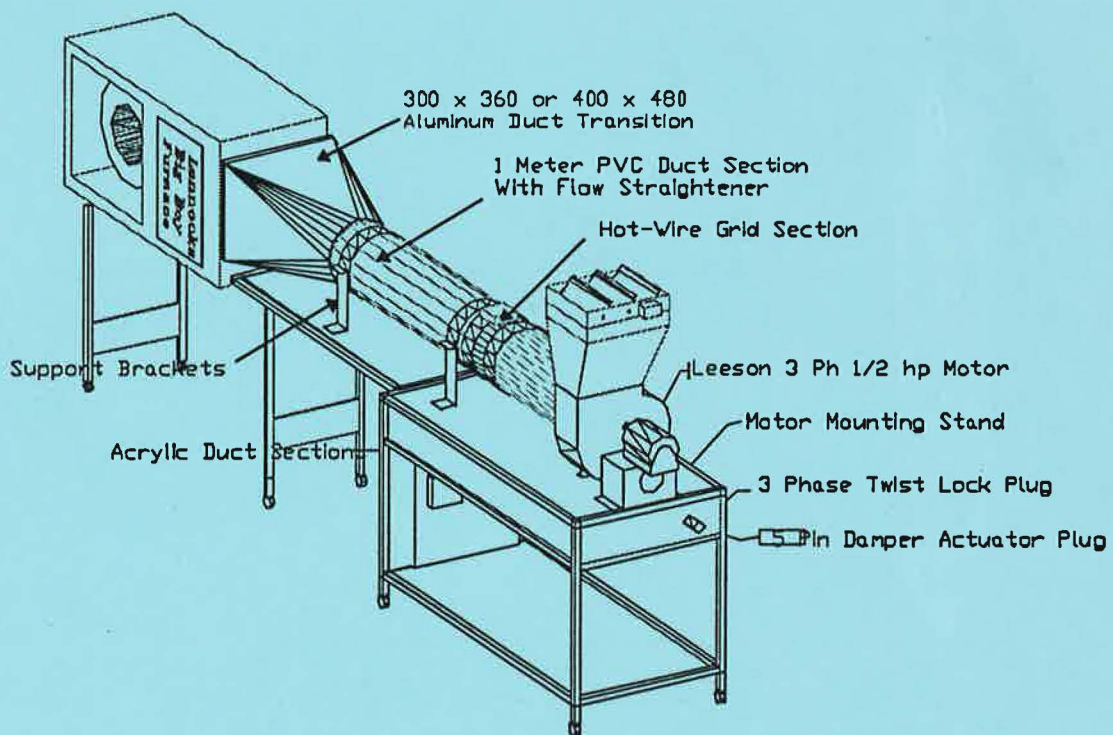


Appendix II

FANalyzer Version 1.0 Operation & Maintenance Manual



April, 96

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Table of Contents

1. OVERVIEW	1
1.1 INTRODUCTION TO THE ULTIMATE HVAC PERFORMANCE TESTING TOOL.....	1
1.2 ORGANIZATION OF THIS MANUAL.....	1
2. COMPUTER AND SOFTWARE CONFIGURATION	2
2.1 GENERAL HARDWARE AND SOFTWARE REQUIREMENTS.....	2
2.2 DAQ AND LABVIEW INSTALLATION.....	3
2.2.1 <i>Data Acquisition Card Installation and Installation of SCB68 Connector board</i>	3
2.3 SOFTWARE INSTALLATION.....	3
2.3.1 <i>Installing LabVIEW Version 3.1 & NIDAQ Board Configuration Utility</i>	3
2.3.2 <i>Installing the FANalyzer LabVIEW Virtual Instruments</i>	4
2.4 USE OF VIRTUAL INSTRUMENTS.....	6
2.5 USE OF EXCEL TEST DATA SPREADSHEETS.....	6
3. FAN FANALYZER COMPONENT DESCRIPTIONS & ASSEMBLY	7
3.1 TEST BENCH PANEL AND INSTRUMENTATION BOX.....	7
3.2 COMPONENT DRAWER.....	7
3.3 ASSEMBLY OF WIND TUNNEL AND FITTINGS.....	8
3.3.1 <i>Control Damper</i>	8
3.3.2 <i>Variable Speed Blower</i>	9
3.3.3 <i>Flow Measuring Duct Assembly</i>	11
3.4 FANALYZER EXTERNAL SENSORS & DEVICES.....	11
3.4.1 <i>Temperature Sensors</i>	11
3.4.2 <i>Tachometer</i>	13
3.4.3 <i>Load Cell</i>	15
3.4.4 <i>Power Outlet</i>	15
3.4.5 <i>Hot-Wire Grid</i>	16
3.5 FANALYZER INTERNAL DEVICES.....	19
3.5.1 <i>Pressure Measurement System</i>	19
3.5.2 <i>Power Measurement System</i>	20
3.5.3 <i>Instrumentation & Meter Box</i>	20
3.6 ASSEMBLY OF MOTOR TORQUE MEASUREMENT SYSTEM.....	22
3.6.1 <i>Sub Components</i>	22
3.6.2 <i>Assembly</i>	22
3.6.3 <i>Installation of Load Cell</i>	24
3.6.4 <i>Motor Wiring Installation</i>	24
4. TEST ROUTINES	25
4.1 MOTOR EFFICIENCY TEST (CSA C747).....	25
4.1.1 <i>General Procedure</i>	25
4.1.2 <i>Test Configuration</i>	25
4.1.3 <i>Running the Single Point Test</i>	26
4.1.4 <i>Running the Multi Point Test</i>	27
4.1.5 <i>Obtaining "No Load" Values</i>	28
4.2 MODIFIED AMCA 210-85 FAN EFFICIENCY TEST: TYPE B, FREE INLET, DUCTED OUTLET.....	28
4.2.1 <i>Use of Motor Test Results</i>	28
4.2.2 <i>General Procedure</i>	28
4.2.3 <i>Present Limitations of Multi Point Fan Test</i>	29
5. SAMPLE TEST DATA	35
5.1 FAN PERFORMANCE TEST REPORT.....	35
5.2 ELECTRIC MOTOR TEST REPORT.....	36

6. GENERAL SPECIFICATIONS..... 37

Table of Figures

Figure 1 Simplified vi Hierarchy of Library and Sub vi's 4
Figure 2 Control Damper, Actuator, and Transition 8
Figure 3 Control Damper & Blower Profile 8
Figure 4 Automatic Control Damper vi Front Panel 9
Figure 5 Fan Test Key Components 10
Figure 6 Rigid Coupling with Keyway for 5/8 in Shaft 10
Figure 7 Installing Collar to Blower Assembly 11
Figure 8 Temperature vi Front Panel 12
Figure 9 Test Bench Front Panel 12
Figure 10 Tachometer Components 13
Figure 11 Tachometer vi Front Panel 14
Figure 12 Power Switch Front Panel 15
Figure 13 Hot Wire Grid Configuration 16
Figure 14 Fan Test Assembly Schematic Showing Main Components 16
Figure 15 Hot Wire Grid Calibration Curve & Equation for High Flows 17
Figure 16 Air Flow Meter vi Front Panel 18
Figure 17 Pressure Gauge vi Front Panel 19
Figure 18 Pressure Plug Locations 19
Figure 19 Motor Test Cradle Dynamometer 22
Figure 20 Torque Cradle Coupled to Control Blower 25
Figure 21 Front Panel of Single Point Motor Test.vi 26
Figure 22 FANalyzer Set-up with Typical Furnace 30
Figure 23 Multi Point Fan Test vi Front Panel 31
Figure 24 Sensor PC Board Layout 34

List of Tables

Table 1 LabVIEW Virtual Instrument Descriptions and Quick Reference 5
Table 2 Blower and Speed Drive Specifications 9
Table 3 MAMAC Pressure Gauge Range and Accuracy 20
Table 4 *Instrumentation Box Contents* 20
Table 5 Motor Loading Impeller Selection 26
Table 6 FANalyzer Wiring & Cable Table 32
Table 7 SCB 68 Connector Board Channel Table 33
Table 8 Wiring Terminal Block Description for FANalyzer PC Board 34
Table 9 General Specifications 38

1. Overview

1.1 Introduction to the Ultimate HVAC Performance Testing Tool

The FANalyzer is a performance testing device with many potential applications and users. Its primary purpose is to facilitate fast, accurate and automated testing of motor efficiencies and fan efficiencies. Outputs are graphically illustrated on standardized reporting forms. The forms permit analysis of all key variables, including speed, pressure, flow, torque, power, temperature, voltage and power factor.

Once familiar with the basic efficiency tests, users can also use the FANalyzer for single point testing of any performance factor. A variety of virtual instruments (computer graphics that function just like an instrument panel) have been developed for this purpose. For example, the user might wish to determine the best efficiency point for a fan, or motor, or develop a motor performance curve and then analyze the combined motor and fan set.

It is also possible to analyze the interrelationship between all the key variables, including speed, pressure, flow, torque, temperature, voltage and power factors. These factors sometimes interact in surprising ways, and provide insight into techniques for modifying and optimizing designs.

The FANalyzer can be used by an instructor at a technical college, or ventilation appliance manufacturer, or perhaps a researcher investigating HVAC systems. Custom applications can be developed with relative ease.

1.2 Organization of this Manual

This manual is intended to give the user a general operating knowledge of FANalyzer components and familiarity with its operation. This will be done using the most commonly used fan testing configurations such as the Type A, Ducted Inlet/Free Outlet and the Type B, Free Inlet/ Ducted Outlet.

Sections 2 will attempt to illustrate the main components of the FANalyzer and their functions. Each component description will be accompanied by any relevant drawings, LabVIEW virtual instruments, and references to equipment specifications and necessary calculations.

Section 3 will describe configurations for three of the most common tests including, Inlet Chamber Fan Efficiency, Outlet Chamber Fan Efficiency, and Motor Efficiency. In some cases, motor efficiency can be combined with fan efficiency testing where possible. This case has been accommodated for in a combined configuration which will be discussed briefly in this section.

Section 4 describes Computer and DAQ hardware configuration. Basic set up and description of components is provided but this section is not meant as a programming manual. Explanations will be given for LabVIEW virtual instruments provided for use with the FANalyzer only. FANalyzer users with more general interest in the use of LabVIEW or who wish to experiment with new Test vi's, may obtain users manuals from National Instruments or contact Sheltair to discuss custom programming needs.

2. Computer and Software Configuration

2.1 General Hardware and Software Requirements

The computer system requirements specified here are the minimum required for adequate processing speed. Development has been performed using a Pentium 90 MHz PC with 16 MB Ram and a 17" colour monitor. As most computer users already know, processing speed can never be too high, just too expensive in most cases. The hardware for the system outlined below can be acquired for a cost of about \$2,500 Cdn.

Minimum PC Hardware Requirements

- IBM Compatible PC 486 DX2 66 with 8 MB Ram, (however, a Pentium 100 with 16 MB RAM is recommended);
- 200 MB Available Hard Drive Space;
- 15" Super VGA Colour Monitor;
- 2 button serial mouse;
- ISA slot for DAQ Card;
- Ink Jet or Laser Printer of your choice;

Provided Data Acquisition Hardware

- National Instruments ATMIO16E DAQ Card & External SCB68 Connector Board

Software Requirements

- MS Windows 3.1 or Windows 95;
- Microsoft Excel Version 5.0 or 7.0 for Windows 95;
- LabVIEW Base Package Version 3.1 (Provided);
- MS Word for Windows version 6.0 or 7.0 for Windows 95

Electrical System Requirements

Any 115 VAC, properly grounded electrical service will satisfy the FANalyzer needs. The Computer system should be connected to a plug which is on a separate circuit to the FANalyzer.

The FANalyzer will draw about 12 to 14 Amps when operating on its own with a typical 1/2 hp test motor and the FANalyzer variable speed fan operating at full load. The FANalyzer has a 15 Amp HRC Fuse installed in the main supply (with a spare) which probably blow before the breaker does. Fifteen amps is equivalent to 1.5 kW of output power at 85% Power Factor.

Computer Stand

A computer stand has not been provided with the FANalyzer. The addition of a monitor extension arm and a keyboard tray wide enough to hold a mouse at keyboard level is encouraged. During the development of the system it was found that the most convenient method was to place the PC central processor (if in a "Tower" type case) under the FANalyzer bench. Though ample space exists on the test bench surface for a keyboard and mouse, a separate computer stand would be an asset.

2.2 DAQ and LabVIEW Installation

2.2.1 Data Acquisition Card Installation and Installation of SCB68 Connector board

Installation of the AT MIO-16E10 DAQ card from National Instruments is similar to the installation of any other peripheral card such as a modem or video card. It must be in your computer. A simple procedure would be as follows:

1. Installation of the ATMIOE10 DAQ Card

- a) Turn off your PC and remove the outer case to access the mother board;
- b) Remove any static charge from hands by touching any metal or other conductive surface;
- c) Remove the DAQ board from protective bubble wrap;
- d) Install the DAQ Card in an available ISA slot. You will recognize the ISA slot as it will be the only one that will accept the DAQ card's male pin connection block. Make sure that the card is pressed firmly to the bottom of the slot and that the connector block is not shifted over by one pin. The card should rest fully in the socket so that the fastening screw at the top outer corner of the board aligns well with its threaded receptacle;
- e) Fasten board with screw (you probably had to remove a protection cover to get at the extra slot in your PC and now have an extra screw)
- f) Replace the cover on the PC and boot up.

2. Connecting the DAQ Board to the SCB-68 Connector Box

- a) Using the R6868 68-pin flat ribbon cable, plug in the DAQ board from your PC to the SCB-68 connector box on the FANalyzer, located in the bracket behind the instrumentation box. When connecting to the PC board or to the connector box, be very cautious when inserting so that pins are kept straight. If you have difficulty inserting the cable remove and inspect pins and straighten if required.

