ME331 Project 2

By
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(i) Flow from A to B

Assumptions:
- Fluid is Incompressible
- Pump operates at steady-state
- Temperature is constant
- Viscosity is the same for both systems
- 90 elbow K=0.3
- Valve K=0.3
- Inlet K=0.5
- Exit K=1.0
- Temperature is 20C
- Qdot is held constant for pump change in pressure

1. Pressure drop:

$\Delta P = \frac{M}{LT^2}$ $\quad p = \frac{M}{L^3}$ $\quad \mu = \frac{M}{LT}$ $\quad Q = \frac{L^3}{T}$ $\quad \omega = \frac{1}{T}$ $\quad d = L$ $\quad v = \frac{L}{T}$ $\quad h = L$ $\quad Length = L$

$\Delta P = f(p, u, Q, D, w)$

$M/LT^2 = f(M/L^3, M/LT, L^3/T, L, 1/T)$

$M: 1 = a + b$

$T: -2 = -b - c - e$

$L: -1 = -3a - b + 3c + d$

$$\pi_1 = \frac{\Delta P D^4}{\rho Q^2}$$

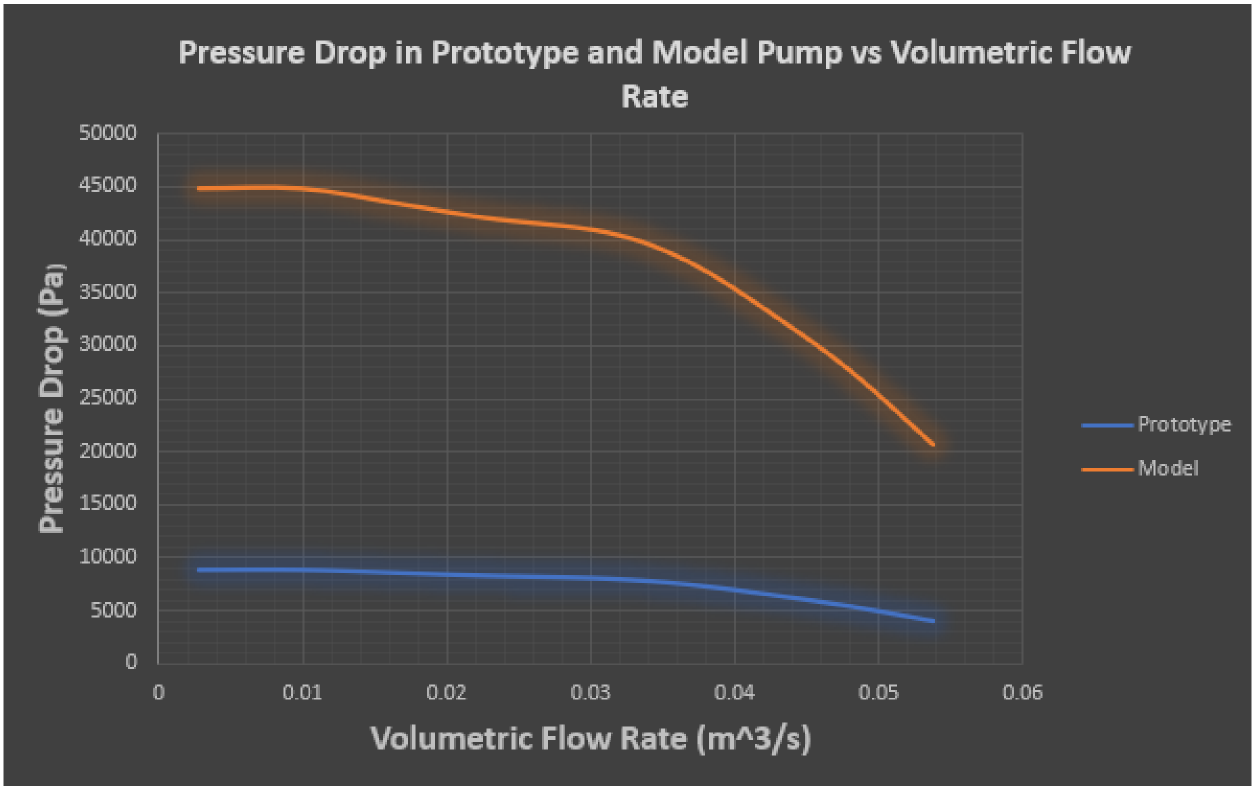
$$\pi_2 = \frac{\mu D}{pQ}$$

$$\pi_3 = \frac{D^3\omega}{Q}$$

$$\Delta P_p = \frac{\Delta P_m D_m^4 \rho Q^2}{\rho Q^2 D_p^4}$$

Delta P (Prototype) At Each Volumetric Flow Rate (Pa)	Delta P (Model) At Each Volumetric Flow Rate (Pa)
8853.333	44820
8851.358	44810
8580.741	43440
8306.173	42050
8035.555	40680
7490.37	37920
6536.296	33090
5447.901	27580
4084.938	20680

Graph of Relationship observed above:



2. Pipe Diameter:

$$\pi_1 = \frac{\Delta P D^4}{\rho Q^2}$$

$$\pi_2 = \frac{\mu d}{p Q}$$

$$\pi_3 = \frac{D^3 \omega}{Q}$$

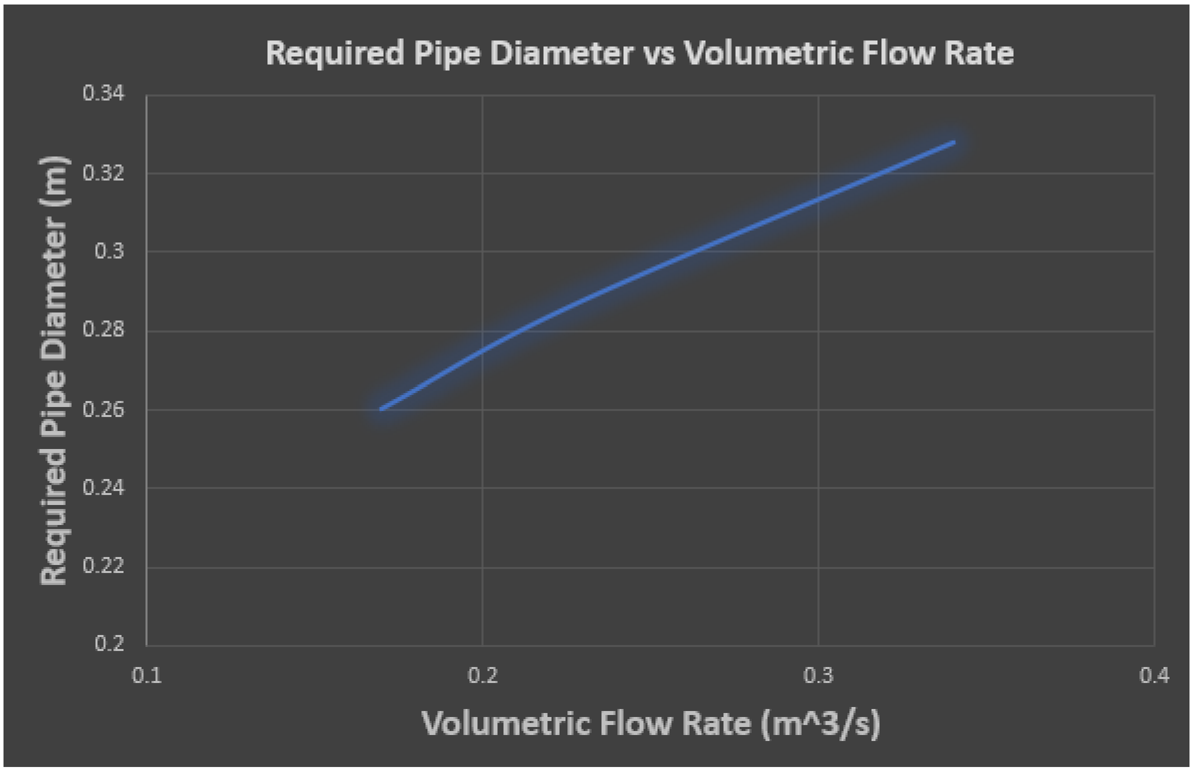
$$D_p = \left(\frac{D_m^3 \omega_m Q_p}{Q_m \omega_p}\right)^{1/3}$$

