Study and Calibration of Pressure Sensor and Flow Meter

List of symbols

P_1 Upstream pressure (before the flow meter)
P_2 Downstream pressure (after the flow meter)
C_d Coefficient of discharge
P_{atm} Atmospheric pressure (N/m^2)
P_0 Total pressure (N/m^2)
P_{static} Static pressure (N/m^2)
$\dot{m}$ Mass flow rate (kg/s)

1. Objective

To study different types of pressure sensors and flow meters, and to
1. Calibrate a differential pressure sensor.
2. Characterize different flow meters (orifice, nozzle, and venturi).

2. Apparatus

I. **Experimental Setup:** The open-circuit low speed wind tunnel consists of a centrifugal blower driven by an electric motor. The blower draws in air from the atmosphere and discharges through the pipe. A butterfly valve located downstream of the blower is used to control the air mass flow rate. The flow meters are fixed downstream of the valve in the order as shown in the figure. Velocity profile is obtained at the exit, which is used for calculating the mass flow rate.

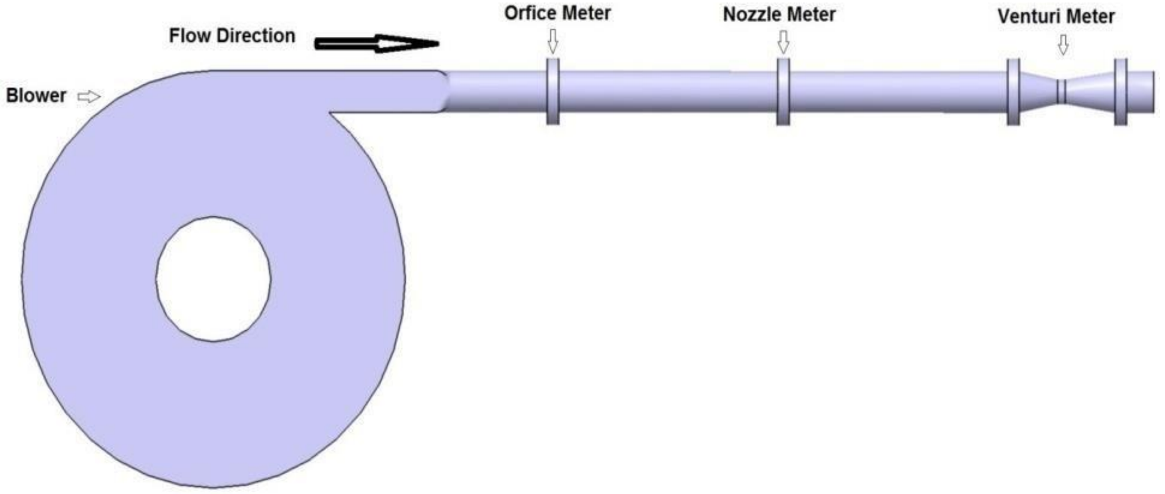
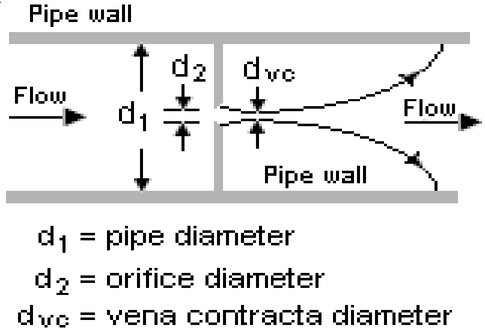


FIG 1: Schematic of the experimental setup

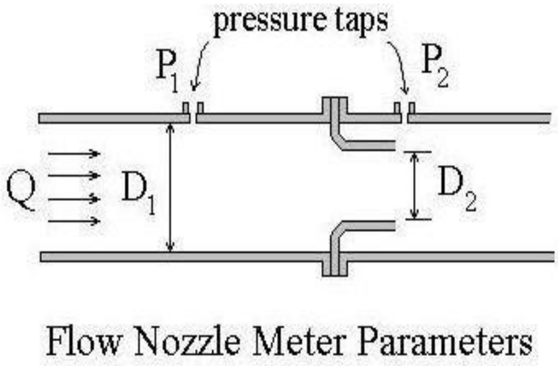
II. **Differential pressure sensor:** An electronic differential pressure sensor is used to determine the pressure drop across the flow-meters. The sensor sends an electronic signal (DC voltage) based on the pressure difference between the two ports connected to it. For the present experiment, one sensor of 0 to 1000 N/m^2 range is used.

