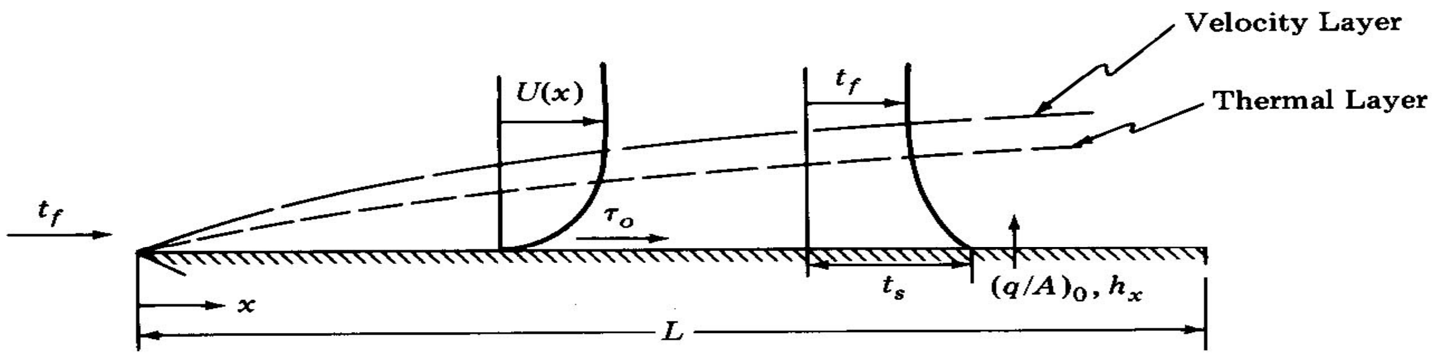
# Convection

- Region near surface where fluid has undergone a change in temperature because of heat transfer is the thermal boundary layer.
- $T \leq 0.99\, T_\infty$




- Newton's Law of Cooling

$$\dot{q}'' = h_x \left(T_W - T_\infty\right)$$

# Heat Transfer Coefficient

- Energy balance at wall-fluid interface

$$h = -k_f \left( \frac{\partial T}{\partial y} \right)_{y=0} \Big/ \left( T_w - T_\infty \right)$$

- Nusselt Number, Nu

$$\mathrm{Nu_x} = \frac{\mathrm{h_x x}}{\mathrm{k_f}} = \mathrm{f}\left(\mathrm{Re_x}, \mathrm{Pr_f}\right)$$

