluid flowing
- Slope average = 0.00015.
- Neglect the weight of the circular gate and the buoy
- Discharge pipe is needed.
- Is there cavitation in the system
- Can the valve in the pipe fail?
- Water T = 60°F
- Neglect minor losses
- If pipe closes suddenly
- What if object is placed in the bottom channel

Data and Variables

Water T = 60°F

Total fluid = at least 3%

Water level = 38 in

Pipe length = 2500 ft

n (coeff of friction) = 5.30

diameter = 0.5

slope = S = 0.00015

$\gamma_{water} = 62 \frac{lb}{ft^3}$

Object is cylinder 5 ft / 1 foot side

$g = 32.2 \, ft/s$

Materials

Water — buoy in water tank

Pipes — Mercury in U-tube

Valves — Cylinder object

flow nozzle

Procedure

(a) We need to determine the pump power in hp

Before solving the problem, reconginize what is given.

Pump efficiency of 60% = 0.60

Pipe length = 11 ft

Total discharg = 2300 ft

Specific weight water (γ) = 64. lb/ft³

From Table F.1 Schedule 40 Pipe 80 NPS = 3 in

DW = 80mm

flow area = 0.05132 ft² or 4.768×10⁻³ m²

$Q = A v$

$Q = (2\ ft^2/s)(0.03) = 0.06\ ft^3/s$

3%

$v = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} D_L^2}$

$v = 29.0\ ft$

$v = \frac{0.06\ ft^2/s}{\frac{\pi}{4}(0.05132\ ft^2)^2}$

$z_2 = 40\ ft$ $z_1 = 10\ ft$

$f = 0.020$ (friction)

We need to figure out the pump head in order to find pump power

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

Pressure = $P_1 = P_2 = 0$ $v_1 = v_2 = 0$

$z_1 + h_A - h_L = z_2$

Reconginize the friction loss in suction and discharge line, are minor losses. This equation solves for pipe loss

$$h_L = f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right) = (0.020)$$

$$= 0.020\left(\frac{11\ ft}{0.05132\ ft^2}\right)\left(\frac{29\ ft}{2(32.2\ ft^2)}\right)$$

$$= 1.930\ ft$$

Pump head

$h_A = z_2 - z_1 + h_L$

$= (40\ ft - 10\ ft) + 1.930\ ft$

$h_A = 31.93\ ft$

Power equation

$$P = \frac{h_A \gamma Q}{e_m} =$$

$$= \frac{(31.93\ ft)(62.4\ lb/ft^3)(0.06\ ft^3/s)}{0.60}$$

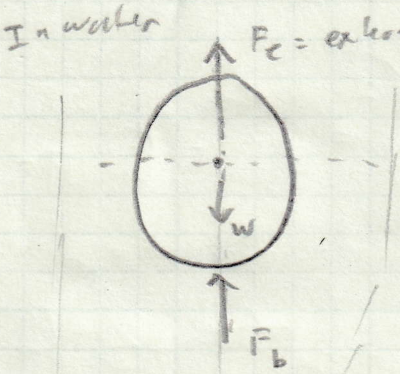
$$= 199.24\ lb\cdot ft/s \left(\frac{1}{550\ ft\cdot lb/s}\right)$$

Pump power = **0.36 hp**

Procedure

(b) How large is the buoy to open the gate when the it reaches 39 inches.

The buoyant force is $F_b = \gamma_f V_d$



Resultant force = $F_R = \gamma h_c A$

Force acting on buoy as it sinks

$F_b + F_e - W = 0$ $\qquad F_e = -F_b$

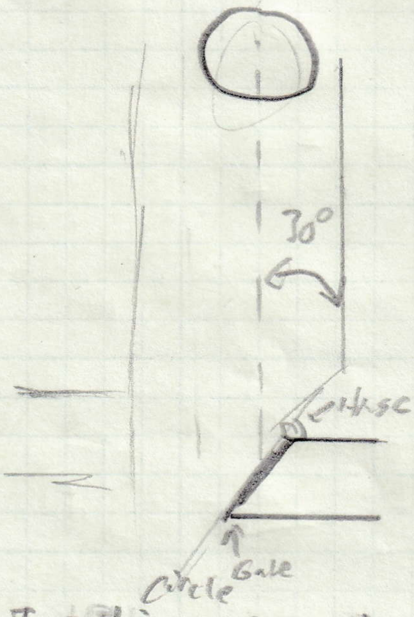
Neglect the weight and circular gate weight

Vertical height of tank

$h_c = 39 + \cos^\circ 30 = 39.87$ in

Area of the gate

$A = \frac{\pi}{4} D^2 = \frac{\pi\, 10^2}{4} = 78.54\ in^2$



Now we have the area.