2.3 Software Installation

2.3.1 Installing LabVIEW Version 3.1 & NIDAQ Board Configuration Utility

The LabVIEW 3.1 for Windows Base Package consists of 16 diskettes. As per instructions in the manuals provided, load the LabVIEW software onto your root hard drive. The installation will require about 40 MB of disk space. Also provided is the NI-DAQ Version 4.81 software. The NI-DAQ software is not needed to run LabVIEW and is included for those users who intend to operate the DAQ board without LabVIEW. If required, insert the setup disk for the NI-DAQ software and follow instructions for installation.

Once you have completed the installation of LabVIEW, and the DAQ board as outlined in Section 2.2, you are ready to configure the data acquisition system. Follow the general procedure below:

1. From your Windows Program Manager (or Start menu in Windows 95) select the LabVIEW Program Group and run the NI-DAQ Configuration Utility (WDAQCONF.exe). If Windows has not created the Program Group, then RUN the WDAQCONF.exe file which should be located in the directory in which NI-DAQ was installed (c:\nidaqwin).
2. Set up the DAQ Board with NI-DAQ

- a) When the configuration window appears you should see a list of devices, most of which should be blank. If Device 1 in the list reads ATMIO-16E10, then the device has correctly installed itself; or
- b) If the slider menu shows Device 1 blank, then choose the "Configure/Test Device #1" button on the left of the dialog screen. Follow the procedures in the next dialog to install the board as Device # 1. **MAKE SURE THAT THE ATMIO-16E10 BOARD IS INSTALLED AS DEVICE #1.** This will save lots of headaches later trying to reassign vi's to different Device numbers.

2.3.2 Installing the FANalyzer LabVIEW Virtual Instruments

The FANalyzer requires several virtual instruments to operate the sensors and controls. As shown in Figure 1, there are many levels of vi hierarchy that can be used to store and organized vi's. These lower level LABVIEW vi's have been provided on separate disks as 1) fan-eff.lib and 2)Mtr-eff.lib. The first vi library is for the Fan Efficiency Test and the second is for the Motor Efficiency Test routines.

The files in this set have been compressed using pkzip version 2.04. The extraction of these file requires either PKUNZIP.exe, UNZIP.exe, or Winzip95 or Winzip for Windows 3.1. Instructions for using the UNZIP programs are included with the programs.

Table 1 below gives a list of the FANalyzer vi's and provides a brief description.

LabVIEW vi Simplified Hierarchy (Version 3.1)

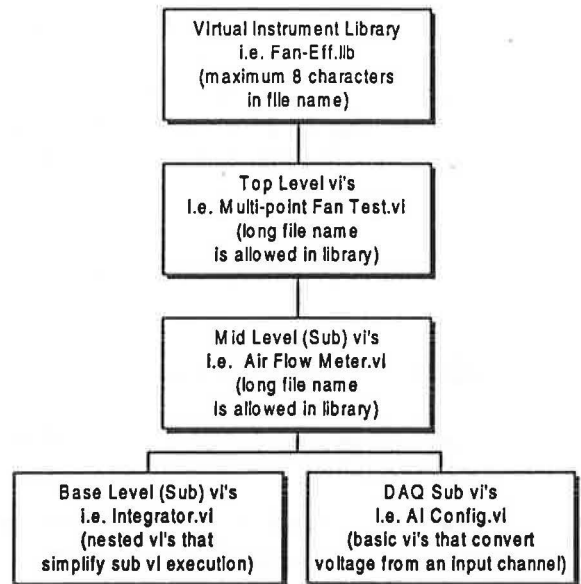


Figure 1 Simplified vi Hierarchy of Library and Sub vi's

Table 1 LabVIEW Virtual Instrument Descriptions and Quick Reference

File Name	Description
VI LIBRARY FILES	
MTR_EFF.LLB	Independent Library file containing all vi's needed for running the Multi-Point Motor Test. Library also includes other independent files. Any vi's in this file can be invoked individually
FAN_EFF.LLB	Independent Library file containing all vi's needed for running the Multi-Point Fan Test. Library also includes other files such as PVI Waveforms.vi. Any vi's in this file can be invoked individually.
VI'S USED ONLY FOR FAN EFFICIENCY TEST	
Multi Point Fan Test.VI	Multi-Point Fan Efficiency Test is the Main VI that is used for performing an automated fan efficiency test. Output is used in combination with Excel test form.
Pressure Gauge 250 Pa.VI	MAMAC Pressure Transducer . Coincides with Static Pressure 1 on FANalyzer Bench. Set at <i>range 0-250 Pa (0 - 1.0 in wc)</i> .
Pressure Gauge 125 Pa.VI	MAMAC Pressure Transducer . Coincides with Static Pressure 2 on FANalyzer Bench. Set at <i>range 0-125 Pa (0 - 0.5 in wc)</i> .
Air Flow Meter.VI	Measures air flow using the Hot Wire Grid. VI is auto-ranging for flows from 20 to 150 cfm and 150 to 1200 cfm.
Control-Fan Speed.VI	Controls the Fan Speed for the 3 phase control fan, used to obtain a zero pressure drop in the wind tunnel component of the Test Rig.
TEMP-3	Temperature Sensor 3 used to reads temperature from Temp 3 on FANalyzer bench. Usually used for air stream temperature.
VI'S USED ONLY FOR FAN MOTOR EFFICIENCY TEST	
MTR-TST1	Multi-Point Motor Efficiency Test used for running the multi-point motor test.
Test Fan Power Switch.VI	Power switch to energize electrical outlet on test bench and energize the fan for testing.
FT70-10C	Running Torque Meter used to measure torque during multi-point motor test
Single Point Motor Test	Single Point Motor Test is a manual version of the multi-point motor test that includes a calibration routine and a single point save feature. Requires (virtually) manual control of damper and application of power to test the motor.
FT70-10F	Calibration Torque Meter used at the beginning of the multi-point motor test to calibrate the torque cradle before each test.
COMMON VI'S FOUND IN BOTH FAN AND MOTOR EFFICIENCY TEST	
PVI_CHTS	Waveform Power Meter used to view power, voltage, and current waveforms in (virtually) real time. Auto-ranging from 1 to 800 watts.
PVI_RMSS	Digital Power Meter used to read power, current, voltage, power factor, and volt-amperes in (virtually) real time. This Sub-vi is used in the fan and motor test vi's in lieu of the Waveform Power Meter.
Tachometer.VI	Tachometer is used to measure motor or fan speed when the tachometer is physically mounted in the appropriate locations.
KM24-SR	Used for Control of Damper Operation. Named KM24-SR because of the model of the Damper Actuator used.
TEMP-1	Temperature Sensor 1 used to reads temperature from Temp 1 on FANalyzer bench. Usually used for ambient air temperature.
TEMP-2	Temperature Sensor 2 used to reads temperature from Temp 2 on FANalyzer bench. Usually used for motor casing temperature.
INTEGRATOR.VI	Used to establish a time delay between automatic damper control corrections.

2.4 Use of Virtual Instruments

The use of the LabVIEW vi's is explained throughout the manual for each of the devices and tests that will be performed with the FANalyzer. The objective is that the operator will mainly just "Point and Click" to start the test once the input parameters have been defined. As a guide, the list below points out some of the key LabVIEW operation procedures that the operator should become familiar with:

1. General run/stop and continuous run mode operation;
2. Adjustment of chart and indicator scales;
3. Mouse operation of Control knobs and dials; and,
4. Mouse operation of slider controls.

These basic methods can be found in the LabVIEW Users Manual provided.

2.5 Use of Excel Test Data Spreadsheets

The Fanalyzer software includes some Microsoft Excel 5.0 (7.0 for Win 95) Spreadsheet applications. These are essentially automated test data forms that open a LabVIEW generated text file from each test and graphically present the data for output to the screen or to a printer.

The LabVIEW files are stored in "tab separated" ASCII test format which can be easily manipulated by Excel into a usable spreadsheet format. An Excel macro has been provided that contains subroutines for loading these text files into the automated spreadsheet forms. A procedure for setting up your Excel program to perform the data loading is detailed below.

Copying the Fan and Motor Test Forms onto Your Hard Drive

In order to ensure that the Test Form Templates are available to Excel, these files must be copied to the appropriate location.

1. If you do not have MSOffice loaded on your PC, create the directories
C:\Msoffice\Templates\;
2. Copy the files "Fan-Test.xlt" and Mtr-test.xlt to this directory.

Loading the Excel Module into the Personal Macrosheet

1. Load Excel on your machine and place the FANalyzer Disk1 into the A: drive.
2. From the Excel file menu choose Open and select the file A:\odsheets.xls and hit Enter;
3. Once the file has loaded choose Macro from the Excel Tools Menu and from the Macro Dialog Box select the macro named "Loadsheets" from the given selection and then click on the Run button;

At this point the Macro will run and will perform the operations of opening your Personal.xls macrosheet, which is normally hidden in your root Excel directory, and copying the sheets named Testdata1 and Testdata2 from the file a:\Testdata.xls into the Personal Macrosheet, and then Loadsheets will append some menu commands to your Excel Tools menu.

Loading Test Data into Excel from the LabVIEW Test Files

Once you have run a test and are ready to load a text file into a Test Form for viewing and printing you can do the following:

1. From the Excel Tools Menu choose the command "Load Fan Test Form" or "Load Motor Test Form";
2. An Input Dialog box will appear from which a default file name "c:\labview\fan-001.txt" or "c:\labview\mtr-001.txt" will be selected. Using the mouse click on the filename and type in the name of the text file you wish to load. **TRY NOT TO MIX FAN TEST WITH MOTOR TEST FILES** or the data will not fit the form.

Using the Excel Test Spreadsheet Forms

Once the Forms are loaded the user will note the following features that are available to both the *Fan Test* and *Motor Test*:

- A chart that shows several typical test parameters on a Specific Unit scale based upon % of Rated values;
- Spinner Controls that allow fast conversion from Imperial to Metric Units;
- Automatic interpolation of Efficiency values at Rated, 75%, and Peak Flow/Power;
- Print Button to allow fast print out of Test form.

When the data loading is complete, the cell pointer will be located in the first input box titled "Fan Manufacturer". Fill in the information in the sheet and select the desired reporting units of measure. *Make sure that all "changeable" fields have been updated.* Do not change any of the fields that have formulae entered in them. These cells/fields reference other data in the sheet.

3. Fan FANalyzer Component Descriptions & Assembly

3.1 Test Bench Panel and Instrumentation Box

Though the Test Bench looks like just that, a bench on wheels, it is essentially the working structure that is used to do the following:

- distribute power to all sensors and working components
- provide a working surface for wind tunnel and torque table testing
- provide storage area for all components when they are not in use.

3.2 Component Drawer

A compartmentalized component drawer has been installed in the main section of the Test Bench. Though the user will ultimately decide what will go where in the drawer, the drawer has been shipped with the following contents:

1. Parts box containing Thumbscrews, couplings, bushings, crocodile clips, and misc. fasteners;
2. Temperature sensors assemblies (3);
3. Tachometer assembly;
4. Load cell assembly;

5. 3 m power cord;
6. Pressure tubing and Static Pressure probes;

The drawer is tightly fitted and should not require a latch. However, care should be taken when transporting the rig, not to damage the drawer or its contents.

3.3 Assembly of Wind Tunnel and Fittings

3.3.1 Control Damper

The control damper is provided with a transition piece as shown in

Figure 2. The *control damper* is fabricated from stainless steel and is foam stripped to provide a relatively good seal. The *transition piece* is aluminum and is built to allow the damper to slide into place with the damper hardware facing down towards the inside of the blower. A *removable slide plate* is provided with the transition piece so that once the damper is fitted in place, the slide plate must be fastened with the screws provided to seal the damper and transition assembly.

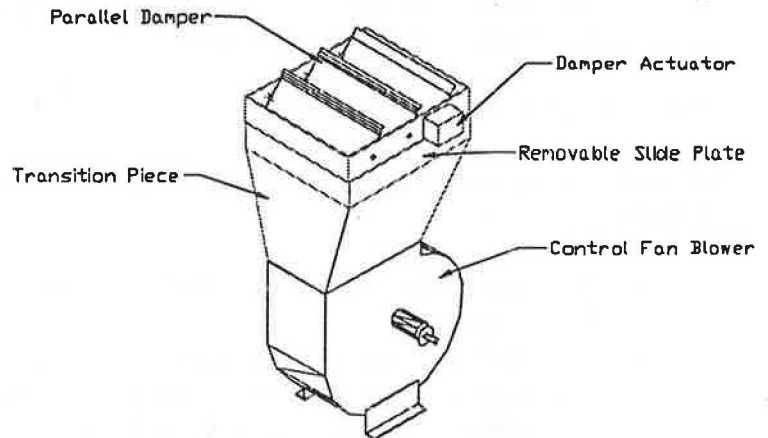


Figure 2 Control Damper, Actuator, and Transition

The procedure below should be followed when the damper is installed to ensure that the damper will swing from the fully open to fully closed position (0 to 90 degrees):

1. Install damper on transition piece as shown in Figure 2;
2. Place the transition and damper assembly on the control fan blower in the clips provided with the vertical face of the blower aligned with the vertical face of the transition as shown in Figure 3;
3. Plug the damper actuator into the 5 pin connector plug on the test bench and lock into place;
4. If damper is not in the fully open position (approximately perpendicular to table) then manually turn the damper blades until they are at full open (The damper can, and probably will, be manually adjusted to allow for more convenient storage). This is the default position at 0 Vdc (normally open);
5. Apply power to the FANalyzer and load the KM24-SR.vi program in LabVIEW;
6. Adjust the Control knob to the 85 degree position (nearly closed) and watch the damper movement. The damper should shut to nearly closed;
7. Adjust the damper manually until it has settled in a nearly closed position (5 degrees open);
8. Using the KM24-SR vi adjust the knob to 90 degrees and the damper should shut tightly.

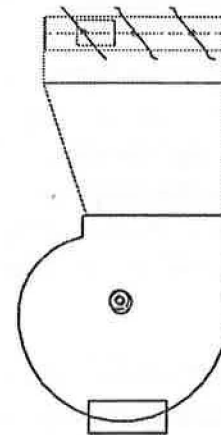


Figure 3 Control Damper & Blower Profile

9. Repeat steps 4 through 8 until the damper opens to full open and closes to full closed using the KM24-SR vi from 0 to 90 degrees.

