ME 449/549 Lab Assignment 2

Spring 2006 due 25 April 2006

1 Background

The thermal management laboratory has three small wind tunnels used for heat transfer experiments. The wind tunnels provide air velocities from 0 to 2 m/s (0 to 350 ft/min). Before we use the wind tunnels to measure convective heat transfer coefficients, we wish to characterize the velocity profile in the test section. It is desirable to have a uniform velocity profile in the central part of the wind tunnel cross section.

The primary objective of the lab is to determine whether the design of the wind tunnel inlet is important in providing a uniform flow at the test section. You will use a thermal anemometer to measure the two dimensional velocity profiles $u(x, y)$ in the three wind tunnels in the lab. Each wind tunnel has a different inlet design.

2 Apparatus

Figure 1 is a sketch of the test section for the wind tunnels. It also shows the square flange face at the entrance to the wind tunnel with no inlet. Figure 2 depicts two different inlet designs for the wind tunnel. The inlet on the left side has four curve walls made of smooth plastic. Only the top and bottom curves are visible in the elevation view in Figure 2. The inlet on the right side of Figure 2 has S-shaped typical of well-designed wind tunnels. The S-shaped inlet is a prototype made out of poster board.

The test section of all three wind tunnels is constructed of 3/4 inch thick, cabinet grade plywood. The internal dimensions of the test section are six inches high by 12 inches wide by 24 inches long. Flanges on each end of the test section facilitate attachment to the downstream fan section, and to the inlet, if one is present.

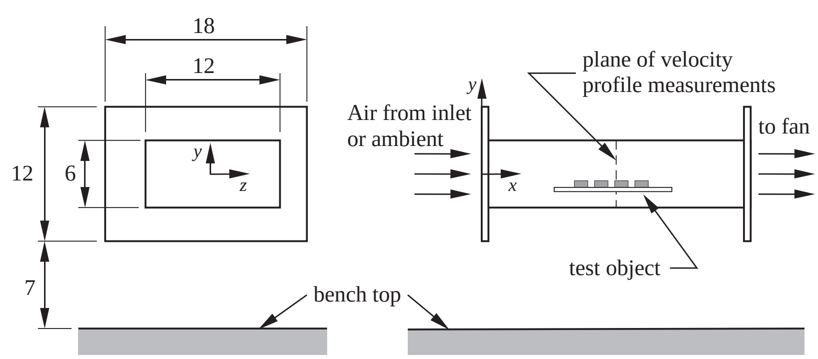

Figure 1: Geometry of the wind tunnel test section. All dimensions in inches.

