ME331 Project 1

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[i] Problem Statement

The problem we are asked to solve is determining parameters around the water tank and water pump. Specifically we are asked to determine the pump power for each height of the pressurized water tank. Then the inlet pressure must be calculated for each height of the water tank given. Finally we must determine the total force on the deflector plate based on the conditions from each height of the water tank and Find the conditions that give the largest and smallest force on the deflector plate.

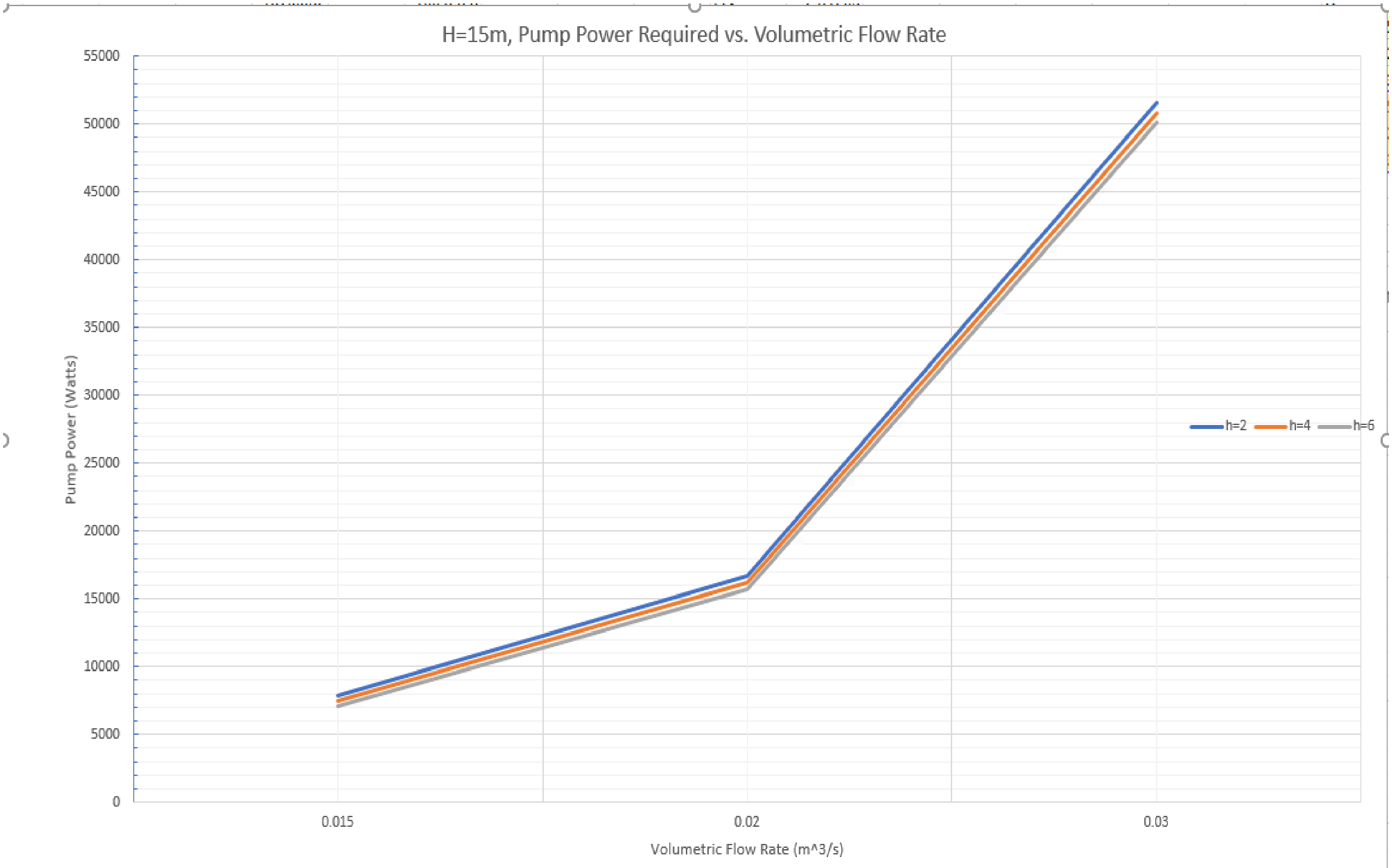
2. Assumptions:

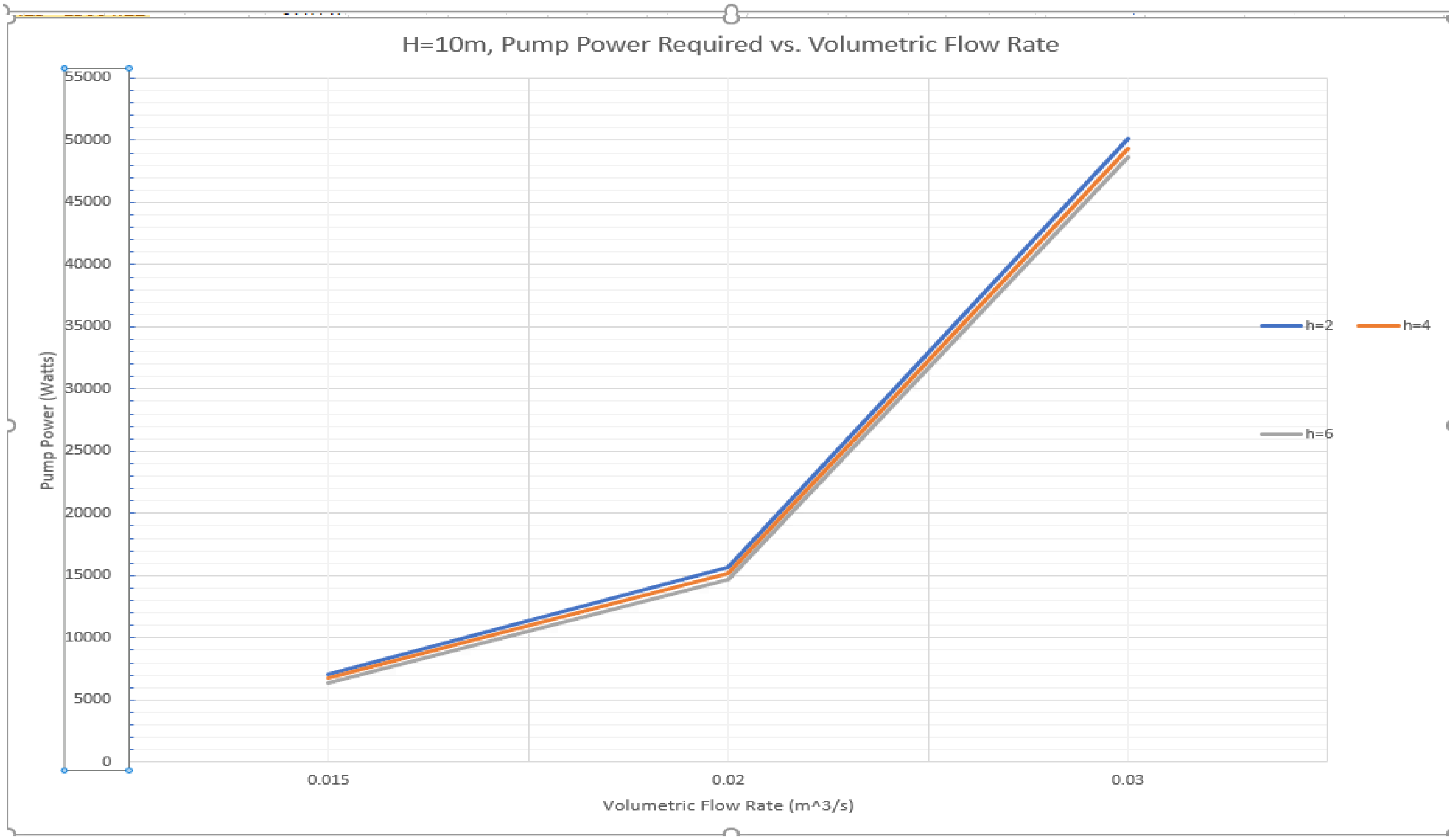
- Density is constant
- Pump operates at steady-state
- V1 = 0
- P1 = Pt (gage)
- P2 = 0 (gage)
- Steady flow
- E loss is constant