Following this procedure should allow the damper to operate as intended. The damper has been calibrated by Sheltair to operate within the 0 to 90 degree range with the LabVIEW voltage output. If this changes for any reason, refer to the Belimo Damper Actuator specification sheet provided for adjustment instructions.

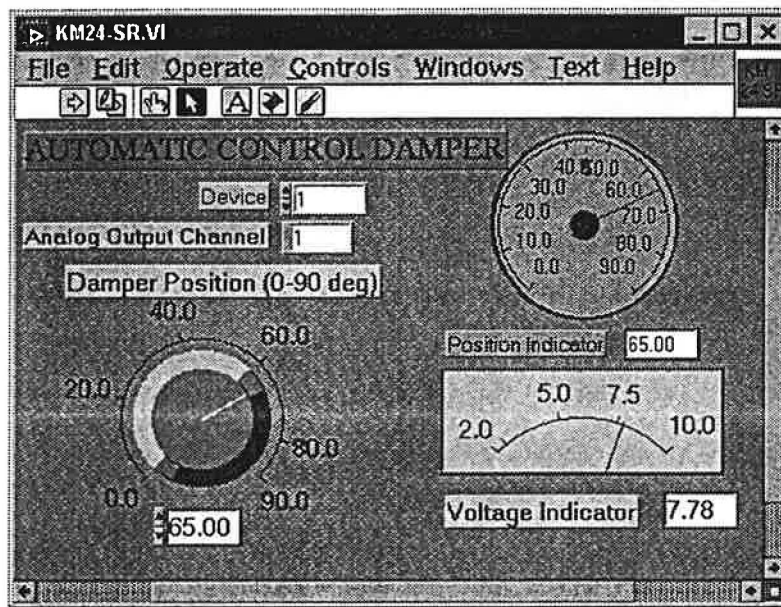


Figure 4 Automatic Control Damper vi Front Panel

3.3.2 Variable Speed Blower

The Control-fan/blower, shown in Figure 2 above, is designed to be connected to the Leeson 3 phase ½ hp motor. The Blower/Motor/Variable Speed Drive combination as configured will perform within the ranges shown in Table 2:

Table 2 Blower and Speed Drive Specifications

Sub Component	Parameter	Lower Limit	Upper Limit
Leeson ½ hp Motor	Speed (RPM)	60	1700
	Power Consumption (W)	25	500
Blower	Air Flow L/sec (CFM) @	¹ 25 (52)	550 (1150) @
	Static Pressure (Pa)	5	125

As illustrated in Figure 5, the motor mounting stand, Lesson ½ hp motor, blower, and rigid shaft-coupling, will require a basic assembly. The motor has been provided with an easy to install, 4 wire twist-lock plug. The plug, which is rated at 250 VAC and 20 Amp, can only be inserted into the mating outlet which is provided on the side panel at the end of the test bench as in Figure 5.

¹ At 60 RPM

The top of the test bench is fitted with ¼ " x 20 nut inserts arranged in a pattern to accommodate the motor stand, the blower support brackets, and the PVC duct support brackets. Further assembly procedures will be discussed in more detail in Section 4.

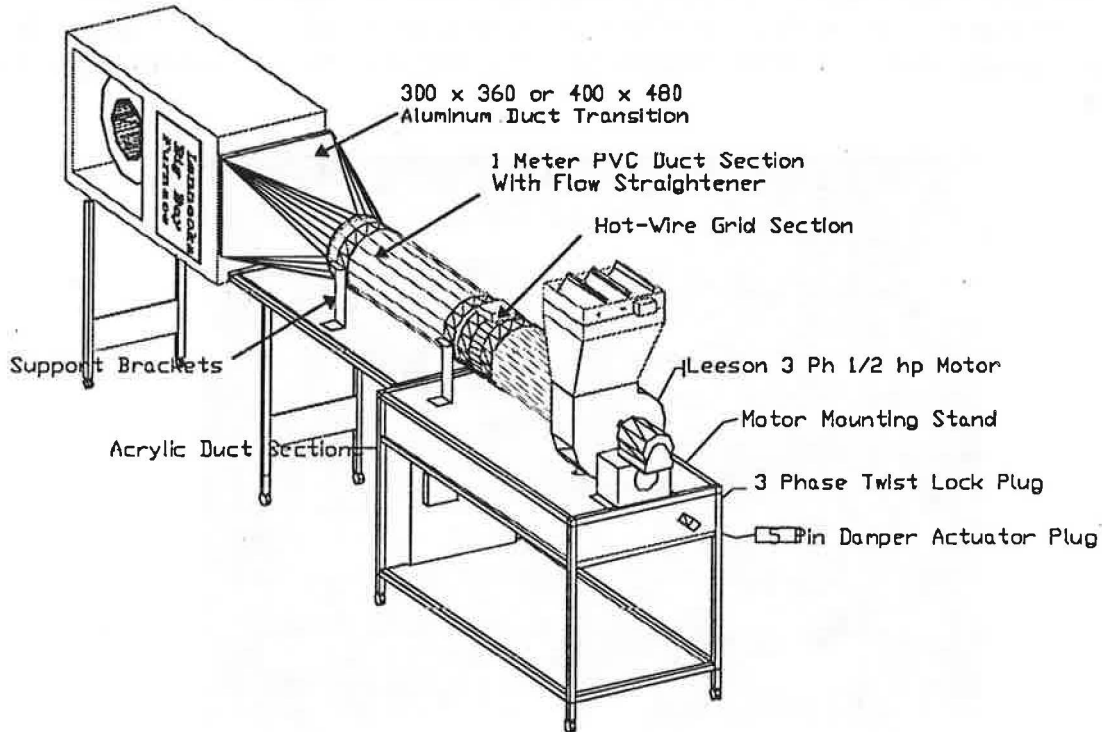


Figure 5 Fan Test Key Components

Control Fan Blower-Motor Mechanical Connections

Shaft Coupling: The Dayton blower has been modified with a shaft and bearing assembly which must be connected to the motor using either the rigid coupling Figure 6 or the slider coupling provided in the accessories box. Also provided are appropriate hexagon (Allan) keys for tightening set screws on couplings.

Fan Impeller: A 9" x 5 ½ " fan impeller is pre-installed on a 5/8" precision ground CRMS shaft which has been pre-drilled with 4 holes to hold set screws in place at the blower bearings. Should the fan impeller become loose, an 3/16" Allen Key wrench has been provided that can be used for tightening.

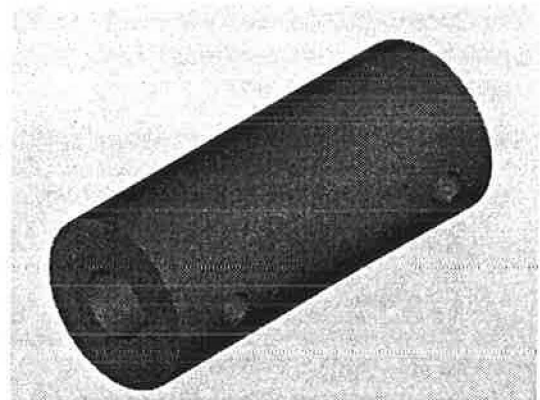


Figure 6 Rigid Coupling with Keyway for 5/8 in Shaft

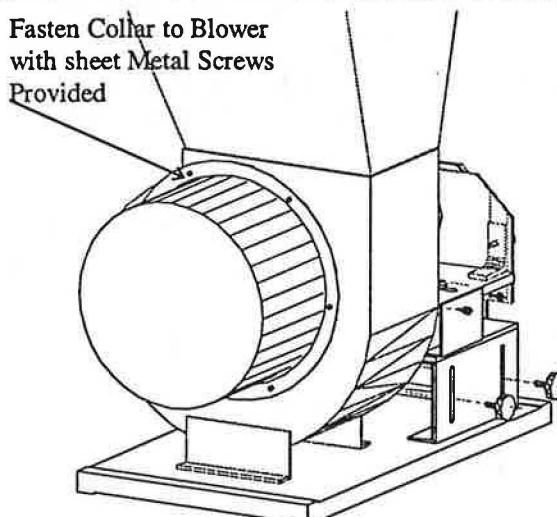
General Installation Notes: All set screws should be checked and tightened each time the blower-motor combination is re-installed on the test bench.

3.3.3 Flow Measuring Duct Assembly

The Flow measuring duct assembly consists of 5 main component groups as follows:

1. Blower Connection Collar
2. Acrylic Exit Duct Section
3. Hot-Wire Grid Section
4. Main Flow Development Duct Section
5. Various Duct Transition Fittings.

Flow Duct Assembly

1. Beginning from Component 1, the Blower connection collar is a 10 3/4" diameter aluminum section with a 2/4" flange that has been drilled for 6 sheet metal screws. Using the #10 screws provided, and ideally using a nut driver, fasten the collar to the blower. The collar has been cut to fit the scroll of the fan casing which helps to find the location of the first sheet metal screw.

2. The Acrylic duct can now be temporarily slid into the Collar with the double course of weather-stripping being inserted first. The user may want to support this duct temporarily using a block or other support piece.
3. Next rest the PVC main duct section on the 2 11" diameter support brackets as shown in Figure 5. The accessories box should include some #10 x 1/2" Hex head screws that will thread directly into the nut inserts that are pre-installed in the support brackets. These can now be used to install the Upper half of the circular support brackets which can be installed over the end of the main tunnel.

Fasten Collar to Blower
with sheet Metal Screws
Provided

Figure 7 Installing Collar to Blower Assembly

3.4 FANalyzer External Sensors & Devices

3.4.1 Temperature Sensors

The FANalyzer is fitted with three LM35 high precision (± 0.5 K) Temperature sensors. The specifications for the LM35 sensors has been included in Appendix III of the FANalyzer Final Report. These sensors can be used for any application the user requires, however, as a convention different functions have been assigned to each of the three sensors as listed:

- Temp 1 Ambient air temperature measurement.
- Temp 2 Motor winding or casing temperature measurement.
- Temp 3 Air temperature rise in fan airstream.

For example, Temp 1 and Temp 3 can be used for a temperature differential measurement across a fan-motor set from which energy losses to the air can be estimated. This can be used as a rough check on Fan efficiency. Each sensor has been sealed with a heat shrink shield to protect it from moisture, and, in the case of Temp 2, to attenuate electrical noise from windings..

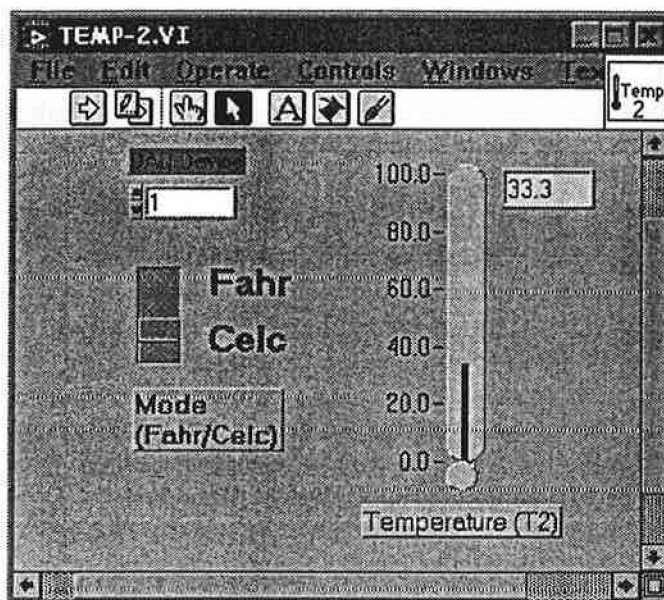


Figure 8 Temperature vi Front Panel

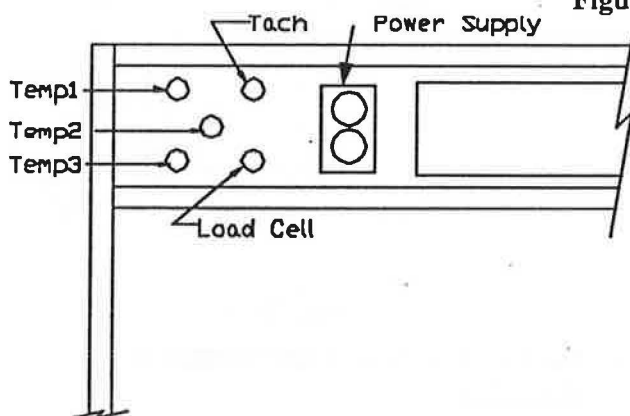


Figure 9 Test Bench Front Panel

The Front Panel of a Temperature vi is shown in Figure 8. These vi's can be invoked at any time by loading them directly from the LabVIEW vi Motor or Fan Test libraries, and are named and numbered to coincide with labels near each four-pin connector plugs on the (physical) Front Panel of the FANalyzer Test Bench. A diagram of the Test Bench Front-Panel is shown in Figure 9.

From the Front Panel, the choice of Fahrenheit or Celsius measurement is available by clicking the toggle switch.

3.4.2 Tachometer

3.4.2.1 Description

A tachometer uses a *reflective infrared sensor* which consists of an infrared emitting diode and an NPN silicon phototransistor. The specifications for the sensor are included in Appendix II of the final report. The sensor is mounted at the end of a shielded cable and placed in a section of flexible chrome conduit as shown in Figure 10. A high strength magnet is mounted at the base of the cable support strap, which allows for simple mounting to any fan housing, furnace cabinet, or other metal component.

