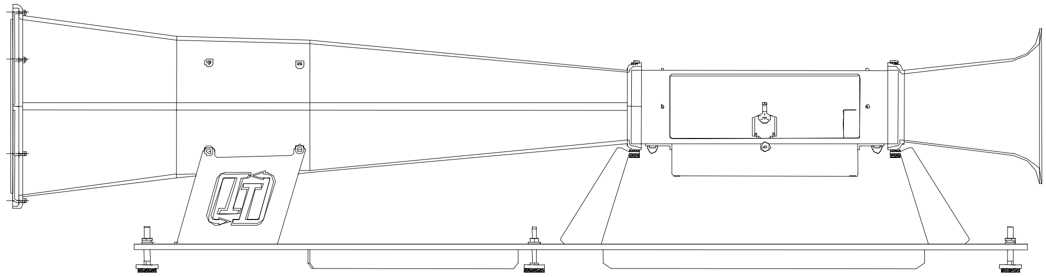
INTERACTIVE INSTRUMENTS



Jet Stream 500

Instruction Manual

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Safety Guide

- **Follow the instructions** and be sure to follow all warnings on the equipment and in the manual for trouble free service.
- **Be sure that a supervisor is present** whenever the Jet Stream 500 is in operation. It is the responsibility of the supervisor to read and understand this manual before operating the equipment.
- **This product is supplied with a grounded power cord**. Be sure that you use a wall socket that conforms to this cord. Bypassing the ground for any reason may cause personal injury. When using an extension cord, be sure the cord is capable of handling the power requirements of the wind tunnel. The cord should not be any longer than required.
- **Everyone within the immediate area of the Jet Stream 500 *must* wear proper ear protection** before the instrument is started. The wind tunnel is capable of producing sounds in excess of **100 db** which may cause loss of hearing.
- **A security key has been supplied** that prevents the Jet Stream 500 from operating when the key is turned off. The supervisor should have possession of the key to prevent unauthorized use of the product.
- **Before starting the Jet Stream 500, be sure that the room is secure of any objects** that may be blown around while the Jet Stream 500 is under operation. This includes papers, books, and small objects that may become airborne due to the exhaust wind.
- **It is the supervisor's responsibility to *inspect* the Jet Stream 500** to insure it is in proper working order and that none of the built-in safety features are bypassed before and during operation.
- **Be sure that the pitot tube is not bent or plugged before operating the Jet Stream 500**. If the pitot tube becomes blocked or damaged, the wind speed will not be under the proper control of the microprocessor and the wind speed may increase until the error condition is displayed.
- **Do not bypass the fan's power cord.** Doing so *will* damage the wind tunnel as the propeller blade is not designed for full speed operation. Since the speed is controlled by the microprocessor, the final speed is regulated to prevent full speed operation under normal use.
- **Turn off this product when not in use or during a lightning storm.** Unplug the wind tunnel from the wall to avoid damage due to lightning or when left unattended for long periods of time.
- **Do not attempt to service, repair or disassemble this product yourself** as removing covers may expose you to dangerous voltage or other hazards. *No* user serviceable parts are inside. Refer all servicing to Interactive Instruments, Inc.
- **Do not expose this unit to rain or moisture.** The wind tunnel must be used in a protected building to prevent shock hazards.
- **This product is intended for instructional use *only*.** It should not be used for the development of designs that could potentially injure humans.

Installation and Setup

Unpack the wind tunnel from the shipping container. Retain the packing material provided the unit must be returned to the factory at a later date. **Do not ship the unit in anything other than this container or damage to the tunnel will result.**

After unpacking everything, you will find a wind tunnel with the test bed, control panel, 9 pin data cable, power cord, and manual. If you are missing any of these parts, please contact Interactive Instruments immediately.

To assemble the wind tunnel, place the tunnel on a flat stable, surface near a wall socket. Place the tunnel in a location at room temperature (70 - 80 degrees) and preferably out of direct sunlight. Be sure that the test bed is on the right hand side of the operator so the wind exhausts to the left. Place the control panel in front of the wind tunnel so it is accessible to the operator. Plug the 9 pin data cable into the rear of the test bed and also into the rear of the control panel. Secure both ends with the cable screws supplied.

Plug the power cord into the rear of the control panel, but do not plug the power cord into the wall socket yet.

Inspect the wind tunnel for shipping damage. If any damage was caused in shipping, please contact Interactive Instruments immediately. Operating a damaged tunnel may result in additional damage to the tunnel or personal injury.

Be sure the intake and exhaust ports are free from obstruction. There should be no papers or shipping material in the test area or around the Jet Stream 500 during operation.