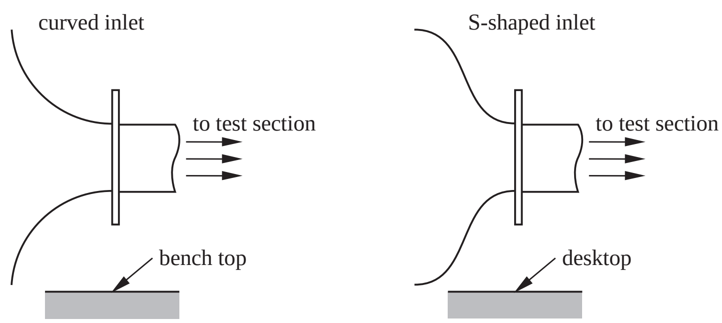

Figure 2: Curved and s-shaped wind tunnel inlets

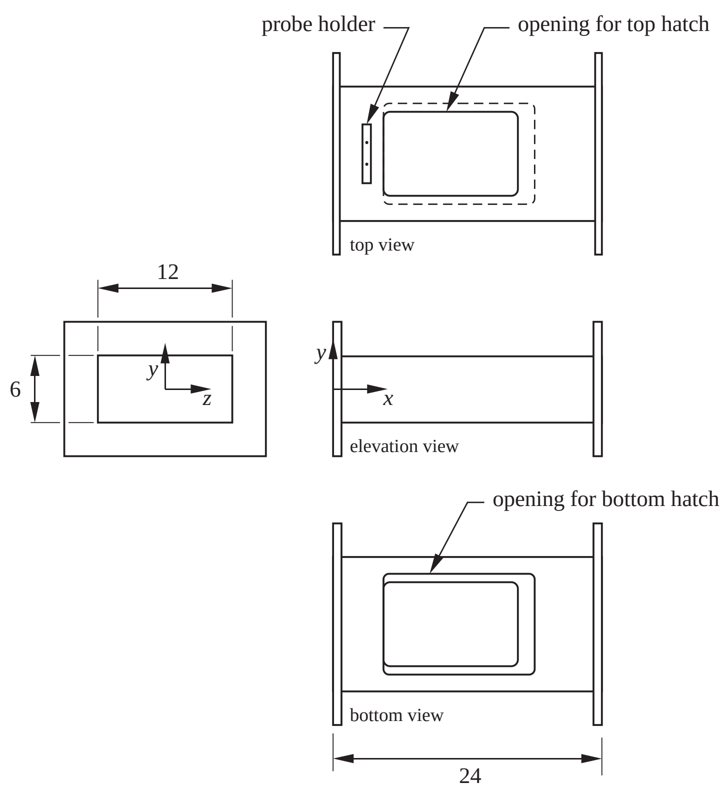

Figure 3: Different views of the test section. The top hatch has a plexiglass cover. The bottom hatch is made of plywood and is designed to hold the device under test. The diagram shows the wind tunnel with both hatches removed.

The normal orientation of the wind tunnel is shown in Figure 1. Air moves along the length of the horizontal test section. The shortest cross section dimension (6 inches) is normally in the vertical direction. To perform the velocity profile measurements, the wind tunnels are rotated on their side so that the bottom hatch opening is easily accessible. In this orientation, the shortest cross section dimension is horizontal. Figure 4 is a photograph of the wind tunnel with the curved inlet lying on its side. The bottom hatch is now on the side facing the viewer. The probe positioning assembly is located in the hatch.

The air speed in the wind tunnel is controlled with the damper upstream of the fan, and by adjusting the fan speed with the variac. Coarse adjustments to the air speed are made with the damper. Fine adjustments to the air speed are made with the variac.

The top hatch of the wind tunnel is made from 3/4 inch thick plexiglass. The bottom hatch is made with the same 3/4 inch plywood as the rest of the test section. The hatches are sealed with foam weather stripping that is inset into grooves in the outer surface of the test section. The hatches are held in place with toggle clamps.

The velocity sensor is a TSI Model 8350, hand held, thermal anemometer. The sensor is designed for making nominal air speed readings in HVAC ducts. The velocity sensor is mounted to a manually operated positioning system that is attached to a specially constructed bottom hatch. Knobs on the positioning system are used to move the sensor in the y-z plane at a fixed x position. The position of the probe is determined from manual readings of scales attached to the positioning assembly.