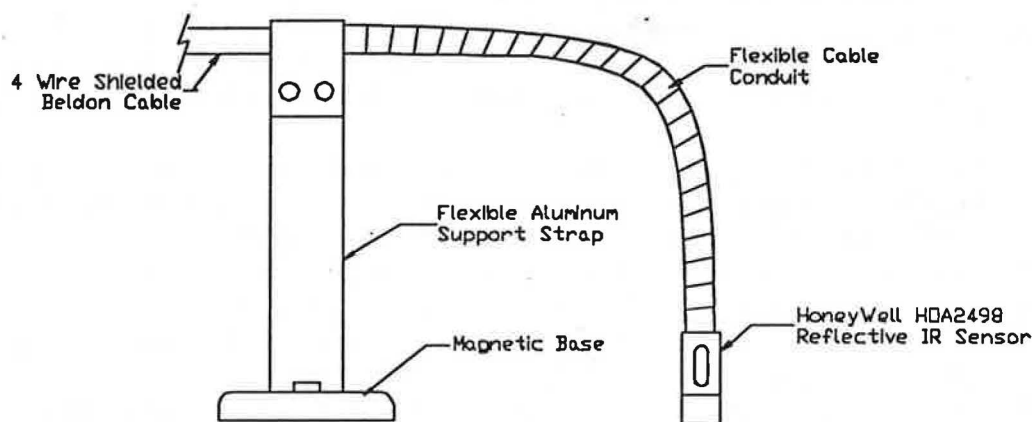


Figure 10 Tachometer Components

Only a single pulse per shaft (or impeller) revolution is needed to obtain the motor speed measurement. This regularly repeated pulse is measured using the DAQ board Pulse Counter and then related to speed using the LabVIEW Tachometer vi.

3.4.2.2 Installation

The Tachometer has been found to be very finicky in its set up and it is important that the operator take great care in its placement to ensure consistent results. Although the device could be made more sensitive to the reflected IR signal through alteration of resistor values and transistor currents, a more sensitive tachometer was avoided since erroneous signals were often generated by stray light sources. Hence, to ensure accurate readings, some extra set up time is required. Experience with the device installation will reduce set up time to only a few seconds in some cases. Initially, some trial and verification of measured readings with expected readings.

A recommended procedure for tachometer set up is as follows **CAUTION** make sure fan or motor is de-energized during Tachometer set-up:

1. Find a suitable location for speed measurement. This should be a flat or cylindrical surface (with at least one rectilinear axis such as the shaft a coupling) on any rotating part of the fan impeller, or motor shaft. Make sure that there is enough space to install the sensor head and that the air stream is not greatly influenced by the presence of the sensor;

2. Cut a small section of reflective Mylar™ film about 1 or 2 cm² as a TARGET and attach it to the selected measurement surface using clear tape or ideally a temporary glue such as “Glue Stick™” paper glue as an adhesive. Make sure the TARGET is properly secured and flattened on the measurement surface or the reflected signal will be diverted;
3. Plug the Tachometer into the marked 5 pin plug on the Test Bench Front Panel and unravel the tach cable. Try to keep the cable protected from damage i.e. from foot traffic around the bench .
4. Install the Tachometer in a convenient location near the TARGET using the magnetic base or tape and then manipulate the flexible cable and aluminum support strap until the sensor head is about 12 mm away from the TARGET. This may require a few iterations of removal and replacement of the Tachometer base from the object.
5. Once a rough placement has been established, the sensor must be further manipulated until it is 12.5 mm (+/- 3 mm) from the reflective TARGET. Also the face of the sensor must be parallel to the TARGET therefore the Tachometer Flex-Cable should be perpendicular to TARGET.
6. With the LabVIEW program running on your computer, load the *Tachometer Test.vi* from the Motoreff or the FanEff vi library (or use a Voltmeter) to measure the voltage at the terminal (Ctr Gate 0 or Channel ACH 4 in the SCB 68 connector board).
7. Spin the motor/impeller so that the Tachometer passes over the Mylar film.
8. If Voltage drops to near zero Vdc from 5.21 Vdc then placement is OK.
9. Apply wiring connections to the test motor, energize the motor from the Test Bench, and apply power using the Power Switch.vi (See Section 0)
10. Load the *Tachometer.vi*. and run the vi (explained below). If a reasonably stable (+/- 5 RPM) speed does not register then start over from Step 1 and adjust position until speed readings are steady.

It is also important to keep the Mylar surface clean for maximum reflectivity, since the tachometer sensor has a low tolerance for set-up error. Though this procedure may seem tedious, this measurement is critical to both the Fan and Motor Efficiency tests and patience is required.

3.4.2.3 Usage of Tachometer.vi

The Tachometer vi (Front Panel shown in Figure 11) can be used on its own, as well as embedded within a master vi. To use the vi the user can load it from either the fan or motor test vi library. The vi can be run continuously or for a single point measurement, as is the case with all the virtual instruments. However, due to the fact that the DAQ Pulse Counter is more ideally suited for higher frequency measurement, the measurement must be repeated

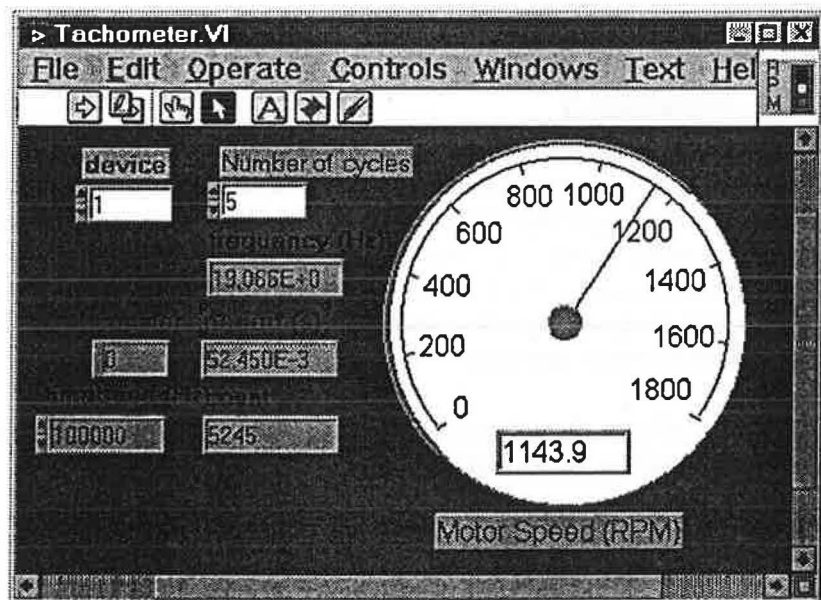


Figure 11 Tachometer vi Front Panel

several times and the results averaged. The only input that the user may want to adjust is how many times the vi averages the single pulse counter measurements. To do this change the value of the "Number of Cycles" control input to a higher value. The default value is 5 cycles which takes just less than 1 second to complete a run.

3.4.3 Load Cell

3.4.3.1 Description

The Load Cell which is an FT70-10 lbf force transducer supplied by Intertechnology Ltd. In Vancouver, is the key component in the Motor Test System. **CAUTION The Load Cell must be handled with great care at all times**, especially during installation in the slide mechanism on the load cell leveling table (see Figure 19). The wiring connection to the load cell is quite fragile, despite protection efforts (strain relief clip, metal strengthener).

Detailed manufacturer specifications for the FT70-10 "Force Sensor" have been included in Appendix II of the Final Report.

3.4.4 Power Outlet

The Test Bench Front Panel has a 115 VAC power source with a standard, grounded 2 receptacle outlet. In order to perform any electrical power analysis, the user must use the FANalyzer Power Source. The power outlet is normally De-energized (in the Off State) and in order to Energize the Power Switch vi must be used. Power Switch.vi shown in Figure 7, can be loaded from one of the supplied LabVIEW Libraries.

Note that to operate the Power Switch.vi, clicked the switch into the ON position (or OFF position) and then click the RUN button. The vi will not execute if the RUN command (the right-pointing arrow on the menu bar) is not issued.

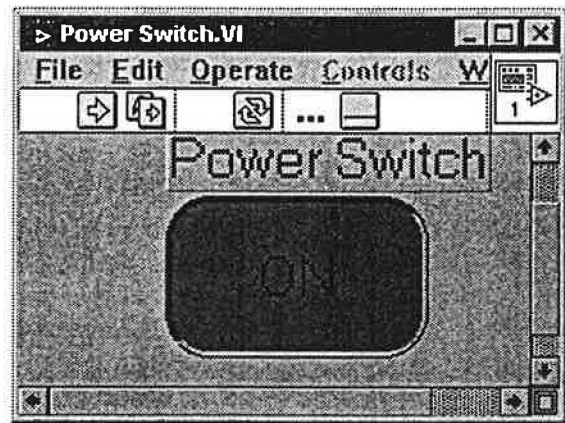


Figure 12 Power Switch Front Panel

3.4.5 Hot-Wire Grid

3.4.5.1 Description

A schematic diagram of the Hot-wire grid is provided in Figure 13. Calibration curves for air flow ranges from 15 L/sec (32 cfm) to 600 L/sec (1250 cfm) are also included in equation form and shown graphically in Figure 15.

The sensors were typically sampled at rates of 1000 samples per second with 2000 time-averaged samples per measurement. Several thousand data points were collected over the calibration range.

3.4.5.2 Installation

The installation of the Hot wire grid assembly is straightforward in that it only needs to be inserted in the wind tunnel between the Main Flow Duct Section and the Acrylic Duct section (see Figure 14 sections 4 and 6). The Hot Wire Grid was calibrated with the wiring junction box oriented as shown in

Figure 13 Hot Wire Grid Configuration

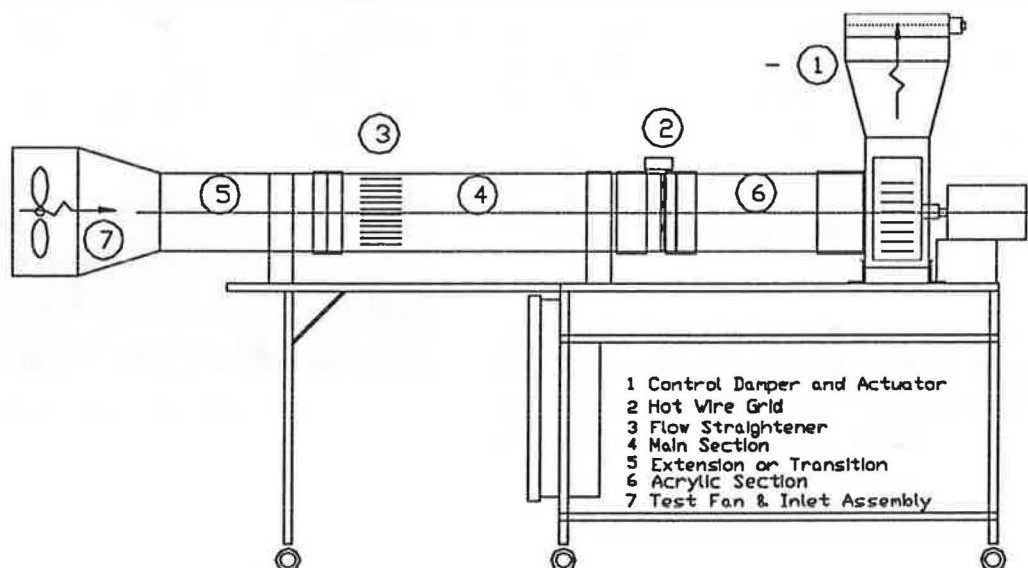
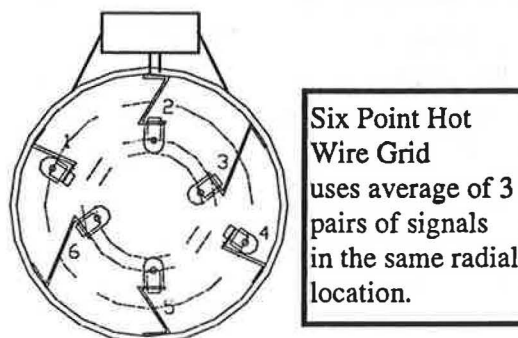


Figure 14 Fan Test Assembly Schematic Showing Main Components

Figure 13. It is important to note that the Hot Wire assembly within the short duct section in which it is housed, should be placed nearest to the front, or nearest to the Acrylic duct section. An arrow indicating the air flow direction has been laminated to the outer side of the Grid housing.

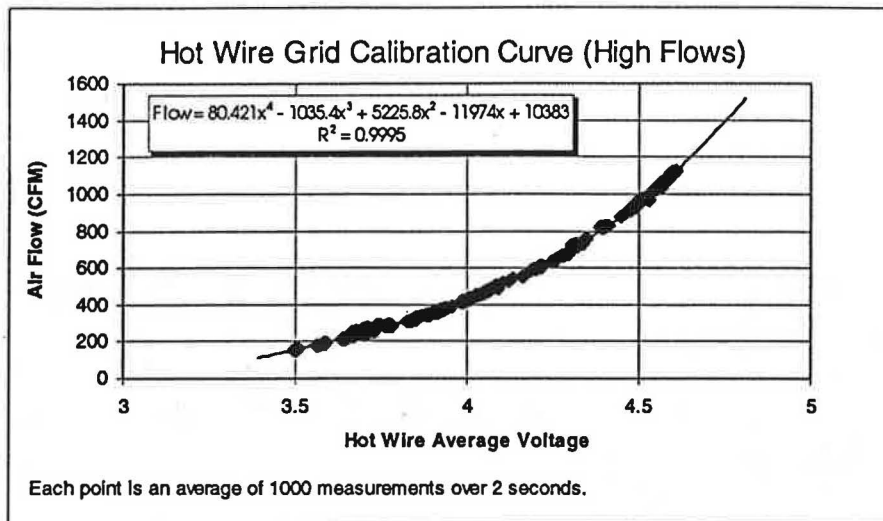


Figure 15 Hot Wire Grid Calibration Curve & Equation for High Flows

3.4.5.3 Use of Air Flow Meter vi

The Air Flow Meter vi is included in the Fan Test library file and can be used as a stand alone sub-vi or it is called upon by the Multi Point Fan Test .vi during a complete test. There are presently 2 flow ranges defined in the meter which are automatically selected when the voltage measured is above or below a given value. These ranges, which correspond to the calibration curves in the figures above, are as follows:

- Low Range: 10 to 80 L/sec (21 to 165 cfm); and
- High Range: 80 L/sec to 600 L/sec (165 to 1250 cfm).

