INSTRUCTIONAL GUIDE FOR THE OPERATION OF THE IIHR LOW-TURBULENCE WIND TUNNEL DATA ACQUISITION SYSTEM

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IIHR Monograph No. 119

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July 1999
PREFACE

The Low Turbulence Wind Tunnel, designed and built during 1984 – 1988, is one of the facilities housed in the Iowa Institute of Hydraulic Research Wind Tunnel Annex. Among its notable features are a high degree of mean-flow uniformity, a turbulence level estimated to be less than 0.05 percent, quiet operation, and almost total optical access to the test section. The tunnel is used for basic research in aerodynamics. Models tested in the wind tunnel include wings, ships, missiles, and cooling towers. Some of these models are on display in a showcase close to the tunnel.

Joel Walter, IIHR Graduate Research Assistant, developed during his Ph.D. thesis work a comprehensive automated system to operate the tunnel and to conduct measurements with hot-wires and pressure probes. During the development of the system, Joel generously shared its use with other researchers through impromptu, hands-on training courses. After his departure from IIHR, the task of training new users become increasingly difficult because the sequence of computer- and hardware-related procedures involved in making these measurements was based solely on word-of-mouth transmittal. Subsequently, Joel prepared extended guidelines (denoted JAW Manual in the text) for operating the wind tunnel and the associated equipment. However, these guidelines assumed good knowledge about the equipment, and the need for a simplified version become apparent.

The sole purpose of the present monograph is to provide a user-friendly tool for future researchers, regardless of their previous experiences to conduct experiments in the Low Turbulence Wind Tunnel. This instructional manual is based on Walter's guidelines. It contains a set of instructions for operating the tunnel and the associated instrumentation with emphasis on their control using LabVIEW software. In addition to acknowledging Walter's contribution, the author thanks Paul Kodzwa, an undergraduate student in Mechanical Engineering for editing the manual, and to Visiting Professor H.T. Kim, who kindly and patiently assisted in the compilation of some parts of the manual. Special thanks are due to Professor V.C. Patel for his support and general guidance during completion of the present work.

Marian Muste
July 1999
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1 Wind Tunnel Setup and Operation

This manual is designed to give step-by-step instructions on how to use the Low Turbulence wind tunnel. The primary focus of this manual is on the functionality of the system, not on the technical background behind each instruction. For more complete information please refer to the manual prepared by Dr. Joel Allan Walter (hereafter referred to as JAW). This chapter explains how to start up and operate the wind tunnel and using the LabView-based automated data acquisition system specially designed for this facility. Additionally, more information about individual sections of the program can be obtained by selecting “Get Info” under the File selection of the Menu Bar.

1.1 Setup and Initialization

1.1.1 Starting Up

Ensure that the fan motor has power by examining the large gray box on the east wall of the Wind Tunnel Annex. The switch should be in the On position.

Move to the platform neighboring the wind tunnel.

Turn on the Indexers located in the large box directly over the door to the inside of the wind tunnel. This is simply a metal switch on the exterior of the box.

Turn on the power to the Validyne Signal Conditioner (VSC). Connect the output connector to the Digital Multimeter (DVM).

Turn on the DVM.

Turn on the computer.

Load LabView by clicking on its respective icon.
Open LWT\IIHR.Lib\IIHRTop\Misc.lib\IIHR LTWT Init. ² (30 seconds).
Initialize LabView before Powering-Up the Scanivalve

When the IIHR LTWT Init VI opens a small window superimposes on the screen with a countdown. Turn on the power for the Scanivalve control and positioning circuit before the countdown expires. Then click on the button labeled 'Do It Now'. A loud whirring noise should be heard as the Scanivalve is adjusted to its last setting.

- Turn on the power to the Scanivalve Solenoid Control first and the Scanivalve Positioning Circuit (the gray rectangular box). These are located in the cabinet underneath the computer desk on the left-hand side.

- Click on the Scanivalve window and change the number in the blue box from zero to 10 ⇒ (this is the short circuit pressure). A loud whirring noise should be heard as the Scanivalve is adjusted.
Zero the VSC by adjusting the Zero knob on the Validyne until a zero reading is achieved on the DVM. An appropriate reading for this procedure is about $10^3$ V. Make sure that the DVM scale range setting is appropriate and is connected to the VSC.

**Adjusting the Knobs on the VSC**

These knobs will only operate if the lever on the knob is adjusted up. Remember to lock the knob when you are done!

**Reference Pressure and Temperature**

A reference pressure is read in the tunnel test section. A pressure differential reading is taken between port 10: test section and port 40: settling chamber, this corresponds to the drop in pressure across the tunnel contraction. A short circuit pressure reading is when the pressure differential is zero, hence a reading is taken between port 10 and port 10 both located in the test section.

### 1.1.2 Turning on the Wind Tunnel and Setting the Span for the Validyne Signal Conditioner

The procedure above is a preliminary to starting up the wind tunnel. The Initialization program zeroes the Statham pressure probe and initializes the Scanivalve. Before the wind tunnel is turned on, determine the maximum velocity that will occur during the experiment, and subsequently, the maximum rpm. Once the highest motor rpm has been determined, please continue on. The following explains how to set the span for the VSC first and then for the Statham Signal Conditioner (SSC).
Set the Scanivalve to port 40 so that the Validyne sense the pressure drop across the wind tunnel entrance section vs. the settling chamber. ⇒

Using the IIHR Robicon Speed Control VI, set the rpm value in the blue box to the maximum rpm that was determined previously. ⇒

Go to the fan control box that is located on the wind tunnel wall across from the platform and push the Start button.

Alternate Ways of Setting Fan Motor Speed

The fan motor is capable in operating in several different modes. There are two specific modes by which the motor can be controlled directly. By setting the control knob on the panel to Phase Lock Thumbwheel allows control of the fan speed by the setting on the thumbwheel decade. The Manual setting allows control of the fan speed by the small dial on the panel. To return control of the fan to the computer set the knob to Phase Lock Thumbwheel Comp. Note: the emergency stop button is regular stop, the control wiring is reversed.