3. Equations:

- $m_{dot} = \rho Q$
- $m_{dot} = \rho AV \Rightarrow V = \frac{m_{dot}}{pA}$
- $m_{dot} = 14.955 \frac{kg}{s}, \ 19.94 \frac{kg}{s}, \ 29.91 \frac{kg}{s}$
- $V = 11.94 \frac{m}{s}, \ 15.92 \frac{m}{s}, \ 23.87 \frac{m}{s}$
- $m_{dot}(\frac{P_t}{\rho} + \frac{V^2}{2} + gh)_{in} + \eta W = m_{dot}(\frac{P_2}{\rho} + \frac{V^2}{2} + gH)_{out} + E_{loss}$
- $m_{dot}(\frac{P_t}{\rho} + gh)_{in} + \eta W = m_{dot}(\frac{V^2}{2} + gH)_{out} + (K * m_{dot} * \frac{V^2}{2})$
- $W = (m_{dot}(\frac{V^2}{2} + gH)_{out} + (K * m_{dot} * \frac{V^2}{2}) - m_{dot}(\frac{Pt}{\rho} + gh)_{in})/\eta$

4. Results:


H=15m, Pump Power Required vs. Volumetric Flow Rate
Pump Power (Watts)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
0.015
0.02
0.03
Volumetric Flow Rate (m^3/s)
h=2
h=4
h=6


H=10m, Pump Power Required vs. Volumetric Flow Rate
Pump Power (Watts)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
0.015
0.02
0.03
Volumetric Flow Rate (m^3/s)
h=2
h=4
h=6

	Q	h=2	h=4	h=6
H1	0.015	7107.404	6739.651	6371.899
	0.02	15669.7	15180.68	14691.65
	0.03	50114.87	49381.33	48647.79
H2	0.015	7838.783	7471.031	7103.278
	0.02	16642.28	16153.25	15664.22
	0.03	51573.73	50840.19	50106.64

5. <u>Discussion:</u>

The results found for pump power at different heights shows a clear relationship between pump power and height. As our graphs show, H (height of pipe exit) increases, the power required by the pump also increases. There is also a relation with the height of the tank itself, when the tank is at a lower height, there is more power required from the pump. This is logical because as the height of the tank increases, the pump inlet pressure will also increase, which in term allows the pump to require less power. The validity of these results are obviously not exact because there were assumptions that we made that are stated in [i], part 2, although variance caused by these assumptions are essentially neglectable for our purposes.

[ii] Problem Statement:
This problem asks us to find the inlet pressure of the pump for the different cases in part 1. To do this we are going to use hydrostatics to solve for the inlet pressure of the different tank heights and the different tank pressures. It is given that the three tank heights are 2, 4, and 6 meters and the two tank pressures are 20 and 30kPa. The pump is located at the bottom of the tank, at the inlet of the pipe.