The Front Panel of the Air Flow Meter vi is shown in Figure 16. The graph scale can be changed by the operator while the vi is running but will change to an appropriate scale automatically as the flow range changes.

Should the user want a more stable flow measurement, the Number of samples can be increased to any amount. The sample rate, which is presently set at 1000 Samples/sec, will dictate the speed of the measurement (i.e. 2000 samples at 1000 Samples/sec will take 2 seconds to complete a run).

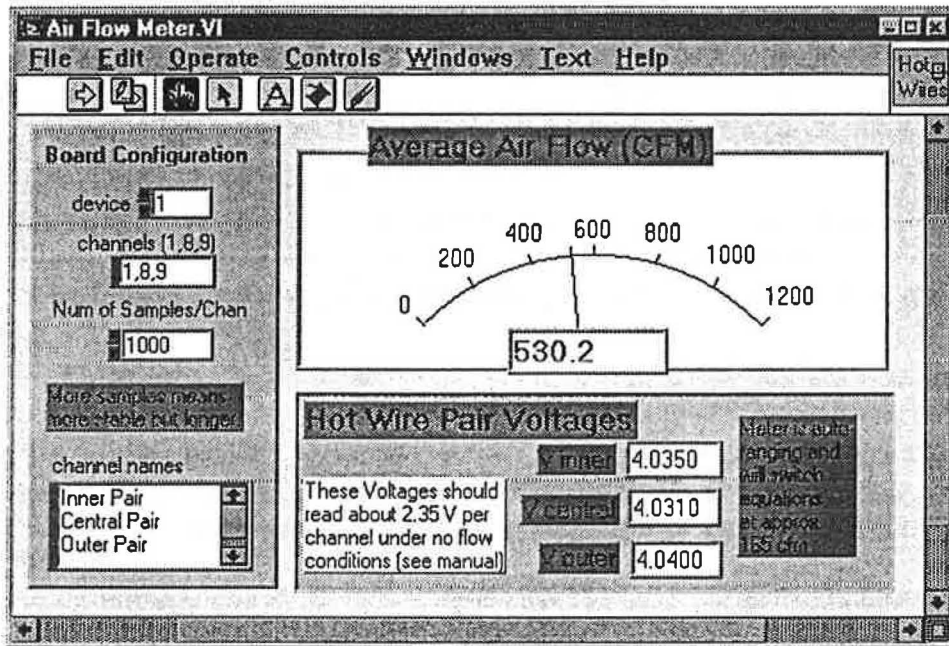


Figure 16 Air Flow Meter vi Front Panel`

3.5 FANalyzer Internal Devices

3.5.1 Pressure Measurement System

3.5.1.1 Description

Low Pressure measurement is performed using 2 MAMAC PR274 electronic pressure transducers. The pressure transducers are located in the Instrumentation Box and are powered by a dedicated MAMAC Power Supply at 15 Vdc.

The transducers output a 4-20 mA signal that has been converted to a voltage using a 221 Ω precision resistor. The transducers pressure ranges are jumper selectable from +/- 60 Pa (0.25 in wc) to 0 - 250 Pa (0 - 1.0 in wc), with six jumper combinations. The two transducers, have been set to 0-250 Pa and 0-125 Pa respectively.

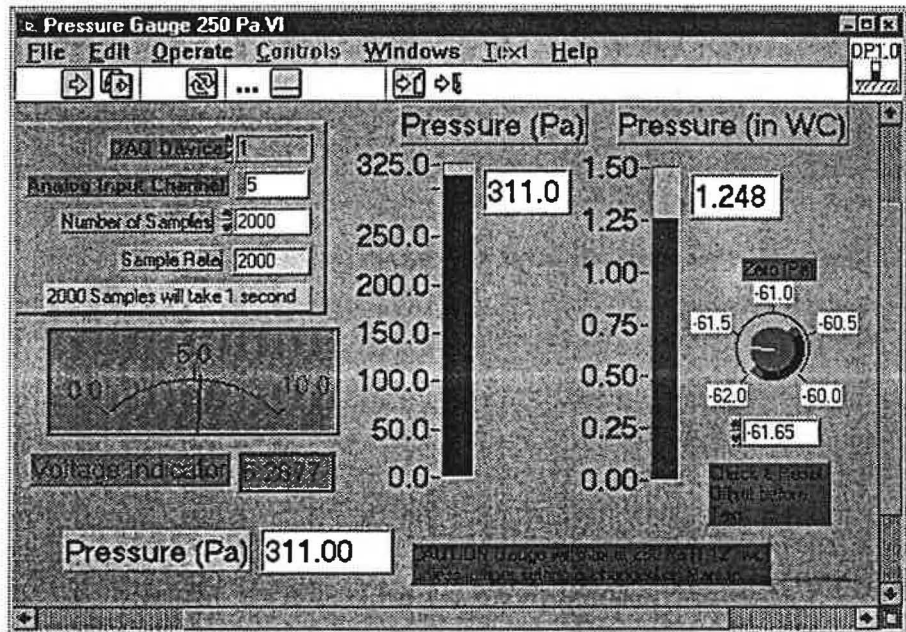


Figure 17 Pressure Gauge vi Front Panel

3.5.1.2 Usage

Four “quick connect” plugs are provided on the outside of the Instrumentation Box (top right hand side) that are labeled as shown in Figure 18. The Pressure Gauge vi (Figure 17) is a High Level vi that can be used on its own or within a Master vi e.g Multi-Point Fan Test.vi. Metric and Imperial units of pressure are shown simultaneously. The pressure scale is not auto-ranging but can be changed by highlighting the indicator scale and manually changing the upper limit. The Pressure vi for the 125 Pa gauge is similar.

These gauges can read within acceptable accuracy at *over-range* pressures as high as 150% of the maximum indicated range value. Operation above 150% of range is not advisable. The table below shows the preferred scale ranges and reported accuracy.

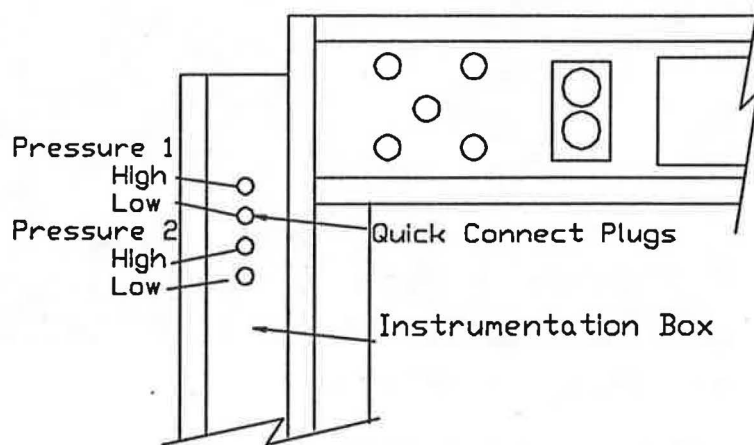


Figure 18 Pressure Plug Locations

Table 3 MAMAC Pressure Gauge Range and Accuracy

Pressure Range	Minimum (Pa)	Maximum (Pa)	Accuracy	Over-Range (Pa)
Pressure 1	0	250	+/- 1% range	375
Pressure 2	0	125	+/- 1% range	200

The user must anticipate the sense of the pressure e.g. Negative or Positive. *A rule of thumb for positive gauges is that the pressure tubes must always be connected so that the High Pressure “port” will sense a positive pressure.* For example if a static pressure measurement is made in a duct at the inlet of a fan, the pressure will (probably) be negative. In this case, the Low-Side pressure plug should be used and the High side should be referenced to a point downstream from the fan or open to atmosphere. Similarly, if a static pressure measurement is made at the outlet of a fan, the pressure will likely be positive and the High-Side pressure port should be used.

3.5.2 Power Measurement System

Power measurement is done using direct analysis of voltage and current waveforms in LabVIEW, sampled at over 30,000 samples/sec each. The Power vi averages the values over a few cycles to obtain an average power consumption.

Figure 19 shows the front panel for the Power vi. This is the Power panel that will be most often seen when using the Power vi to meter. The vi is wired to output all important parameters (as seen on the panel) to the a data file during most test execution. As is the case with most of the FANalyzer sub vi’s, operation will be mainly invisible, except to the more adventurous users.

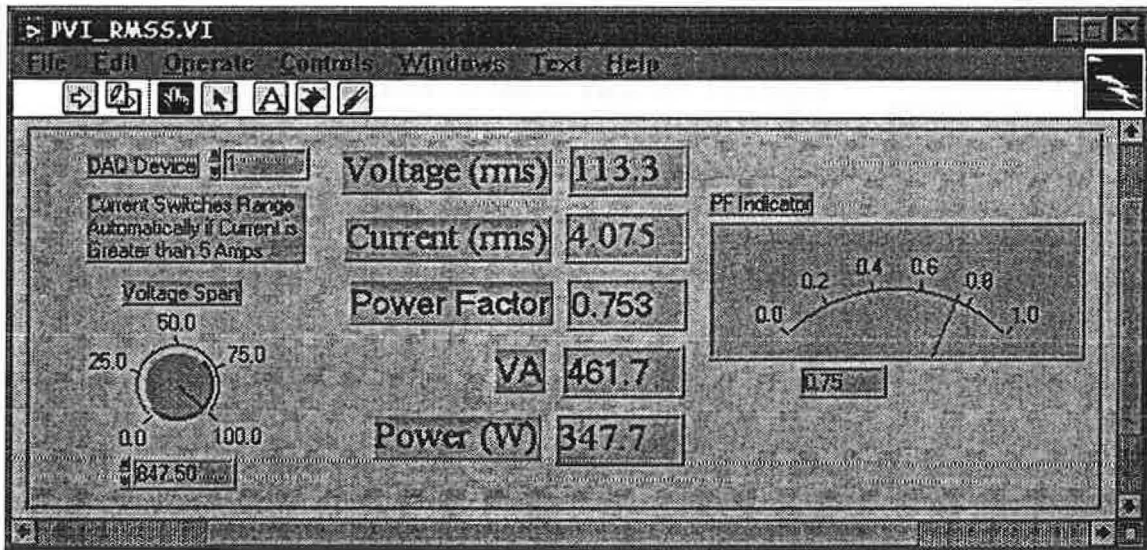


Figure 19 Digital Power Measurement vi

3.5.3 Instrumentation & Meter Box

The instrumentation box is located on left hand side end of the Test Bench. It is an aluminum hinged electrical box 18" long x 25" high x 8" in depth. A schematic drawing of the instrumentation box contents is included in this manual. The Table 4 below lists the contents of the instrumentation box.

Table 4 Instrumentation Box Contents

<i>Qty</i>	<i>Description</i>
1	120 Volt AC Terminal and Power distribution Block
1	+/- 12 VDC and 5 VDC Instrument power supply
1	Frequency drive signal isolator board
1	115 to 12 VAC transformer and resistive divider for low voltage signal
2	MAMAC 50/5 Amp Current transformers
2	MAMAC "range selectable" low pressure differential transducers
1	MAMAC 0 to 24 VDC at 1 amp power supply for pressure transducers
1	Custom PC Board with Tachometer, Load Cell, Hot wire, AC voltage, and AC current circuitry, components, and terminal blocks.
1	Low voltage dc terminal block1
1	24 VAC transformer
1	24 VAC relay with power transistor circuit for remote switching of test motors.
	Power supply and signal wiring to/from temperature sensors
	Misc. wiring terminations

Table 6 provides a listing of the wiring and cable routing to and from the Instrumentation Box. This table can be referred to when troubleshooting connection problems. Table 7 describes DAQ Board connector box channel listing. The channels numbers listed in this table are the same channels numbers that are used by LabVIEW vi's to acquire signals from the sensors.

3.6 Assembly of Motor Torque Measurement System

3.6.1 Sub Components

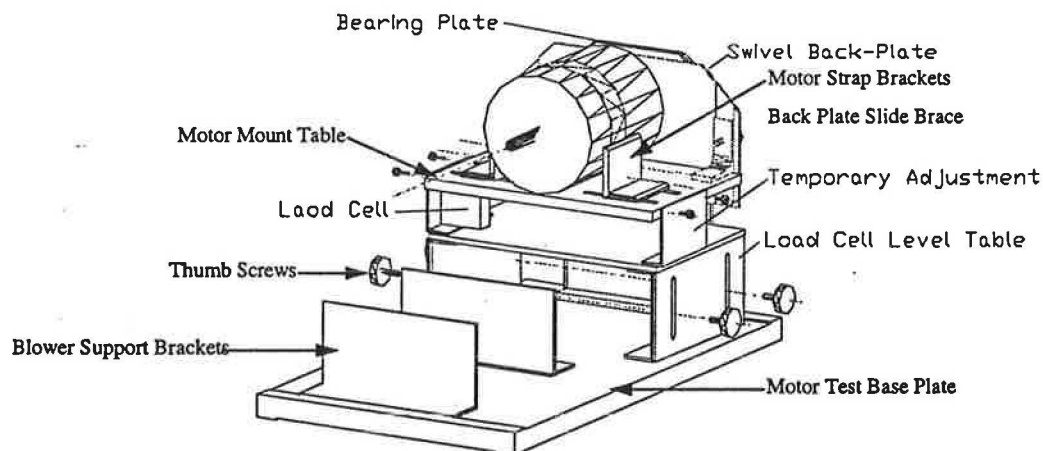
The Torque Cradle consists of the following main components which will require partial assembly. In order to save space for shipping, these components were shipped separately and will require a partial assembly. These are

1. Load Cell Level Table
2. Motor Mount Table
3. Motor Height Plate
4. Bearing Support Plate
5. Motor Test Baseplate
6. Temporary Adjustment Brackets
7. Back-Plate Slides
8. Motor Strap and Bracket Assembly
9. Blower/Damper Assembly (with interchangeable impellers)
10. Shaft Couplings and Reduction Sleeves

3.6.2 Assembly

As illustrated in Figure 19, the motor is mounted on a flat table and strapped tightly into place using a ratcheting clamp (not shown). The procedure for assembly of the system is detailed in this section.

