

AerE 344: Undergraduate Aerodynamics and Propulsion Laboratory

Lab Instructions

Lab #03: Pressure Transducer Calibration

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AerE344 Lab # 03: Pressure Transducer Calibration

In this lab exercise, you will calibrate a pressure sensor and learn to run the Undergraduate Aerospace Wind Tunnel (Blue Wind Tunnel). The pressure sensor calibration will be conducted in such a way that you will be able to quantify the uncertainty in the calibration. The wind tunnel exercises will introduce you to the parts of the wind tunnel, the instrumentation and the data acquisition system.

The report for this project should be in a formal lab report form.

Part 1: Pressure Sensor Calibration

What will be available to you for this portion of the lab:

- A Setra pressure transducer that you will calibrate
 - This sensor has a full-scale range of +/- 5 inH₂O
 - This sensor has a zero-pressure voltage near zero but not exactly zero. You must record this zero-pressure voltage so that you can record changes in voltage with respect to this reference.
- A plenum chamber and blood pressure cuff pump for generating pressure
 - A clamp is also provided to holding the pressure constant during your tests.
- A Mensor manometer to be connected to the plenum chamber. This will be your working standard for calibrating the smaller sensor.
- A computer with a data acquisition system capable of measuring the voltage from your pressure transducers.

Tips:

1. Be sure to choose 1~2 group members to be the lead operators for this project. Inform the TA of your choice.
2. Check that the Mensor manometer (the standard device for the calibration) is connected to the plenum chamber—the reference port of the manometer may be left open to the atmosphere.
3. Connect your Setra pressure sensor (the device to be calibrated) to the plenum chamber—the reference port of this sensor may also be left open to the lab.
4. Check that the output of the sensor is connected to the computer data acquisition box. This will be a BNC connector from the sensor to the data acquisition box.
5. Practice applying pressure to the plenum as a test. **Do not apply more than 5 inH₂O to the sensor.** Is your pressure reading somewhat steady or does it fluctuate widely? You will need to set the data acquisition parameters to determine the period over which you will average your voltage. 1 second? 2 seconds? 10 seconds?
6. Consider taking data up and down through the pressure range several times to observe repeatability.
7. Plot your results to determine if your results are reasonable.

To consider:

- If you can only generate positive pressure with the hand pump, how can you test your sensor for negative pressures?
- Try to estimate the uncertainty that is appropriate for reading the Mensor pressure from its front panel.

Part 2: Measurement of the Undergraduate Aerospace Wind Tunnel

In this exercise, you will be learning to use the Undergraduate Aerospace Wind Tunnel and estimating the flow rate through the wind tunnel by acquiring a “ q -map” (Dynamic Pressure Distribution) of the wind tunnel test section. The q -map is just a profile of the dynamic pressure throughout the test section. The wind tunnel velocity for this test should be approximately 10 m/s.

What will be available to you for this portion of the lab:

- A Setra manometer to be used with a Pitot tube.
- A Pitot tube mounted to a traverse for measuring velocity profiles in the wind tunnel.
- A thermometer and barometer for observing ambient lab conditions (for calculating atmospheric density).
- A computer with a data acquisition system capable of measuring the voltage from your pressure transducer.

Tips:

1. Connect the Pitot tube to one of the Setra manometers. The total port of the Pitot tube should be connected to the main port of the manometer. The static port of the Pitot tube should be connected to the reference port of the manometer. The front panel of the manometers read in units of inH₂O.
2. Check the connections from the Setra manometer to the data acquisition (DAQ) system breakout board. Determine which DAQ channel is connected to the manometer.
 - a. The Setra output comes from the IN+ and IN- connectors on the back of the manometer.
 - b. DAQ channels are numbered as follows: Ch. 0 is connected to the terminals labeled ACH0 (+) and ACH8 (-), Chan. 1 is connected to the terminals labeled ACH1 (+) and ACH9 (-), Chan. 2, is connected to the terminals labeled ACH2 (+) and ACH10 (-), etc.
3. Start LabVIEW and start the data acquisition program.
4. Obtain the ambient lab temperature and pressure from the thermometer and barometer mounted on the wind tunnel. Use these to calculate the ambient air density ρ .
5. Calculate the dynamic pressure corresponding to a tunnel velocity of 10 m/s (dynamic pressure, q , can be estimated as $q = 1/2\rho V^2$). Start the wind tunnel and slowly increase the speed to see if the manometer reads correct pressures.

6. When you are confident of your calculation method, you can start acquiring velocity data points in the wind tunnel using the Pitot tube on the traverse. You must make the best estimate you can of the flow rate through the wind tunnel by taking velocity measurements at only several locations (10~20 locations) in the test section (for improved estimates you would take measurements at many more locations).
 - a. Is your pressure reading somewhat steady or does it fluctuate widely? You will need to set the data acquisition parameters in LabVIEW to determine the period over which you will average your voltage. 1 second? 2 seconds? 10 seconds?
 - b. Using LabVIEW, acquire voltage from the manometer for a range of positions of the Pitot tube—every 1.0 inches from the starting point.
7. The dynamic pressure map that you measure here will be part of your report as will your flow rate estimate.

Lab Exercise #03: Pressure Sensor Calibration and Wind Tunnel Introduction

Writeup Guidelines

You may turn your lab report to your TAs. The report for this project should be a lab report. See course website for details on exactly what constitutes a formal lab report.

The calibration and uncertainty analysis you conduct for this exercise will be used in subsequent lab exercises and write-ups, so do not discard any of the analysis you did for this lab.

Required Plots for your Report:

- Plot of applied pressure versus pressure transducer output from your calibration tests
- Plot of dynamic pressure distribution from your wind tunnel tests
- Plot of velocity distribution from your wind tunnel tests.

Your report must provide details on:

- How you estimate your uncertainty (e.g. 1s, 2s, 10s data length) for your calibration experiment—in an appendix, you should show your uncertainty calculations.
- Wind tunnel velocity.

HANDY LAB INSTRUCTIONS

- Be sure to take a voltage measurement from the pressure sensors when the tunnel is turned off. This is your “zero-pressure” voltage reading, v_0 , that you will need for converting the voltage to pressure.
- The front panels of the Setra manometers report in units of inH₂O. To get an accurate measure from the front panel, you must account for the fact that the zero-pressure reading is often non-zero.
- You can convert voltage from the pressure sensors into pressure using the following expression:

$$P = C(v - v_0)$$

where C is the calibration coefficient of the pressure sensor, v is the voltage from the manometer and v_0 is the zero-pressure voltage.

- The relationship between the dynamic pressure measured with the Pitot tube and the wind tunnel velocity is given by the following relation:

$$q = \frac{1}{2} \rho V^2$$

where q is the dynamic pressure, ρ is the air density and V is the wind tunnel velocity.

Calibration Coefficients (Just for reference):

For “Setra1” the calibration coefficient, C , is 746.52 Pa/volt

For “Setra3” the calibration coefficient, C , is 248.84 Pa/volt

Conversions and Physical Constants:

1 inH₂O = 248.84 Pa

1 inHg = 3386.39 Pa

Temp(K) = Temp(C) + 273.15

Temp(R) = Temp(F) + 459.67

Temp(C) = (Temp(F) – 32) * 5/9

Gas constant for air, $R = 287 \text{ J}/(\text{kg K}) = 1716 \text{ (ft lb)}/(\text{slug R})$