Level the wind tunnel using the 5 adjustable feet to eliminate measurement errors. If the tunnel is operated on an uneven surface, the lift and drag forces may be inaccurate. If the tunnel is not stable during operation, vibrations may also affect the results. To level the Jet Stream 500 properly, start by shortening all of the adjustable feet to the shortest position. Then look at the level above the test area and use this as a guide to make the remaining adjustments. If the bubble in the level is out of the center circle, adjustments will be necessary. If the bubble is closest to the motor (large end of the tunnel), lengthen the feet nearest the intake (small end) first. If the bubble level is closest to the intake, lengthen the feet under the motor. Be sure to adjust them in pairs. Next, adjust the feet side to side to place the bubble in the center of the level. Once the tunnel is level, be sure that all of the outside feet are touching the ground. This can be checked by placing paper under each foot and pulling on it to check the clearance. If a foot is not touching, adjust it so it is. Once the tunnel is level and stable, adjust the foot in the center of the tunnel base until it touches the floor. Check to see that the Jet Stream is stable by rocking the tunnel. If it is balanced properly, the tunnel will not rock.

Verify that the control panel's main power is off before plugging the control panel into a 110 volt, 60 Hz grounded wall outlet. Since the wind tunnel's fan motor may draw as much as 10 amps, be sure the wiring and circuit protection is rated at 15 amps or more. Do not bypass the ground pin on the power cord, this is needed for your safety.

Activate the wind tunnel by turning the Security key counterclockwise to unlock the controller.

Power up the unit by toggling the power switch located in the rear of the control panel. As the control panel is powering up, it should display the following messages on the LCD panel:

`Testing System`

If the display prompts

`*** SYSTEM ERROR ***`

This is due to the microcontroller detecting an error in the system. Please refer to the **Error Condition** section of this manual for more information.

The control panel will default all values in English units (pounds and miles per hour). The controller can be configured to display the data in metric units (kilograms, kilometers per hour). See Menu for Select Units option.

Be sure that *everyone* in the immediate area is wearing proper ear protection as the Jet Stream 500 can produce noise levels in excess of **100 db**. **Continued use without proper ear protection can cause hearing loss.**

If everything is OK, press the ▲ (up arrow) or enter a wind speed number followed by ↵ (enter) key on the keypad to increase the wind speed. The fan should begin to run and the display will prompt with the actual wind speed. If there are any strange noises, turn off the control panel and call Interactive Instruments for further instructions.

Please review the remainder of this manual for useful information and testing details.

Overview

The Jet Stream 500 is a complete wind tunnel package, engineered to study basic aerodynamic principles of model aircraft wings, CO_2 cars along with other objects. The design is optimized to instruct students in junior high, middle school, high school and university level classes with a focus on ease of use. Since the wind tunnel is designed as a general instrument, the uses are limitless. From airfoil to automobile or even rocket research, the learning value goes a long way.

Easy to Operate

The tunnel is controlled with an easy to use remote control panel. Starting the tunnel is as easy as entering the desired test velocity on the control panel. A 20 character by 4 line display is continuously updated to accurately reflect the system's wind velocity along with the forces generated on the test model. A one horse power electric motor with a 10" propeller is powerful enough to produce winds of 80 miles per hour. This is fast enough to test virtually any model. Instrumentation located in the test area also monitors lift and drag forces exerted on the test model so forces can be displayed in *real time* on the display panel. Precision strain gages mounted under the test bed accurately measure the forces on the model without having to attach them directly to the model. This allows for easy mounting and unmounting of the test model. The lift over drag (L/D) ratio is also computed and displayed on the display panel to demonstrate airfoil design efficiency.

Quality Design

The test area is free of turbulence due to following stringent wind tunnel design rules. By extending the length of the tunnel and using a special flow straightener, the Jet Stream 500 has virtually eliminated the test area turbulence that is common in poorly designed tunnels. This allows the instrumentation to *precisely* measure the forces within the tunnel to less than 1%. Wind velocity is constantly monitored hundreds of times a second to maintain a steady flow over the test model. Using a pitot static tube connected to a differential pressure transducer, the wind velocity is electronically monitored and controlled. This provides a *constant* wind speed independent of the size or angle of the test model. The actual wind velocity is displayed on the control panel which allows studies to be conducted over a wide range of conditions.

Versatile

An easy to access 5.25" x 5.25" x 16" test chamber allows various models to be quickly mounted for testing. The test bed is easily removed from the tunnel for unrestricted access in mounting and unmounting models. The test section is made of a clear plastic so the model can be viewed while under test. An angle of attack adjustment is available to adjust the airfoil +/- 30° with a resolution of 5° so the model can be tilted without remounting airfoil models. This allows the lift and drag forces to be measured at various angles and is very useful for demonstrating an airfoil's stall speed. CO_2 car designs can also be optimized for speed by measuring the model drag at various wind velocities. With the drag force measured to 0.001 lbs., small design changes can be studied.

Self Contained

The tunnel also performs an automatic self test every time the unit is powered up. If an error is detected within the wind tunnel, the display informs the operator of the error condition and disables operation. The test also detects calibration and functional problems before allowing the tunnel to operate. The built-in force gages are *automatically* zeroed before each test to keep the display in calibration, therefore the unit should *never* require recalibration.

Safety

The Jet Stream 500 is designed with safety in mind. The Jet Stream 500 is capable of automatically shutting down if it detects a problem. A security lock is also added to disable the unit when a supervisor is not present to prevent unsupervised operation of the wind tunnel.

Overall, the Jet Stream 500 is an invaluable tool when it comes to visually demonstrating basic to advanced aerodynamic principles to students.