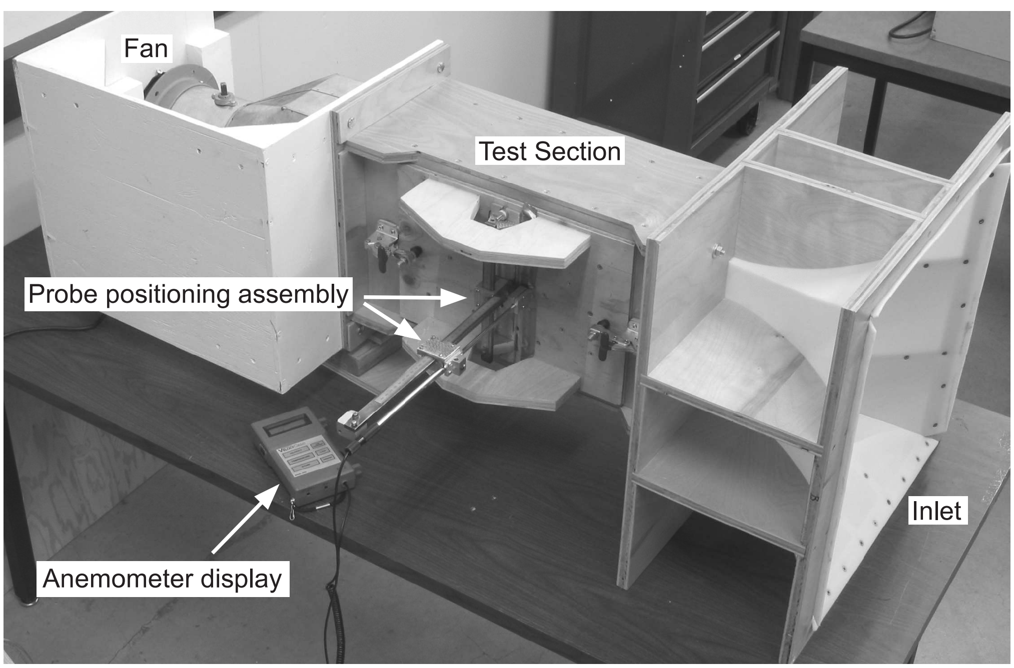

Figure 4: Front view of wind tunnel with curved inlet.

Table 1: Nominal velocity values for different lab groups

Velocity (ft/min)	Group Members
100	
150	
200	
250	
300	
350	
400	

3 Laboratory Experiments

Form groups of no more than two. Choose a nominal velocity Table 1.

3.1 Probe Comparison

Before performing the velocity profile measurements, obtain a rough indication of the accuracy of the velocity measurements. Insert both anemometers in the plastic probe holder in the top of the wind tunnel with the curved inlet. Locate the probes so that the sensor element is midway between the top and bottom walls of the wind tunnel. Make sure that both sensors are aligned with the red dot on the probe tip facing directly upstream. Make a series of velocity measurements over the full range of adjustment of the wind tunnel.

1. Plug the fan power cord directly into a wall outlet. Set the variac to 100 percent.
2. Set the flow rate through the wind tunnel by adjusting the damper. It is not necessary to adjust the velocity to give round integer values for the velocity.
3. Adjust the time constant of the anemometer until the reading is nominally constant. A shorter averaging interval allows the readings to be made more quickly. A longer averaging interval reduces the fluctuations in the readings.
4. Estimate the uncertainty in the velocity measurement for each anemometer by recording the magnitude of the velocity fluctuations. You should note any changes to this fluctuations during your experiment.
5. Record the velocity indicated by both anemometers
6. Adjust the damper to a new position and repeat the preceding step. *Use a random order of damper positions.* Do not make the measurements in order from low velocity to high velocity, or vice versa. Do not move the anemometers during this experiment.

3.2 Velocity Profile Measurement

Collect data for velocity profiles $u(y)$ at two z locations: $z = 0$, and either $z = -3$ inch or and $z = +3$ inch. At each z location make velocity measurements across the full range of y positions obtainable with the probe support. Take more closely-spaced readings where the velocity gradient is higher near the wall: one reading every 0.25 inch within 1.5 inch of each wall, and one reading every 0.5 inch in the center of the duct.

While you are making the velocity profile measurements, do not stand near the inlet of the wind tunnel.

1. Make a quick sketch of the measurement apparatus.
2. Record the model number and manufacturer of the instruments.
3. Record the ambient pressure and temperature in the lab
4. The bottom hatch of the wind tunnel can be oriented in one of two positions. Arrange the bottom hatch so that the velocity measurements will be taken *closer to the inlet* of the wind tunnel.
5. Record the time at the beginning of the velocity profile measurements
6. Move the anemometer to the center of the wind tunnel. Adjust the damper and the variac supplying power to the fan speed to get the desired nominal velocity. *Do not adjust the variac to less than 80 percent of full scale power!*
7. Adjust the averaging interval of the anemometer until the reading is nominally constant. A shorter averaging interval will allow the readings to be made more quickly. Record the position and air velocity.
8. Make a series of velocity measurements as a function of y, while holding z fixed. Before moving on to another z position, return to three randomly chosen y positions and repeat the velocity measurements. Do not check in advance what the readings "should" be.
9. Move the anemometer to two additional z positions and repeat the preceding step.
10. Before turning off the equipment, estimate the uncertainties in the position and velocity measurements.
11. Record the time at the end of the velocity profile measurements.