- Flat plate solution:  Average Nusselt Number

$$Nu_L = C \,\mathrm{Re}_L{}^n \,\mathrm{Pr}_f{}^m$$

# Heat Transfer Coefficient

- Laminar correlation

$$Nu_L = 0.664 \, \mathrm{Re}_L^{0.5} \, \mathrm{Pr}_f^{1/3}$$

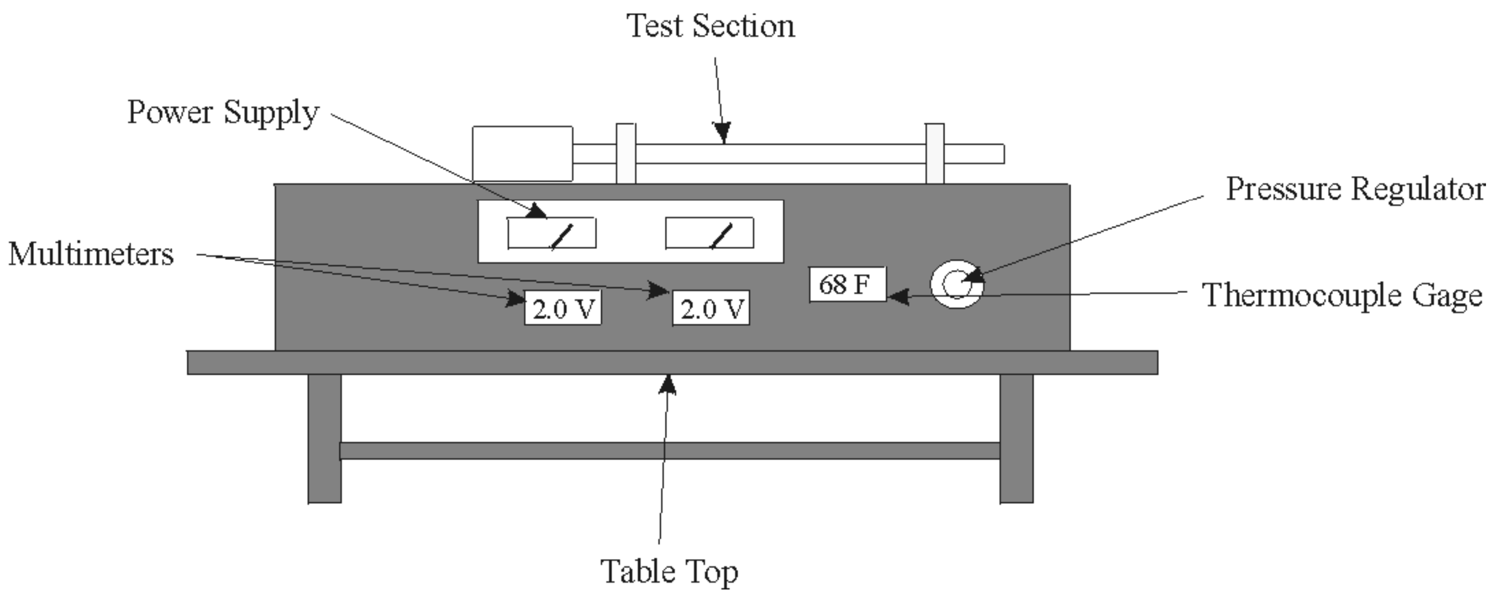
- Turbulent correlation

$$Nu_L = 0.037 \, \mathrm{Re}_L^{0.8} \, \mathrm{Pr}_f^{1/3}$$

- Transition

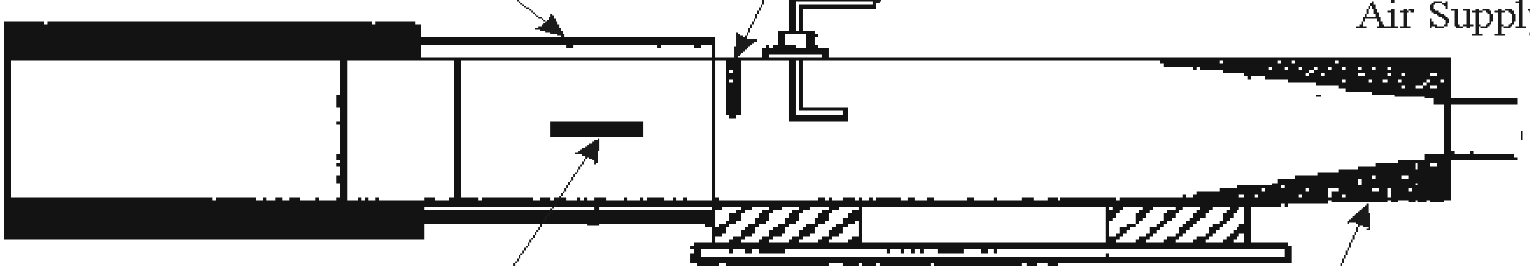
$$\mathrm{Re}_c = 5 \text{ x } 10^5$$

# Experiment Apparatus




- Pressure Regulator controls air flow rate
- Power supply supplies power to the heating element in the test section.

