Inside Wind Tunnel 1

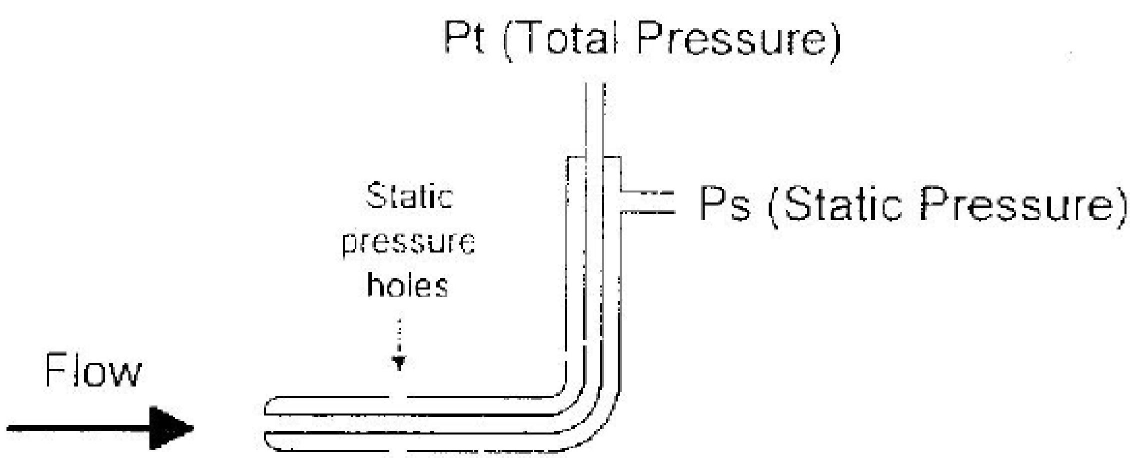
The term **pitot tube** is used to encompass a specific class of instruments that measure fluid pressures. The three basic types of pitot tubes are as follows:

1. Pitot tube – measures the total pressure of a moving fluid, also known as total pressure tube or stagnation tube.
2. Static tube – measures the static pressure of a fluid.
3. Pitot-static tube – simultaneously measures the total and static pressure in moving fluids, also known as a total-static tube.

Static pressure is the pressure that would be measured by an instrument moving with the flow. Since this is impractical, it is measured by an opening that is perpendicular to the flow – thus not including the pressure force as a result of the velocity of the flow. (Static pressure is also known as bursting pressure and is the pressure that is being exerted on the duct sidewalls.)

Total pressure is the sum of two pressures – static pressure and velocity pressure, and is measured by placing an opening (coupled to a meter) directly facing the flow.

The device to be used in this experiment will be the pitot-static tube and is depicted in the following figure:

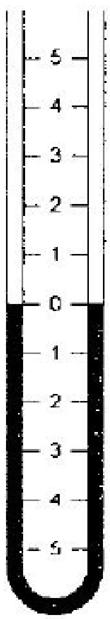


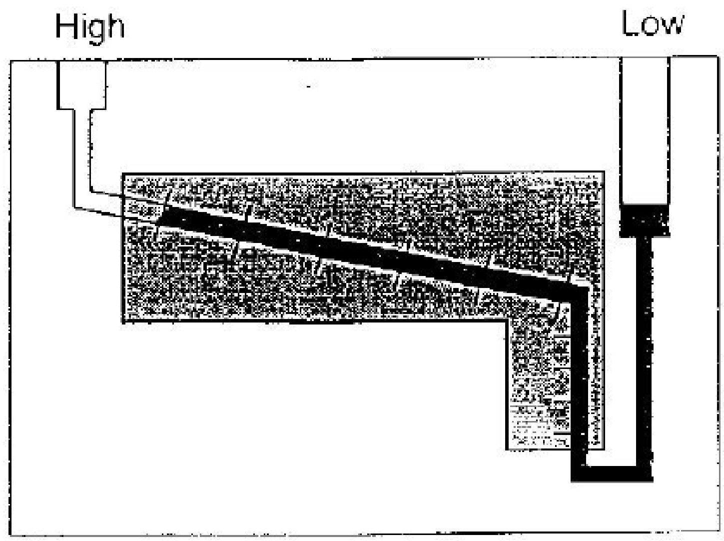
The pitot-static tube measures both the total and static pressure which can then be used to calculate the velocity of the air flow (as seen in Inside Wind Tunnel 2). The geometry of a pitot tube affects its measuring capabilities, with the shape of its head determining its sensitivity to non-parallel flows, i.e. yaw and pitch angles. The length of the sensor head determines its sensitivity to flow velocity or Mach number, with longer sensor heads being more accurate over wider flow ranges. The pitot tubes used on the Hampden H-6910 Wind

Tunnel are modified Prandtl type and have an upper limit for static pressure of approximately Mach 0.7 (due to the formation of local shock waves near the tip of the sensor).

