Instrument Calibration – Lab 6:

Date Performed: 03/29/2023

Lab Instructor's name: Mark Vanpoppelen

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Name: (Printed)
Will Buziak

Signature:

# Lab Report #6 – Flow

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ABSTRACT

The flow lab walked student's through the process of comparing different measurement devices for flow rate of a fluid through a pipe. Using a series of meters, students will measure the readings and compare. Since the student knows the flow rate from the control valve, they will be capable of analyzing the effectiveness of each method of measurement. In a closed loop, water flows from a reservoir below a series of measured tubes that provide different methods of measuring the amount of water flowing through the tube. Using a multitude of mathematical relationships, the student will then walk through the associated errors and be able to perform a cost analysis on the different mediums of measuring the system's flow rates. The student should consider the inner workings of each meter and the properties that are utilized to measure.

## I. Introduction

The flow rates lab utilizes a dense, but simple system of tubes, pumps, meters and valves that feed and return water to a reservoir. The intent is to measure the flow rate of water by comparing the relative height or pressure the water travels in the tube. What are a few different methods in which we can measure the water in this manner and what are the associated errors? The unique benefit for the flow rates lab is the direct relationship between a physical phenomena and a mathematical solution, which is perhaps more noticeable for the average student than the relationship between signal processing and filters.

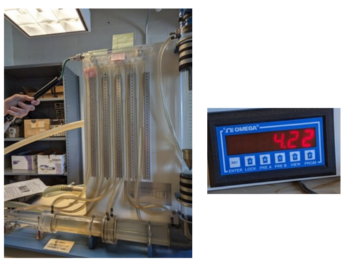


Figure 1
Initial setup

### *A. Theory*

The relationships in this lab revolve around the weight of water relative to the "weight" of atmospheric pressure and temperature of the room. The student will walk through the data sheet measuring the relative height through each kind of meter and measure the time it takes for each cycle. This will lead the student to find the volumetric flow rate through each system of tubes. In many respects, this system works much like a traditional scale, or a sort of "teeter totter" that uses the masses of water and atmospheric pressure against each other to measure it's relative height. The student will use these relationship to measure the height of the water through an orifice, venturi and vortex meter.

### *B. Data Reduction*

The readings on each tube are initially in the units of mmH20 (millimeters of water). This is due to the nature of the system measuring the height of the water in the tube relative to a datum. Therefore, the first equations relate the measurements collected to a change in pressure, from there the equations will calculate the respective volumetric flow rates measured in each meter.

The density of water (ρ) is assumed to be constant at 1000 kg/m^3 and is used as the linkage between weight and volume.

1. $$Q_{ref} = \frac{\dot{m}_w}{\rho}$$

2. $$\dot{m}_w = \frac{Reference\ mass}{Time}$$

3. $$Pa = mmH_2O * 9.81$$

4. $$v_{ven} = \sqrt{\frac{2(\Delta P_{ven})}{\rho}}$$

5. $$Q_{ven} = K_0 v_{ven}$$

6. $$v_{ori} = \sqrt{\frac{2(\Delta P_{ori})}{\rho}}$$

7. $$Q_{ori} = K_0 v_{ori}$$

8. $$Q_{vor} = K_{vor} f_{vor}$$

9. $$error = \left| \frac{Q_{ven} - Q_{ref}}{Q_{ref}} \right| * 100$$

## Results and Discussion

The error for each meter was with respect to the flow rate range. For example, in trial 4, the venturi has the highest error (46.7 percent) while in trial 5 the vortex has the highest error (30.8 percent). These differences in error with respect to flow rate give insight to the inner workings of each kind of meter. The venturi meter measures the change in pressure due to a difference in volumetric flow. The orifice meter uses the pressure of water after forcing it through a small opening in a tube while the vortex meter uses the pressure of water in a vertical tube to measure it's height.

Other observations include the venturi meter measuring higher flow rates than it's counterparts and the vortex often measures lower in magnitude. This could perhaps hint at the forces utilized in each measurement. Due to the venturi manipulating the change in velocity and pressure of the fluid, it can be extrapolated that the venturi would be ideal for measuring faster moving fluids, for instance. Extraneous errors can include the setup of the meters as well as their distance from the control valve can have an impact on the integrity of the meter's reading due to pumping and friction losses. The positive is that these losses are present in real life scenarios which gives the lab a certain real world integrity.