Guide to the Jet Stream 500

Loading a test model:

To load a test model, be sure the wind tunnel is stopped by pressing the ↵ (enter) key to return to 0 MPH. Then turn off the main power on the back of the control panel. Turn the two test bed fasteners under the test area counterclockwise 1/4 turn each to drop the test bed from the test area. Be careful not to bend the pitot tube. Once the test bed is cleared from the tunnel, you may attach the test model to the angle of attack arm using the supplied T brackets. The best position to mount the model is in the center of the test area (staying away from the walls of the test area). If the model is close to a test wall, the wind effects will disrupt the test results. Also, be sure the model is attached firmly or it may vibrate or come loose from the arm, damaging the flow straightener behind the test area. Once the model is in place, carefully reinsert the test bed back into the test area and lock in place by turning the two fasteners 1/4 turn clockwise. Once secured, verify that the model and test bed is properly aligned and locked in place before applying power to the tunnel.

Important Note: Be sure that while attaching the model you don't exert excessive force to the arm or damage will result to the sensitive sensors in the test bed. If a sensor is damaged, it must be returned to Interactive Instruments for repair.

Before starting a test:

- Verify that the wind tunnel is properly setup (*see* **Installation and Setup procedure**)
- Be sure the test model is firmly attached to the test arm
- Check to see that the test bed is inserted and locked into the test area
- Set the desired angle of attack by adjusting the knob under the test bed
- Make sure that everyone in the room is using proper ear protection
- Turn on the wind tunnel's main power
- Insert the Security key and turn to the unlocked position

Starting a test:

It would be best to let the tunnel warm up for a few minutes before pressing the start button. This would allow the sensitive electronics to warm up and give more accurate results. If the tunnel is very cold (below 60 degrees F), be sure to let the tunnel warm up for at least 15 minutes (with the wind tunnel powered up but halted) before collecting data. This will allow time for the sensitive electronic measurement equipment to reach calibration temperature. Since the tunnel is calibrated in room temperature between 70 to 80 degrees F, more accurate results will be obtained if operation is limited to room temperature. Operation outside of this range may give inaccurate wind speed and force measurements.

You are now ready to activate the wind tunnel:

Key in the desired wind speed value (in MPH or KPH) followed by ↵ to activate the wind tunnel fan. With the fan running other wind speed values can be entered as well. The up/down keys will increase or decrease the wind speed in 0.5 MPH increments. You may also hold the up or down key down and the wind speed will slowly ramp.

Note: Whenever the wind speed is set to 0 MPH, the forces are automatically set to zero. This is to compensate for the weight of the model under test.

Adjusting the wind speed:

Various wind speeds can be set at any time by keying in a new speed on the keypad or use the ▲ or ▼ arrows to increase or decrease the wind speed in 0.5 mph increments. As the wind speed is adjusting to the new wind speed, the desired wind speed is displayed on the LCD. Several seconds later, the display will prompt the actual measured wind speed in the tunnel. Wind restrictions created by the test model will be compensated by the microprocessor to maintain the desired wind speed even if the angle of the model is adjusted, altering the tunnel's internal wind resistance.

Options Menu:

Pressing the (menu) key displays a list of options as shown below

```
     Main Menu
→1) Select Units
 2) Max Speed
```

The menu options can be selected by entering a number on the keypad or by using the up/down arrows followed by ↵. The two main menu items enable the operator to select the display units or establish the maximum allowed wind speed. Pressing the (menu) key a second time will cancel the menu.

Select Units

Pressing the 1 key in the main menu displays a menu to selection between English and Metric display units as shown below.

```
     Select Units
→1) English Units
 2) Metric Units
```

With English units selected, the lift and drag forces are displayed in pounds (lb) and the wind speed in miles per hour (MPH). Selecting metric units displays the lift and drag forces in kilograms (kg) and the wind speed in kilometers per hour (KPH). Since L/D is unit-less the units are not displayed. When the controller is powered up the display units default to English.

Max Speed

Pressing the 2 key in the main menu prompts for the maximum allowed wind speed as shown below. This option is useful to limit the tunnels capability. In some environments it is sometimes necessary to limit the speed for safety reasons or to minimize the noise level.

```
Enter Wind Speed
_
```

Enter a value between 10 and 80 MPH and any command larger than the max wind speed will be clamped to the max speed. To prevent a student from raising the max speed, the controller will not allow the max wind speed to be raised above a previously set value. When the controller is powered up it is automatically configured for a maximum allowed speed of 80 MPH.

Viewing the results:

The LCD panel will display the current wind speed in miles per hour (or kilometers per hour) along with the lift (both positive and negative), and drag forces exerted on the test model due to the wind. The lift over drag (L/D) of the test model is also calculated and displayed which is a common measurement in airplane wing designs. If the drag force is zero the L/D becomes infinite so the display prompts with the value "-.---".

IMPORTANT:

If the test model should become loose or disconnect from the test bed during a test, quickly decrease the wind speed to 0 to shutdown the tunnel by pressing the ↵ key. Once the wind speed has reached zero, you may remove and repair the test model. If the wind tunnel has been damaged, have the tunnel repaired before continuing any further testing by contacting Interactive Instruments.