Once the maximum tunnel fan speed has settled, examine the reading on the DVM. This should be very close to 5 V (± 10^3 V). If need be, change the DVM's scale for a 5V reading. If it is not close to 5 V, use the Span knob on the VSC to increase or decrease its span.
Pressure Transducers

A piezoelectric pressure transducer senses pressure by means of an impedance diaphragm. The diaphragm deforms due to an electrical impedance differential between the high and the low pressure sides of the transducer. The current diaphragm inside the Validyne transducer is sized for pressure differentials corresponding to higher rpm values (700-800 rpm). If much lower values are used the diaphragm should be replaced for more accuracy in sensing the pressure differentials.

Important

The pressure drop across the settling chamber and the entrance section are temperature sensitive. Thus if this procedure is conducted while the tunnel is warming up, a loss of data resolution may occur as the tunnel reaches a steady state temperature. It takes approximately one hour for the tunnel to reach this steady state temperature; this approximation will vary depending on the time of the year the tunnel is in use.

1.1.3 Setting the Span For The Statham Signal Conditioner

This particular operation requires the careful use of the Rouse manometer. It is advisable that the user becomes familiar with the usage of the manometer by reading the manometer's manual.

Open the following path - IIHRLib\IIHRLibs\SerialLib\Metrabyte SigCon.
Set the pointer under *Device Select* to Device 2 - Pressure. ⇒

**Important Hardware / Software Check**

The following instructions refer to the *Command Selector* box in the center of the window. A good hardware check is to observe the same number appear in the Result, Response String, and Raw Response VI boxes. If the number in the Raw Response box is different, there may be a problem with the communication between devices.

- Select **Write Enable**. Clicking on the center field, selecting this option and then releasing the mouse button achieves this. ⇒
- Select **Read Zero**. ⇒
- Record the value returned in the Result space on the screen (referred to onwards as $x$).
Read the pressure drop off the Rouse Manometer by following these 8 easy steps.

- **Check that the pressure tubes are connected into the appropriate ports**
- **Turn the knob to the '0' position (this is the waiting position).**
- **Zero the Rouse Manometer (Set counter to zero without using the handwheel)**
- **Turn the knob on the left hand side to '+' (a height difference between the fluid columns on the manometer should become present)**
- **Turn the handwheel until the column fluid levels become equal.**
- **Record value (referred to onwards as y).**
- **Reading the counter, reverse the handwheel until the counter value becomes zero.**
- **Turn knob to the '0' position (this is the waiting position).**

**Reading The Rouse Manometer Counter**

Remember that the display on the Rouse manometer in mili-inches. That is, the value that is read from the manometer needs to be divided by 1000. So if a value 2159 is read off the manometer, the value that is inputted in the program is 2.159 in.

- Select **Write Enable** in the command selector box. ⇒
- In the **ASCII Number** space located at the bottom of the screen input the value:  
  \[100y - x\]
- Select **Maximum - M2521 Only** in the command selector box. ⇒
- On the menu bar at the top of the screen select **Operate | Reinitialize All to Default**.
1.1.4 Calibrating the Statham and Validyne Transducers

Open the following path IIHRLib\IHRTop\xducer.lib\Two_xducer_Calibration.

![Two x-ducer Calibration VI Screen](image)

1. is an array which determines the operating points the tunnel will use during calibration. The points are labeled 0 through 3. Values can be added if need be.

2. Set how many points that are going to be used for the calibration in 1.

**Pressure Transducers**

The validyne pressure transducer is used with pressure probes. The statham pressure transducer is used to regulate the fan speed by reading the pressure differentials across the tunnel contraction; additionally used in the periodic calibration of the hot-wire anemometers.
**Calibration Points**

If the Validyne is used, it has to be calibrated over its capable voltage range. That is from +5 to −5 volts. To calibrate the Validyne over the negative pressure range, a repeated pair of rpm values is required. One pair accounts for the positive pressure range, and the other for the negative. Hence, when the points for calibration are set, the values are inputted twice to calibrate the Validyne over the negative pressure range.

**Calibration for Positive and Negative Pressure Ranges**

To perform calibrations including both negative and positive pressure ranges the following steps are required.

When the operating points (rpm’s) are reached where the negative pressure range will be examined, after the dialog box comes up, follow this procedure.

Usually, port 10 (the entrance section pressure) is connected to the low side of the Validyne transducer.

- Remove the port 10 connection from the low side of the Validyne transducer and clamp it.
- Identify the tube for port 40 (the settling chamber pressure) and attach this connection to the low side of the Validyne transducer.
- Open Scani_Move.DIO-96 (the Scanivalve VI). This can be achieved by moving to the menu bar and clicking Window | Scani_Move.DIO-96.
- Click on the blue box and change its value from 40 to 10. ⇒
- After the tunnel settles at the desired rpm, read the Rouse manometer as previously stated.

**Do Not Forget**

To return the port settings across the Validyne after the calibration is complete.
After a few seconds a dialog box will ask you to input a pressure in inches of kerosene (alcohol).

Take the reading of the Rouse manometer as outlined before. Enter this value in inches in the box and click OK.  

Evaluating the Calibration

The key values to examine on the above screens are the RMS and Intercept values for the VSC and SSC (these are labeled 3 and 2 on Figure 5). These should be as small as possible. Typically RMS and Intercept values for the SSC and the VSC run between $10^{-4}$ and $1 \times 10^{-3}$. The SSC should have better results in both categories versus the VSC. Remember to scroll downward in the VI to access the calibration curves.
1.1.5 Shutting Down The Wind Tunnel

It is vital that this operation be carried out in order. This is to ensure that the various circuitry in the computer system and wind tunnel motor are in no way damaged.

