ME 4/549 Lab Assignment 3
Spring 2003 due 4 May 2006

1 Overview

The purpose of this lab exercise is to learn how to measure a fan curve with a flow bench.

1.1 Apparatus

Figure 1 is a schematic diagram of a flow bench in the thermal lab. The thermal lab has two flow benches, one large and one small. Both flow benches have the same operating principle and use similar instrumentation. To keep the presentation simple, a generic flow bench design will be described here.

In Figure 1 the *Device Under Test* (DUT) can either be a fan, in which case the purpose of the experiment is to obtain the fan curve. The DUT can also be a passive system such as an enclosure for electronics, or vent material such as a perforated plate. If the DUT is passive, then the purpose of the experiment is to obtain the system curve and loss coefficient.

Figure 2 is a block diagram of the instrumentation for the flow bench. The sensors consist of two differential pressure transducers, thermocouples connected to a zone box, and a thermistor to measure the zone box temperature. The sensor wires are routed to a connector block, which connects the signal lines to an Agilent 34970A digital multimeter (DMM) and switch unit. The diagram in Figure 2 also shows a computer to store data acquired by the DMM/Switch. The computer is not used in the current experiment so that you can get acquainted with the basic operation of the flow bench and its instrumentation. In next week's lab you will repeat the experiments using the data acquisition system to store the sensor outputs.

The output of the pressure transducers is linearized so that *nominally*

$$\frac{\delta p - \delta p_{\min}}{\delta p_{\max} - \delta p_{\min}} = \frac{V_{\text{out}} - V_{\min}}{V_{\max} - V_{\min}} \tag{1}$$

where δp is the pressure *differential* across the ports. The output range of the transducers is fixed at $V_{\min} = 1\,\text{V}$ and $V_{\max} = 5\,\text{V}$. Thus, *a quick estimate* of the measured pressure is

$$\delta p = \delta p_{\min} + \frac{1}{4}(\delta p_{\max} - \delta p_{\min})(V_{\text{out}} - 1) \tag{2}$$

Slightly more accurate calibration equations for the pressure transducers are given in the Appendix on page 5. MATLAB programs to evaluate the curve fits are available at `www.me.pdx.edu/~gerry/class/ME449/labs/`. For final data reduction you can use either the curve fits to the calibration data, or the simple scaling in Equation (2).

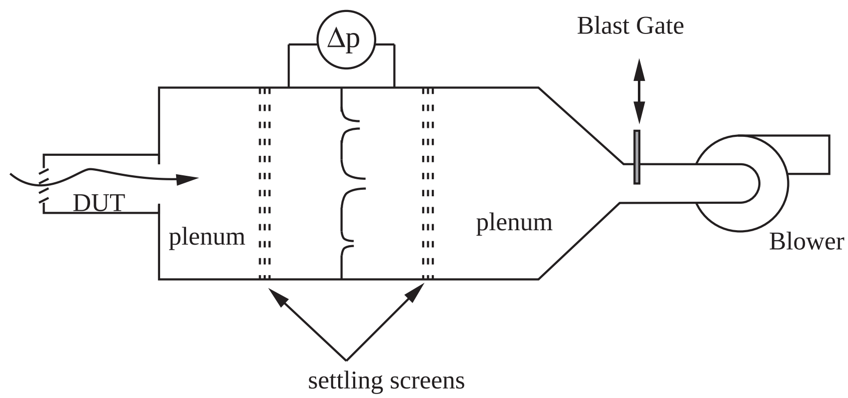

Figure 1: Flow bench schematic

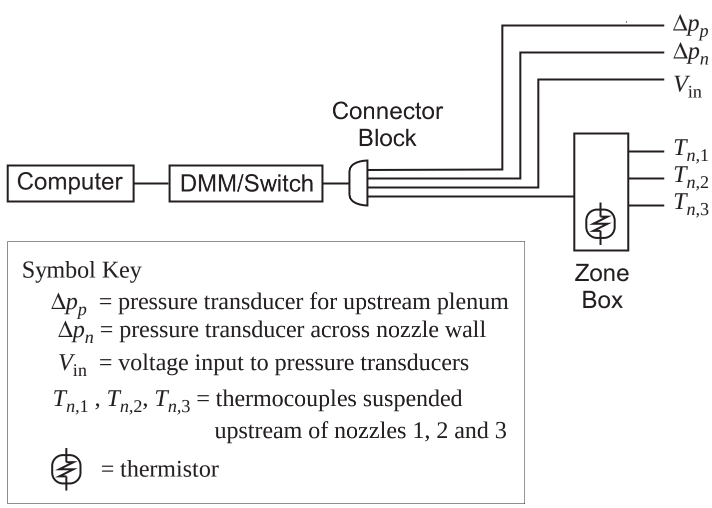

Figure 2: Block diagram for flow bench instrumentation

1.2 Prepare for Measurements

1. Use calipers to measure the inside diameter of the nozzles in the flow bench. Measure at the downstream end of each nozzle. Repeat the measurement at least three times, each time at different angular positions relative to the horizontal.

2. Make a sketch of the connections between the pressure taps, manometers, and pressure transducers.

3. Record the model numbers of the instrumentation used in the flow bench laboratory.

2 Fan curve as function of supply voltage

The speed of a DC motor can be controlled by adjusting the supply voltage: higher voltage results in higher speed. The goal of the experiment is to measure the fan curve of a DC fan running at a fixed supply voltage. Each group will obtain a single fan curve at a specified voltage. By sharing data, groups will be able to determine the effect of fan speed (or supplied voltage) on the fan curve.

2.1 Set-Up

1. Secure the fan to the inlet of the flow bench. The fan should be mounted on a press-board plate with a hole that just fits the fan diameter. The press-board plate is attached to the inlet of the flow bench with duct tape. Make sure there are no leaks around the edge of the fan, or around the edge of the press-board mounting plate.