# Test Section

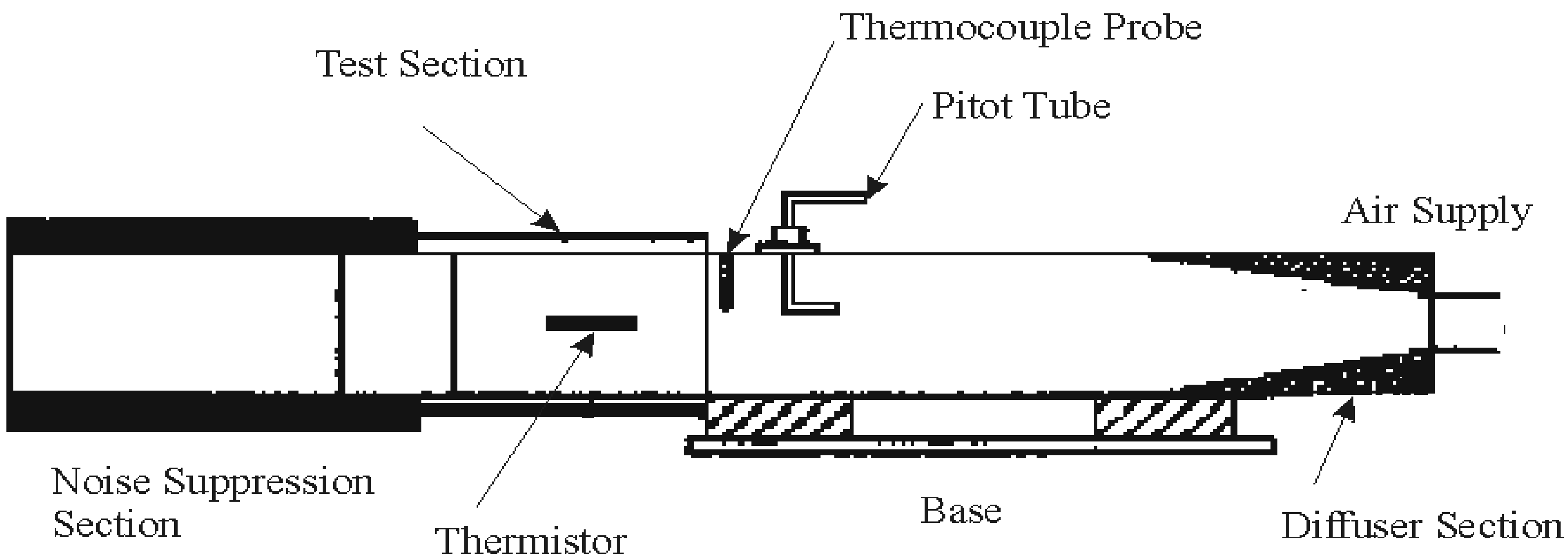



$$h_x = \frac{\dot{q}''}{(T_w - T_\infty)} = \frac{\dot{q}/A}{(T_w - T_\infty)}$$

$$h_x = f(Re, \ Pr)$$

- Measure freestream air temperature (thermocouple)
- Measure heat input to disc and its temperature (thermistor)
- Measure air velocity (pitot tube)

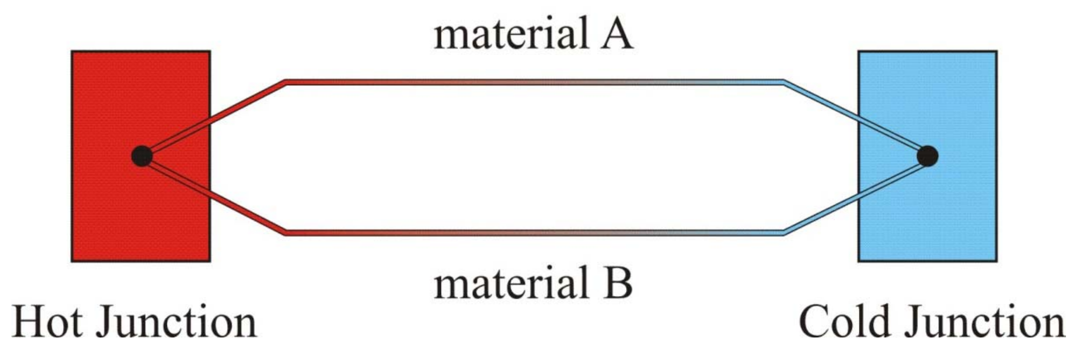
# Test Section




- **Measure freestream air temperature (thermocouple)**
- Measure heat input to disc and its temperature (thermistor)
- Measure air velocity (pitot tube)

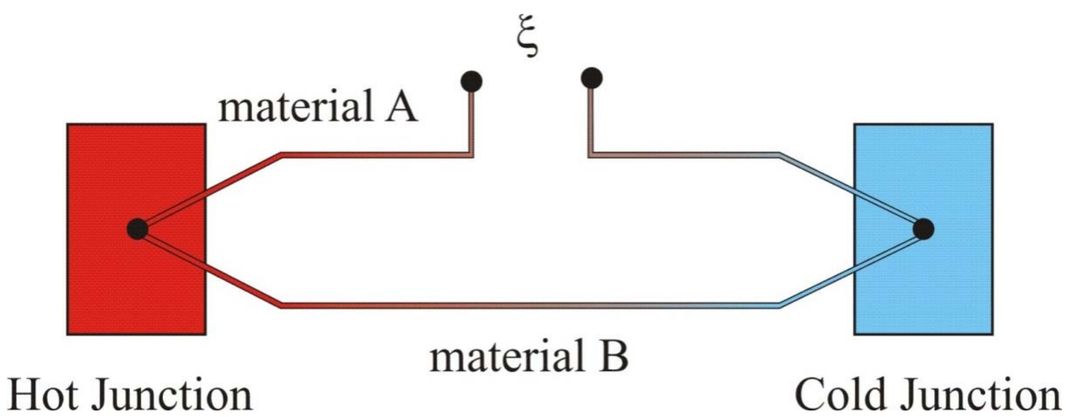
# Thermocouple

- When two dissimilar metal wires are joined at each end and the junctions are held at different temperatures, a current will flow through the circuit.