We can find the resultant force

$F_R = \gamma h_c A$

$= (62.4\ lb/ft^3)\left(\frac{39.87\ in}{12}\right)\left(\frac{78.54\ in^2}{12^2}\right)$

$= (62.4\ \frac{lb}{ft^3})(3.239\ ft)(0.5454\ ft^2)$

$F_R = 110.2$ lb ← How big the buoy would be

Inertia of circular gate – we need this when gate is pulled

$I_c = \frac{\pi D^4}{64} = \frac{\pi\, 10^4_{in}}{64} = 490.87\ in^4$

reference axis to centroid

$L_c = \frac{h_c}{\cos 30^\circ} = \frac{39.87\ in}{\cos 30^\circ}$

$L_c = 44.88$ in

Continued from (b)

$$L_p - L_c = \frac{I_c}{L_c A}$$ transfer theorem

We need to find $L_p - L_c$ which is just the reference axis to the location of resultant force plug values in

$$L_p - L_c = \frac{I_c}{L_c A} = \frac{490.87\,in^4}{48.98\,in\,(78.54\,in^2)}$$

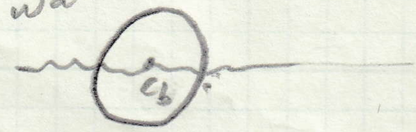
$$L_p - L_c = 0.1276 \approx \boxed{0.128\,in}$$

In order to find out if the bouy is stable. the meta center must be greater than the center bouyancy. $y_{mc} > y_{cb}$ (stable)

$$y_{mc} = I_c = 490.87\ in^4 = 3.409\ ft^2$$

center of gravity is equal to

$$y_{cb} = \frac{L_c}{2} = \frac{22.44}{12}\,in = \underline{1.87\,ft}$$



$$3.409\ ft^2 > 1.87\,ft$$

The bouy is stable because $y_{mc} < y_{cb}$

(C) U tube manometer. Find energy losses

K = 5.30 Pressure resistance

Computing loses

h = 20 inches between 2 taps

$$\frac{\Delta p}{\gamma} = K \frac{V^2}{2g}$$

Energy loss

$$h_L = 5.30\left(\frac{V^2}{2(32.2\ ft/s)}\right)$$

Find V^2 Based on Schedule 40 Pipe 80

$$V = \frac{Q}{A} = \frac{0.06\ ft^2/s}{\frac{\pi}{4}\left(\frac{0.20\ in}{12}\right)^2}$$

