CM3215 ChemE Transport Lab:

Calibrate Two Flowmeters and Explore Reynolds Number

Pre-laboratory Assignment
Familiarize yourself with Reynolds number, rotameters, and orifice meters. Find an accurate calibration curve for the Honeywell DP meter at your lab station (your own calibration curve or one from the archive) and have the equation <u>and the plot of the equation</u> in your lab notebook. Prepare a safety section in your laboratory notebook detailing all safety issues associated with this laboratory. Prepare the data tables in your notebook you will use for data acquisition. All sheets of paper in your lab notebook must be affixed on all four sides with clear tape before the start of lab.

Answer these questions as part of your prelab (write the answer in the notebook):

1. What should you plot (what versus what) to get a straight line correlation out of the orifice meter calibration data?
2. In this experiment we calibrate the rotameter for flow directed through ½", 3/8", and ¼" tubes (nominal sizes); will the calibration curve be the same for these three cases or different?
3. What is "dead heading" the pump?

Introduction
Two types of flow-rate meters are installed in our laboratory stations: a rotameter and an orifice flow meter. Both need to be calibrated against a standard. The standard we use is to measure the flow rate with the pail-and-scale method.

The dimensionless flow rate is the Reynolds number, a dimensionless number that is useful in determining the flow type for flows in tubes. Characterization of the type of flow occurring in piping systems is critical in designing heat and mass transfer equipment.

Theory: See lecture.

Overall Objectives and Strategy: Calibrate both the rotameter flow meter and the orifice flow meter at your station and determine the effect of flow path on the calibration curves obtained. Also, determine the Reynolds number range achievable on laboratory apparatus. Address all other objectives as discussed in **Data Analysis** below.

Experimental Procedures

Overall procedure:

1. Prepare the work station for isothermal water flow (see Procedure A in the appendix).
2. Turn on Ohaus electronic scale (Model CD-33: WI-09) that is attached to the balance under Tank 1 by plugging in the AC/DC power converter (120 VAC -> 9VDC 500 mA) into the AC outlet. When the Ohaus scale is on it will show the following on its screen: "Weight 4.160 kg (for example)." Press "Tare" key. It will show "0.000 kg."
3. Ready the Honeywell DP meter (see Procedure B in the appendix)
4. Set flow path through the desired line (1/4inch, 3/8inch, ½ inch) and turn on the pump.
5. Fix the water flow rate to the desired rotameter setting by gradually opening needle valve WV-5 counterclock-wise, observing closely the rotameter reading. **CAUTION: air trapped in the system can cause the rotameter float to move rapidly, possibly causing damage**.
6. Determine mass flow rate for this rotameter setting by following the

Pail-and-Scale Procedure (see Procedure C in the appendix).

7. Record the pressure drop across the orifice meter $\Delta p_{orifice}$, in mA current signal from the DP meter. This measurement is for the orifice meter calibration. For each data point in this lab, therefore, you have a rotameter reading (which you set), mass flow rate (from the pail-and-scale), and orifice pressure drop $\Delta p_{orifice}$ (also correlates with flow rate). If the DP meter signal exceeds the maximum recordable pressure across the DP meter, use the Bourdon gauges (record upstream and downstream pressures; subtract values later).
8. Repeat steps 4-7 for different flow paths and rotameter readings until you have documented data for 10-90% flow on the rotameter (if 90% rotameter reading is not achievable, go to the maximum flow rate that your rotameter reaches with the needle valve full open). To avoid systematic error, perform the different flow-rate tests in random order. Obtain true triplicates of all data; do not do the same flow rate twice in a row. Do not do the same flow path as a group.
9. Be mindful of the time constraints and of your objectives. Obtain as wide a range of data as you can.
10. Shut down the station (see Shut Down procedure in the appendix).

Data Analysis

1. Calculate average mass flow rate for each rotameter setting on each tube ($n = 3$). Calculate replicate standard errors and error from error propagation; determine which dominates. If neither error dominates, combine in quadrature.
2. Based on the average mass flow rates calculated above, obtain average velocity and Reynolds number for each run through the three different long tube sections. Use the actual inner diameter of the tubing in your calculations rather than the nominal inner diameter; <u>the copper tubing is type L.</u>
3. Generate a calibration curve of flow rate (gpm) versus rotameter reading. Show the source data on the same graph, with error bars showing the error in flow rate.