Analyzing the test results:

The wind speed is displayed on the LCD panel as a measured wind speed. The static pitot tube in the test area takes a sample of the active and passive air pressures and passes them to a sensor that calculates the wind speed. This speed is used for two reasons. One is to display the wind speed for your reference, and the second reason is for the microcontroller to control the speed of the fan. Without the wind speed control, the microprocessor would not be able to compensate for test variations and fluctuations in line voltage.

The Lift and Drag force calculations are measured with sensitive electronic sensors that are capable of measuring up to 1.8 lbs. The measurements are averaged over a 50 millisecond period to remove possible errors due to mechanical vibrations or electrical noise. As noted earlier, since the model exerts its own weight on the sensors, this force must be subtracted from the measured force when the wind speed is 0. The wind speed and drag force is also automatically zeroed at this time to automatically calibrate the electronics before every test. This is to insure accurate and consistent results on every test.

The L/D ratio is derived by dividing the lift force by the drag force. This measurement is an important parameter in the study of airplane wing design. As you can see, if the lift force is high and the drag force is low the model wing would be very good for gliders. Inversely, if the lift is low and has a large drag, it would be very poor in a glider design. The larger the L/D ratio the longer a glider can stay up. Varying the angle of attack or placing the wing into a stall condition will vary the L/D for a wing. The L/D ratio can be positive or negative depending on the direction of lift. If the lift force is in the positive direction (upward) the L/D ratio is positive, but if the lift is negative (downward) the L/D ratio will also be negative.

Adjusting the Angle of Attack:

The angle of attack can also be adjusted either before starting a test or while a test is underway. To adjust the angle, wind speed should be zero before making the adjustment. If adjustments are made with forces exerted on the model, the adjustment knob may not operate properly. Be sure the wind speed is 0 before adjusting. The test arm may be adjusted +/- 30° by turning the adjustment knob in front of the test bed. To make the adjustment, gently push the knob in to align with the test bed and rotate the knob to the desired angle. As you can see, the lift and drag forces are directly affected by the angle of attack adjustment. This is an excellent tool to demonstrate the effects of stall speed and stall angle by adjusting the angle until stall occurs.

Stopping a test:

Pressing the ↵ key will return the wind speed to 0 MPH. Once the wind speed has returned to zero, the test bed may be removed to substitute test models. If the tunnel is not to be used for extended periods of time or the supervisor is leaving the room, be sure to turn off the tunnel's main power, lock and remove the security key. This is to prevent unsupervised operation of the tunnel. As the wind tunnel is capable of strong wind speeds, a supervisor must be present during operation to prevent injury.

Error Conditions:

If during a test the wind tunnel detects an error condition, the fan will automatically be turned off and the display will prompt with the error. The following table explains each error condition:

"Keypad is Locked"

If the security key is locked, the wind tunnel is disabled until unlocked. If this occurs, turn the security key to the unlocked position before operating the tunnel.

"SYSTEM ERROR"

When the microprocessor detects a problem during power up, this message is displayed. If this problem occurs, power down and back up to see if the problem re-occurs. If the problem persists, call Interactive Instruments.

"Wind Sensor Error"
"Drag Sensor Error"
"Lift Sensor Error"

One of these messages is displayed if the microprocessor detects a problem with an internal sensor. This may be due to the test bed not being properly secured to the test area or the pitot or fan intake being blocked. Also verify the wind tunnel power and data cable are properly plugged into the rear if the control panel. Check for these possible problems before calling Interactive Instruments.

"Cable Disconnected"

If the tunnel's data cable becomes disconnected from the control panel, this message will be displayed until the cable is reconnected between the control panel and the test bed. Be sure to only use the cable supplied by Interactive Instruments.

"Wind Speed Error"

If the controller can't properly control the wind speed, the wind tunnel is disabled and this message is displayed. This error is typically caused by not having the fan power cable connected to the controller or something blocking the air flow to the pitot static tube. Check for these conditions before calling Interactive Instruments.

Available Options

Wind Tunnel Control Program

An optional Microsoft Windows™ graphical computer interface is available which allows full functional control of the wind tunnel. The software is an easy to use Windows program with built-in help that will allow you to quickly master the features of the Jet Stream 500 (*see* **Figure #1** below). The lift and drag forces are displayed graphically in real time with respect to the wind velocity. L/D and C(x) can also easily be displayed graphically to show the relative performance of aircraft wings and automobiles. The graphical and tabular data can then be printed or stored to disk for further comparison.