# Thermocouple

- If the circuit is open, there is an emf across the wires which is dependent on the two dissimilar materials and the temperature difference.

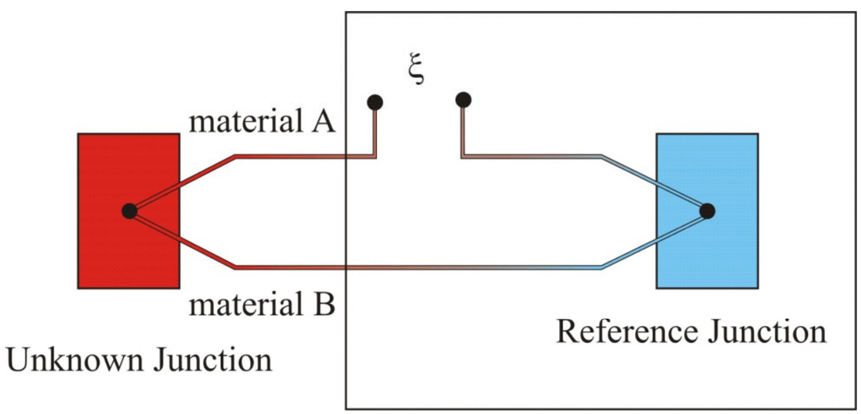



$$\xi \propto \alpha \left(T_H - T_C\right)$$

$$T_H \propto T_C + \frac{\xi}{\alpha}$$

# Thermocouple

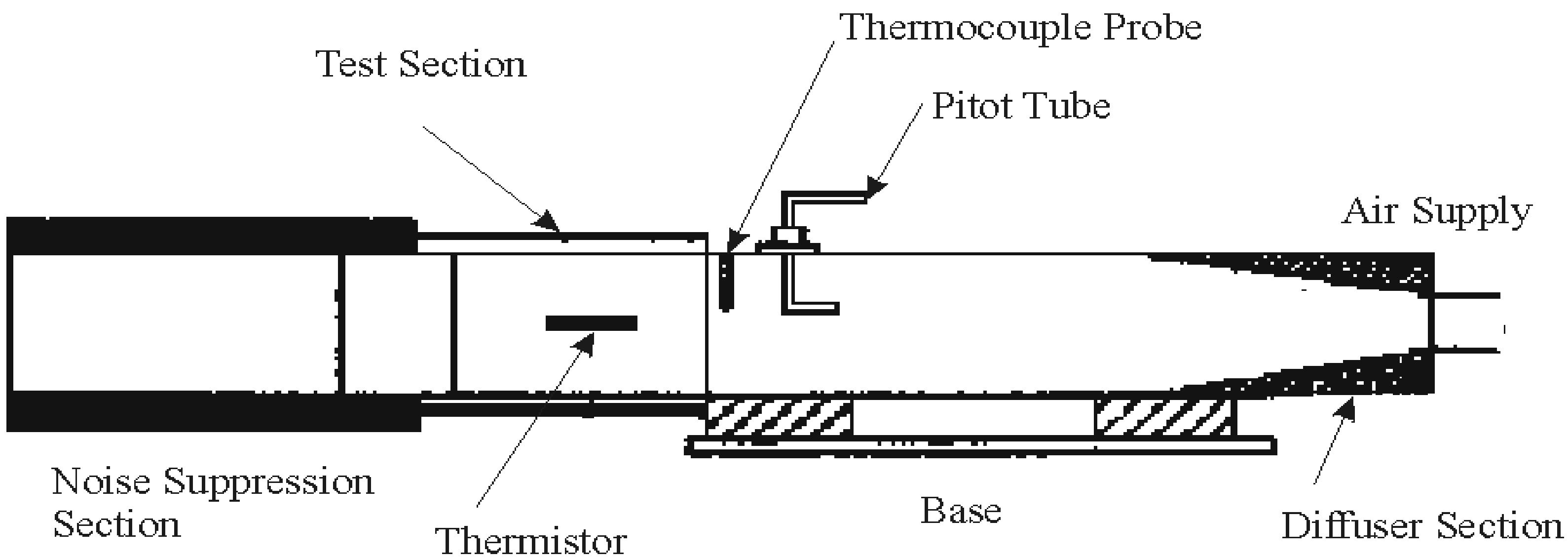
- Current electronic equipment can simulate the cold (reference) junction and is not seen by the user.





