Carleton University
Faculty of Engineering and Design
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MAAE 2300 [L01] : Fluid Mechanics 1

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Flow Through a Venturi Meter

Lab 1

Tuesday February 4^{th}, 2020

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Summary

This lab proves the principle of venturi tubes. It is shown using a vacuum connected to one end of the venturi tube, and the other open to air. There are various points where the flow is measured using monometers. These monometers use dyed water to visually show the trends of pressure, and velocity through a venturi. This report will outline the flow analysis, procedure, and setup of the experiment.

Flow Analysis

To analyze the flow, we use Bernoulli's equation. Bernoulli's Equation can be applied to a system if it has ideal flow and if Pressure is the same at the inlet and outlet of the system. Bernoulli's equation can be defined as;

$$P_1 + \tfrac{1}{2}\rho V_1^2 + \rho g z_1 = P_2 + \tfrac{1}{2}\rho V_2^2 + \rho g z_2 \qquad \text{(Equation 1)}$$

For experiment 1, there is no significant change in height, so we can neglect z_n.

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$$

$$\Delta P = \tfrac{1}{2}\rho(V_2^2 - V_1^2) \qquad \text{(Equation 2)}$$

We can also use the conservation of mass to simplify the system.

$$\dot{m_{in}} = \dot{m_{out}}$$

$$\rho Q_{in} = \rho Q_{out}$$

$$Q_n = A_n V_n$$

$$A_1 V_1 = A_2 V_2$$

$$V_1 = \tfrac{A_2}{A_1} * V_2 \qquad \text{(Equation 3)}$$

To solve Bernoulli's Equation, we combine *Equation 3 and Equation 2*.

$$V_2 = \sqrt{\frac{2\Delta P}{\rho\left(1 - \frac{A_2}{A_1}^2\right)}}$$

Assuming negligible velocity in the atmosphere.

$$P_0 = P_{atm} = P_1 + \frac{1}{2}\rho V_1^2$$

This gives us the two flow rates which allows us to get the venturi coefficient.

$$C_v = \frac{Q_{Actual}}{Q_{ideal}}$$

Experimental Setup and Procedure

This lab was setup using MAAE 2300 Lab manual (Carleton University). There was no deviation from the procedure outlined in Experiment 1, subsection procedure. The figures below outline the experimental setup used in the lab.

Figure 1. Manometer tubes

Figure 2. Flow rate controller

Figure 3. Venturi tube

Figure 4. Vacuum Pump

Result and Discussion

Data collected in the lab is shown in the table below.

Venturi location	Flow 1 (mm)	Flow 1 Delta	Flow 2 (mm)	Flow 2 Delta	Distance to center (in)	Distance to center (mm)
1	114	34	148	73	5.25	133.35
2	114	34	149	74	4.33	109.982
3	115	35	150	75	3.3	83.82
4	123	43	170	95	2.825	71.755
5	130	50	186	111	2.275	57.785
6	144	64	222	147	1.79	45.466
7	163	83	262	187	1.31	33.274
8	190	110	322	247	0.8	20.32
9	247	167	451	376	0.8	20.32
10	240	160	428	353	0.8	20.32
11	194	114	320	245	1.3	33.02
12	180	100	290	215	1.8	45.72
13	158	78	240	165	2.3	58.42
14	146	66	219	144	2.8	71.12
15	141	61	204	129	3.3	83.82
16	135	55	184	109	4.3	109.22
17	80	0	75	0	0	0

Below are graphs showing trends in pressure at different points in the venturi tube.