Windows Control Program Screen

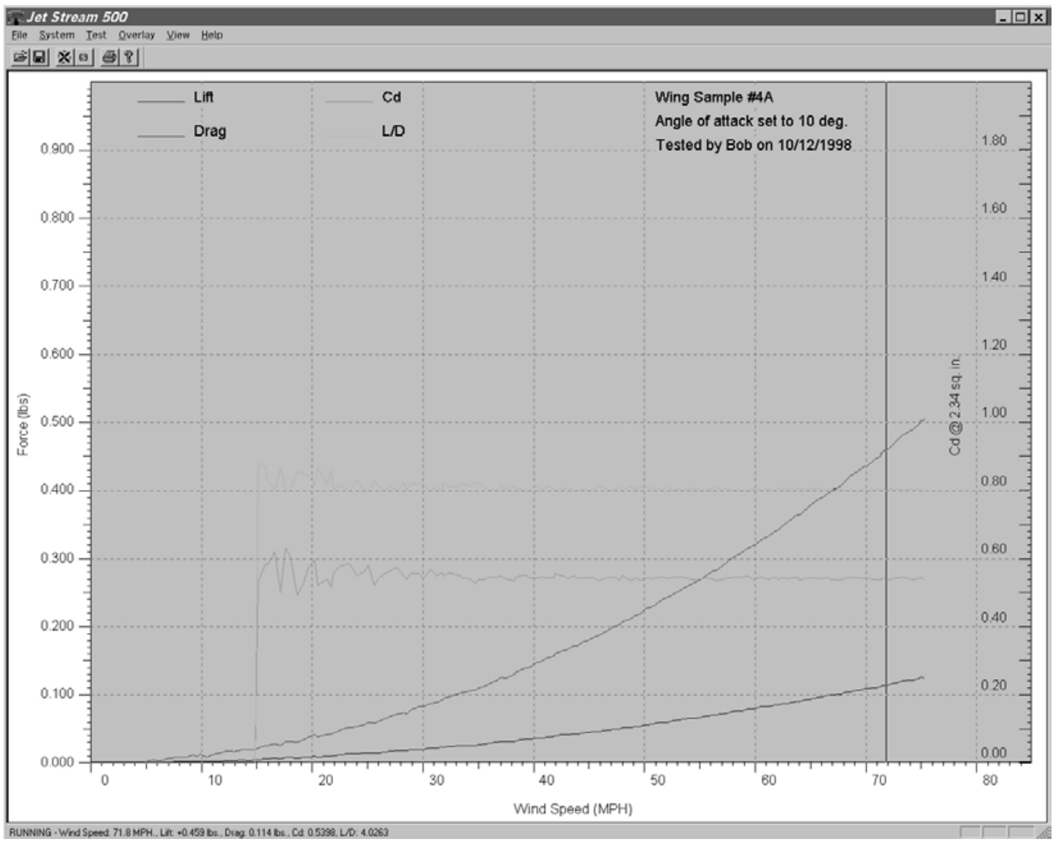

Figure #1

CO_2 Project car test platform

An optional test platform is available that would allow CO_2 project cars to be evaluated within the Jet Stream 500. With a car mounted in the tunnel both the lift and drag can be monitored at various wind speeds to improve model designs. Since the road effect on a car is significant it would be difficult to perform proper car drag tests without a road bed adaptor. The Road Bed Adaptor is designed so CO_2 cars are easily installed and removed without the need for tools.

Jet Stream 500 Specification

Tunnel:	Rugged ABS Plastic construction for superior flow Total tunnel length of 6' 2" Dimensions derived from professional tunnel designs Computer generated design Maximum wind velocity of 80 MPH Safety guards before and after the propeller
Test Area:	Measures 5.25" - h, 5.25" - w, 16.0" - d Precision flow straightener before and after the test area for linear wind flow Clear unobstructed 3 sided viewing area with reflective bottom Measures both lift (+/-) and drag up to 1.8 lb. (0.001 lbs. resolution) Airfoil angle adjustment +/- 30° (5° resolution), without removing model Optional Test bed supports CO_2 project cars
Motor:	Industrial 1 HP, 110 volt ball bearing AC motor for long life 10.5" - 3 blade high speed nylon propeller Microprocessor controlled for constant wind speed
Instrumentation:	Lift and drag forces measured via precision strain gages Wind speed measured and controlled via pitot tube (0.1 MPH resolution) Data is collected by a microprocessor with a 12 bit A/D converter Displays values in Metric or English units
Controls:	Control panel plugs into the tunnel for remote manual control Simple 16 key keypad controls wind speed and selects options Programmable Maximum wind speed limits Manually enter wind speed or ramp speed up or down Display constantly displays lift, drag, and wind speed in real time Lift/Drag (L/D) is also calculated and displayed in real time Security key limits the tunnel to supervised access
Electronics:	12 MHz, 80C32 Microcontroller with 64k of ROM 11 channel, 12 bit A/D converter RS 232 interface @ 4800 baud 4 line by 20 character LCD panel 0 - 1 PSI differential pressure transducer to measure and control the wind speed 0 - 1.8 lb. strain gages to measure the model's lift and drag Computer controlled Solid state motor speed controller
Optional Software:	Easy to use Windows graphical interface with built-in help Graphically displays lift, drag, L/D, and C(x) with respect to wind speed Overlay graphical test results for quick comparison Displays graphical results in Metric or English units Data can be imported to most spreadsheets for further analysis High resolution graphs can be printed on color printers

Technical Information

The Jet Stream 500 was developed by researching existing wind tunnel designs which are currently used by aerodynamic research companies. With the help of their research, we were able to develop a professional design at a reasonable cost. The main tunnel was constructed with a molded ABS plastic shell with a smooth inside finish which is critical in a small wind tunnel design.