III. **Manometer:** Pressure measuring devices using liquid columns in vertical or inclined tubes.

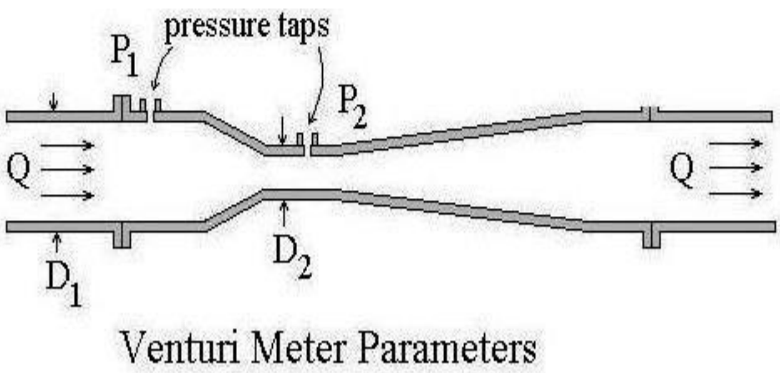
IV. **Flow meter and Pitot probe**



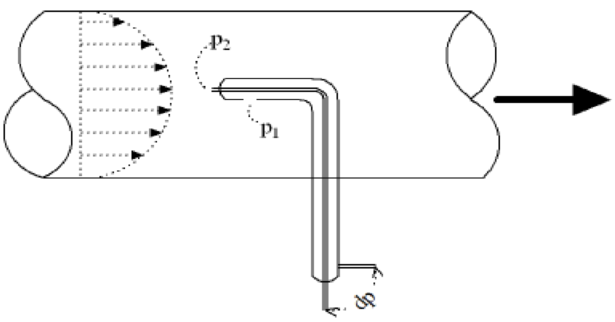
Orifice meter



Nozzle meter



Venturi meter



Pitot Probe

3. Precautions

- The pressure applied to the sensor should be within the range specified on the sensor.
- Ensure sufficient time for the pressure to stabilize after repositioning the probe at each point.
- Make sure that, there are no blockages in the pipes.
- Align the Pitot probe parallel to the flow.
- Do not block the flow at the exit, during data acquisition.

4. Procedure

I. Familiarize with the basic principles of data acquisition.

II. Note down the ambient temperature and pressure.

III. Calibration of pressure sensor:

1. Connect the high-pressure port of the pressure sensor to the calibrator via T-joint and leave the other port of the pressure sensor open to the atmosphere.
2. Obtain the output voltage from the sensor at different pressures applied using the hand pump.
3. Using the acquired data, find the best-fit curve (one degree in single variable), which defines the calibration equation for the sensor.

IV. Calibration of Flow meter:

(a) Connect the pressure taps of flow meters to the manometers using rubber tubes.
(b) Switch on the tunnel and set the mass flow rate using the butterfly valve.
(c) After steady state is reached, obtain the pressure data from the manometers.
(d) Traverse the pitot probe vertically, to determine the velocity profile across the cross-section of the pipe. Use this profile to determine the mass flow rate of air in the pipe.
(e) Repeat the above two steps for different flow rates.

5. Performance Parameters

1. Coefficient of discharge $$C_d = \frac{\dot{m}}{\dot{m}_{the}}$$

2. Theoretical mass flow rate $$\dot{m}_{the} = \sqrt{\frac{2\rho\Delta P}{\frac{1}{A_2^2} - \frac{1}{A_1^2}}}$$

3. Flow velocity measured using Pitot probe $$V = \sqrt{\frac{2(P_0 - P_{static})}{\rho}}$$

Where,

P_0 = Total / stagnation pressure
P_{static} = Static pressure
ΔP = Pressure difference across flow meters ($P_1 - P_2$)
A_1 = Area of pipe/duct
A_2 = Area of throat of flow meter
ρ = Density of air
V = Velocity at the exit of venturimeter measured using Pitot probe

$\dot{m}$ = Actual mass flow rate = $\rho \times A_1 \times V_{avg}$

V_{avg} = Average velocity at the exit of venturimeter = $\frac{\int_0^R V \times 2\pi r dr}{\pi R^2}$