Referring to Figure 19 and Figure 20 the steps for assembly are as follows:



1. Place Motor Test Base Plate on Test Bench;
2. Obtain the 2 - 1 1/4", 12 - 3/4", and 4 - 3/8" Thumb Screws from the Component Drawer;
3. Using 4 of the 3/4" Thumb Screws, fasten the blue aluminum Bearing Plate (with tapered bushing and bearing shaft) to the Base Plate. There is only one orientation in which the plate will fit. Make sure that the Stainless Steel Taper Bushing is facing outward as shown in Figure 20;
4. With the milled pockets facing the center of the Base Plate, slide the Swivel Back-Plate onto the shaft of the Bearing Plate until the set screws touch the Bearing Plate, then back off about 2 mm so

that the plate swings freely. Tighten the bearing sleeve to the shaft with the 2 set screws and using the hex key provided in the tool kit;

5. Assemble the **Load Cell Level Table** using 4 - 1" Thumbscrews in the side slots and 4 - ¾" Thumbscrews at the base;
6. Next Fasten the **Load Cell Level Table** to the **Base Plate** using 4 - ¾" Thumbscrews. This is easier to do when the Level Table fasteners are loosened, and the Table is raised to 5" or more from the Base Plate. The Table height adjusts from a minimum of 3 7/8" to about 6" from the Base;
7. Fasten the two L shaped **Temporary Adjustment Brackets** to the **Load Cell Level Table** as shown in Figure 19 using the 10-5/8" Hex Head Cap Screws provided. The **Load Cell Level Table** has 4 threaded nut-inserts installed for this purpose.
8. Fasten the **Temporary Adjustment Brackets** to the **Motor Mount Table** using the small 3/8" x 5/8" Thumbscrews and tighten until a gap exists of approx. 1/8" between the edge of the Table and the inside face of the brackets. The objective of the temporary adjustment brackets is to maintain a constant distance between the Load Cell Level Table and the Motor Mount Table of about 2 3/8 inch. *The Thumbscrews will be remove before the start of the test.*
9. Bolt the **Back-Plate Slide Braces** to the **Motor Mount Table** using the ¼ -20 bolts
10. Next connect the **Swivel Back-Plate** to the **Slide Braces** using the large 1 ¼" Thumbscrews and the ¼ x 20 Lock-nuts provided in the accessories box. Tighten the Thumbscrews only loosely at this point until the motor diameter is determined
11. Measure the Motor Radius with a caliper
12. While holding the underside of the **Motor Mount Table**. loosen the Thumbscrews and raise the **Motor Mount Table** until the distance from the center of the shaft bearing on the **Swivel Back-Plate** is approximately equal to motor radius (+/- 2%) hand-tighten the Thumbscrews firmly. (Note that the **Load Cell Level Table** will rise with the **Motor Mount Table** due to the Temporary Adjustment brackets)
13. Bolt the **Motor-Strap Brackets** into the slots as shown in Figure 19 using the four 5/16" x ¾" carriage bolts provided and leave the bolts finger tight. Leave the red strap and the ratchet clamp extended to allow room to insert the motor.
14. Prepare the Test motor by removing all external clamping devices, cutting down the shaft length² to no more than 2 ¼ inch (normally this is between 1 ¾ to 2 ¼ inch but new motors are usually delivered with extra shaft length up to 6 inch), and freeing up the wiring harness. For larger motors (1/2" and 5/8" shaft, it may be preferable to drill a ¼" diameter hole in the flat of the motor shaft to accept the setscrew of the shaft coupling. This hole only needs to be about 0.125 inch in depth.
15. Place the **Test Motor** on the **Motor Mount Table** as shown, with the front face of the motor approximately flush with the front edge.
16. Strap the motor to the plate using the ratchet clamp and the Key (wrench) provided in the accessories kit. Tighten until the motor can no longer turn in the strap. Do not overtighten!
17. Install the Blower with the blower support brackets onto the Motor Test Base Plate in the nut-insert holes provided, using four 1" diameter ¼ x 20 Thumbscrews. Make sure that the fan inlet is facing away from the motor.

² Experience has shown that care is required when cutting motor shafts not to bend the shaft or offset the motor armature. Tolerances between the armature and the stator windings are very high and very slight radial shaft misalignments lead to significant motor vibrations when both load and motor are fixed, such as is the case with the test system.

18. Couple the Motor to the Fan-Impeller using the rigid shaft coupling. The system should look similar to Figure 20. Shaft reducers have been provided for motor shafts diameters of 1/2" and 3/8".
19. Spin the Shaft Coupling until one setscrew is aligned with the pilot hole in the impeller shaft, and the other setscrew is aligned with the pilot hole, or with a flat spot on the motor shaft. *This is critical to keep the shaft from spinning within the coupling.*
20. Finally, tighten all Thumbscrews, bolts, and setscrews, except the **Temporary Adjustment Brackets** and spin the coupling by hand. It should turn freely, and the motor mount table should not move.

3.6.3 Installation of Load Cell

1. Remove the load cell from the protective foam case;
2. With the cable facing away from the Motor Mount Table, slide the clear acrylic base of the Load Cell into the Load Cell mounting slide plate located at the front left hand side of the Motor Mount Table.
3. Slide the Load Cell plate to Position 4, as marked on the plate.
4. Install the 10 x 32 x 1 1/4 inch Thumbscrew Adapter Pin through the top of the Mount plate and thread it into the center hole on the Load Cell. **CAUTION Do not tighten Load Cell Adapter Pin!! Leave threaded but loose in the Load Cell!**
5. Plug the Load Cell Cable connector into the receptacle marked "Load Cell" on the Front Panel of the FANalyzer test bench.

3.6.4 Motor Wiring Installation

1. Tape the motor wiring harness to the stationary Bearing shaft at the back of the **Bearing Plate**, using electrical tape or a cable tie. **CAUTION The wiring harness must not impede the swiveling of the Cradle assembly.**
2. Separate the appropriate motor leads. A Line, Neutral, and Ground lead (if available) are required. Connect these to the standard three wire grounded 120 VAC cable with three-prong plug using "Marrett" type wirenuts.
3. Insert the plug into the Test Bench Power Supply located on the Front Panel of the Test Bench.

The Motor Test System is now ready to energize. Please read through the next section before starting a test.

Temperature sensor Temp 2 should be installed on the Motor Casing as recommended in Section 5.7 of the C747. Temperature sensor Temp 1 should be located in ambient air best representing the temperature of the space in which the motor is located. Immediately before starting the software test procedures, remove the thumbscrews.

4. Test Routines

4.1 Motor Efficiency Test (CSA C747)

4.1.1 General Procedure

Performing the motor test will require a cursory knowledge of the CSA C747 Test standard for small motors¹. It requires that a motor efficiency test be performed within a range from “no load” to about 125% of rated load. For example a ½ hp motor this would be 0.635 hp. A draft copy of the Standard has been included in Appendix III. The operator should read through Section 5 of the Standard to become familiarized with the CSA requirements. These guidelines should be followed for performing accurate motor tests. However, for most testing purposes, the FANalyzer Multi Point Motor Test automated procedure can be used.

The FANalyzer motor efficiency test procedure is based on percent of rated motor output. At least six points are required, beginning from 125% of rated load, to “no load”. Motors can be tested over the range of 1/60 HP to ¾ HP, at RPMs from 1000 to 2500.

Motor Temperature rise has a significant effect on motor winding resistance and resultant efficiency, as indicated by equation in Section 5.7 of the CSA C747 standard. In accordance with the C747 standard, the rated voltage and frequency are applied to the motor and the motor is run until a condition of thermal equilibrium is reached. For typical motors from ¼ to ½ HP, this steady state condition requires about two hours of continuous operation. As an alternative to waiting the full two hours, the operator can monitor the motor temperature (using the Temperature vi or the Single Point Motor Test vi) until the winding (or casing) temperature rise is less than 0.5 degree C over a 15 minute period.

4.1.2 Test Configuration

The Motor Efficiency test configuration consists of the following components:

1. Motor Torque Test Assembly
2. Selection of Motor Loading Impellers using 8 ½ x 5 ½, 8 ½ x 3, inch forward curve , single inlet blower wheels.
3. Parallel (3) Blade Automatic Control Damper
4. FT70 10 lb. Load Cell
5. Temperature Sensors 1 and 2
6. Multi Point or Single Point Motor Test vi

After completion of the Motor Test System Assembly from Section 3.6.2 use the table below to select the motor loading impeller to be used:

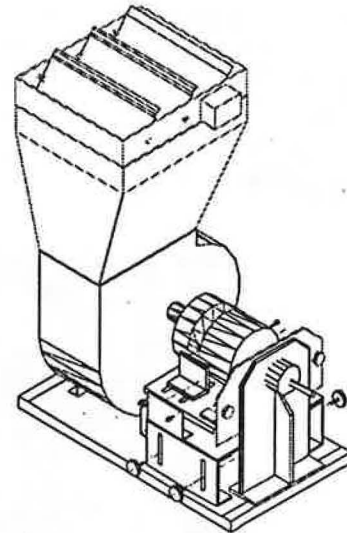


Figure 20 Torque Cradle Coupled to Control Blower

Table 5 Motor Loading Impeller Selection

Motor Size	Loading Impeller Required
¼ hp to ¾ hp	8 ½ x 5 ½,
½0 hp to ¼ hp	8 ½ x 3
1/60 hp to 1/20 hp	6 x 3 ½

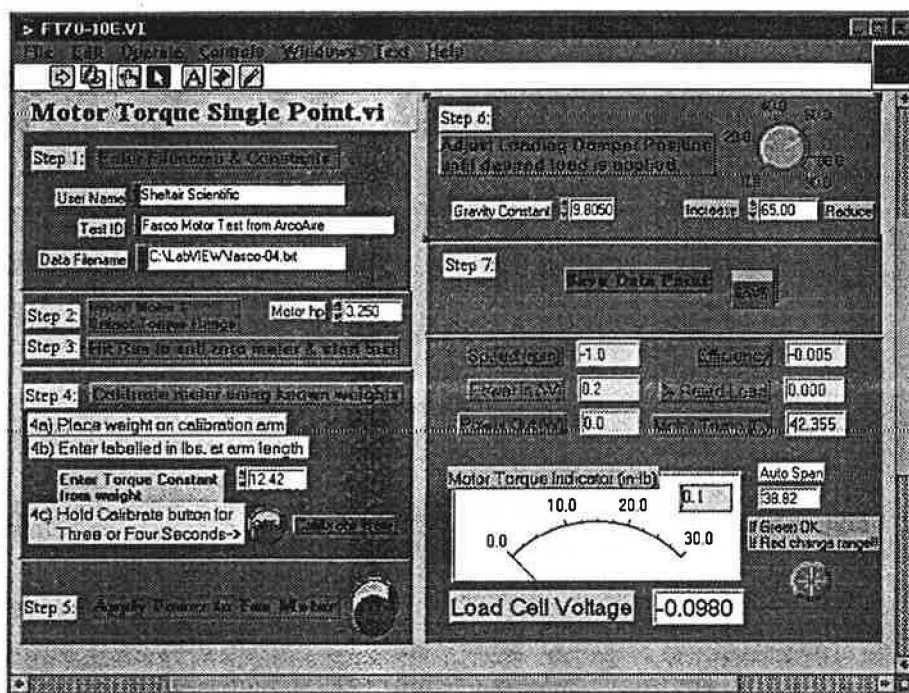


Figure 21 Front Panel of Single Point Motor Test.vi

Installation of the Loading Impellers can be done using the 5/16" sheet metal screw "Nut Driver" provided in the accessories kit. Note that the two smaller load impellers should be mounted on the ½" impeller shaft. Make sure that all setscrews are tightened securely.

To obtain the 100% loading required for the motor warming period, use the Single Point Motor Test vi. Follow the procedure outlined on the Front Panel of the vi.

4.1.3 Running the Single Point Test

To familiarize the user with the Motor Test, it is recommended to run the Single Point Motor Test vi. This vi is designed to perform an automatic spot calibration of the Torque Table before any measurements are made. Follow the procedure on the Front Panel in the proper order. Refer to the procedural notes below for some guidance.

1. Step 4 requires the use of the Calibration bar provided in the component drawer. Bolt the Calibration Bar to the inside face of the Back Swivel Plate bearing using 2 - ¼ x 20 nuts. Use the calibration weights provided and note the values indicated on each weight. Hang the weight(s) at 12 inches or 8

inches from the end of the bar. Transfer "Torque Constant" values to the appropriate box in the vi Front Panel.

2. Step 5 energizes the motor. **CAUTION** If excessive vibrations are noted after running Step 5, Click the Fan Power button again to de-energize the motor. If this does not work, unplug the motor cable from the Front Panel of the Test Bench and check motor installation.
3. Next use Step 6 to adjust the loading of the motor until the % Rated Power reads approximately 100%. Save this data point (Step 7) and let the motor run until a Steady State temperature has been reached (if required). (Note the calibration coefficients that are indicated on the lower right corner of the vi. These are the Span and Zero constants that are used to translate the Load Cell voltage to units of Torque).
4. After the motor has warmed, close the control damper to 90 degrees (fully closed) and note the % rated power value.
5. Now Open the control damper slowly to 65 degrees and note the % rated power value. Keep opening the damper until the % rated reaches about 150% **CAUTION Do not open the Damper completely if the % Rated Power exceeds 150% at any point.**

Note the maximum and minimum values achieved during this exercise on paper or in a spreadsheet. These can be used to bracket the number of test points and increment for the Multi Point Test outlined in the next section.

Test results can be saved at any time during the test and these values will be appended to the text file that you have selected.