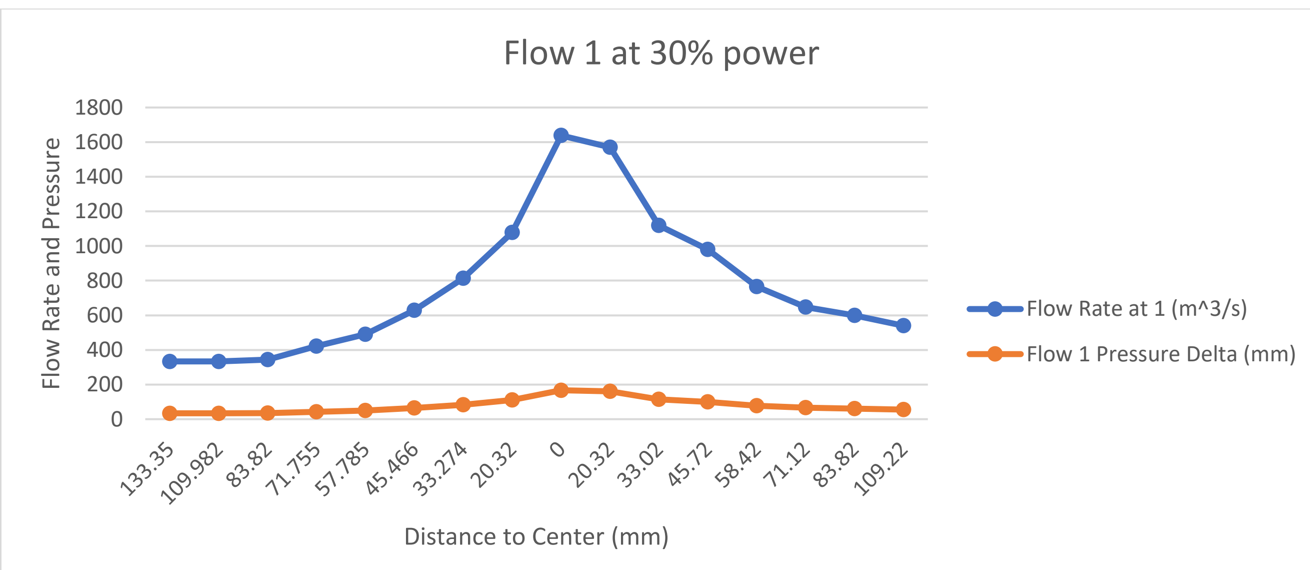

Figure 5. Flow 1

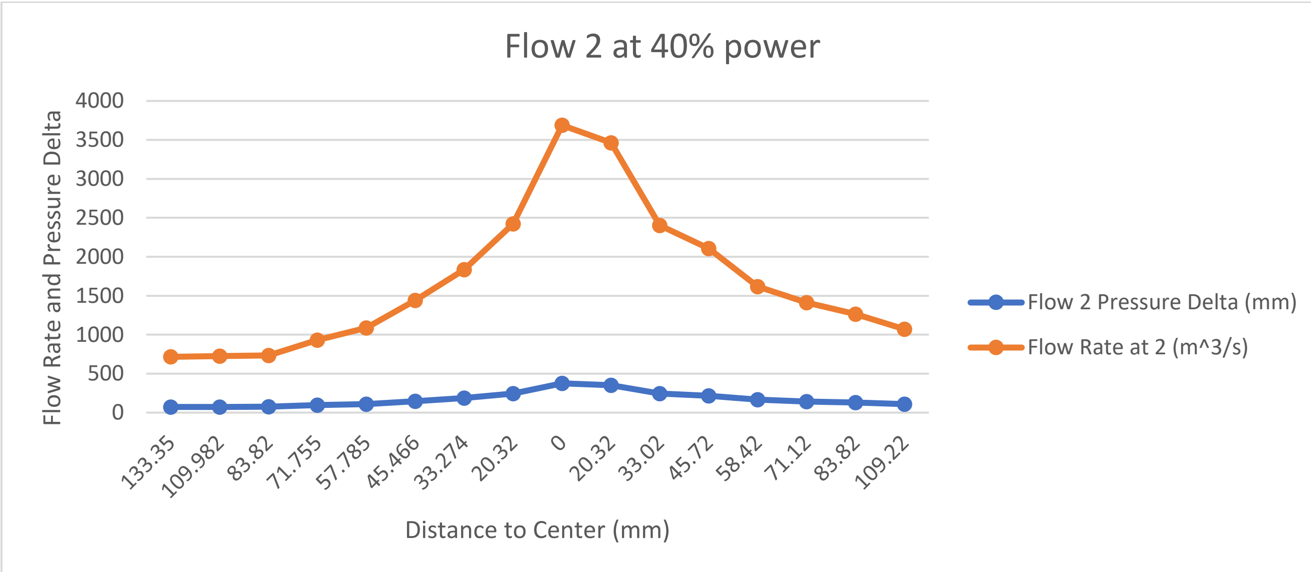

Figure 6. Flow 2

Figure 5 and 6 illustrates the trends found in a venturi tube. As the diameter towards the center decreases the flow rate and pressure increases. This is caused by area decreasing, causing the flow rate to increase inorder to maintain the same pressure at the inlet and outlet of the venture. The monometer tubes shown in figure 1, illustrate the differences in pressure between atmosphere, and different location throughout the venturi.

In order to simplify the experiment, a few assumptions were made;

- No leaks in tubes connecting venturi to monometers
- Linear power supply
- Flow velocity in the atmosphere to be zero
- Venturi has a linear conical shape from center to outside
- Venturi has a smooth and turbulence free inside surface.
- Neglecting slip near the edge of the venturi

All the assumption are sources of error. Another source of error is measuring the venturi on outside and using that diameter to calculate cross sectional area, instead of inner diameter. Below figure 7 and 8 illustrate the flow velocity for two setups, shown above.

