UNIT OPERATIONS LABORATORY 1

CHOKED FLOW LAB

ChEn 475 – Knotts

Introduction

There are two main purposes of this lab. One is to review the concept of compressible flow and give you hands-on experience with such phenomena. The second is to reinforce statistical tools that should have been learned in other courses and to introduce new statistics that are useful in engineering. Engineers use many types use statistics. For example, process engineers use statistics to keep processes running smoothly and maintain quality, research engineers use them to identify if observed phenomena are significant, and safety engineers need them to develop inherently-safe operations. Students learn many of the basics of statistics in other courses, but it is often difficult to see how these techniques are used in engineering. This lab presents you with an opportunity to make the connections between powerful statistical methods and engineering practice.

Day 1 Tasks

To motivate the work, you have been given a memo from me requesting that your team evaluate how well our line of orifices will choke flow and if they can do so to meet a specific design specification. Your first task in this assignment is to demonstrate that you know how to solve the problem.

1. Study the concept of compressible flow and choked flow. Use whatever resources are available to you.
2. Make sure you understand the shape of the orifice and what "squared-edged" means.
3. Familiarize yourself with the experimental apparatus. Determine what you can measure, the limitations of the experimental apparatus, and the things you can change when performing experiments. After learning about the equipment, familiarize yourself with the startup and shutdown procedures and the safety procedures Pass off the **safety sheet** *before* starting any experiments.
4. After learning the needed background, think about how you will respond to my design request. Basically, you need to answer the question: "How can I use the experimental apparatus to determine the conditions necessary for the orifice to choke room-temperature air at a rate of $7.7 \cdot 10^{-4}$ kg/s. What if the temperature ranges from 10 °C to 35 °C?"
5. Write a short (one paragraph) email to the instructor outlining your approach to solving the problem. I want to know what data you will take and how you will use it to solve the problem. You will be able to attach one PowerPoint slide to the email where you can put in equation, graphs, etc. Make sure to effectively communicate to me that you know how to solve the problem.

Deliverables-Statistics

Remember that one purpose of this lab is to improve your understanding of statistics that are often used by engineers. As such, I will give you two workshops on statistical concepts and techniques. The topics

include: the basics of statistics, confidence intervals, and linear regression. You will have one homework assignment to give you practice with these statistical methods. You will also have a quiz on the statistical techniques.

Finally, regarding statistics, you should be able to obtain a significant amount of data over multiple days during this lab. This is especially important for the regressions that you will do. You should plan on performing experiments each day and obtaining data at many conditions. Also, don't delay analyzing the data. This will help you see gaps in the data and determine if more experiments should be performed.

Deliverables-Technical

Remember that the other purpose of this lab is to perform experiments to solve the design problem. A large portion of your time with this lab will concern taking and analyzing data to accomplish this. You will report your findings at the end of the lab in an Oral Presentation. The audience of the oral presentation will be me *and* your peers in the other team doing the methocel experiment. The methocel experiment is also a "statistics" experiment, and this other team is learning the same statistical techniques that your team is but with a different design problem. Make sure to plan your remarks accordingly so that your presentation is neither too basic nor too complex for the audience. Also remember that the statistical techniques learned in this lab are crucial to answering your design problem with confidence, so make sure to include these in some form in your oral report.

Summary of Deliverables

In summary, you have 6 deliverables for this lab as outlined below. Please check your calendar for due dates. Also check the calendar for the times of the statistics lectures and *suggested* activities for each day.

Deliverables

1. Theory email (Individual; email it to Dr. Knotts)
2. Statistics homework assignment (Individual; email it to TA)
3. Statistics oral report (Team; real-time presentation only, nothing to turn in)
4. Statistics quiz (Individual; turn in to Dr. Knotts)
5. Leadership report (Individual; email it to Dr. Knotts)
6. Lab notebook (Team; email it to TA)

To: Engineering Development Team

From: Thomas Knotts

Date: 22 August 2019

Re: Evaluating the Suitability of Our Line of Orifices to Choke Flow

As you know, our company manufactures several lines of orifice that are designed to choke flow. Due to manufacturing imprecision, the meters do not always perform exactly as predicted from theoretical relationships. One of our customers has approached us to supply orifices that will choke room-temperature air at a flow rate of $7.7 \cdot 10^{-4}$ kg/s. The supply line to the meter has a maximum pressure of 80 psig. We believe that our line of 1-mm orifices will satisfy these specifications.

Please use the system found in the laboratory to determine if we should sign a contract with this customer. If you recommend signing, please also provide information on how to maintain a choked flow rate of $7.7 \cdot 10^{-4}$ kg/s for room-temperature air as well as for temperatures that dip to as low as 10 °C or increase to no more than 35 °C so that disturbances in the supply line can be controlled.

For your information, relationships for flow through square-edged orifices (like ours) are available in Perry's Handbook and may be useful.