Repeat your measurements for the same nominal speed for two wind tunnels: one with the round inlet and one with the square inlet.

4 Report

1. For the anemometer repeatability data, plot the velocity reading of one anemometer on the x axis, and the velocity reading of the other anemometer on the y axis. Add a straight line with slope of one to the plot. Create a second plot with the velocity reading of one anemometer on the x axis, and the difference between the two anemometer readings on the y axis. Comment on the agreement between the two anemometers. How does the magnitude of the disagreement compare the uncertainty of the velocity measurements?

2. Create two plots of the velocity profile data: one for each inlet design. Put velocity on the horizontal axis and y on the vertical axis. For each inlet, put the velocity profiles for the three z locations on the same plot. The result should be similar to those in Figure 5.

3. Create a plot to compare the centerline velocity profiles for the different inlets. The result should be similar to Figure 6.

4. Briefly discuss the following features of the velocity profiles

   - Uniformity and symmetry relative to the centerline.
   - Importance (effect) of inlet on uniformity of the velocity profile.
   - Anomalous features (if any).

5. Rank the inlets according to their ability to provide a uniform flow in the test section. Which inlet design (including no inlet) do you recommend?

6. How would you propose to experimentally determine whether the flow is fully developed?

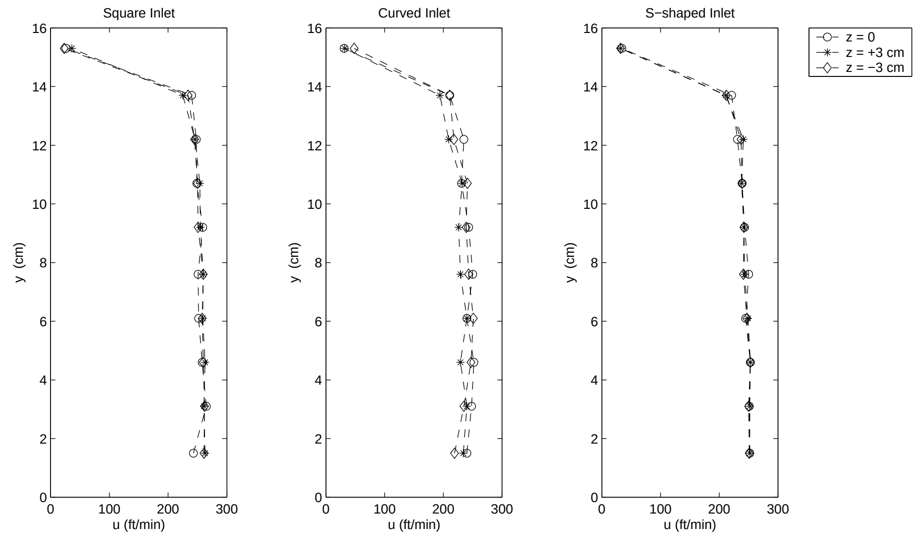

Figure 5: Comparison of velocity profiles at different z locations for $V_{\mathrm{nom}} = 250\,\mathrm{ft/min}$

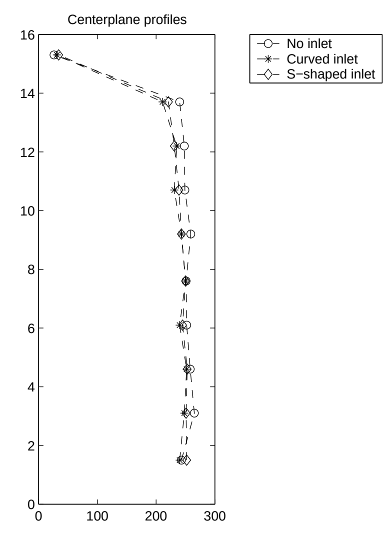

Figure 6: Comparison of velocity profiles on the center plane of the three wind tunnels for $V_{\mathrm{nom}} = 250\,\mathrm{ft/min}$.