## II. Conclusion

The methods utilized in measuring the volumetric flow rate of a fluid are heavily reliant upon the laws that govern many of the fluid's properties such as gravity, temperature and velocity. Due to the mathematical relationships that tie each of these properties together also mean that there are different methods of measuring volumetric flow and each method is ideal in different conditions. Each method of measurement also requires a slightly different setup and in some cases measures different phenomena. Each method of measurement can be compared to a reference weight and height to measure it's competence in measuring fluid flow. Due to what is known about the reference weight, the engineer can then use this information to compare with the readings of each meter.

Depending on the conditions of the system, it is often up to the engineer to understand the pros and cons of each method of measurement in order to arrive upon an optimal solution. Utilizing what is known about fluid dynamics, engineers can utilize a venturi meter to analyze the pressure drop over a change in cross sectional area of the tube, while methods like orifice meters utilize a small opening to force fluid through and measure it's pressure. These methods can be utilized in real world applications by mechanical and structural engineers as they consider the effects of moving fluid around everyday objects and buildings.

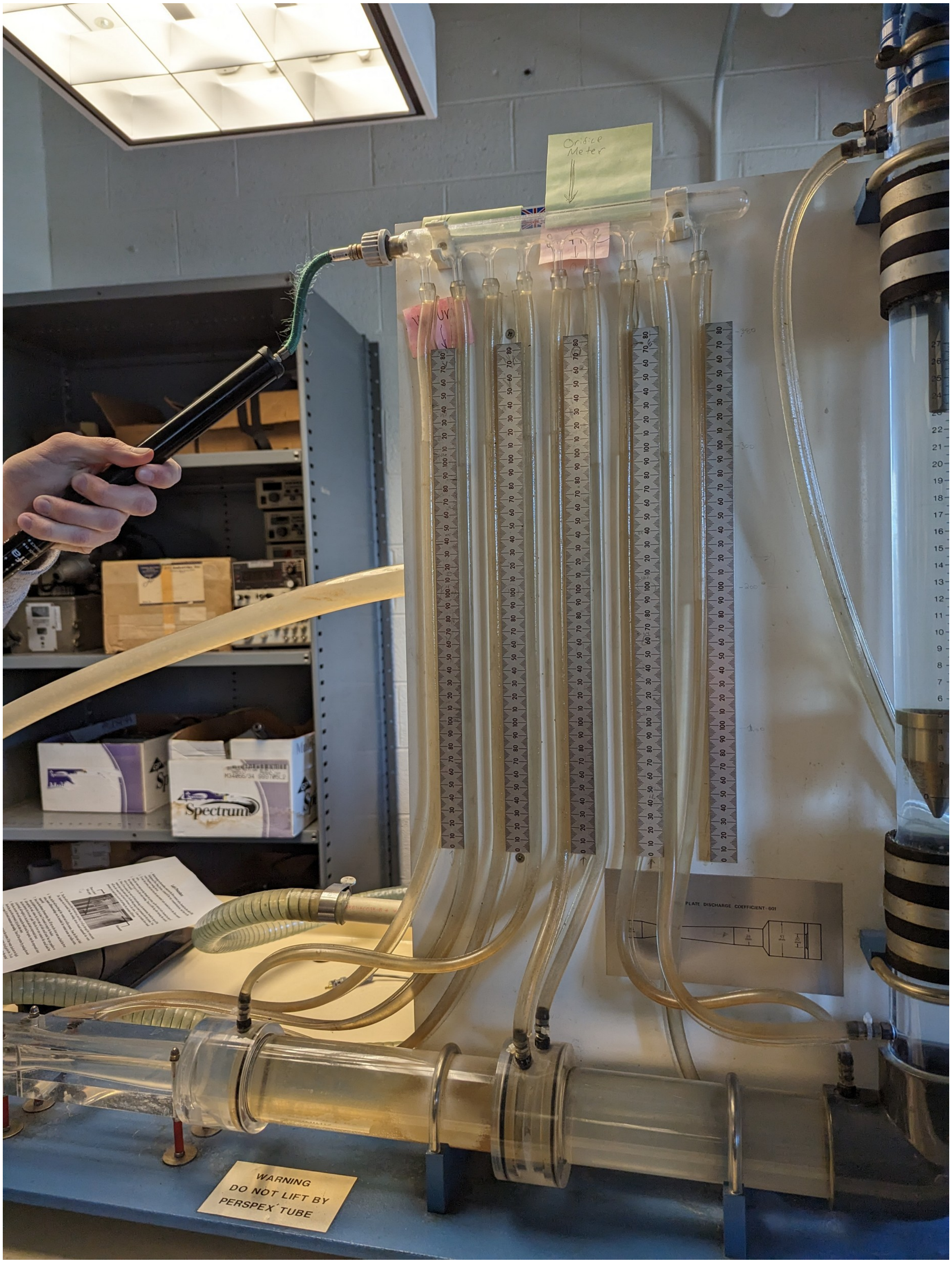
## References

[1] M. Vanpoppelen, "MABE 345 Lab Report Required Sections.docx" U.S., Knoxville, TN, 2023.

[2] V. Aloi. (2023, February). ME/AE/BME 345 Instrumentation and Measurements class notes. [Online]. Available e-mail: valoi@utk.edu