- Turn off the fan by pressing the Emergency Stop button on the wind tunnel control panel.
- Turn off the power to the Scanivalve Positioning Circuit (the gray box) and then the Scanivalve Solenoid Control.
- Exit LabView.
- Turn off the computer, the VSC and the indexers.
2 Hot-Wire Setup and Operation

Hot-wire probes are highly accurate instrumentation for measurement of instantaneous velocities. There are three types of hot-wire probes, single, cross-wire and triple wire that measure simultaneously one, two and three velocity components respectively. This section centers on setting up, calibrating and operating a single-wire probe. Nevertheless, by making small changes these procedures are applicable to other hot-wire configurations. Additionally, more information about individual sections of the program can be obtained by selecting “Get Info” under the File selection of the Menu Bar.

2.1 Setup

2.1.1 Hardware

2.1.1.1 Setting Up the Hot-Wire and its Connecting Accessories

After it has been determined which hot-wire probe is to be used for measurements, follow the instructions below. The hot-wire probe is connected to a specialized socket on the wind tunnel traverse. For each type of hot-wire probe, there is a different type of socket. The cables run from the probe through the bottom of the tunnel to the anemometers (each wire in the probe is connected, via a cable, to its own anemometer). These settings are made prior to all other adjustments and settings. Once the setup is complete, it is not necessary to repeat the above procedures if the probe remains the same during the measurements. The following instructions refer to the use of the 55M10 anemometers.
**Probe Alignment**

It is very important that the probe socket is properly aligned so that the offset angles are initially zero. This initial alignment should be done carefully using a surveyor's scope. For complete details of this procedure, consult JAW Chapter 5, page 41.

Once the probe socket has been aligned, connect the cables to their respective anemometers. Note how long the cables are (usually 5 meters in length).

**Anemometer Setup**

1. Ensure that the **Function** dial is set on **Std. By**.
2. Set the **Volt Range** dial to 1V.
3. Set the **Probe Type** switch to Wire.
4. Set the **Gain** dial to 1.
5. Cable Accordingly.

- Insert the short circuit hot-wire in the probe socket.
- Turn on DVM.
- Turn on switch located in back of anemometer.
- Set the **Function** dial to **Res. Meas**.
- **Carefully** adjust the **Zero Ohms** screw using a screwdriver dial so that it deflects to the red scale mark.
- Remove the short-circuit probe and connect the probe to be used.
- Set the decades so that the meter deflects to the red scale mark. Record this value (referred to as $x$ onwards). Note: **Start this procedure using the Units Dial first**.
- Set the **Function** dial to **STD. BY**
Examine the label on the probe to be used. The following table exemplifies values for a single wire probe. If this was a cross-wire probe, there would two columns, and for a triple-wire there would be 3.

<table>
<thead>
<tr>
<th>Sensor No.</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{20}$</td>
<td>3.4</td>
</tr>
<tr>
<td>$R_l$</td>
<td>0.5</td>
</tr>
<tr>
<td>Sensor TCR</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Table 1: Sensor Properties for a Cross-Wire Probe

Calculate the operating resistance $R_o$ (the resistance used during the measurements), by the following procedure:

- **Determine the ambient sensor resistance when the tunnel velocity is zero.**

  $$ R_w = \times R_L $$

  where $R_w$ is the sensor ambient resistance, and $R_L$ is the lead resistance (read off the probe information label).

  $R_o$ should be slightly higher than the value given on the probe label. This is because the ambient temperature in the tunnel is never as low as 20°C. The value $\times$ is actually the sum of the lead resistance and the sensor resistance at zero tunnel velocity.

- **Determine the overheat sensor resistance by**

  $$ R_w = R_w \times N $$

  where $N$ is the overheat ratio (this is usually set to 1.7).

- **Determine the operating resistance, $R_o$ by**

  $$ R_o = R_w + R_L $$

  Set the decade resistance on the anemometer to $R_o$.

  Set the **Function** dial to the **Operate** position and set the scale to 10 V. Cross check this value with the display on the DVM. When there is no wind velocity in the tunnel, the DVM reading should be in the voltage range of 2.5 - 2.9 V.
2.1.2 Software Setup
The following instructions refer to the use and setup of a cross-wire.

2.1.2.1 Sensor Properties
Open /IIHR lib/Hotwire.llb/Sensor Properties

Figure 6: Sensor Properties VI Screen
Depending on what type of probe you are using, fill in the necessary sensor information in the columns relating to the wires. That is if a cross-wire probe is being used, type in the sensor properties in the Sensor 1 and 2 columns. If a single wire is being used, input information in the Sensor 1 column only.

**Always Run This VI Before You Proceed**

If you do not enter any new information in this VI, or even if you have but have not executed it, the program will only use the last set of logged information. This can be disastrous if the last probe used has vastly different properties.

- Insert the sensor information for the cross-wire. ⇒

### 2.1.2.2 Calibration

The purpose of this operation is to relate the bridge voltage, \( E_b \), to the velocity approaching the probe \( U \), i.e. to obtain the relationship

\[
E_b = A + BU^2 \quad \text{(King's Law)}
\]

At this stage it is assumed that the Statham transducer has been calibrated. Please refer to Section 1.1.3 in this manual. Hot wires require periodic recalibration (the sensors can operate in general for about 2 hours before losing a unsatisfactory degree of accuracy). The calibration itself takes around 30 minutes to complete.

- Open IIHR Lib/Xwire.llb/Xprobe Speed Calibration.