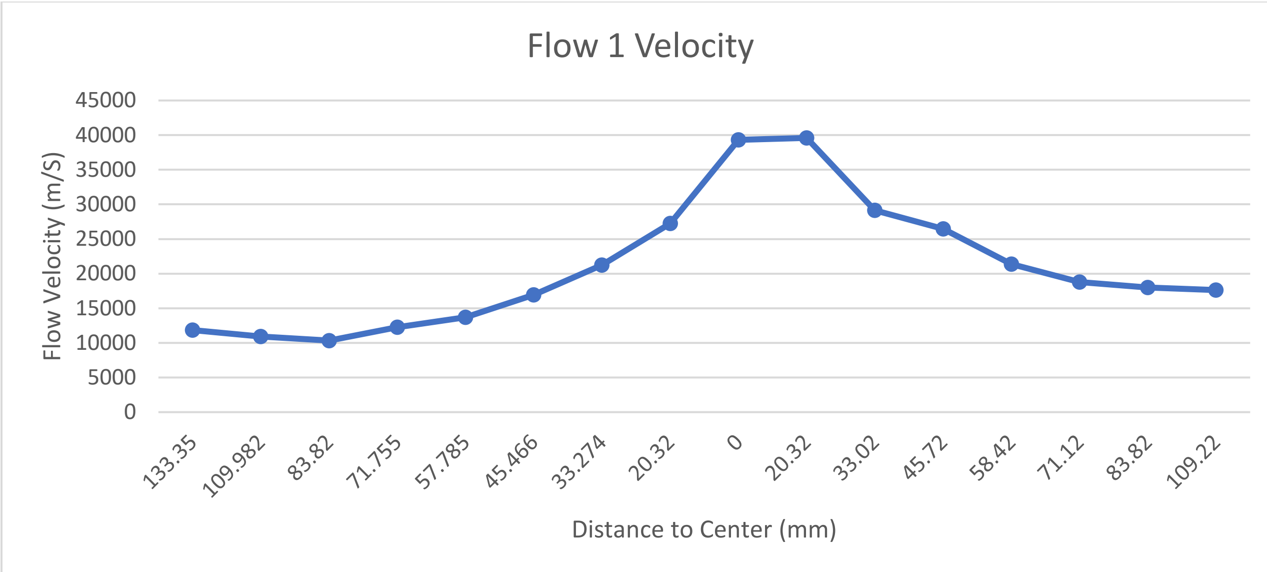

Figure 7. Flow 1 Velocity

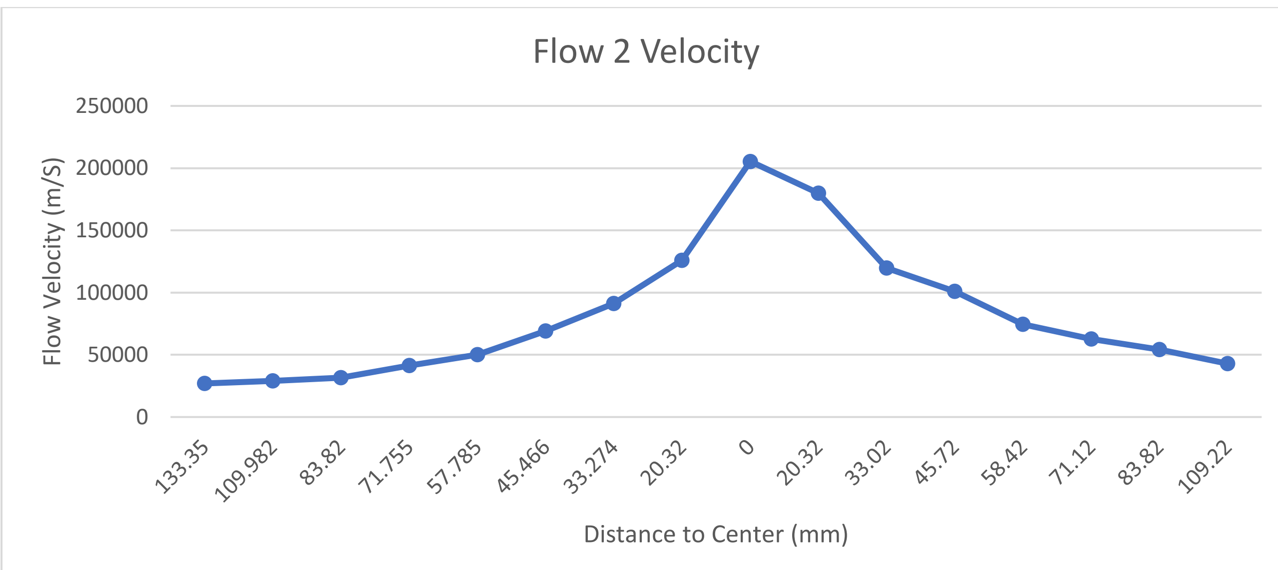

Figure 8. Flow 2 Velocity

Below is the calculation for Q_{ideal}.

$$Flow\ velocity\ computed\ in\ excel. Appendix\ 1A \qquad V_3 = 58078\frac{m}{s}$$

$$Area\ Computed\ in\ Excel. \qquad A3 = 0.028208m^2$$

$$Q_{ideal} = 1638.27\ \frac{m^3}{s} \qquad , Q_{Actual} = 1638.27$$

$$C_v = 1$$

Conclusion

In conclusion the experiment was a success, and proves that as the area decreases for a given tube, the pressure, and velocity increases to maintain the same flow rate.

References

Carleton. (2020). *Universty Logo*. Retrieved from Resources: https://carleton.ca/duc/resources/

Carleton University. (n.d.). *MAAE 2300 Lab Manual.* Retrieved from CuLearn: https://culearn.carleton.ca/moodle/pluginfile.php/3682974/mod_resource/content/1/MAAE%202300%20Laboratory%20Manual%202020.pdf

Appendix

A1. Excel Tables

A2. Data sheet