4.1.4 Running the Multi Point Test

The multi point test can be run once the motor is at operating temperature. Open the vi and input the required data in the vi panel. The important information required for this vi is the Motor Rated hp, the desired percentage of rated hp to use for the first point, and the increment between the test points. Use the information obtained from the Single Point Procedure to select the required increment between test points. The example below will help with this process.

Example: Increment and Number of Point Selection

If

Maximum % rated power achieved = 115%

Minimum % rated power achieved = 35%

Then

Select Increment 10%

Select Max Rated = 115%

Select Number of Test Points = 8

This will allow the Test Routine to find the 8 required points starting at 115% and reducing by 10% to a minimum of 35%. The test vi will automatically adjust the Loading using the Control Damper until each point is achieved to with +/- 1%.

Enter the span and zero calibration coefficients in the appropriate fields in the vi Front Panel (See Section 4.1.3 Step 3).

Once the test is finished e.g. when the 35% point is acquired, the test will shut off the motor and save the data to the specified file.

4.1.5 Obtaining "No Load" Values

At the end of the motor test it is necessary to obtain a no load value for the motor being tested. To do this disconnect the motor from the load (impeller) via the shaft coupling and allow the shaft to spin freely. Using the Fan Power vi or the Single Point Motor Test vi, energize the motor. If you are using the Single Point Motor Test vi for a test, let the test continue to run after the last load point is obtained and saved, perform the disconnection procedure above, energize the motor and note the Voltage, Current, and Power Input values from the Front Panel. Also note any offset Torque value at the end of the test. If the offset is significant, then the test data may be require a correction

The "no load" value can be obtained at any time by connecting the motor wiring and using the Power vi independently. The no load speed can also be checked using the Tachometer though additional set-up time may be required (section 3.4.2.3).

CAUTION If the motor is being moved or manipulated on the Motor Table at any time, be sure to disconnect the Load Cell, and reinstall the Temporary Adjustment Brackets on the Motor Mount Table (see section 3.6.2).

4.2 Modified AMCA 210-85 Fan Efficiency Test: Type B, Free Inlet, Ducted Outlet

4.2.1 Use of Motor Test Results

After the motor test has been completed, the test data can be transferred into a spreadsheet matrix and accessed after a fan efficiency test to establish the intermediate system losses. Using a polynomial fit of the data acquired during the motor test, any combination of motor speed, motor torque, or Power input can be used to estimate the motor efficiency at any given fan test condition. Use of Input Power vs. Motor Efficiency has been found to correlate best. A test procedure, and associated vi and Excel Macro, will soon be available for correlating Motor and Fan Test data as an addendum to this Manual.

4.2.2 General Procedure

The FANalyzer is presently most easily used for testing fan efficiency in a Type B configuration, as illustrated in the AMCA Standard 210-85, Figure 7. Excerpts from the AMCA Standard have been included in Appendix III and should be reviewed by the user. Fan configuration for testing is beyond the scope of this manual and the user is referred to the above Standard and the Air Flow Test Standard HVI 916, for further information on fan test configuration.

The main components of the flow measurement system are as follows:

1. Air Flow Chamber assembly;
2. Static Pressure Sensors;
3. Ambient Temperature Sensor
4. Tachometer;
5. Winding Temperature Sensor; and,
6. Duct Transition Fittings.

Figure 22 gives an idea of what the FANalyzer set-up might look like for a residential furnace fan test. The user is referred back to Section 3.3.3 and Figure 5 for details on assembly of test sub-components. Installation of the External sensors is outlined in previous sections.

The FANalyzer test involves running the test fan over a number of operating points at a single speed setting³. Because a Single Point Fan Test vi does not yet exist, use the Multi Point Fan Test vi in the Fan_eff.llb library file (Figure 23). Open the vi and input the required data in the vi front panel. The important information required for this vi is the Maximum Static Pressure expected the fan to use for the first point, the desired pressure increment between the test points, and the number of points. Refer to the example below for point and increment selection for the motor test for an example of the process.

As in the motor test, the vi will automatically adjust the static pressure using the Control Damper until each point is achieved to within +/- 1%.

Once the data has been entered and the starting parameters assigned, run the vi and the test will start with the fan at a shut-off position (control damper closed). The FANalyzer then increases the flow rate (reducing the Static Pressure) and records each data point in turn until the last data point is acquired. The FANalyzer, as currently designed, does not actually permit a zero flow condition, due to leakage and other factors, but the results are still adequate for this purpose. However, a procedure for determining absolute shut off conditions is included at the end of this section.

4.2.3 Present Limitations of Multi Point Fan Test

At present the FANalyzer Multi Point Fan Test cannot modulate both the Control Damper, and the Control Fan simultaneously. When the Damper is fully open, a residual pressure drop will occur in the flow duct that must be zeroed out.

To do this, the user must adjust the Control Fan Speed while the test is running to achieve a condition of zero near static pressure. The Control Damper will then resume modulation, under the new flow conditions, until the desired increment is reached.

An automated test routine is presently being developed, that will result in the fan being cycled through all conditions, from shut off to full flow, by first modulating the control damper, and then, if necessary, increasing the control fan speed to automatically to achieve a condition of zero static pressure.

Another routine is also being developed for finding the Best Efficiency Point (BEP) automatically. At present, to pick any point on the fan efficiency curve, the user must manually modulating the control damper and control fan speed, and cycling through several vi Panels to obtain the data. Fortunately for most cases, the Multi Point Fan Test vi will find a good approximation of the BEP and will report the highest efficiency in the Test Report.

³ Speed setting is fixed at rated motor power output but in most cases actual speed will vary considerably with load. Some variable torque motors maintain a constant speed within a wide range of loading.

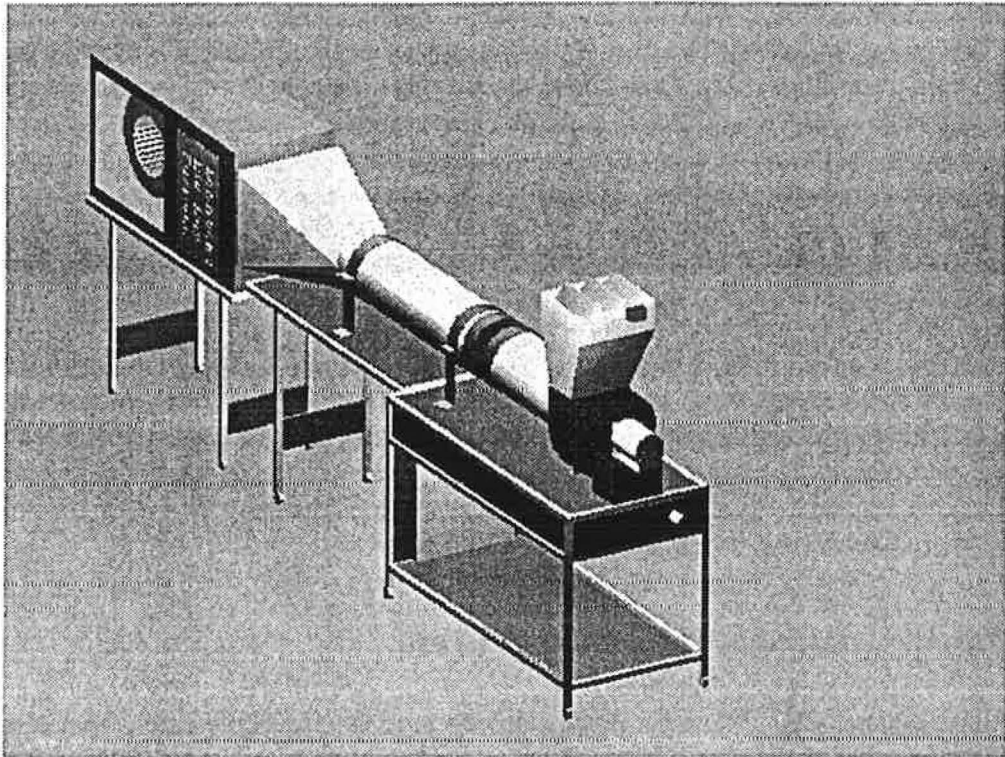


Figure 22 FANalyzer Set-up with Typical Furnace

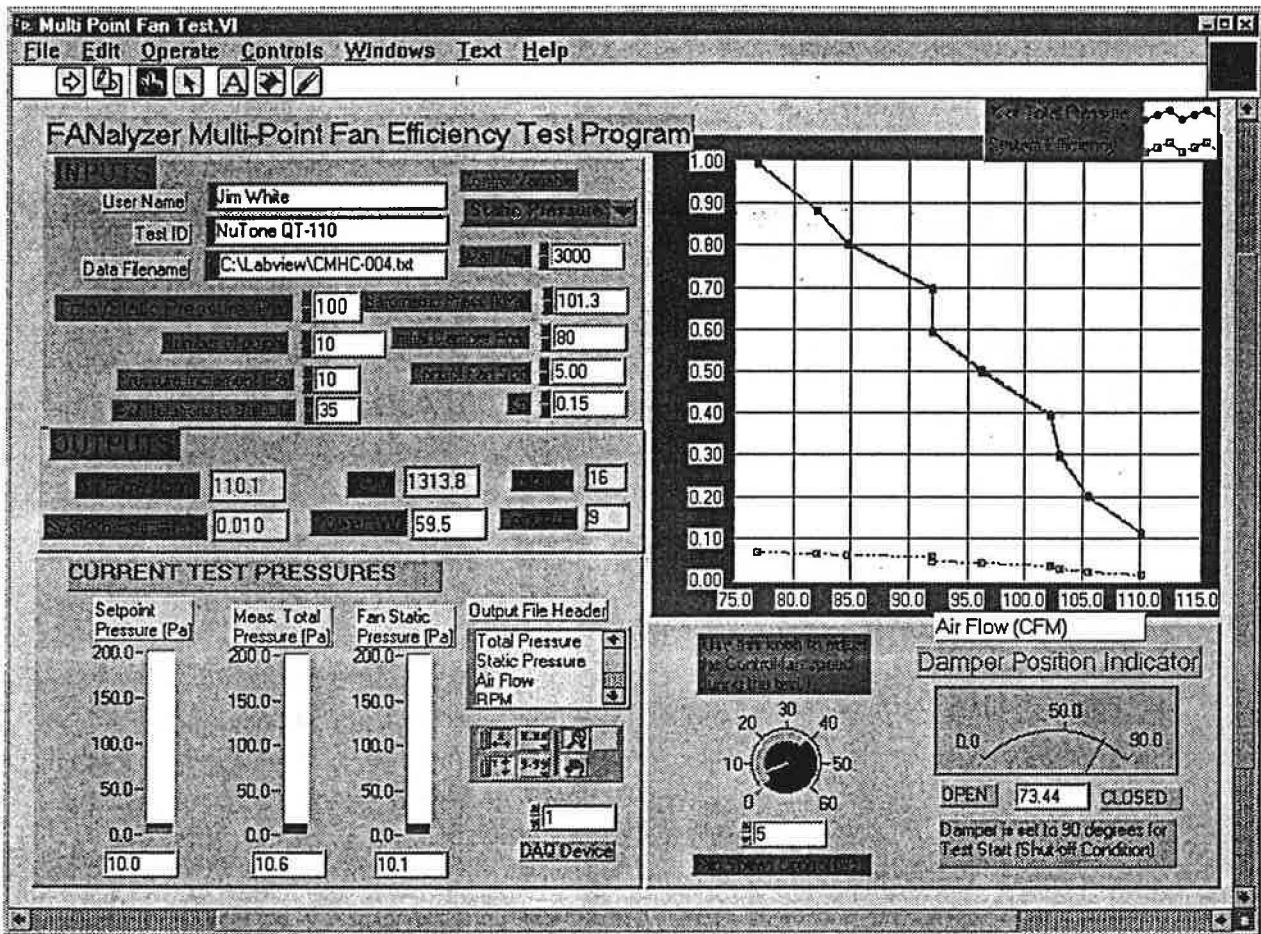


Figure 23 Multi Point Fan Test vi Front Panel

Table 6 provides a listing of the wiring and cable routing to and from the Instrumentation Box. This table can be referred to when troubleshooting connection problems. Table 7 describes DAQ Board connector box channel listing. The channels numbers listed in this table are the same channels numbers that are used by LabVIEW vi's to acquire signals from the sensors

Table 6 FANalyzer Wiring & Cable Table

Cable ID	Description	No. of Wires	To	From	Channel	Voltage
1	3 Hot wires	4	SCB	Mtr box	1,8,9	0-10 DC
2	3 Temp sensors	4	SCB	Mtr box	6,14,15	0-10 DC
3	2 Pressure Sensors	3	SCB	Mtr box	5,10	0-10 DC
4	Current & Voltage	4	SCB	Mtr box	2,3,11	0-10 DC
5	Load cell & Tach	3	SCB	Mtr box	Counter 0	5 DC
6	Fan Spd & Run Ctrl	4	Mtr box	SCB	0	0-10 DC
7	Damper Control	2	Mtr box	SCB	1	0-10 DC
8	Temp 1	4	Bench	Mtr box	na	12 DC
9	Temp 2	4	Bench	Mtr box	na	12 DC
10	Temp 3	4	Bench	Mtr box	na	12 DC
11	Tachometer	5	Bench	Mtr box	na	5 DC
12	Torque Table	4	Bench	Mtr box	na	12 DC
13	Fan Spd & Run Ctrl	4	Bench	Mtr box	na	0-10 DC
14	Damper Control	4	Bench	Mtr box	na	0-10 DC,24 AC
15	Frequency Drive Power	3	Bench	Mtr box	na	115 VAC
16	Test Motor Power	3	Bench	Mtr box	na	115 VAC
17	Input Power Main	3	Mtr box	AC Main	na	115 VAC
18	Power to Control Fan	3	motor	Bench	na	208 VAC
19	To Relay for Power to bench	3	motor	Bench	na	209 VAC