<u>Manometer:</u>

A manometer is a device that indicates the pressure difference between two points by the offset in height of a liquid, usually in a "U" shaped tube. Pictured below are two types of manometers. Both of these must be in the **vertical position** to produce accurate readings.





The manometer on the left is the simple type made by placing a tube in a "U" shape with a vertically aligned ruler in the center. On this device, it usually doesn't matter which side is connected to the higher pressure point. However, when calculating the pressure difference, the total distance between the left and right liquid levels must be used, which is usually double the reading on the built in ruler. To zero this device, liquid may be added or removed, or sometimes the ruler may be moved until liquid levels are equal and at zero.

The manometer on the right is a reservoir manometer with an inclined section for greater accuracy. On this type of manometer, readings are directly read from the built in ruler. It is **very important**, however, <u>that the higher pressure point be connected to the appropriate side</u> of this type of manometer, which is usually the non-reservoir or inclined side (left side). Zeroing this device usually involves either adjusting a plunger on the side (which raises or lowers the liquid level) or sliding the ruler up/down until the liquid line is over the zero. Note, for accurate readings, the line formed by the upper most edge of the liquid and its **reflection** is used to determine the precise location of the liquid level.

It is customary to record pressure readings in whatever scale is marked on the manometer, but be sure to record the units of the scale (in, mm, etc.). If it does not specify that the scale is in "inches of water", record the specific gravity of the liquid used. Also, a common abbreviation used is "W.C." (for inches water column) and is equivalent to the pressure that supports a one inch high column of water at standard conditions. A typical variation of the pressure formula is as follows:

$$\Delta P = \rho g h \qquad \text{or} \qquad \Delta P = \rho_{H_2O}(SG)gh$$

Volume Calculations:

The conservation of mass equation involved in the wind tunnel is:

$$\rho_1 V_1 A_1 = \rho_2 V_2 A_2$$ (ρ = density, V = velocity, A = area)

Since air is relatively incompressible at the pressures and temperatures created in the wind tunnel, the equation can be reduced to:

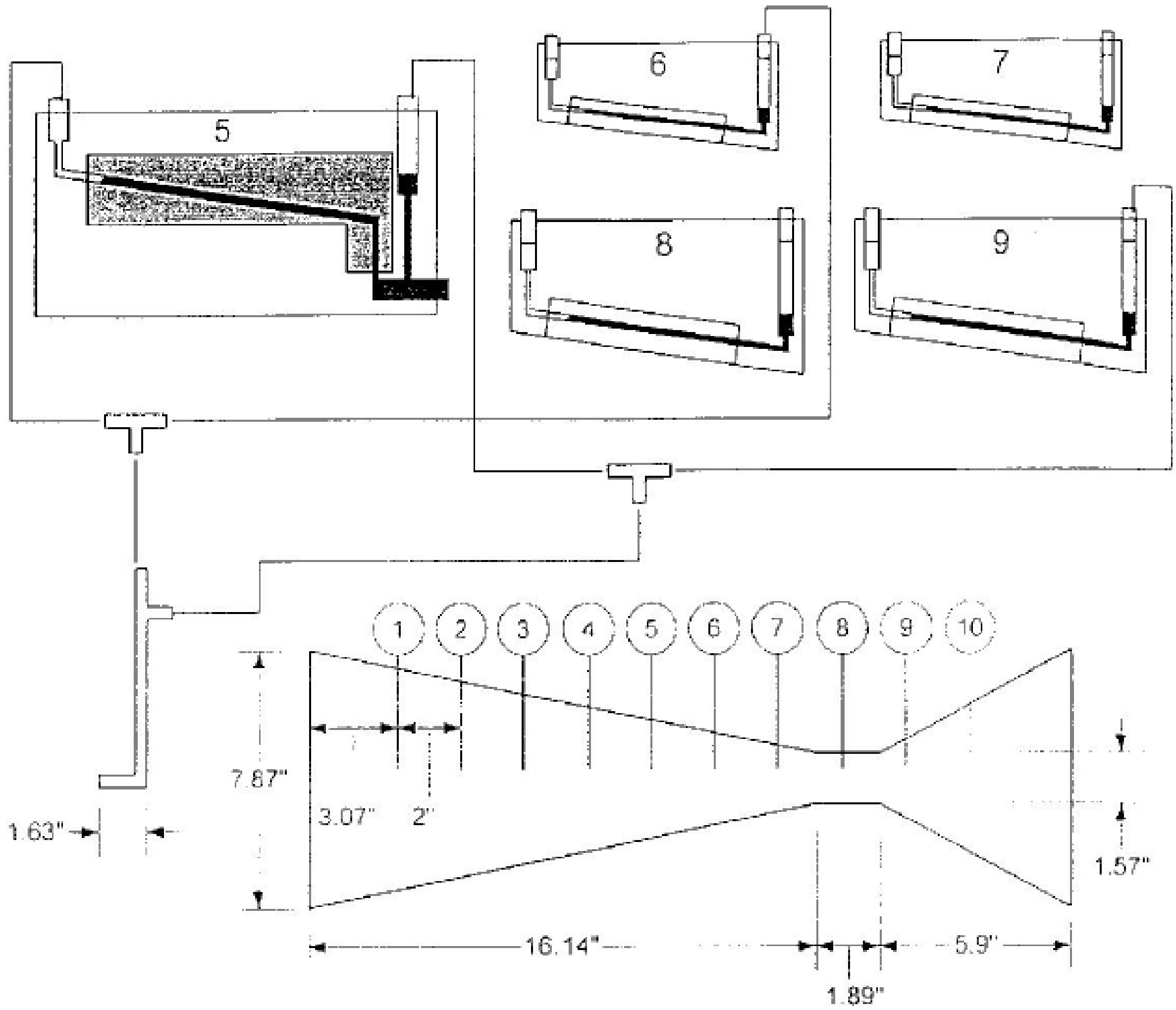
$$V_1 A_1 = V_2 A_2 \qquad (or\ Q_1 = Q_2)$$

Therefore, if the area decreases, the velocity will **increase**.

When calculating the area at each of the openings, it is important to take into account the fact that the pressures will be read at the tip of the pitot tube which is 1.63" back from the opening. Assuming that the width of the tunnel is "W", then the areas at 9 and 10 will be:

$$A_9 = 1.57W \qquad A_{10} = 2.9W$$

Use the information and geometry above to derive one equation for the area at holes 1 through 8 using N as the hole number and W as the width in the equation. (A_N = …)



Procedure:

1. Turn off the fan and power if necessary.
2. Install the convergent-divergent duct as shown.
3. Connect the hoses with tees to the appropriate manometers shown.
4. Turn the fan on to 70.
5. Place the probe through hole #1 and adjust it so the tip is the center.
6. Record the pressures. <u>When taking the readings, it is important to not shake or bump the table as well as to not walk neat the inlet or exit of the tunnel.</u>
7. Repeat steps 5, 6, and 7 with holes #2-#10

The following pressure readings are in inches of H_2O. (Note, that if a single tube is connected to the low side of a manometer, then the reading is negative.)

Hole #	Area (in^2)	Total Pressure (Manometer 6)	Static Pressure (Manometer 9)	Velocity Pressure (Manometer 5)	Calculated Velocity Pressure
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

8. Calculate the area of the duct for each tube position. (Note: The area should be calculated from the tip of the pitot-static tube.)
9. Determine the Calculated Velocity Pressure and compare to the Velocity Pressure from manometer 5.
10. Graphically show how the duct cross-sectional area (assume W=1) effects both the measured and calculated velocity pressure.
11. Answer the following questions in your conclusions/discussion section.

Questions:

1. What type of pitot tube is used in this experiment?
2. What is another name for static pressure?
3. How is velocity pressure calculated?
4. What is the upper limit of the probes used in this experiment (in MPH)?
5. Are the total pressure readings in this experiment positive or negative? What are the readings relative to? If the fan were turned around, what should the readings be? (positive or negative)
6. Looking at the graph, is the change in velocity pressure linear with the change in area? If not, what ratio or function does the velocity pressure appear to change by with respect to the change in area?
7. What is the maximum pressure (in psi) that could be exerted on the walls of the installed duct based on your measurements?
8. How would you check the pressure of a bicycle tire using the wind tunnel and/or its meters?