The test bed can easily be removed from the tunnel for simple access in mounting and unmounting test models. With other tunnel designs, the test model must be mounted to the test area where working room is limited. All of the sensitive electronic sensors are located inside the test bed so you won't have to worry about damaging sensors.

Control Electronics

A microcontroller is used to control, monitor, and display the information on the LCD panel. The microcontroller is an Intel 80C32 design which is an 8 bit processing unit with built-in RAM, UART, timers, and interrupt controller. Attached to the 8032 is a 64k EPROM which is used for both the control program and look up tables. A 12 bit, 11 channel Analog to Digital converter (A/D) is connected to the 80C32 via serial link. The A/D converter is capable of sampling the data and transmitting the data in as little as 30 microseconds. This would allow sampling rates as high as 33,000 samples per second for a single channel. Since the Jet Stream 500 currently samples three of the channels every 10 ms, the sampling rate is 300 samples per second. The LCD panel is a 4 line by 20 character which is also connected directly to the 80C32 microcontroller.

Force Sensors

The electronic sensors are used to measure the lift and drag by using precision strain gages and high gain amplifiers to measure the forces exerted on the test model. These forces change the resistance of the strain gages, and the voltage measured across the resistance is measured with a high gain amplifier. Since the change in resistance is very slight, amplifiers are needed to measure the changes before the analog to digital (A/D) converter can measure the force. Since the voltage output is directly proportional to the force, the voltage is in direct relation to the test model's force. Both the lift and drag forces are measured the same way except the lift sensor must be capable of measuring positive as well as negative forces. Since an airplane wing can produce a positive (upward) lift and a negative (downward) lift, this sensor is mounted so it can measure forces in both directions. Without this, we would only be able to measure lift in one direction. Since the wind speed can only be in one direction, the drag is measured in the positive direction only.

Wind Speed Sensor

The wind speed is measured with the use of a static pitot tube and a precision differential pressure sensor. This combination allows precise measurement of the wind speed within the tunnel. The pitot tube is the metal tube that is bent at a 90 degree angle located in front of the test area. This tube is modeled after those used on airplanes today. The tube actually contains an inside tube to measure the air pressure pointing in the direction of the wind (the active pressure), and the outside tube measures the air pressure of the tunnel (static pressure) (*see* **Figure #2** below). Measuring the difference between these two pressures (active - static pressure) gives an accurate measurement of the wind speed. A precision pressure sensor is used to measure the very small differences in pressure. Since the pressure of a 10 MPH wind creates less than .002 psi, the sensors are very sensitive. Even changes in room temperature can affect the results of the sensors. The output of the pressure sensor is amplified 1300 times so the A/D converter can properly read the wind speed. The wind speed is not in direct relation to the pressure (p) $(p = \frac{\rho v^2}{2})$, where ρ is the density of air at room temperature and v is the velocity of wind. As you can see, the relationship between pressure and wind speed is the wind velocity is proportional to the square root of the measured pressure $(v = \sqrt{\frac{2p}{\rho}})$. This conversion is done within the microprocessor by reading in the differential pressure (p), multiplying by a constant $\frac{2}{\rho}$, and taking the square root.