- In the RPM Settings Box, set low, high and incremental fan speeds. There should be at least 14 readings taken from the low motor speed to the highest value (a suggested set of values is 160, 800 and 40 respectively). ⇒ 2.
Figure 7: Xprobe Speed Calibration VI Screen

- **A/D** – kept the same

- Set the **Fit Type** *(Recommend – Polynomial order 4)*

- Set the **Temperature Drift Correction** *(Recommend – 1st Order)*

- Set the **Software Offset** *(Recommend – 0.00 V)*

- Set the **Jorgensen Coefficients** *(Recommend – 0.2)*

- Set the **Sensor Angle** *(for cross-wire recommend – 45°, this will not appear on a single probe calibration)*.
2.2 Operation

This process encompasses the following sub-operations, traversing the lead screws to specified positions in space, taking measurements, and writing the data to a file. Before proceeding, it is necessary to develop a Traverse File. This contains the positions that the probe assumes for measuring velocity profiles. Prior knowledge of the flow features is useful in determining the positions to take measurements. For measurements that can interfere with objects positioned in the wind tunnel, the traverse order of motion is important and may lead to accidents. The procedure outlined here is typical for all "...oop Traverse" Vis. All these programs require the same format for measurement probe positions. Furthermore, all these Vis write similarly formatted output files. For clarification of the movement order, please refer to the JAW manual, pages 19-23.

Open IIHRLib/IIHRLibs/Traverse.lib/Create Traverse File

Figure 8: Create Traverse File VI

Enter the traverse positions as strings in this VI with a carriage return between each entry. This method may sometimes prove more convenient than using Excel or some other editor.

Be careful: no entry, including the last one in each column, can have more than one carriage return after it. Additional <CR> are interpreted as zero.
Important

Ensure that the experiment has a well-defined absolute zero point. That is, the user has to define the point (0,0,0). The DAQ system uses a positioning algorithm based on the relative displacement of the traverse 3-D components.

- Type in the x, y and z values at which measurements are to be taken according to the established coordinate system. => The VI will return a prompt for a filename to save coordinates. Type in a filename.

Important

The DAQ system takes the first set of x, y, z values in this file as a reference point from which subsequent measurements are taken. Hence, before the experiment is initiated, make sure that the probe is located precisely at the first set of coordinates.

- Open IIHR.Lib/IIHRLibs/Traverse.llb/oop Loop Indexer Driver.

- By inputting values in the blue boxes, move the traverse to the first point of the newly created traverse file. =>

![oop Loop Indexer Driver](Figure 9 oop Loop Indexer Driver)
2.2.1 Measurements

In the pictures below, the following convention is applied:

Letters A-Z refer to common features to all VT's.

Numbers refer to specific features to VT's of a particular class.

2.2.1.1 Single Wire Measurements

- Open IIRTop/Hwire/1-Wire oop Traverse

- Input profile file names corresponding to each profile that is to be measured. These files will contain the measurement data for each profile that was measured. Enter names with neither an extension nor a directory pathname. Other sub­screens on the VI record these inputs. Refer to JAW Manual, section 4.5.1, and section 4.5.2 (pages 31-33) for a complete explanation of this feature.

- The Output File Comment is primarily useful for identification of the output files by the user. This will appear on the first line of the ASCII output file.
Anything can be put in this field. For easy reference, it is suggested that the following format be used:

*The type of probe used, the some specific identification number for the probe (in case there are two of the same type), the traverse order, the barometric pressure at the time of the experiment and anything else that is not recorded elsewhere.*

- **C** – This switch can be used to temporarily stop the experiment. The VI will finish its current measurement, move to the next position, and put up a dialog box stating that the experiment has been interrupted. To continue the experiment, click on the toggle switch again. Using this to stop the fan and check something in the tunnel is acceptable unless the ROBICON Speed Control VI is used to reduce the fan speed. Hence, press the Emergency Stop button when this procedure is done.

- **D** – *ADC* - Refer to JAW Manual, section 4.2.1.3, page 24 for complete details of this feature.

- **E** – The Current Data box merely states the measurement data at the last measured point. This does not have to be adjusted and is self-explanatory.

- **F** – Select the format of the output data files. Merely depressing the necessary buttons does this. “Reduced” refers to the standard data file in IIHR ASCII format. “Raw” refers to the hot-wire raw data file, which contains raw voltages, calibration data, and all of the other information necessary to reconstruct the reduced data. The error file is used for dual and triple-sensor probes, but not for the single sensor. There is currently no reason to create this file with single sensor experiments.

- **G** – Maintain (Split between Figures 11 and 12)
  - Select the manner in which the experimental setup will be maintained during measurements (it is recommended to maintain the dynamic head).
  - Input the value at which the system should maintain the apparatus at.
  - Input the RPM that the system should reset to once measurements have been completed.

- **1** - Set the Temperature drift correction to **1st Order**

- **2** – *Offset Angles* - Refer to JAW Manual, section 4.6.1, page 35 for complete details of this feature.
The following refer to sections on the second 1-Wire oop Traverse VI Screen shown on the next page.

Figure 11: 1 Wire oop Traverse Screen 2

- **Input the folder name under which the profile files will be stored.**

- **Plot Parameters.** These are used to determine how data is presented on the main display (Figure 11). For more details about this feature, refer to JAW Manual, section 4.2.1.11, page 26.

- **This controls probe angular displacements. Set the stepper motors to a determined value (suggest 750). For more details about this feature, refer to JAW Manual, section 4.2.1.9, page 26. Basically, this feature allows you to rotate a tunnel axis to meet a user-specified angle.

- **Automatic Speed Calibration.** Define the coordinates of a point that can be "theoretically" considered to be at the tunnel freestream velocity (that is a point that is far away from the region where the flow is disturbed by the model under examination in the wind tunnel). Input values for fan speeds and increments; this process is identical to that previously done in Section 2.1.2.2. Set the time intervals at which recalibration will be conducted. For more details, refer to JAW Manual, section 4.5.4, page 33. Lastly, set the Maximum Cone Angle in degrees.
— Stepper Motors. Set the stepper motors to a specific value (the suggested value for this is 750). For more details, refer to JAW Manual, section 4.2.1.12, page 27.

