MAE 253 - Experimental Aerodynamics I
Lab 1 – Pressure Transducer Calibration
Final report due date: 02/05/2018

Objective: Using the pitot-static tube and water manometer systems:

- Create a calibration curve for the pressure transducer.
- Determine the pressure transducer calibration factors.

Theory: One of the important flow characteristic needed to determine the aerodynamics of a system is the airspeed. The pitot-static probe is the most commonly used instrument to measure fluid flow velocity. The basic pitot-static tube, shown in Fig. 1, consists of a tube with its primary port aligned and facing the fluid flow and the secondary port on the surface of the tube parallel to the flow. When placed in a moving fluid, the primary port brings the fluid to a rest as there is no outlet for the flow to continue. The resulting pressure is the total or stagnation pressure (P_{total}) of the fluid flow. The secondary port measures the static pressure (P_{static}) of the flow. The dynamic pressure ($P_{dynamic}$) can then be measured as,

$$P_{dynamic} = P_{total} - P_{static}$$

which in turn can be used to measure the freestream flow velocity using the equation,

$$U_\infty = \sqrt{\frac{2P_{dynamic}}{\rho}}$$

where ρ is the density of the fluid.

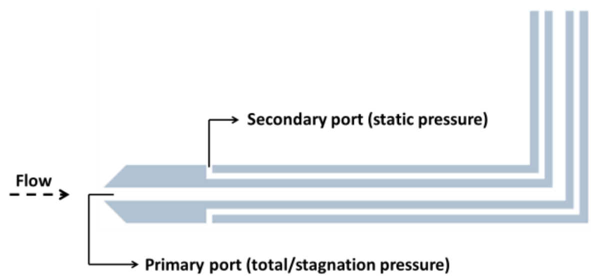

Figure 1: Schematic of a pitot-static tube
(Source: https://commons.wikimedia.org/w/index.php?curid=3301685).

One of the oldest and still existing pressure measurement systems is the manometer due to its accuracy and simplicity of operation. The manometer is generally a U-shaped glass tube partially filled with liquid, as shown in Fig. 2. This manometer has no moving parts and requires no calibration. Manometry measurements are functions of gravity and the liquid's density, both physical properties that make the manometer a standard for accuracy. When each of the legs is connected to unknown pressures, the difference in column height indicates the difference in pressures. This difference in pressures can be calculated using the expression,

$$\Delta P = P_2 - P_1 = \rho_{water} g h$$

where g is the acceleration due to gravity and h is the difference in column heights.

Though accurate, due to the bulkiness of the manometer, a more realistic solution is needed to measure pressures on moving vehicles. Today, electromechanical pressure sensors, which convert the applied pressure to an electric signal, are widely used for pressure sensing applications. While different types of pressure sensors with varying measurement techniques exist, one of the more common sensors are the capacitive pressure sensors. The sensor is based on the working principle of a capacitor which consists of two conductive plates separated by an insulator/dielectric (Fig. 3).

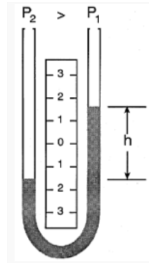

Figure 2: Schematic of a U- tube manometer
(Source: https://www.sensorsmag.com/components/manometer-basics).

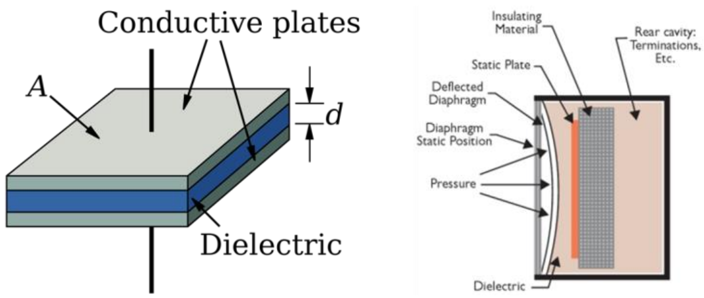

Figure 3: Schematics of a capacitor (left) and a capacitance pressure sensor (right).

Capacitance is measured using the equation,

$$C = \frac{\mu A}{d}$$

where μ is the dielectric constant of the material, A is the area of the plates, and d is the spacing between the plates. In a capacitance pressure sensor, one of the conductive plates is replaced by a flexible conducting diaphragm (Fig. 3). When pressure is applied, the diaphragm deflects, which causes a change in d thereby leading to a change in capacitance. The electronics in the sensor are calibrated to generate specific voltage changes for corresponding changes in capacitance which in turn can be used to measure the current for a given applied pressure.

Experiment: Using the wind-tunnel (WT) temperature and pressure transducers, manometer, and multimeter system record the following data for different flow velocities:

Table 1: Data collected for the pressure calibration experiment

$P_{transducer}$ (psf)	$h_{manometer}$ (inches)	I_{sensor} (mA)	$T_{transducer}$ (^{o}F)
from WT transducer	from manometer	from multimeter	from WT transducer

You are required to create two calibration curves for the Ashcroft® pressure sensor ($P_{manometer}$ vs. I_{sensor}) by applying a linear fit through the collected data points for increasing and decreasing flow velocities.

The following constants can be used to help with your analysis:

1. Water density, ρ_{water}: 997.71 kg/m^3
2. Acceleration due to gravity, g: 9.8 m/s^2

In the final report,

- All results must be presented in SI units.
- Plot the collected data points along with the two linearly fitted calibration curves for the pressure sensor.
- Provide the coefficients of the linear fit equations.
- Determine if the system has hysteresis.
- *EXTRA CREDIT* – Is the wind-tunnel pressure transducer calibrated correctly? Explain your answer with the appropriate plots and analysis.
- Present your code in the Appendix.