http://en.wikipedia.org/wiki/Thermocouple

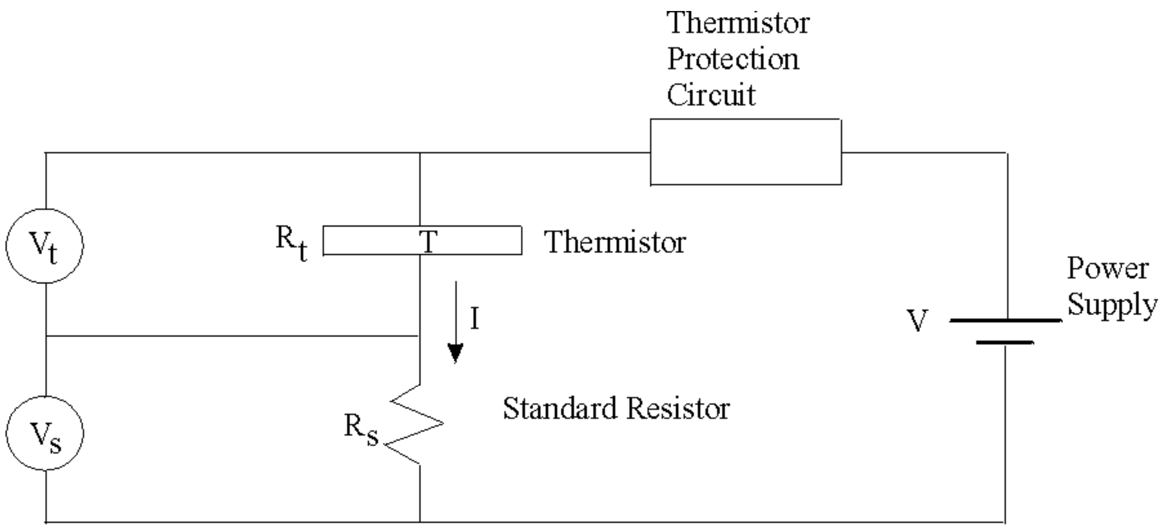
# Test Section




- Measure freestream air temperature (thermocouple)
- **Measure heat input to disc and its temperature (thermistor)**
- Measure air velocity (pitot tube)
- Measure disc (thermistor) temperature

# Electrical Circuit

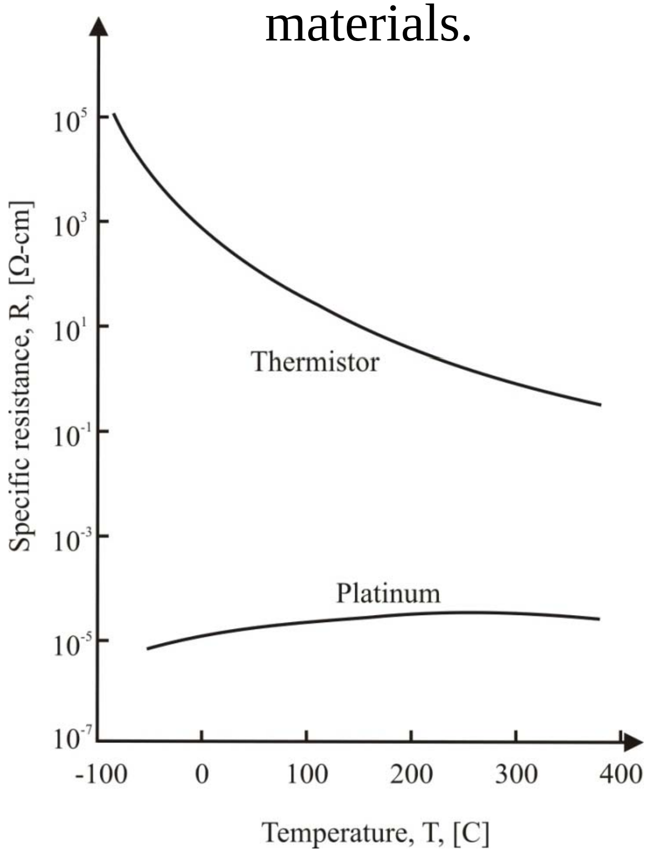
- Power supplied to thermistor is dissipated by the thermistor and heats the thermistor.
- Measuring the thermistor resistance can determine its temperature.