For Data Post-processing, please refer to JAW Manual, Chapter 7. This chapter provides procedures for converting and formatting data files for other software packages and VPs.
2.2.1.2 X-Wire Measurements

- Open IIHRTop/Hwire/2-Wire oop Traverse

- **A** - Input profile file names corresponding to each profile that is to be measured. These files will contain the measurement data for each profile that was measured. Enter names with neither an extension nor a directory pathname. Other sub­screens on the VI record these inputs. Refer to JAW Manual, section 4.5.1, and section 4.5.2 (pages 31-33) for a complete explanation of this feature.

- **B** - The Output File Comment is primarily useful for identification of the output files by the user. This will appear on the first line of the ASCII output file. Anything can be put in this field. For easy reference, it is suggested that the following format be used:

  *The type of probe used, the same specific identification number for the probe (in case there are two of the same type), the traverse order, the barometric pressure at the time of the experiment and anything else that is not recorded elsewhere.*

- **C** - This switch can be used to temporarily stop the experiment. The VI will finish its current measurement, move to the next position, and put up a dialog box stating that the experiment has been interrupted. To continue the experiment, click...
on the toggle switch again. Using this to stop the fan and check something in the tunnel is acceptable unless the ROBICON Speed Control VI is used to reduce the fan speed. Hence, press the Emergency Stop button when this procedure is done.

- **D** — ADC- Refer to JAW Manual, section 4.2.1.3, page 24 for complete details of this feature.

- **E** — The Current Data box merely states the measurement data at the last measured point. This does not have to be adjusted and is self-explanatory.

- **F** — Select the format of the output data files. Merely depressing the necessary buttons does this. "Reduced" refers to the standard data file in IIHR ASCII format. "Raw" refers to the hot-wire raw data file, which contains raw voltages, calibration data, and all of the other information necessary to reconstruct the reduced data. The error file is used for dual and triple-sensor probes, but not for the single sensor. There is currently no reason to create this file with single sensor experiments.

- **1** - Set the Temperature drift correction to 1st Order

- **2** — Offset Angles. Refer to JAW Manual, section 4.6.1, page 35 for complete details of this feature.

The following refer to sections on the second 2-Wire oop Traverse VI Screen shown below.
Plot Parameters. These are used to determine how data is presented on the main display (Figure 11). For more details about this feature, refer to JAW Manual, section 4.2.1.11, page 26.

This controls probe angular displacements. Set the stepper motors to a determined value (suggest 750). For more details about this feature, refer to JAW Manual, section 4.2.1.9, page 26. Basically, this feature allows you to rotate a tunnel axis to meet a user-specified angle.

Cooling Velocity. Input the required parameters for Jorgenson Coefficients (JAW manual, section 4.6.7, page 38) and Sensor Angles (JAW Manual, section 4.6.4, page 37). These should be identical to the values input in the Calibration procedure. With regard to the Reduction Method, method 0 returns instantaneous velocities in wire coordinates and method 1 returns them in user coordinates. For more details about this feature, refer to JAW Manual, section 4.6.8, page 38.

Automatic Speed Calibration. Define the coordinates of a point that can be “theoretically” considered to be at the tunnel freestream velocity (that is a point that is far away from the region where the flow is disturbed by the model under examination in the wind tunnel). Input values for fan speeds and increments, this process is identical to that previously done in Section 2.1.2.2. Set the time intervals at...
which recalibration will be conducted. For more details, refer to JAW Manual, section 4.5.4, page 33. Lastly, set the *Maximum Cone Angle* in degrees,

- Stepper Motors. Set the stepper motors to a specific value (the suggested value for this is 750). For more details, refer to JAW Manual, section 4.2.1.12, page 27

For Data Post-processing, please refer to JAW Manual, Chapter 7. This chapter provides procedures for converting and formatting data files for other software packages and VI's.
2.2.1.3 Triple-Sensor Hot Wire Measurements

- Open IIHRTop/Hwire/3-Wire oop Traverse

**Figure 14: 3-Wire oop Traverse Screen 1**

**A** - Input profile file names corresponding to each profile that is to be measured. These files will contain the measurement data for each profile that was measured. Enter names with neither an extension nor a directory pathname. Other sub-screens on the VI record these inputs. Refer to JAW Manual, section 4.5.1, and section 4.5.2 (pages 31-33) for a complete explanation of this feature.

**B** - The Output File Comment is primarily useful for identification of the output files by the user. This will appear on the first line of the ASCII output file. Anything can be put in this field. For easy reference, it is suggested that the following format be used:

> The type of probe used, the some specific identification number for the probe (in case there are two of the same type), the traverse order, the barometric pressure at the time of the experiment and anything else that is not recorded elsewhere.

**C** - This switch can be used to temporarily stop the experiment. The VI will finish its current measurement, move to the next position, and put up a dialog box...
stating that the experiment has been interrupted. To continue the experiment, click on the toggle switch again. Using this to stop the fan and check something in the tunnel is acceptable unless the ROBICON Speed Control VI is used to reduce the fan speed. Hence, press the Emergency Stop button when this procedure is done.

- **D** - ADC - Refer to JAW Manual, section 4.2.1.3, page 24 for complete details of this feature.

- **E** - The Current Data box merely states the measurement data at the last measured point. This does not have to be adjusted and is self-explanatory.

- **F** - Select the format of the output data files. Merely depressing the necessary buttons does this. “Reduced” refers to the standard data file in IIHR ASCII format. “Raw” refers to the hot-wire raw data file, which contains raw voltages, calibration data, and all of the other information necessary to reconstruct the reduced data. The error file is used for dual and triple-sensor probes, but not for the single sensor. There is currently no reason to create this file with single sensor experiments.

1. - Set the Temperature drift correction to **1st Order**

2. - **Offset Angles**: Refer to JAW Manual, section 4.6.1, page 35 for complete details of this feature.

The following refer to sections on the second 3-Wire oop Traverse VI Screen shown below.
Plot Parameters. These are used to determine how data is presented on the main display (Figure 11). For more details about this feature, refer to JAW Manual, section 4.2.1.11, page 26.