Static Pitot Tube used to measure wind speed

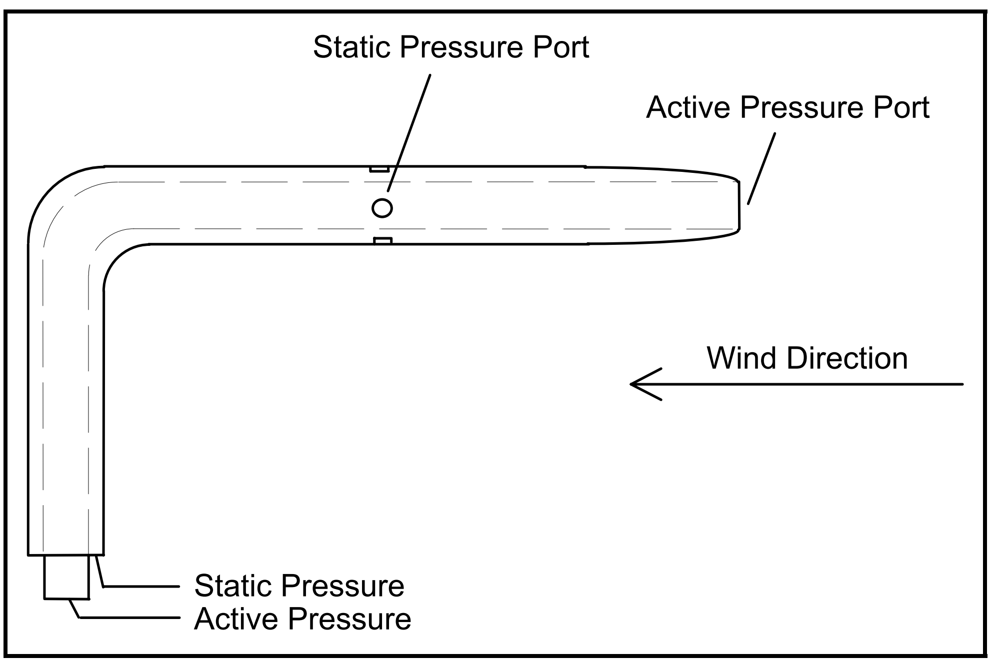

Figure #2

Wind Speed Control

The microprocessor uses the wind speed to control the speed of the fan. By comparing the desired wind speed (set by the wind speed control dial) to the actual speed (measured), the microprocessor determines the error between the two speeds and adjusts the speed of the fan accordingly. This is done by using simple velocity PID control algorithm by combining the proportional (P), integral (I), and differential (D) velocity error signals to derive the output control to the fan. The proportional error signal is derived from the error between the current wind speed and the desired. For example, if the current wind speed is 25 MPH and the desired is 35, the proportional error would be 10 (35 - 25). Using a proportional control algorithm is acceptable for most control systems, but is not very good at quickly reducing the error. To improve the system response the integral and differential terms are added. The integral error term is calculated by factoring the error signal with respect to time. The longer the error signal persists the larger the integral term becomes. This term is responsible for rapidly changing the output signal if the error is not reduced quickly. For example, if the proportional error of 10 lasted for 100 milliseconds generated an error of 5 and the error is not reduced after time, the integral error becomes 10, 15, 25, etc. The final error signal is derived from the differential term. This term adjusts the error signal depending on the rate of change of the measured error. If the error signal varies too slowly, the differential term is increased to speed up the response, but if the error term is changing too quickly, the differential term is reduced to slow the response. This term is useful in adjusting the error output depending on how quickly the system responds to the output. For example, if the current error is changing slowly and the error signal is large, the output signal is increased to quickly adjust. If the change in error is large but the error is small, the output signal is reduced. Combining the three error signals into one is called a PID control system. Using a velocity PID control is a quick and efficient method for controlling the wind speed in the tunnel.

Once the actual and desired speeds are identical, the wind speed error becomes zero and the fan speed stabilizes to maintain a constant wind speed. If the line voltage should fluctuate during a test, the actual wind speed will drop and the microprocessor will detect the error and add more to the fan control to compensate. All of this is repeated every 1/10 of a second to maintain a stable and accurate wind speed.

Fan Motor Control

The fan motor is made up of a 1 HP, 110 volt AC industrial motor. The speed of the fan motor is controlled by using a solid state relay that feeds power to the motor. To control the motor's speed accurately, it is necessary to have the microprocessor monitor the wind speed and control the motor directly. This is done by controlling how much power reaches the motor. Since the motor is an AC motor, we are able to control how much power was delivered by chopping the AC power into small segments and passing just enough power to the motor to run at the desired speed (*see* **Figure #3** below). This is done by having the microprocessor detect when the 110 volt AC wave reaches 0 volts (the crossover) to start a timer. If only half of the power is needed, the timer would wait for enough time to pass before turning on the solid state relay. Because a solid state relay stays activated until the voltage crosses zero volts, we are able to send a controlled amount of power to the motor which allows us to directly control the fan motor speed. Since we use 60 cycle power in the US, the process must be repeated twice for every cycle at 60 times a second (every 8.333 milliseconds). The microprocessor is very busy making sure the fan is at the proper speed. As you can see, by varying the microprocessor timer values from 50% to 60%, different wind speeds can be generated.

60 Cycle AC Wave form

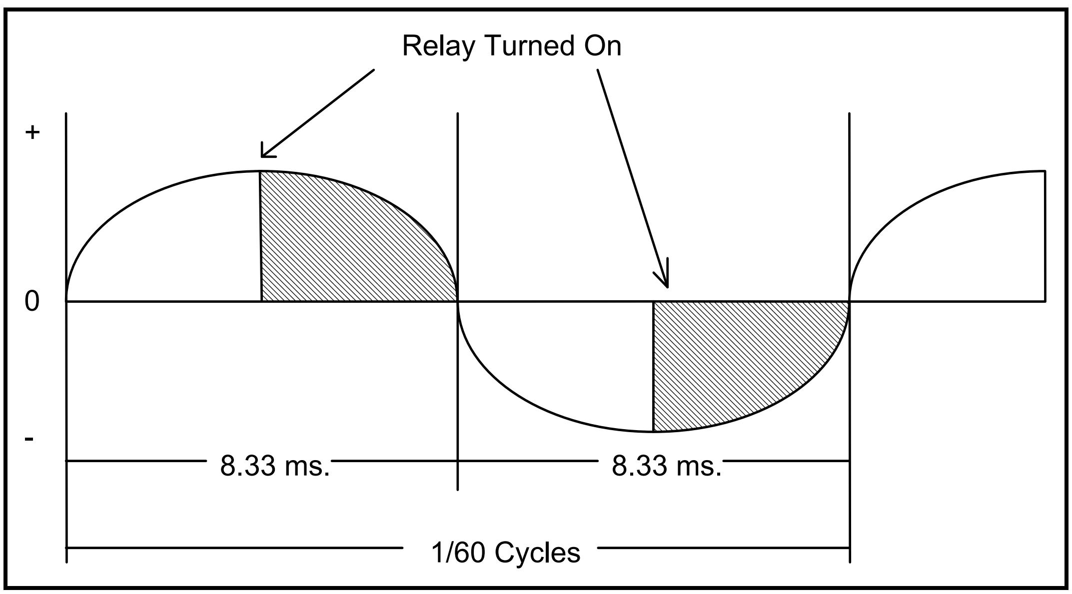

Figure #3

Troubleshooting

LCD does not display information

- Check to see that the control panel fuse is not blown.
- Check to be sure the control panel is properly plugged in and turned on.