2. Select the proper pressure input to the transducer that measures the difference in pressure between the first plenum and the ambient. For the fan curve measurement, connect the plenum pressure to the *high side* of the pressure transducer. Do not disconnect the tubing. Rather, slide the selector to the appropriate position "A" or "B".

3. Turn on the DMM/Switch and power supply for pressure transducers. Adjust the power supply so that it produces 15 Volts DC. Using the rotary knob on the front of the DMM, verify that the output of the pressure transducers is close to 1 Volt when the DUT fan and the flow bench fan are both off.

4. Attach the power leads of the fan to a DC power supply. This is *not* the power supply used to provide excitation to the pressure transducers. Turn on the supply and adjust the voltage to an appropriate value for the fan. Do not select a voltage less than 60 percent of the nominal voltage for the fan. Maintain the same supply voltage to the fan for the duration of the fan curve measurements described in § 2.2.

2.2 Data Collection

A sample data sheet is provided in the appendix of this assignment.

1. Record the time at the beginning of the flow rate measurements

2. Record the ambient pressure from the barometer near the front door of the lab.

3. Open the side door of the flow bench and select a nozzle. Remove the plug for that nozzle and make sure the other nozzle plugs are secure. Record the nozzle diameter. Close the hatch.

4. Record the resistance of the thermistor in the zone box. Write down three to five readings from the DMM display, then use the average of those readings in the data reduction.

5. Adjust blast gate to a low flow (not off) positions.

6. Record the nominal voltage supplied to the fan.

7. Turn on the blower of the flow bench.

8. Monitor the pressure differential across the flow nozzle, and the pressure differential between the ambient and the upstream plenum. When these values have stabilized record:

   a. Δp between the ambient and the upstream plenum as indicated by the inclined manometer.
   b. Δp across the nozzle indicated by the Dwyer gage.
   c. Voltage output of the pressure transducer attached to the upstream plenum.
   d. Voltage output of the pressure transducer across the nozzle.
   e. EMF of the thermocouple upstream of the active nozzle.

9. Adjust the blast gate to a new position and return to step 8. Make readings across the full range of nozzle pressure differentials for the fan. Be sure to include the no-flow condition for the fan (blower turned off, maximum plenum pressure drop) and the free air condition (flow rate adjusted so that plenum pressure differential is zero).

   Note: Do not overpower the fan with the flow bench nozzle. It is easy to open the blast gate far enough that the flow rate (caused by the flow bench blower) exceeds the free air capacity of the fan under test. This condition will occur when the upstream plenum pressure drops below ambient. To avoid this condition make sure that the transducer for the upstream plenum has an output greater than or equal to 1 Volt.

10. For each of the preceding measurements, estimate and record the magnitude of any fluctuations in the signals.

11. Record the resistance of the thermistor in the zone box. Write down three to five readings from the DMM display, then use the average of those readings in the data reduction.

12. Record the time at the end of the flow rate measurements.

Turn off the blower and return to step 3 to select another nozzle. Choose nozzles so that pressure rises for the entire range of fan flow rates is covered. A total of 10 to 20 data points per fan curve is sufficient. Again, be sure to cover the entire range of fan operation, from $\Delta p = 0$ to $Q = 0$.

2.3 Share data with other groups

After completing the experiment, enter your data into the `fanCurveData.xls` spreadsheet at `http://www.me.pdx.edu/~gerry/class/ME449/data/` and send it to me (Gerry) via email.

3 Fan Curve Report

1. Convert your raw data to pressure drop and flow rate. Plot the $\Delta p = f(Q)$ data and obtain a polynomial least squares fit to the fan curve. Report the degree of the fit and the coefficients of the fit.

2. From the class web site, download at least one additional data set for the fan you measured. Reduce the raw data and add it to the plot of the fan curve created in step 1.

3. Find the manufacturer's fan curve data. Create a plot of $\Delta p = f(Q)$ that contains your measured data, the data from the other group, and the manufacturer's data.

4. Compare the fan curves for different supply voltage. Does the fan output increase decrease with supply voltage? Briefly discuss any interesting features of the fan curves. Do the class measurements agree with the manufacturer's data?

Table 1: Coefficients in the calibration equation for pressure transducers.

Range inch H_2O	Model and Serial Number	c_1 (inch H_2O/V)	c_2 (inch H_2O)
0–0.5	PX653-0.5D5V 10523258	0.125039641376784	−0.124734996011382
±2.5	PX653-2.5BD5V 00204071	1.25083247439622	−3.75388723704910
0–3	PX653-03D5V 01212460	0.750664358028092	−0.753430174833871
0–10	PX653-10D5V 00100382	2.50600948477838	−2.51613612227667

Appendix

Pressure Transducer Calibration

The pressure transducers in the thermal lab have linearized output. The calibration data supplied by the manufacturers is used to obtain curve fits of the form

$$\delta p = c_1 V + c_2. \tag{3}$$

Table 1 gives the calibration coefficients for the transducers in the lab.

Blank Data Sheet

The blank data sheet in Table 2 on the next page is provided to stimulate your thinking about what to record and how to record it. You should create your own version of this table in your notebook.

Table 2: Data recorded manually during flow bench experiment.

Start time: ______________

Stop time: ______________

Thermistor reading at start: ______________

Thermistor reading at stop: ______________

Ambient Pressure: ______________

Reading	Nozzle Diameter (inch)	Plenum Manometer (inch H_2O)	Nozzle Δp Gage (inch H_2O)	Plenum Δp Transducer (V)	Nozzle Δp Transducer (V)	Nozzle T-couple (mV)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
⋮						
Unsteadiness estimate						