2. Assumptions:

- Pt is gage pressure
- P_{inlet} measured in gage pressure
- Density is constant
- CV is around the pump, slightly including the pipe going into and out of the pump
- Eloss occurs in the piping system, thus Bernoulli's energy equation is valid when looking only at the pump, before the piping system.
- Steady Flow
- Follows streamline
- No flow machines

3. Equations:

$$\left(\frac{P_t}{\rho} + \frac{V^2}{2} + gh\right)_{in} = \left(\frac{Pinlet}{\rho} + \frac{V^2}{2} + gh\right)_{out}$$
$$\left(\frac{P_t}{\rho} + gh\right)_{in} = \left(\frac{Pinlet}{\rho} + \frac{V^2}{2}\right)_{out}$$
$$P_{inlet} = P_t + gh\rho - \frac{\rho V^2}{2}$$

4. Results:

Table of Pin values at each h

	Pt = 20000Pa Q1	Pt = 20000Pa Q2	Pt = 20000Pa Q3	Pt = 30000Pa Q1	Pt = 30000Pa Q2	Pt = 30000Pa Q3
h = 2	-31506.8 Pa	-86781.9 Pa	-244473 Pa	-21506.8 Pa	-76781.9 Pa	-234473 Pa
h = 4	-11945.7 Pa	-67110.8 Pa	-224912 Pa	-1945.7 Pa	-57220.8 Pa	-214912 Pa
h = 6	7615.465 Pa	-47659.6 Pa	-205350 Pa	17615.47 Pa	-37659.6 Pa	-195350 Pa

5. Discussion:

While our values are negative for the pressure inlet into the pump may seem odd, this is because of the relative pressure gradient between the pump and tank. In order for the water to flow at the required mass flow rate into the pump there needs to be a negative pressure at the pump to cause the flow through the pipe. Based on our results as h (the height of the tank) increases the pressure increases across the pump. Pin also increases as Pt is increased. The pressure decreases as Q increases into the pump.

[iii] Problem Statement:

This problem asks us to find the conditions that give us the smallest and largest force magnitudes on the deflector plate given the various conditions. It is given that the deflector plate is at an angle of 110 degrees to the horizontal, the deflector plate moves at a constant velocity of 0.25Vout, 40% of the water flow is directed upward, and 60% is directed downward. To do this we are going to use conservation of linear momentum to solve for the x/y components of the resultant force and then solve for the magnitude, given the different conditions.

2. Assumptions:

- Flow is along the deflector plate in both directions
- Velocity is constant
- Flow areas are equal to flow areas at the pipe exit
- Velocity in the y direction is 0 at the pipe
- Density is constant
- CV consists of deflector plate and incoming/outgoing flow

3. Equations:

$$V_{rel} = V - V_b = V = 0.25V \Rightarrow V_{rel} = 0.75V$$

$$F_{Rx} = -(m_{dot}V_{rel}) + (0.6\,m_{dot})(V_{rel}sin(20)) + (0.4\,m_{dot})(-V_{rel}cos(70))$$

$$F_{Ry} = (0.6\,m_{dot})(-V_{rel}cos(20)) + (0.4\,m_{dot})(V_{rel}sin(70))$$

$$m_{dot} = \rho * A_{in}V_{rel}$$

$$F_{R=}\sqrt{F_{Rx}^2 + F_{Ry}^2}$$

$$\theta = tan^{-1}(\frac{F_{Ry}}{F_{Rx}})$$

4. Results:

Table of x and y forces and theta results

	Frx (N)	Fry (N)	Fr (N)	Theta (degrees)
m1V1	-91.199	-18.046	92.968	11.193
m2V2	-162.133	-32.083	165.276	11.193
m3V3	-364.493	-72.126	371.56	11.193

5. Discussion:

The results that we calculated are logical because both the x and y resultant forces should be negative as the force from the stream pushes the plate up to the right. Because of this, the resultant force will in fact push down left (negative x negative y). Also as our mass flow rate and velocity increase, the resultant force also increases, which does make sense because it is an increased applied force that requires a higher resultant force to keep our system in equilibrium. Our system is not 100% accurate because of some assumptions such as the area of the stream stays the same before and after hitting the plate, although this would not cause a huge difference in calculations and is a reasonable assumption.