Required Diameter Pipe at $6\frac{ft^3}{s}$ (in)	Required Diameter Pipe at $8\frac{ft^3}{s}$ (in)	Required Diameter Pipe at $12\frac{ft^3}{s}$ (in)
$0.2604m\ (10.255in)$	$0.2866m\ (11.285in)$	$0.3281m\ (12.918in)$

Required Diameters for the pipe based on largest volumetric flow rate:

10.225 in 11.285 in 12.918 in

Graphs of Relationship observed above at, $6\frac{ft^3}{s}$ $(0.17\frac{m^3}{s})$, $8\frac{ft^3}{s}$ $(0.2265\frac{m^3}{s})$, $12\frac{ft^3}{s}$ $(0.3398\frac{m^3}{s})$



3. Total Pump Power:

$V = 3.19,\ 3.51,\ 4.02\ m/s$

$R_e = 828184,\ 1002948,\ 1315005$

$m_{dot} = 169.378,\ 225.758,\ 338.8625\ kg/s$

- $E_{loss} = E_{fric} + E_{minor}$
- $m_{dot}(\frac{P_t}{\rho} + \frac{V^2}{2} + gh)_{in} + \eta W = m_{dot}(\frac{P_2}{\rho} + \frac{V^2}{2} + gH)_{out} + E_{loss}$
- $W = \frac{m_{dot}(\frac{P}{\rho}+\frac{V^2}{2}+gH)_{out}+E_{loss}-m_{dot}(\frac{P}{\rho}+\frac{V^2}{2}+gh)_{in}}{\eta}$

Model pump:

Pump diameter: 8 inches (0.2032 m)

Pump revolution rate: 40π radians/sec

Prototype pump:

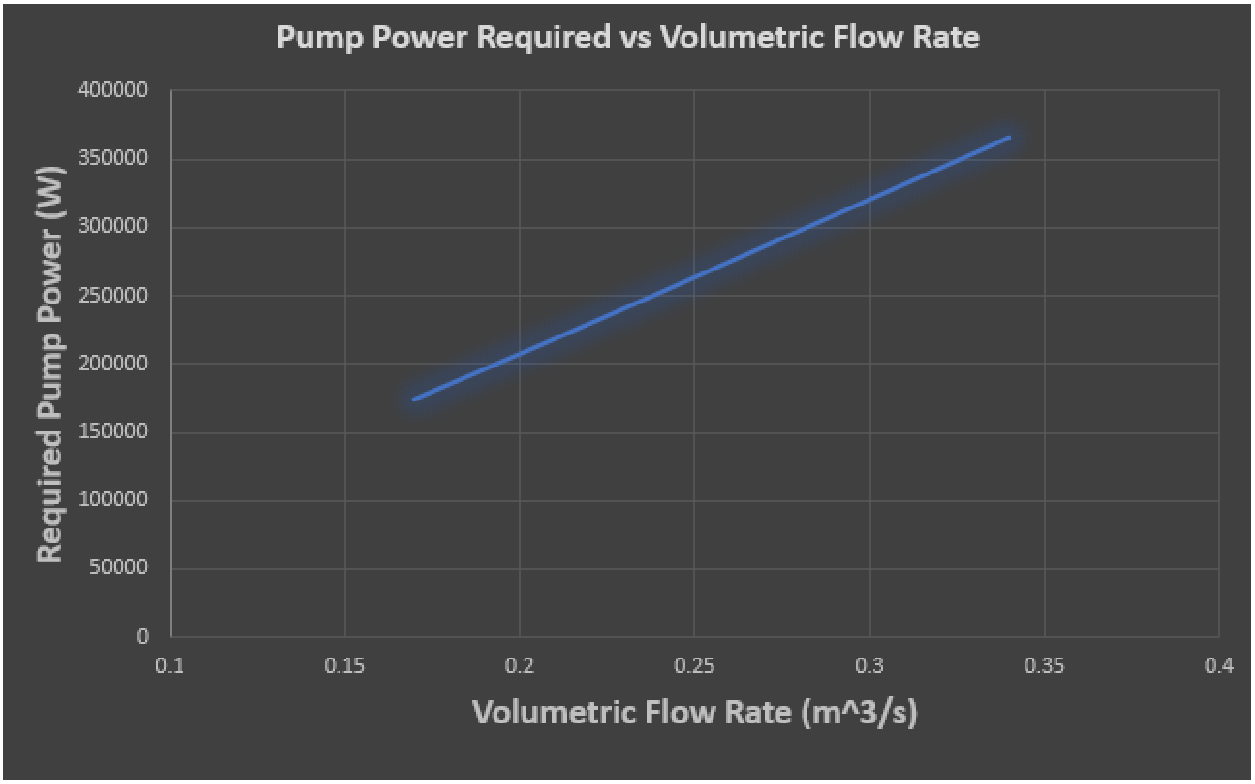
Pump diameter: 12 inches (0.3048 m)
Pump revolution rate: 60π radians/sec
Efficiency: 75%