This controls probe angular displacements. Set the stepper motors to a determined value (suggest 750). For more details about this feature, refer to JAW Manual, section 4.2.1.9, page 26. Basically, this feature allows you to rotate a tunnel axis to meet a user-specified angle.

Cooling Velocity. Input the required parameters for Jorgenson Coefficients (JAW manual, section 4.6.7, page 38) and Sensor Angles (JAW Manual, section 4.6.4, page 37). These should be identical to the values input in the Calibration procedure. With regard to the Reduction Method, method 0 returns instantaneous velocities in wire coordinates and method 1 returns them in user coordinates. For more details about this feature, refer to JAW Manual, section 4.6.8, page 38.

Automatic Speed Calibration. Define the coordinates of a point that can be "theoretically" considered to be at the tunnel freestream velocity (that is a point that is far away from the region where the flow is disturbed by the model under examination in the wind tunnel). Input values for fan speeds and increments, this process is identical to that previously done in Section 2.1.2.2. Set the time intervals at which recalibration will be conducted. For more details, refer to JAW Manual, section 4.5.4, page 33. Lastly, set the Maximum Cone Angle in degrees.

Stepper Motors. Set the stepper motors to a specific value (the suggested value for this is 750). For more details, refer to JAW Manual, section 4.2.1.12, page 27.

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For Data Post-processing, please refer to JAW Manual, Chapter 7. This chapter provides procedures for converting and formatting data files for other software packages and VTs.
3 Pressure Probe Setup and Operation

Pressure probes are used to measure pressure and differential pressures that can subsequently be used to determine velocities. The software described in this manual supports Pitot-static, 5-Hole and 7-Hole probes. This section describes the setup, operation and data processing for pressure probes. Additionally, more information about individual sections of the program can be obtained by selecting “Get Info” under the File selection of the Menu Bar.

3.1 Setup

3.1.1 Hardware

3.1.1.1 Setting Up Pressure Probes

The use of Pitot-static, 5-hole, and 7-hole pressure probes require a Scanivalve (for positioning the pressure to be measured), a pressure transducer, and a data acquisition system. After it has been determined what type of pressure probe is to be used for measurements, follow the instructions below.

Attach numbered pressure lines to the necessary ports on the object/pressure probe. Choose which port to start connections and connect the remaining tubes in ascending and sequential order. The Tygon tubes leading from the 5-hole and 7-hole probes are numbered to facilitate this.

Connect the numbered pressure lines to their respective values on a Scanivalve.

Connect the Scanivalve output to the high side of a Validyne transducer. The low side is exposed to a constant pressure (typically atmospheric).
Surface Pressure and Pressure-Probe Measurements

It should be noted that any pressure coefficient that is measured must be adjusted so that it has some meaning. Generally, measurements will take the form:

\[ C_p = \frac{p - p_{\text{ref}}}{\rho U^2} \]

The problem is \( p_{\text{ref}} \) does not have any meaning even if the pressure tap at the test section is used, so it is not necessary to measure \( C_p = 1 \) at a stagnation point, nor will \( C_p = 0 \) be found in the freestream.

If surface pressure measurements to be taken, it may be desirable to reference the measurements to another point on the body (which can be done after the experiment) such that the adjusted measurement at that position will be \( C_p = 0 \). This should allow comparison with CFD or potential flow, as long as those pressures have been adjusted the same way.

For pressure probe measurements, one of the measurements has to be outside the region of viscous influence, preferably in the freestream. There, the total pressure coefficient can be adjusted to 1. The total and static pressure coefficients at all other measuring stations can be adjusted by this amount (such that their difference, proportional to the dynamic pressure, is unchanged), thus allowing comparisons with CFD or potential flow. The static coefficient could be required to be 0 in the freestream, but it is measured less accurately than the total coefficient, and it is never known if blockage is influencing the static pressure.

\(<\) Ensure that the Validyne is switched on.

Important

When time averaged measurements are taken, ensure that the tubing of the smallest diameter and length is used. This improves the overall system frequency response. This is especially important for the tubing between the Scanivalve and transducer. Do not put any tees in the tubing from the probe to the Scanivalve. This dramatically increases frequency response time.
3.1.2 Software Setup

3.1.2.1 Calibration

To calibrate the Validyne signal generator, follow the same procedures as established in Section 1.4.1 of this manual. This refers to zeroing the transducer, determining the maximum pressure differential that the transducer will experience and setting the span of the Validyne to it. These procedures should be initiated before the tunnel is turned on. Since pressure probe measurements are often partly negative, the Validyne should be calibrated over a negative and positive voltage range (see Section 1.4.1 and JAW Manual, section 3.3.3, page 17).

Using the VI Scani_Move.DIO-96, click on the Scanivalve window and change the number in the blue box from zero to the port being used as the reference pressure ⇒ (this is the short circuit pressure). A loud whirring noise should be heard as the Scanivalve is adjusted.

Zero the VSC by adjusting the Zero knob on the Validyne until a zero reading is achieved on the DVM. An appropriate reading for this procedure is about 10⁻³ V. Make sure that the DVM scale range setting is appropriate and is connected to the VSC.

After starting up the tunnel, adjust the Scanivalve to the port that will receive the highest pressure during the experiment. This should be very close to 5 V (± 10⁻³ V). If need be, change the DVM’s scale for a 5V reading. If it is not close to 5 V, use the Span knob on the VSC to increase or decrease its span.
3.2 Operation

This process encompasses the following sub-operations, traversing the lead screws to specified positions in space, taking measurements, and writing the data to a file. Before proceeding, it is necessary to develop a Traverse File. This contains the positions that the probe assumes for measuring velocity profiles. Prior knowledge of the flow features is useful in determining the positions to take measurements. For measurements that can interfere with objects positioned in the wind tunnel, the traverse order of motion is important and may lead to accidents. The procedure outlined here is typical for all “.oop Traverse” Vis. All these programs require the same format for measurement probe positions. Furthermore, all these Vis write similarly formatted output files. For clarification of the movement order, please refer to the JAW manual, pages 19-23.