Calibration Error is displayed

- Be sure the test bed is properly secured.
- Check the pitot tube for blockage or damage.
- Make sure the wind tunnel intake or exhaust ports are not blocked.
- Verify that the model does not touch the walls of the test area.
- Check that the 9 pin data cable is plugged into the control panel, test bed, and secured.

Numbers are erratic

- Low wind speeds may give erratic L/D results. Wind speeds greater than 30 MPH are recommended for proper L/D measurements.
- Make sure the model is firmly attached to the test arm. Vibrations can cause erratic results.
- Large test models may cause excessive turbulence within the tunnel and cause the model to vibrate. Reduce the size of the model and re-test.
- Check to see that the wind tunnel is on a stable platform and all of the feet are properly adjusted.

System Error

- If a system error occurs, be sure that the test model does not weigh more than 1 lbs. Oversize models may place to much weight on the instrumentation. Remove the model and power up the tunnel to see if the model is causing the system error. If problems persist, call Interactive Instruments for further instructions.

Wind Speed not controllable

- Check the pitot tube for blockage or damage.
- Check that the 9 pin data cable is plugged into the control panel, test bed, and secured.

Tunnel Not Connected is displayed

- Check that the 9 pin data cable is plugged into the control panel, test bed, and secured.

Fan not running

- Be sure the fan power cord is properly plugged into the rear of the control panel.
- Check to see that the fan fuse is not blown.

Angle of Attack not adjustable

- Check that the wind speed is at zero MPH before making adjustments to the angle of attack.
- Be sure to press in on the adjustment knob to link the knob with the test area.

Circuit Breakers keep tripping

- Be sure the wind tunnel is plugged into an outlet capable of 15 amps or more.

Limited Warranty

Interactive Instruments, Inc. warrants the **Jet Stream 500** against defects in material and workmanship for a period of *one* year from receipt by the end user (*proof of purchase required*). If Interactive Instruments, Inc. receives notice of such defects during the warranty period, Interactive Instruments will either, at its option, repair or replace products which prove to be defective.

Should Interactive Instruments be unable to repair or replace the product within a reasonable amount of time, customer's alternative exclusive remedy shall be a refund of the purchased price upon return of the product.

If this product was purchased as part of a system in a coordinated shipment or as a system add-on, it is warranted against defects in material and workmanship during the same period as the system.

Exclusions

The above warranty shall not apply to defects resulting from:
improper or inadequate maintenance by customer; customer-supplied software or interfacing; unauthorized modification or misuse; operation outside of the environmental specifications for the product; or improper site preparation and maintenance.

Glossary

A/D Converter	The component that converts analog signals from the force and pressure sensors and converts them to digital data for the microprocessor.
Angle of Attack	A vertical adjustment that can be made to the model under test to vary the angle of the model with reference to the wind direction.
Control Panel	The main control panel that is used to control the operation of the wind tunnel.
Data Cable	9 pin cable that connects the test bed to the control panel.
Drag	Force exerted on the model in the same direction of the wind.
Error Condition	Prompts are displayed on the LCD panel when the controller recognizes an error condition.
Fan	A 3 blade 10.5" propeller used to generate the wind speed.
Force Sensor	Electrical sensors that are used to measure the lift and drag forces exerted on the test model.
LCD	Liquid Crystal Display which is used to display the test results and error conditions on the control panel.
L/D	Lift divided by Drag ratio is derived by dividing the drag force into the lift. This ratio is commonly used to determine the characteristics of airfoils.
Lift	Force exerted on the test model that causes the model to raise or drop due to the wind speed.
Microprocessor	The digital controller that monitors the wind speed, model forces, control panel functions, updates the LCD panel, and performs the required calculations for operation.
Static Pitot Tube	A tube that is used to sample the static and active pressure in an air stream to determine the current wind speed within the tunnel (*see* **Pressure Sensor**).
Power Cord	110v power cord which powers the control panel and fan motor.
Pressure Sensor	The sensor that measures the static and active pressures from the pitot tube so the pressure difference can be measured by the microcontroller to determine the wind speed.
Security Key	A key that is located on the control panel that disables the operation of the wind tunnel when locked.
Stall	The condition where the airfoil cannot produce enough lift because of excessive turbulence due to the angle of attack and/or the wind speed.
Strain Gage	*See* **Force Sensor**.
Test Area	Area within the wind tunnel where the test model is placed.
Test Bed	Area within the wind tunnel where the test model is mounted. The test model is removable for easy placement of the test model.
Test Model	The model that is attached to the test arm on the test bed.
Test Arm	The post that is used to mount the model under test to the test bed.