Pipeline specifications:

Required flow rates: 6, 8, 12 ft^3/s $(0.17,\ 0.2265,\ 0.3398\ m^3/s)$
Reservoir A elevation: 15m
Reservoir B elevation: 75m
Pipeline length: 350m
Pipe material: to be selected
Pipe has 6 elbows; one gate valve; sharp edge inlet & exit Analysis

Pump Power at $6\frac{ft^3}{s}\ (0.17\frac{m^3}{s})[kW]$	Pump Power at $8\frac{ft^3}{s}\ (0.2265\frac{m^3}{s})[kW]$	Pump Power at $12\frac{ft^3}{s}\ (0.3398\frac{m^3}{s})[kW]$
173.939	236.608	365.515

Graph of Relationship observed in table above:



4. Impact of minor losses:

The minor losses cause a maximum loss of around 9035.653W, which is not a huge impact on our system. The diameter of the pipe affects our minor losses rather heavily. As the diameter increases, the velocity decreases which causes minor losses to decrease. This means that as diameter increases, our system becomes more efficient causing our losses to decrease.

Minor Loss Type	Estimated Value/Range
Elbows	
90˚	0.2–0.4
45˚	0.2–0.4
180˚	0.2–1.4
Valves	
Gate—open	0.1–0.2
Gate—half open	1.5–5.0
Globe—open	5–12
Globe—half open	4–50
Ball—open	0.05–0.1
Ball—half open	10–20
Pipe inlet from large reservoir	0.5
Pipe exit to large reservoir	1.0
Sudden contraction (from diameter d to D)	$=0.5(1-d^2/D^2)$
Sudden expansion (from diameter D to d)	$=(1-d^2/D^2)$
Diffuser	0.2–1.0

5. Impact of flow direction:

When the flow goes from A to B, the pump has to do extra work because the flow is going against gravity thus, as shown in our energy equation, the potential energy is adding to the required pump power. Everything else in the energy equation was very similar to the flow from B to A, the biggest difference being the potential energy from both reservoir elevations.

6. Pipe material selection:

Considering that our material of choice was rusted steel which gives us a rather large relative pipe roughness. Realistically we should get a more expensive material such as cast iron or even coarse concrete. Changing to one of these materials would decrease the relative pipe roughness, which would decrease our losses to friction thus increasing our systems efficiency. The decrease in pipe roughness with a smoother material would give a lower energy lost in the pipe system.

(ii) Flow from B to A

Assumptions:

- Fluid is Incompressible
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$$\pi_2 = \frac{\mu D}{pQ}$$