- Open IIHRLib/IIHRLibs/Traverse.llb/Create Traverse File

Figure 15: Create Traverse File VI

Enter the traverse positions as strings in this VI with a carriage return between each entry. This method may sometimes prove more convenient than using Excel or some other editor.

Be careful: no entry, including the last one in each column, can have more than one carriage return after it. Additional <CR> are interpreted as zero.
**Important**

Ensure that the experiment has a well-defined absolute zero point. That is, the user has to define the point (0,0,0). The DAQ system uses a positioning algorithm based on the relative displacement of the traverse 3-D components.

- Type in the x, y and z values at which measurements are to be taken according to the established coordinate system. The VI will return a prompt for a filename to save coordinates. Type in a filename.

**Important**

The DAQ system takes the first set of x, y, z values in this file as a reference point from which subsequent measurements are taken. Hence, before the experiment is initiated, make sure that the probe is located precisely at the first set of coordinates.

- Open IIHR.Libs/IIHRLibs/Traverse.dll/oop Loop Indexer Driver.
- By inputting values in the blue boxes, move the traverse to the first point of the newly created traverse file. 

![oop Loop Indexer Driver]

Figure 16: oop Loop Indexer Driver
3.2.1 Measurements
This system has the ability to support Pitot-static, 5-Hole and 7-Hole probes. The following discusses the methods for conducting measurements for each of these devices.

3.2.1.1 Basic Scanivalve Measurements
This primary low-level subVI is used primarily for surface pressure measurements and pressure probe measurements.

- Open IIHR.Lib/IIHRLibs/Serial.lib/Scanivalve DAQ

This should only be used when time-averaged data is sought (no time-series data is produced).

![Scanivalve DAQ Display](image)

Figure 17: Scanivalve DAQ Display
The VI Scani.llb (Scani_Move.DIO-96) specifies the Scanivalve port. The Scanivalve DAQ VI would be used primarily with time-averaged surface pressure measurements, for 5-Hole and 7-Hole Pitot probe measurements, the VI's Pitot-Static oop Traverse, 5-Hole oop Traverse and 7-hole oop Traverse would be used.

In general,

- Set **Check Mean (0) or stdev (1)?** to 0.
- Set **Volt Tolerance (all holes)** to 0.01 V
- Set **Max. Settle time (s) after Scani Move** to 20-25 s.

### 3.2.1.2 Pitot-static oop Traverse

Pitot-static probes measure velocities via Bernoulli's Law.

\[ P - P_{ref} = \rho V_x^2 \quad \text{(Bernoulli's Law)} \]

Where \( p \), \( p_{ref} \) and \( V_x \) are defined in JAW manual pages 13-14.

- Open IIHR.Lib/IIHRTop/Misc.llb/Pitot-static oop Traverse.
- Input profile file names corresponding to each profile that is to be measured. These files will contain the measurement data for each profile that was measured. Enter names with neither an extension nor a directory pathname. Other sub-screens on the VI record these inputs. Refer to JAW Manual, section 4.5.1, and section 4.5.2 (pages 31-33) for a complete explanation of this feature.

- The Output File Comment is primarily useful for identification of the output files by the user. This will appear on the first line of the ASCII output file. Anything can be put in this field. For easy reference, it is suggested that the following format be used:

  The type of probe used, the some specific identification number for the probe (in case there are two of the same type), the traverse order, the barometric pressure at the time of the experiment and anything else that is not recorded elsewhere.

- This switch can be used to temporarily stop the experiment. The VI will finish its current measurement, move to the next position, and put up a dialog box stating that the experiment has been interrupted. To continue the experiment, click on the toggle switch again. Using this to stop the fan and check something in the tunnel is acceptable unless the ROBICON Speed Control VI is used to reduce the fan speed. Hence, press the Emergency Stop button when this procedure is done.

- Refer to JAW Manual, section 4.2.1.3, page 24 for complete details of this feature.

- Refer to JAW Manual, section 4.6.1, page 35 for complete details of this feature.

- The Current Data box merely states the measurement data at the last measured point. This does not have to be adjusted and is self-explanatory. For more details, please refer to JAW Manual, section 4.3.4, page 29.

- Select the format of the output data files. Merely depressing the necessary buttons does this. “Reduced” refers to the standard data file in IIHR ASCII format. “Raw” refers to the raw data file, which contains raw voltages, calibration data, and all of the other information necessary to reconstruct the reduced data.

- Maintain

  Select the manner in which the experimental setup will be maintained during measurements (it is recommended to maintain the dynamic head).
- Input the value at which the system should maintain the apparatus at.
- Input the RPM that the system should reset to once measurements have been completed.

- **Plot Parameters.** These are used to determine how data is presented on the main display (Figure 11). For more details about this feature, refer to JAW Manual, section 4.2.1.11, page 26.

- **U** – This controls probe angular displacements. Set the stepper motors to a determined value (suggest 750). For more details about this feature, refer to JAW Manual, section 4.2.1.9, page 26. Basically, this feature allows you to rotate a tunnel axis to meet a user-specified angle.

- **J** – **Stepper Motors.** Set the stepper motors to a specific value (the suggested value for this is 750). For more details, refer to JAW Manual, section 4.2.1.12, page 27.

For Data Post-processing, please refer to JAW Manual, Chapter 7. This chapter provides procedures for converting and formatting data files for other software packages and VPs.
3.2.1.3 5-Hole oop Traverse

5-Hole probes measure 3 components of mean velocity and total static pressures. These instruments require separate angular calibration that, in principle, needs to be done only once. However, this is as long as the probe tip is not scuffed or damaged (consult JAW Manual, section 4.3).

