Report for Lab 1: Calibration of Volumetric Flow Measurement Devices

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February 1, 2017

1. Introduction

Three separate volumetric flow measurement experiments were conducted using a variety of common sensors and flow control equipment. In the first experiment, air was directed through an orifice plate, a rotameter, and a dry test meter installed in series. The orifice plate and rotameter were both calibrated using pressure data and measurements taken from the dry test meter. The volumetric flow rate of water from an Isco-pump was calibrated in the second experiment using a calibrated scale and a stopwatch. The volumetric flow rate of air through a MKS controller was measured in the third experiment using a bubble Gilibrator device. The data obtained from the experiments was analyzed to determine the impact of compressibility effects and an uncertainty analysis was performed. The objectives of these experiments were to familiarize the student with calibrating and using volumetric flow rate measurement equipment and to obtain flow rate data that will be used in a later experiment using a controlled flame.

2. Methodology

2.1. Experiment Description

The first experiment directed filtered shop air through an orifice, a rotameter, and a dry test meter that were installed in series. A diagram of the test setup can be found After opening the supply valve to admit air to the test setup, the flow rate was throttled using a valve in the rotameter until the rotameter read each one of the values in A data acquisition system was started and the pressure drop across the orifice was measured using pressure transducers located immediately upstream and downstream of the orifice. Additionally, the temperature of the air was measured at

The volumetric flow rate of water through an Isco-pump was measured in the second experiment using a calibrated scale and a stopwatch. An empty container was placed on the scale and the pump outlet was positioned to discharge into the container. After zeroing the scale with the container on it, the pump was started at the same time that a stopwatch was started. After 90 seconds, the pump was stopped and the weight of the container with water was recorded.

The third experiment

2.2. Equipment Used

A list of all of the equations used to perform the required calibrations and volumetric flow rates as well as an uncertainty analysis of the data collected can be found in Appendix A

2.3. Analysis

The methodology used to determine the

3. Assumptions

To make calibration of equipment possible, at least one measurement device in each experiment was assumed to be calibrated prior to collecting data. These measurement devices were the pressure transducers and the dry test meter in the first experiment, the scale in the second experiment, and the bubble Gilibrator in the third experiment. Information regarding the tolerance of each measurement device can be found in The manufacturer specifications listed in (APPENDIX THING) are assumed to be correct for all measurement devices used in this lab.

The assumed condition in which compressibility effects are significant is as follows:

$$\frac{P_1 - P_2}{P_1} \geq 0.1 \tag{1}$$

in which P_1 is the upstream pressure and P_2 is the downstream pressure, as measured by the pressure transducers.

The following fluid properties were used for each of the experiments:

4. Results

The flow rate in the first experiment blah blah answer the question

We found that water is lighter than air in the second experiment.

We found that human sacrifices are necessary in the third experiment.

5. Conclusion

Appendix A Equipment Tolerances

Instrument	Model	Data
Orifice	OModel	Data
Rotameter	RModel	Data
Pressure Transducer	PTModel	Data
Dry Test Meter	Singer DTM-200[1]	Data
Isco-pump	IPModel	Data
Scale	Smodel	Data
Bubble Gilibrator	BGModel	Data
MKS Thermal Flow Controller	FCModel	Data

[1] The American Meter division of Singer was acquired through a series of transactions by Elster American Meter, therefore specifications on the Elster American Meter DTM-200 were assumed to be identical to the Singer DTM-200.

APPENDIX B UNCERTAINTY ANALYSIS

B.1 METHODOLOGY

The equation for subsonic flow through an orifice is as follows:

$$Q = CEAY\sqrt{\frac{2\Delta P}{\rho_1}} \tag{1}$$

in which Q is the volumetric flow rate, C is the orifice discharge coefficient, A is the area of the orifice opening, Y is a compressibility constant, ΔP is the pressure difference across the orifice, ρ_1 is the density of the fluid upstream of the orifice (air in this case). E is defined as follows:

$$E = \frac{1}{\sqrt{1-(\frac{A_0}{A_1})^2}} \tag{2}$$

in which A_0 and A_1 are the area of the orifice opening and the area of the upstream piping, respectively. The orifice in the first experiment is calibrated by solving for C in equation 1 of this appendix. If it is instead found that choked flow conditions exist (i.e. the flow is sonic), the mass flow rate through the orifice is calculated using the following equation:

$$\dot{m}_{choked} = C\frac{P_0 A_1}{\sqrt{RT_0}}\sqrt{\frac{2k}{k+1}\left(\frac{2}{k+1}\right)^{\frac{2}{k+1}}} \tag{3}$$

in which $\dot{m}_{choked}$ is the mass flow rate of the fluid, k is the ratio of specific heats upstream and downstream of the orifice

B.2 TREE DIAGRAM

B.3 RESULTS

APPENDIX C RAW DATA