   For determining the calibration curve, do not use average flow-rate values: use LINEST and all values of flow rate versus reading that you have obtained.

   Calculate a best-fit line and report slope and intercept (with 95% confidence intervals on both). Be sure to include units when reporting your calibration curve. Compare your rotameter calibration curve with historical data for your lab station.
4. Convert all DP-meter readings for orifice pressure-drop to psi using an accurate Honeywell DP-meter calibration curve for your lab station.
5. Generate two calibration curves for the orifice meter: 1) flow rate (gpm) versus orifice pressure drop DP meter reading in mA (useful in the lab); 2) flow rate (gpm) versus orifice pressure drop in psi (useful to know the range of what pressures and flow rates we observe with this meter). <u>Note: only the psi curve uses the Bourdon gauge data.</u> Calculate best-fit lines; report slope and intercept (with 95% confidence intervals on both). Be sure to include units when reporting your calibration curves.

6. What is the highest flow rate in gallons per minute (gpm) that can be accurately measured with the orifice meter? What is the lowest flow rate that can be accurately measured with the orifice meter?
7. For all operating conditions, report whether the flow is laminar, turbulent, or in the transition region.
8. **Plot and affix your rotameter and orifice-meter calibration curves into your lab notebook for future use.** What are the uncertainty limits on all the calibration curves?
9. In your report, attach raw data tables as an appendix (do not include raw data tables in the report). **Do not put needed tables/graphs in the appendix.** If the report cannot be understood without the figure/table, it goes in the report.
10. Did tube diameter make a difference in the calibration curve obtained? Was your initial guess right or wrong?

Appendix: Procedures and Assigned Operating Conditions

Shut Down Procedure

1. Close needle valve WV-5.
2. Close valves WV-1, WV-2, and WV-3.
3. Turn off pump P-01.
4. Drain T-01 by opening DV-01.
5. Close WV-10 and, if asked to do so by the instructor, drain T-02 by opening DV-02.
6. Disconnect the pressure meters (DP meter or Bourdon gauges) from the pressure taps; turn off the DC power for the DP meter (south wall).
7. Unplug the AC power for the balance.
8. Dry off any wet surfaces with paper towels.
9. Turn off all the electronic devices and store them properly.

Procedure A: Preparation of the work station for isothermal water flow procedure

1. Obtain an Omega DMM thermometer with a thermocouple and be ready to measure the temperature of water in T-02.
2. If tanks are not pre-filled, fill tank T-02 as follows: make sure that Supply Tank (T-02) is empty and clean. If necessary, close the drain valve (DV-2). Close valve WV-11. Open water valve (WV-10) and fill T-02 with water. Once the tank is filled, a water control float valve will shut off water and keep water level constant.
3. Close valves WV-1, WV-2, and WV-3 and close needle valve WV-5.
4. Turn three-way valve WV-4 knob to direct the water flow through rotameter FI-01. Make sure that valves WV-11, WV-6, and WV-7 are closed. Adjust three-way valve WV-8 to direct water to tanks (not to the heat exchanger E-01). Turn three-way valve WV-9 knob to direct water to T-02.

Procedure B: Ready the Honeywell DP meter for use

1. Attach the leads for the station's Honeywell differential pressure (DP-1) meter to the desired pressure taps (red on high-pressure side, black on low-pressure side). Install a multi-meter to measure DC (direct current) milliamp current signals from the DP meter.
2. Turn on DC power to DP-1 or verify that it is on (central power for all lab stations; located on south wall).

Procedure C: Pail-and-Scale the flow rate procedure

1. Allow the flow to stabilize for half a minute after adjusting WV-5.
2. Close DV-1. **CAUTION: there is no overflow protection for T-01.**
3. The moment you direct the flow from T-02 to T-01 by turning three-way valve WV-9, begin timing with an electronic stopwatch.
4. After approximately one minute, redirect the flow back to T-02 and stop timing. Record the elapsed time.
5. **NOTE: To avoid an over-range error on the balance, do not allow tank T-02 to become more than half full.** Drain tank T-02 as necessary.
6. Measure the temperature of the water in T-02.
7. Record the weight of water collected in T-01 from WI-09 and the exact time required. This is known as the "pail-and-scale" method.