# Thermistor

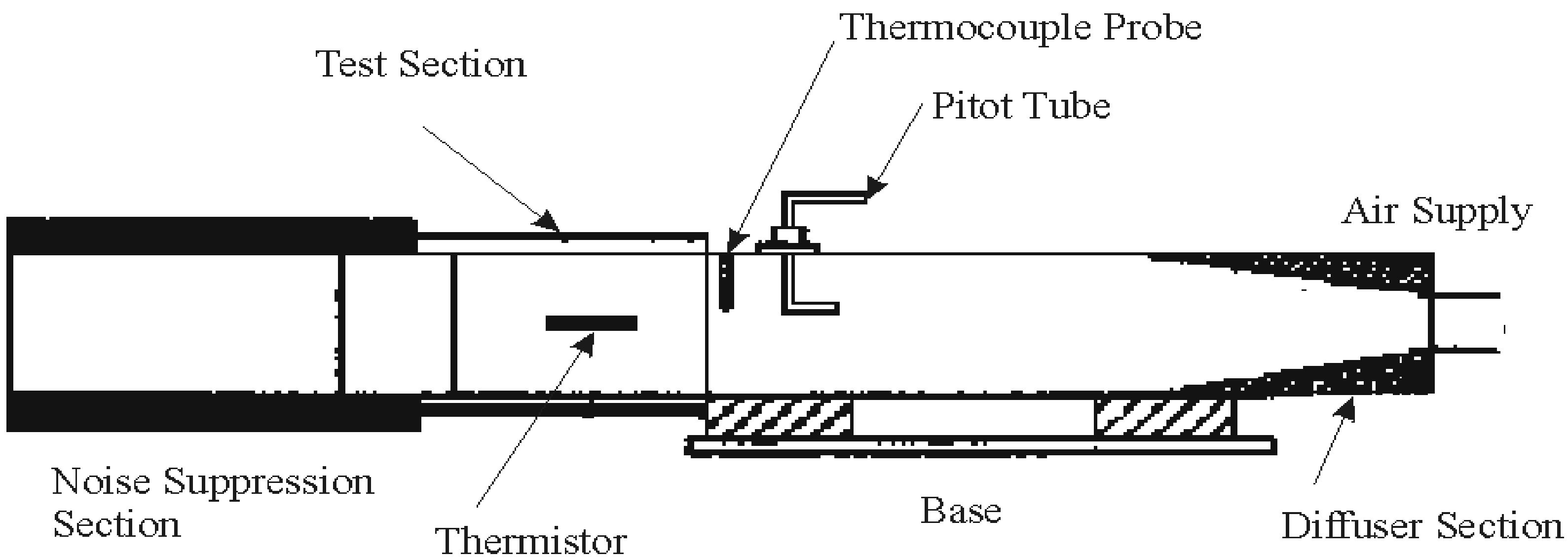
- Thermistor and RTD's (resistance temperature detectors) are electrical resistors whose resistance varies with temperature.

- Thermistors are made of polymer, ceramic, and semiconducting materials.




Adapted from "Mechanical Measurements, 3rd ed.," Beckwith, Buck, and Marangoni.