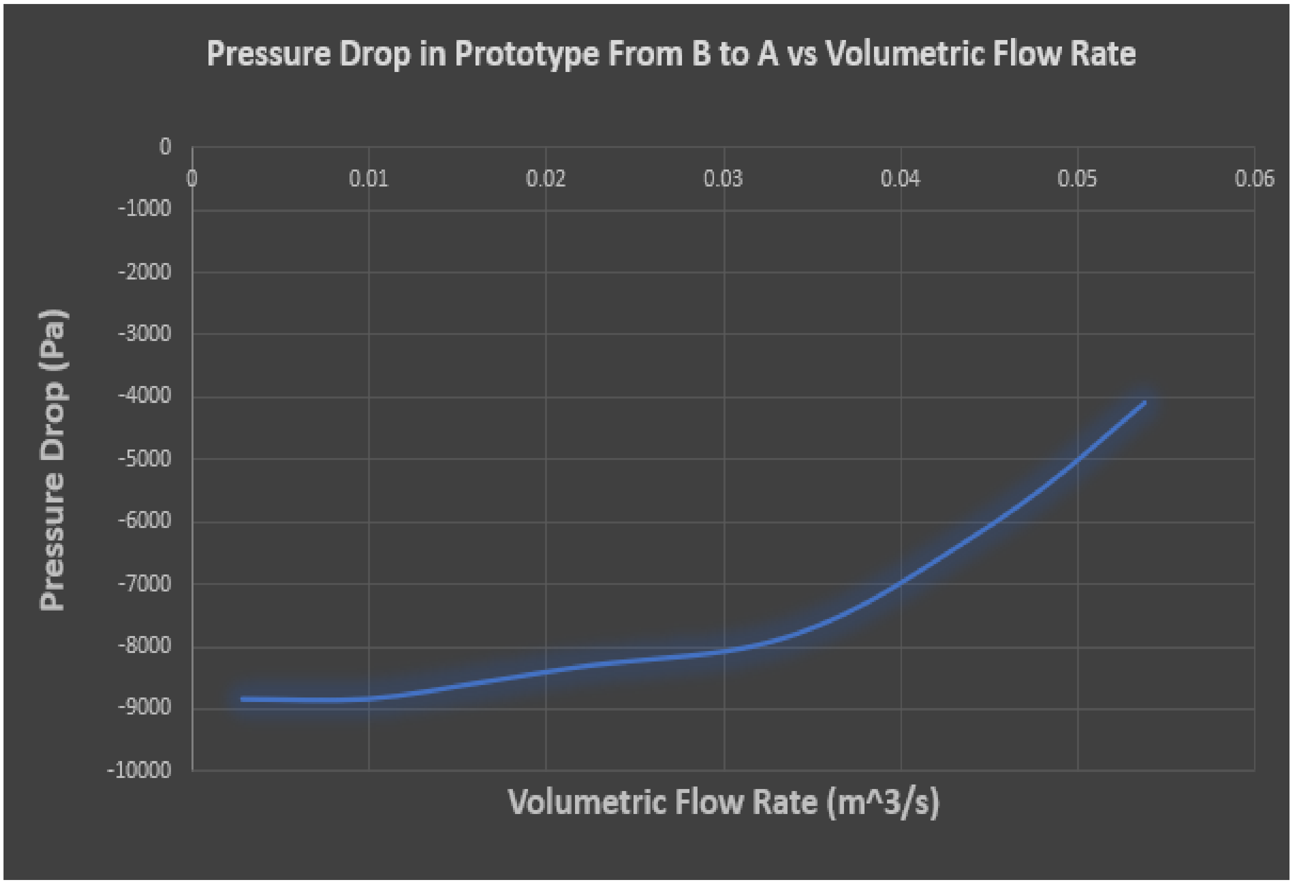
$$\pi_3 = \frac{D^3 \omega}{Q}$$

$$\Delta P_P = \frac{\Delta P_m D_m^4 \rho\ Q_p^2}{\rho Q_m^2 d_p^4}$$

Q is going to be negative because of reversed direction as well as the pressure drop
Thus, giving a negative ΔP_p

Delta P (Prototype) At Each Volumetric Flow Rate (Pa)
-8853.333
-8851.358
-8580.741
-8306.173
-8035.555
-7490.37
-6536.296
-5447.901
-4084.938

Graph of Relationship observed above:



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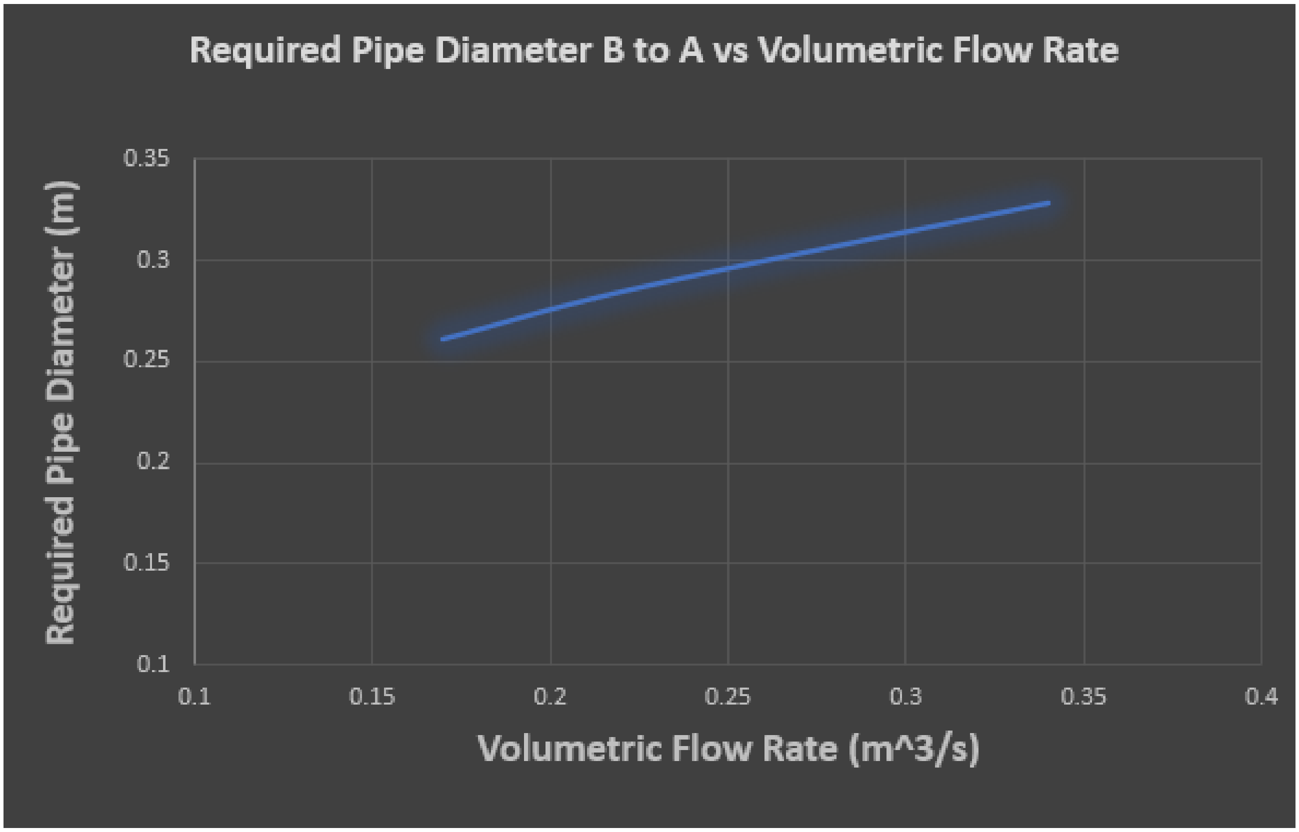
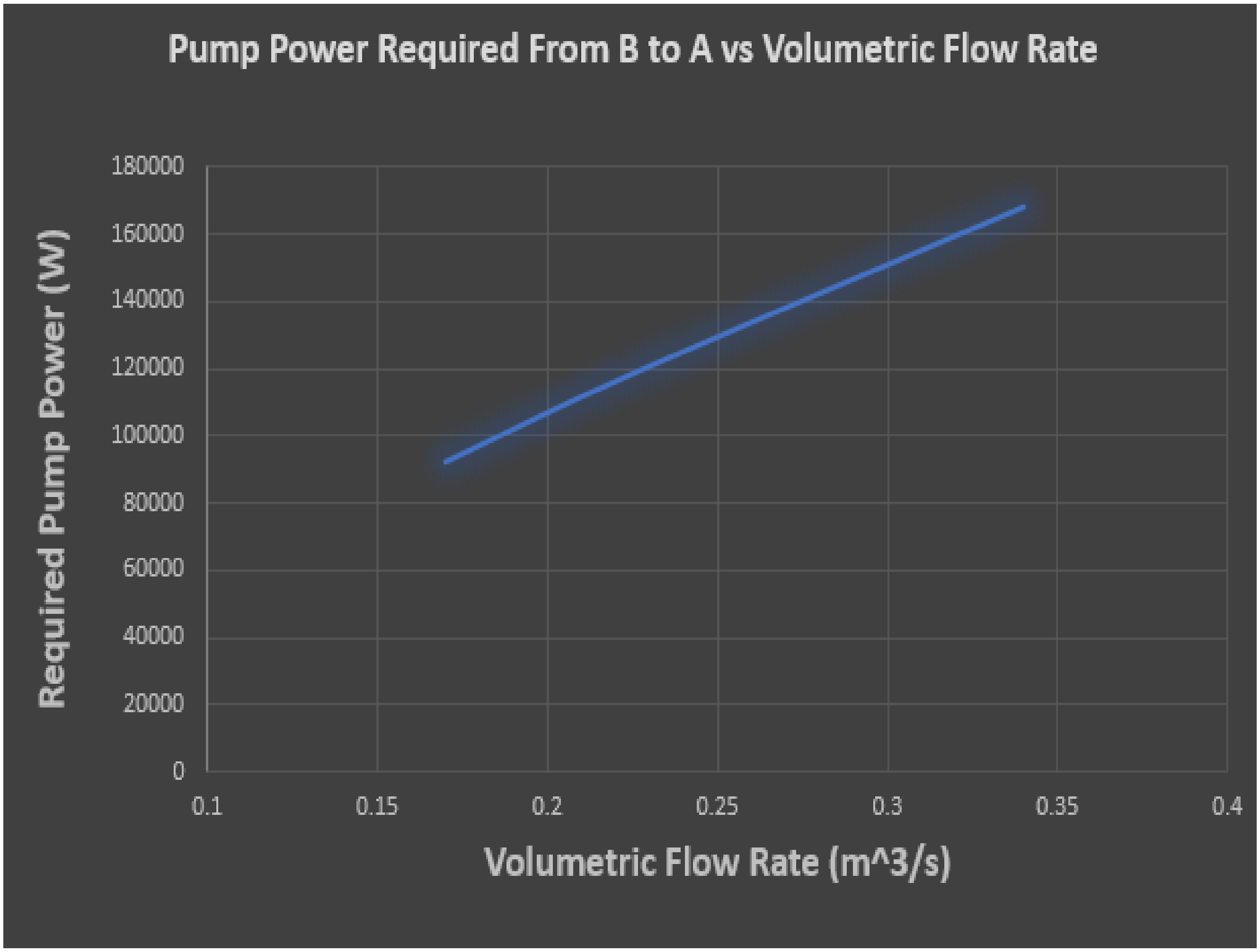