R = Radius of the veturimeter exit

r = radial coordinate at the venturimeter exit

6. Experimental Setup Figures

Fig 1(a): Front Side of Experimental Setup

Fig 1(b): Back Side of Experimental Setup

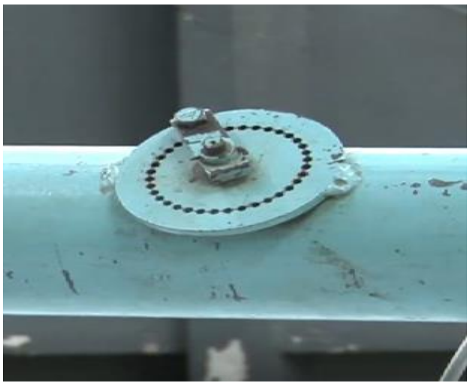


Fig 2: Butterfly Valve

Fig 3: Blower

Fig 4: Differential Manometers

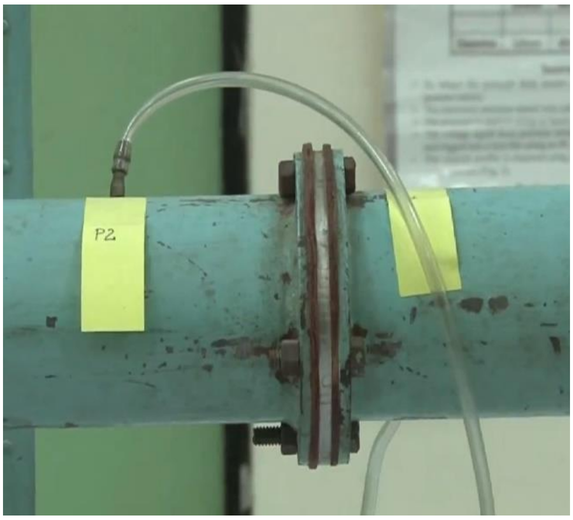


Fig 5: Pressure Ports (P_1, P_2) Across Orifice meter

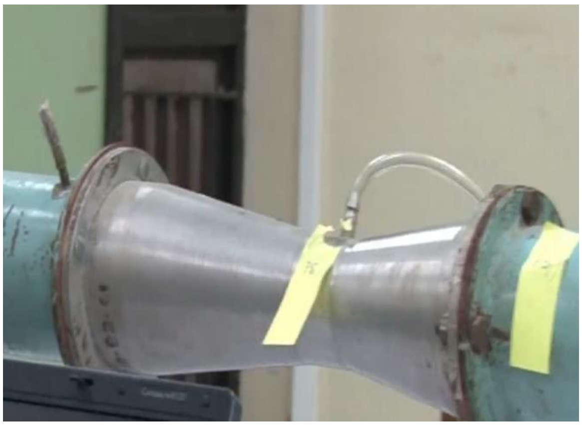


Fig 6: Pressure Ports Across Venturi Meter

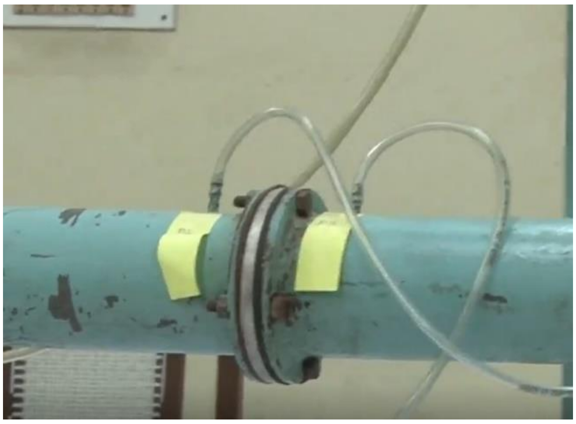


Fig 7: Pressure Ports Across Nozzle meter

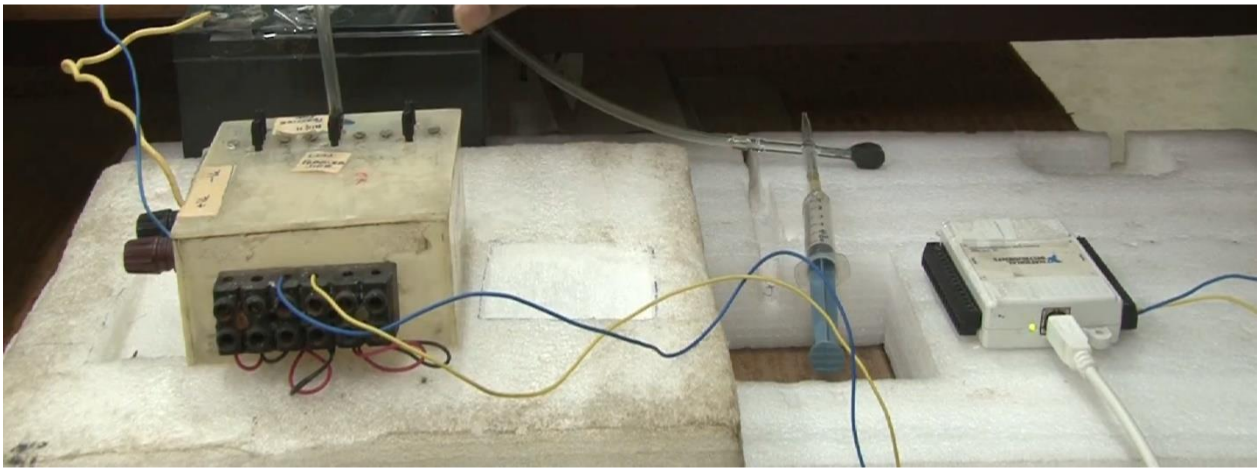


Fig 8: Pressure Sensor and DAQ Card

8. Results and Discussions

- Explain the difference between absolute pressure, gauge pressure and differential pressure.
- Explain in brief about Orifice meter, Nozzle meter, Venturi meter, Pitot probe.
- Plot the data points and the calibration equation for all the sensors indicating the equations representing them.
- Plot the variation of C_d with mass flow rate and pressure drop across the flow meters. Use different plots for different flow meters.
- Plot the velocity profile at the exit of the pipe.
- Comment on the nature of the results and explain inconsistencies, if any.

Appendix:

Dimensions of the flow meters

	Orifice	Nozzle	Venturi	
			Outer Dia	Throat Dia
Diameter	50mm	48mm	82.61mm	43.4mm