Appendix A:  Equipment Information

1.



Appendix B: Handwritten Calculations

Friday, March 31, 2023 10:40 PM

Reference:

$\dot{m}_w: 6/61 = .098$ kg/s

$Q_{ref} = \dot{m}_w/1000 = 9.8E-5$

venturi:

$v_{ven} = \sqrt{\frac{2(196.3)}{1000}} = .626$

$Q_{ven} = 2.5E-4(.626) = 1.566E-4$

orifice:

$v_{ori} = \sqrt{\frac{2(235.4)}{1000}} = .686$

$Q_{ori} = 2.14E-4 \cdot v_{ori} = 1.47E-4$

$Q_{vor} = 3.7E-5 \cdot 4.2 = 1.554E-4$

Appendix C: Complete Data Sheet (data continued on hand written sheet)

Lab No. 6 Data Sheet

*Experiment 1*

Name: Will Buziak

| Device | Variable | Units | Runs | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Rotameter | Scale | | 5 | 10 | 15 | 20 | 22 |
| | | | | | | | |
| Reference Volumetric Flow Rate | Reference Mass | $kg$ | 6 | 6 | 6 | 12 | 12 |
| | Time | $s$ | 61 | 29.72 | 21.26 | 28.5 | 25.16 |
| | $\dot{m}_w$ | $kg/s$ | .096 | .202 | .283 | .421 | .477 |
| | $Q_{ref}$ | $m^3/s$ | 9.8E-5 | 202E-4 | 2.83E-4 | 4.21E-4 | 4.77E-4 |
| | | | | | | | |
| Venturi | $\Delta P_{ven,1}$ | $mm\ H_20$ | 20 | 61 | 102 | 41 | 251 |
| | $\Delta P_{ven}$ | Pa | 196.13 | 598.2 | 1000.27 | 4c2 | 2461.5 |
| | $Q_{ven}$ | $m^3/s$ | 1.91E-4 | 2.73E-4 | 3.536E-4 | 2.24E-4 | 5.55E-4 |
| | | | | | | | |
| Orifice | $\Delta P_{ori,1}$ | $mm\ H_20$ | 24 | 73 | 143 | [illegible] | 326 |
| | $\Delta P_{ori}$ | Pa | 235.4 | 715.86 | 1402.4 | 2569.3 | 3197.16 |
| | $Q_{ori}$ | $m^3/s$ | 1.47E-4 | 2.56E-4 | 3.58E-4 | 4.85E-4 | 5.40E-4 |
| | | | | | | | |
| Vortex | $f_{vor}$ | Hz | 4.2 | 5.53 | 6.76 | 8.33 | 8.91 |
| | $Q_{vor}$ | $m^3/s$ | 1.654E-4 | 2.05E-4 | 2.50E-4 | 3.08E-4 | 3.3E-4 |

Lab Instructor's Signature: 3/29/23