3. Total Pump Power:

- $W = \frac{m_{dot}(\frac{P}{\rho}+\frac{V^2}{2}+gh)out+E_{loss}-m_{dot}(\frac{P}{\rho}+\frac{V^2}{2}+gH)in}{\eta}$
- $E_{loss} = E_{fric} + E_{minor}$
- $m_{dot}(\frac{P_t}{\rho} + \frac{V^2}{2} + gh)_{in} + \eta W = m_{dot}(\frac{P_2}{\rho} + \frac{V^2}{2} + gH)_{out} + E_{loss}$

Pump Power at $6\frac{ft^3}{s}$ $(0.17\frac{m^3}{s})[kW]$	Pump Power at $8\frac{ft^3}{s}$ $(0.2265\frac{m^3}{s})[kW]$	Pump Power at $12\frac{ft^3}{s}$ $(0.3398\frac{m^3}{s})[kW]$
91.916	118.974	168.213

Graph of Relationship observed in table above:



4. Impact of minor losses:

The minor losses cause a maximum loss of around 9035.653W, which is not a huge impact on our system. The diameter of the pipe affects our minor losses rather heavily. As the diameter increases, the velocity decreases which causes minor losses to decrease. This means that as diameter increases, our system becomes more efficient causing our losses to decrease.

5. Impact of flow direction:

When we calculated the power required for the pump from B to A we found that there was less power required. This is because of the flow going from higher elevation to lower elevation which means that there is more potential energy stored in the fluid thus helping the flow move in the desired direction. This means that the pump has to do less work in order to move the flow at the desired volumetric flow rate. The biggest factor that affected the pump power from B to A compared to A to B was the potential energy stored in the fluid.

6. Pipe material selection:

Considering that our material of choice was rusted steel which gives us a rather large relative pipe roughness. Realistically we should get a more expensive material such as cast iron or even coarse concrete. Changing to one of these materials would decrease the relative pipe roughness, which would decrease our losses to friction thus increasing our systems efficiency overall.