Table 7 SCB 68 Connector Board Channel Table			
Channel	Parameter	Colour	Cable
ACH0	Built in Temperature Junction		
ACH8	Hot Wire 1	Red	1
AIGND	Common Ground	Green	1
ACH1	Hot Wire 2	Black	1
ACH9	Hot Wire 3	White	1
AIGND	Common Ground	Purple	
ACH2	AC Volt Line	Tan	4
ACH10	AC Volt N/Ground	Pink	4
AIGND	Common Ground	Green	
ACH3	Test Motor Current 1	Red	4
ACH11	Test Motor Current 2	Green	4
AIGND	Common Ground	Green	
ACH4	Tachometer Test Voltage	White	
ACH12	Load Cell Signal	Yellow	5
AIGND	Common Ground	Green	
ACH5	Static Press 1	Black	3
ACH13	Static Press 2	Black	3
AIGND	Ground	Silver	
ACH6	Temperature 1	Red	2
ACH14	Temperature 2	White	2
AIGND	Ground	Black	
ACH7			
ACH15	Temperature 3	Black	2
AIGND	Common Ground		
AOGND			6
DAC1 OUT	Damper position control		7
AOGND DAC0 OUT	Control Fan Speed		6
DOGND DO1	To Relay for Power to Bench		6

Table 8 Wiring Terminal Block Description for
FANalyzer PC Board

T#	Color	Parameter
Terminal Block 1		
1	Green	Ground
2	Red	Hot Wire 1
3	Red	Test Motor Current 2
4	Tan	AC Volt Line
5	Green	Test Motor Current 1
6	Black	Hot Wire 2
7	White	Hot Wire 3
8	Yellow	Load Cell Signal
9	Orange	Tachometer
10	Pink	AC Volt N/Ground
11	Brown	Free
12	Blue	Free
Terminal Block 2 (Tachometer) From Left		
1	White	
2	Green	
3	Black	
4	Red	

Terminal Block 3 (Load Cell) from top	
1	Green
2	Black
3	White
4	Red

AC Terminal 4 (CT's and PT's)			
1	1.0 VACp-p	4	Neutral
2	CT1 HI	5	Ground
3	CT2 HI		

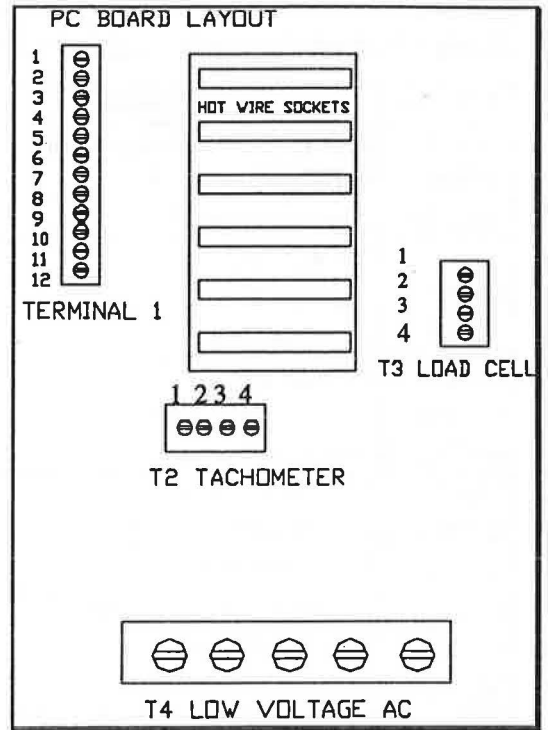


Figure 24 Sensor PC Board Layout

5. Sample Test Data

FANalyzer Fan Performance Test Report

Test Method: Modified ASHRAE/AMCA 210-85 Fan Efficiency Test Method

Test ID: Arcoaire Blower Medium Speed

Test Agent: Brian Sikorski

Test Date: 02/20/96:11:06 PM

Peak Efficiency **25.6%**

1. Fan Description

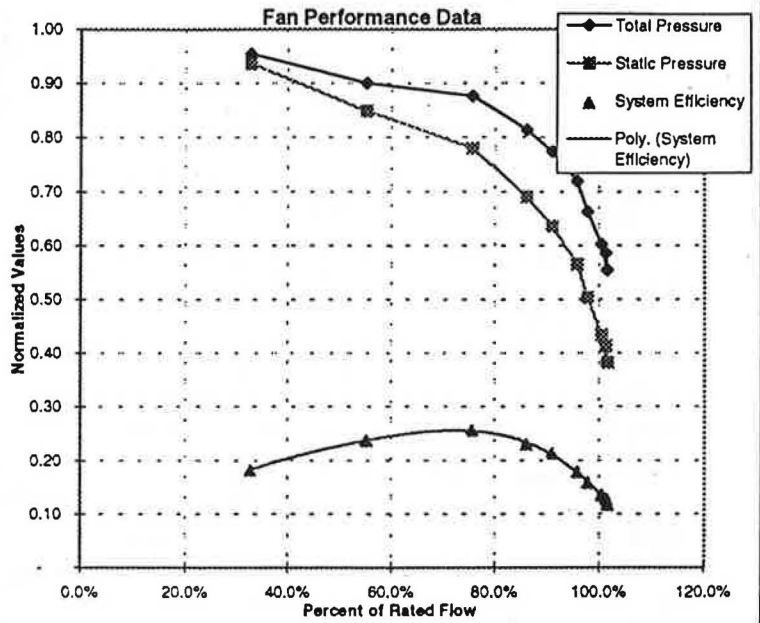
Fan Manufacturer	ArcoAire
Model Number:	GUI075A016
Serial Number	NA
Rated Blower Motor (Hp)	0.25

2. Design Conditions

Select Units	
Rated Air Flow	1050.0 CFM
@ Static Pressure	1.00 in wc
Drive Type	Air over
Rated Speed (RPM)	2500
Speed Setting (Hi/Med/Low)	Medium

3. No Flow Conditions

Select Units	
Static Pressure	1.25 in wc
Power In (W)	110
Ambient Temp (C)	25.0



4. Load Measurements

% Rated Flow	Total Pressure	Static Pressure	Air Flow	RPM	Current	Power In	Power Factor	Temperature		System Efficiency
	in wc	in wc						Deg C	Deg C	
32.7%	1.19	1.17	343.3	1,139	3.12	259.8	71.5%	101.0	26.1	18.2%
55.4%	1.13	1.06	581.6	1,115	3.46	306.0	77.8%	101.0	25.6	23.7%
75.9%	1.09	0.97	797.0	1,089	3.90	356.9	81.2%	101.0	25.9	25.6%
86.2%	1.02	0.86	904.8	1,061	4.33	398.1	83.0%	101.0	25.7	23.0%
91.1%	0.97	0.79	957.0	1,044	4.58	420.2	83.6%	101.0	26.2	21.3%
96.0%	0.90	0.71	1007.8	1,013	5.08	468.8	85.2%	101.0	26.1	17.8%
97.9%	0.83	0.63	1027.7	987	5.34	483.4	85.3%	101.0	26.3	15.7%
100.5%	0.75	0.54	1055.2	944	5.63	500.1	84.7%	101.0	26.1	13.5%
101.6%	0.69	0.48	1066.4	915	5.86	518.2	84.5%	101.0	25.7	11.6%
101.3%	0.73	0.52	1064.2	945	5.63	504.3	84.9%	101.0	25.7	12.8%

Efficiency at Rated Output : **13.4%** Based on linear interpolation.
 Efficiency at 75% Rated Output: **25.2%** Based on linear interpolation.

Get Efficiencies

Print Form

5.2 Electric Motor Test Report

FANalyzer Electric Motor Efficiency Test Report

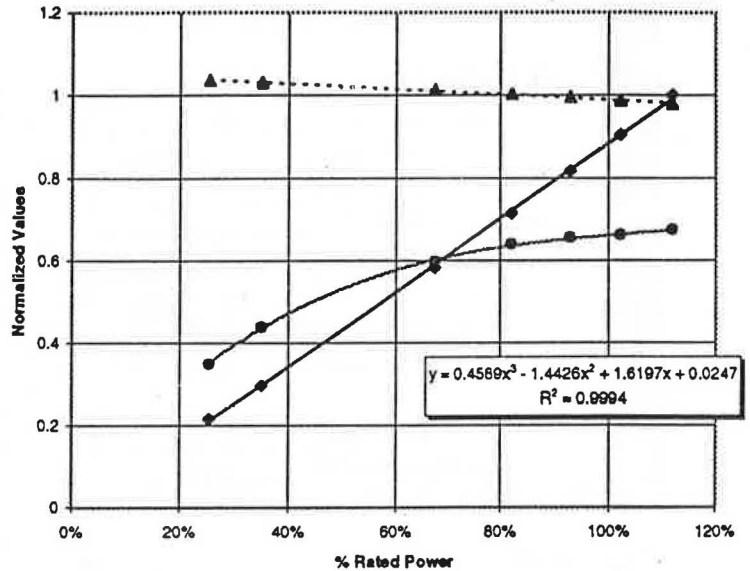
Test Method: Modified CSA C747 Small Motor Efficiency Test Method

Print Form

Test ID: Sheltair Scientific Ltd.
 Test Agent: Fasco Motor from ArcoAire Furnace (Medium Speed)
 Test Date: 02/20/96:01:22 AM

Motor Nameplate Description

Manufacturer	Fasco Industries
Model Number:	OEM
Serial Number	NA
Rated Power (Hp)	0.25
Rated Current (A)	
Type	PSC
Frame	Nema 48
Rated Speed (RPM)	1140
Frequency	60
CSA Enclosure	
Insulation Class	F



No Load Measurements

% Voltage Rating	
Line Voltage (Volts)	120
Line Current (A)	0.8
Power In (W)	110
Ambient Temp (C)	26.0

◆ Specific Torque ▲ Specific Speed ● Efficiency
 — Poly. (Efficiency) ····· Linear (Specific Speed) — Linear (Specific Torque)

Load Measurements

%Rated_Power	Torque	Speed	Current (A)	Power In (W)	Power Factor	Voltage (Volts)	Ambient	Winding	Power Out (W)	Efficiency (%)
	N-m	(RPM)					Deg C			
112%	1.784	1,116.6	2.80	314.1		113.50	26.0	37.0	208.8	67.4%
102%	1.614	1,126.0	2.60	291.6		114.10	26.0	38.9	190.6	66.1%
93%	1.456	1,135.5	2.30	268.6		114.70	26.0	39.0	173.4	65.5%
82%	1.276	1,144.5	2.10	243.0		114.90	26.0	39.3	153.1	63.9%
67%	1.039	1,155.2	1.90	216.4		115.40	26.0	39.8	125.8	59.7%
35%	0.531	1,176.0	1.30	150.0		116.00	26.0	40.3	65.4	43.9%
25%	0.384	1,181.0	1.20	143.1		116.20	26.0	40.6	47.5	34.9%

Efficiency at Rated Output : 65.8% Based on linear interpolation.

Efficiency at 75% Rated Output: 61.4% Based on linear interpolation.

6. General Specifications

MAMAC Pressure Gauge Range and Accuracy

<i>Pressure Range</i>	<i>Minimum (Pa)</i>	<i>Maximum (Pa)</i>	<i>Accuracy</i>	<i>Over-Range (Pa)</i>
Pressure 1	0	250	+/- 1% range	375
Pressure 2	0	125	+/- 1% range	200

Hot Wire Anemometer Specifications (per Hot-Wire)

<i>Shiburu F6305-2 Operating Range</i>	<i>velocity (m/sec)</i>	<i>flow (Liter/sec)</i>	<i>Signal Voltage</i>	<i>Voltage Resolution</i>	<i>Accuracy % Range</i>
<i>Minimum Flow Conditions</i>	0.25	12.7	2.91	1.73%	+/- 3%
<i>Maximum Flow Conditions</i>	11.5	582.7	4.87	0.61%	+/- 3%

External Sensors

<i>Sensor/Device</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Accuracy</i>
Power (FANalyzer/LabVIEW)	2 W	1200 W	± 1%
Voltage (AC Hammond 12 VAC Transformer)	10 V	200 V	± 1%
Current (MAMAC 50:5 amp CT)	0.2 Amp	12 Amp	± 1%
Load Cell (10 lbf FT70 Force Transducer)	0.25 in lb	40 in lb	± 0.1 in lb
Tachometer	50 rpm	5000 rpm	± 2 rpm
LM35 Precision Temperature Sensors	2 C	150 C	+/- 0.5 C

Blower and Speed Drive Specifications

<i>Sub Component</i>	<i>Parameter</i>	<i>Lower Limit</i>	<i>Upper Limit</i>
Leeson ½ hp Motor	Speed (RPM)	60	1700
	Power Consumption (W)	25	500
Dayton Blower Model 2C938	Air Flow L/sec (CFM) @	⁴ 25 (52)	550 (1150) @
	Static Pressure (Pa)	5	125

⁴ At 60 RPM

Power Supply and Distribution

Input to Blower, Test Fan, Damper, and Sensors	<i>Maximum</i>		
	Power (W)	Voltage (V)	Current (A)
Electrical Supply to Instr. Box	1800	120	15 ⁵
Distribution to Bench			
Input to Variable Frequency Drive	550	120	5
Input to Test Fan/Motor (AC) ⁶	1440	120	12
Damper Actuator (AC)	2.8	28	0.1
Input to DC Power Supply for Sensors	24	120	0.2

Shipping Weight and Dimensions (Metric)

Description	Length (m)	Width (m)	Height (m)	Volume (cu. m)	Weight (kg)
Main Test Bench	1.57	0.66	0.89	0.92	90.7
Shipping Crate	1.63	0.71	0.97	1.12	38.6

Shipping Weight and Dimensions (Imperial)

Description	Length (in)	Width (in)	Height (in)	Volume (cu. ft)	Weight (lb)
Main Test Bench	62	26	35	32.7	200
Shipping Crate	64	28	38	39.4	85

Table 9 General Specifications

¹ Canadian Standards Assoc. Std C747, Standard for Testing Efficiency of Single Phase Motors under 1 hp.

⁵ System is fused internally with 15 Amp HRC fuse.

⁶ Fuse will blow if system is operated with Control Blower and Test Fan/Motor operating simultaneously at maximum condition.