$V = 29.0\ ft$

$$h_L = 5.30\left(\frac{29.0^2}{2(32.2\ ft/s)}\right)$$

$h_L = 2.387\ ft/s$ per energy loss in the tube

with the mercury inside the tube that pressure is

$P_0 = \gamma_{Hg} h$

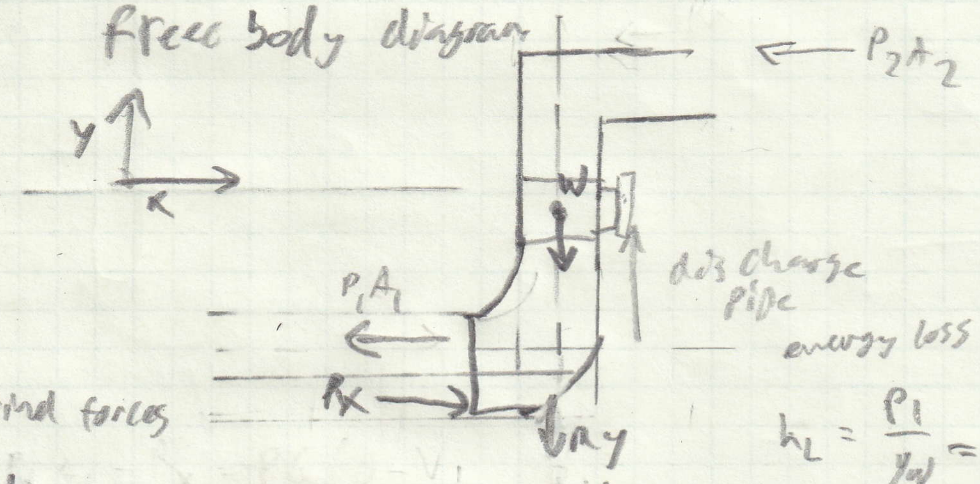
$= 13.54(20\ \text{inches})$

$P_0 = \frac{270.8\ in}{12}$

$P_0 = 22.58$

(d) Find the supports total Horizontal and vertical

Start with free body diagram



energy loss = Pressure / Sg of water

$h_L = \frac{P_1}{\gamma_w}$

$P_1 = h_L \gamma_w$

$P_1 = (1.930\ ft)(62.43\ lb/ft^3)$

$P_1 = 120.49\ lb/ft^2$

$A_1 = \frac{78.54\ in^2}{12^2} = 0.5457\ ft^2$

Find forces

$\Sigma F_x = 0$

$-P_1A_1 + R_x = -P_2A_2$

It's 0 because it's going out of the pipe

$R_x = -P_1A_1 - P_2A_2$

$R_x = (120.49\ lb/ft^2)(0.5457\ ft^2)$

$\boxed{R_x = 65.75\ lb}$

$\Sigma F_y = 0$

$-R_y = -W \qquad R_y = W$

Weight of pipe

based on previous problem

$W = \gamma_w \left(\frac{\pi}{4} D^2\right)(L)$

$W = (62.43\ lb/ft^3)(0.05132\ ft^2)\left(\frac{20\ in}{12}\right)$

$\boxed{W = 5.340\ lb}$

$\boxed{R_y = 5.340\ lb}$

e) Determine pressure drop across nozzle

Flow meter equation ratio: $\frac{D}{d} = 0.5$

$$Q = CA_1\sqrt{\frac{2g\frac{\Delta P}{\gamma_w}}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

Find change of pressure based on the following

$$\frac{A_1}{A_2} = \left(\frac{D}{d}\right)^2 = (0.5)^2 = 4$$

Finding the flow discharge based on table 15.3

$C = 0.984$ Just chose one

Have all variables except ΔP

Find change in pressure

$$\Delta P = \frac{\left(\frac{Q}{CA_1}\right)^2\left((4)^2 - 1\right)\gamma_w}{2g} = \frac{\left(\frac{0.06 ft^2}{(0.984)(0.05832 ft^2)}\right)^2 (16-1)(62.4 lb/ft^3)}{2\left(32.2 \frac{ft^2}{s}\right)}$$

$\boxed{\Delta P = 20.52 \text{ lb}}$

This is the change of pressure drop across the nozzle

8) Basic wall thickness

$$t = \frac{PD}{2(SE + PY)}$$ must use to find thickness

First find water hammer and/or cavitation. This will help ensure the pipes being used are safe.

Cavitation

$$C = \frac{\sqrt{\frac{E_o}{\rho_w}}}{\sqrt{1 + \frac{E_o D}{E y}}}$$

Wave velocity for this equation

$E_o = 200\,GPA$

Values for bulk modulus for water Table 1.3

$E = 2179\,MPa$

$y = 4.768 \times 10^{-3}\,ft^2$

Flow rate

$\rho_w = 1000$

Pressure water

$$C = \frac{\sqrt{\frac{200 \times 10^9\,Pa}{1000}}}{\sqrt{1 + \frac{200 \times 10^9\,Pa}{(2179 \times 10^6)(4.768 \times 10^{-3}\,ft^2)}}}$$

$$C = \frac{14142\,\frac{ft^2}{s}}{138.75\,ft}$$

$$\boxed{C = 101.93\,\frac{ft}{s}}$$

Summary

This whole system is a combination of different pipes and tanks connected. water is flowing through this system to an open channel. The system is all based on the pipes I selected in Table P.1. The idea was to inspect and determine what was best for this system. Calculations that were used were meant to showcase the possible results.