# Test Section

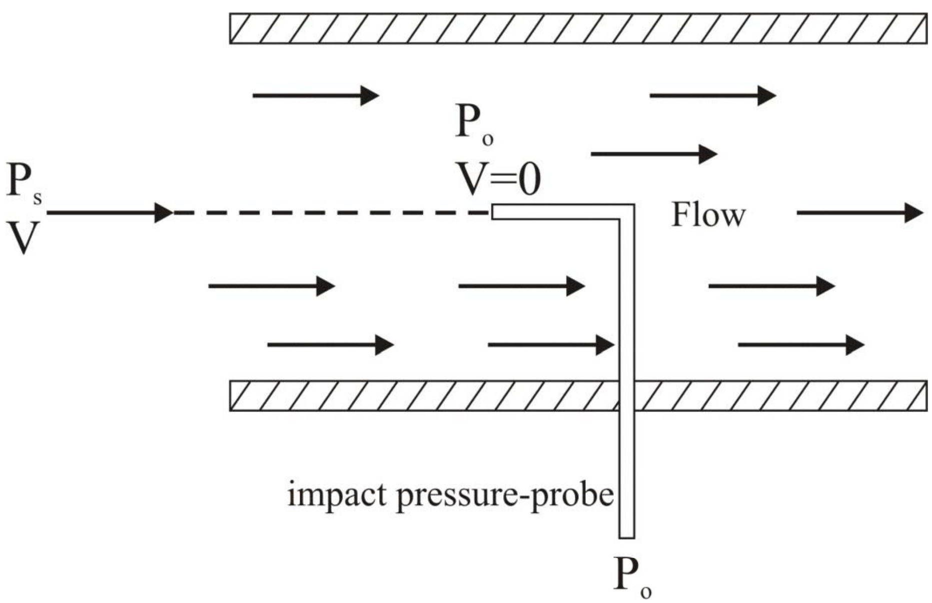



- Measure freestream air temperature (thermocouple)
- Measure heat input to disc and its temperature (thermistor)
- **Measure air velocity (pitot tube)**

# Pressure Probe for Measuring Fluid Velocity

- A small diameter tube is placed with its opening perpendicular to the fluid velocity.

- The fluid at the opening of the tube has zero velocity and thus represents the stagnation pressure or total pressure.



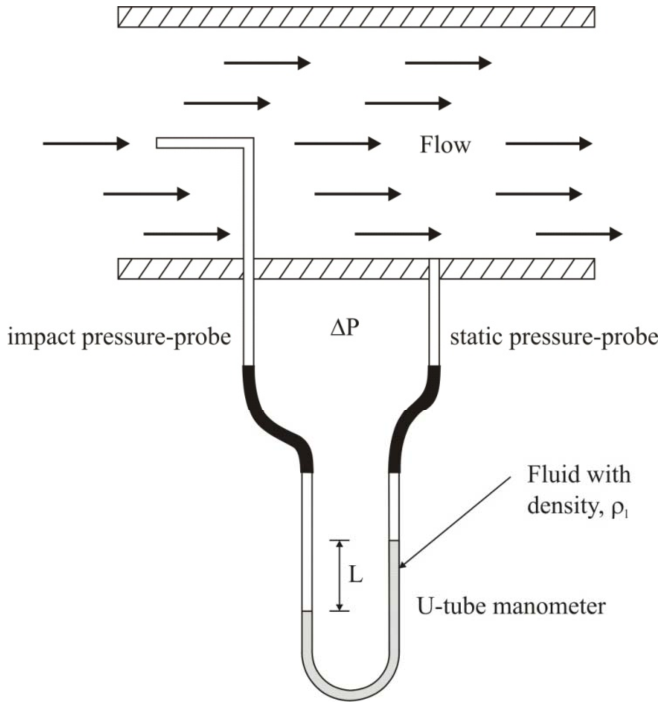

$$P_o = P_s + \frac{1}{2g_c}\rho V^2$$

$$V = \sqrt{\frac{2g_c\left(P_o - P_s\right)}{\rho}}$$

# Pressure Probe for Measuring Fluid Velocity

- The simplest device to measure the stagnation pressure is the manometer.

- Based on the hydrostatic equation, a liquid column of fluid can be converted to a pressure differential.




$$\Delta P = \frac{\rho_l g}{g_c} L$$

So the flow velocity is

$$V = \sqrt{\frac{2 g_c (P_o - P_s)}{\rho}}$$

$$V = \sqrt{\frac{2 g \rho_l}{\rho} L}$$

# Developing Heat Transfer Correlation

- Using the experiment data determine the Nu, Re, and Pr.
- Assume the form of the correlation.

$$Nu = C \operatorname{Re}^{n} \operatorname{Pr}^{m}$$

$$\frac{Nu}{\operatorname{Pr}^{m}} = \ln C + n \ln \operatorname{Re}$$

$$\frac{Nu}{\operatorname{Pr}^{m}} = \ln C + n \ln \operatorname{Re}$$

In this form, the equation is linear.

$$y = y_{o} + nx$$

# Developing Heat Transfer Correlation

- Plot the data and perform linear regression to find the best fit line.