Figure 19: 5-Hole oop Traverse Screen 1

- **A** - Input profile file names corresponding to each profile that is to be measured. These files will contain the measurement data for each profile that was measured. Enter names with neither an extension nor a directory pathname. Other sub-screens on the VI record these inputs. Refer to JAW Manual, section 4.5.1, and section 4.5.2 (pages 31-33) for a complete explanation of this feature.

- **B** - The Output File Comment is primarily useful for identification of the output files by the user. This will appear on the first line of the ASCII output file. Anything can be put in this field. For easy reference, it is suggested that the following format be used:

  *The type of probe used, the same specific identification number for the probe (in case there are two of the same type), the traverse order, the barometric pressure at the time of the experiment and anything else that is not recorded elsewhere.*
- This switch can be used to temporarily stop the experiment. The VI will finish its current measurement, move to the next position, and put up a dialog box stating that the experiment has been interrupted. To continue the experiment, click on the toggle switch again. Using this to stop the fan and check something in the tunnel is acceptable unless the ROBICON Speed Control VI is used to reduce the fan speed. Hence, press the Emergency Stop button when this procedure is done.

- ADC - Refer to JAW Manual, section 4.2.1.3, page 24 for complete details of this feature.

- The Current Data box merely states the measurement data at the last measured point. This does not have to be adjusted and is self-explanatory. For more details, please refer to JAW Manual, section 4.3.4, page 29.

- Input the pathname for the location of the calibration data (for more details about this feature, please consult JAW Manual, sections 4.3.2 and 4.3.3, page 28).

- Offset angles. Refer to JAW Manual, section 4.3.2, page 28 for complete details of this feature.

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![Figure 20: 5-Hole oop Traverse Display Continued](image-url)
3 - Select the dependent variable that should be written to the IIHR ASCII output data file. Merely depressing the necessary Boolean controls does this. Green indicates that the variable has been selected. The output file can have up to 5 columns, the columns move from left to right in correspondence with the cluster of Booleans. (Please consult JAW Manual, section 4.3.5, page 28 for more details).

4 - This informs the VI of the lowest numbered connected Scanivalve port, which is the short circuit pressure.

G -- Maintain

- Select the manner in which the experimental setup will be maintained during measurements (it is recommended to maintain the dynamic head).
- Input the value at which the system should maintain the apparatus at.
- Input the RPM that the system should reset to once measurements have been completed.

H -- Plot Parameters. These are used to determine how data is presented on the main display (Figure 11). For more details about this feature, refer to JAW Manual, section 4.2.1.11, page 26.

I -- This controls probe angular displacements. Set the stepper motors to a determined value (suggest 750). For more details about this feature, refer to JAW Manual, section 4.2.1.9, page 26. Basically, this feature allows you to rotate a tunnel axis to meet a user-specified angle.

J -- Stepper Motors. Set the stepper motors to a specific value (the suggested value for this is 750). For more details, refer to JAW Manual, section 4.2.1.12, page 27.

For Data Post-processing, please refer to JAW Manual, Chapter 7. This chapter provides procedures for converting and formatting data files for other software packages and VI's.
3.2.1.4 7-Hole oop Traverse

- Open IIHR_LIB/IIHRTop/Misc.lib/7-Hole oop Traverse.

Figure 21: 7-Hole oop Traverse Display

- Input profile file names corresponding to each profile that is to be measured. These files will contain the measurement data for each profile that was measured. Enter names with neither an extension nor a directory pathname. Other sub­
screens on the VI record these inputs. Refer to JAW Manual, section 4.5.1, and section 4.5.2 (pages 31-33) for a complete explanation of this feature.

- The Output File Comment is primarily useful for identification of the output files by the user. This will appear on the first line of the ASCII output file. Anything can be put in this field. For easy reference, it is suggested that the following format be used:

  The type of probe used, the same specific identification number for the probe (in case there are two of the same type), the traverse order, the barometric pressure at the time of the experiment and anything else that is not recorded elsewhere.
This switch can be used to temporarily stop the experiment. The VI will finish its current measurement, move to the next position, and put up a dialog box stating that the experiment has been interrupted. To continue the experiment, click on the toggle switch again. Using this to stop the fan and check something in the tunnel is acceptable unless the ROBICON Speed Control VI is used to reduce the fan speed. Hence, press the Emergency Stop button when this procedure is done.

ADC - Refer to JAW Manual, section 4.2.1.3, page 24 for complete details of this feature.

The Current Data box merely states the measurement data at the last measured point. This does not have to be adjusted and is self-explanatory. For more details, please refer to JAW Manual, section 4.3.4, page 29.

Input the pathname for the location of the calibration data (for more details about this feature, please consult JAW Manual, sections 4.3.2 and 4.3.3, page 28).

Offset angles. Refer to JAW Manual, section 4.3.2, page 28 for complete details of this feature.

Select the dependent variable that should be written to the IIHR ASCII output data file. Merely depressing the necessary Boolean controls does this. Green indicates that the variable has been selected. The output file can have up to 5 columns, the columns move from left to right in correspondence with the cluster.

4 - This informs the VI of the lowest numbered connected Scanivalve port, which is the short circuit pressure.

C - Maintain

Select the manner in which the experimental setup will be maintained during measurements (it is recommended to maintain the dynamic head).

Input the value at which the system should maintain the apparatus at.

Input the RPM that the system should reset to once measurements have been completed.

H - Plot Parameters. These are used to determine how data is presented on the main display (Figure 11). For more details about this feature, refer to JAW Manual, section 4.2.1.11, page 26.

— This controls probe angular displacements. Set the stepper motors to a determined value (suggest 750). For more details about this feature, refer to JAW Manual, section 4.2.1.9, page 26. Basically, this feature allows you to rotate a tunnel axis to meet a user-specified angle.

J - Stepper Motors. Set the stepper motors to a specific value (the suggested value for this is 750). For more details, refer to JAW Manual, section 4.2.1.12, page 27.

For Data Post-processing, please refer to JAW Manual, Chapter 7. This chapter provides procedures for converting and formatting data files for other software packages and VI's.