WindOS Wind Tunnel

User Manual

Version 1.2

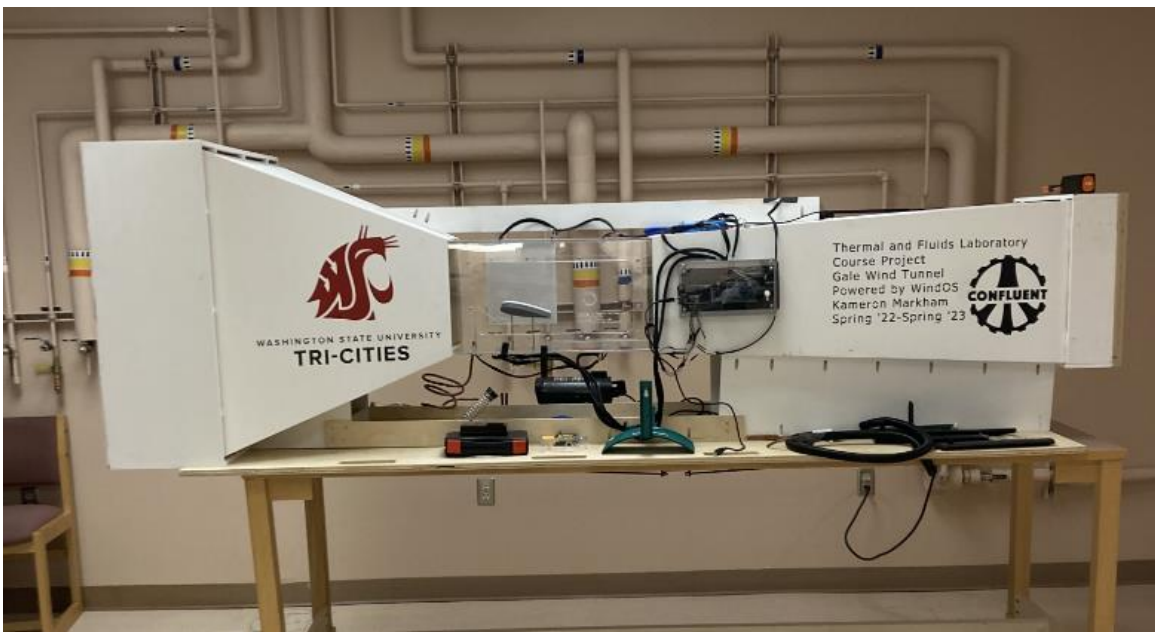

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Table of Contents

Section 1: Introduction

Welcome to the User Manual for the Subsonic Wind Tunnel System. This manual is designed to provide you with all the necessary information and instructions for operating the wind tunnel effectively and safely. Whether you are a student, researcher, or instructor in the field of aerospace engineering, this manual will guide you through the setup, operation, and maintenance of the wind tunnel.

1.1 Purpose of the User Manual

The purpose of this user manual is to familiarize users with the functionality and operation of the Subsonic Wind Tunnel System. It serves as a comprehensive guide, providing step-by-step instructions, safety guidelines, and troubleshooting information. By following the guidelines outlined in this manual, users will be able to conduct aerodynamic experiments, collect data, and gain valuable insights into the behavior of airfoils and other test specimens.

1.2 Overview of the Wind Tunnel System

The Subsonic Wind Tunnel System is a state-of-the-art educational tool designed to simulate airflow around various test specimens. It allows users to study the principles of aerodynamics, investigate lift and drag forces, and explore the effects of different angles of attack. The system consists of several key components, including the test section, computerized interface, load cells, barometer array, anemometer, and associated control and data acquisition systems.

1.3 Important Safety Information

Safety is of paramount importance when operating the wind tunnel system. Users must adhere to the following safety guidelines to ensure a secure and risk-free environment:

- Familiarize yourself with the location and operation of the emergency shut-off (unplug propellor battery) and fire extinguishers.
- Wear appropriate personal protective equipment (PPE) such as safety glasses when working with the wind tunnel system.
- Ensure that all electrical connections are properly grounded and that there are no exposed wires or damaged cables.
- Avoid wearing loose clothing, jewelry, or any other items that could get caught in moving parts of the wind tunnel.
- Do not touch the fog injector piping or any hot surfaces during or immediately after operation, as they may be hot and cause burns.
- Do not operate the wind tunnel system without proper training or supervision.

By following these safety guidelines and using the wind tunnel system responsibly, users can ensure a safe and productive experimental environment.

Next, we will delve into the detailed system overview, providing an in-depth description of each component and its functions.

Section 2: System Overview

In this section, we will provide a comprehensive overview of the Subsonic Wind Tunnel System, including a description of its key components, their functions, and instructions for assembly and installation.

2.1 Description of the Wind Tunnel Components

The Subsonic Wind Tunnel System comprises the following main components:

- Test Section: The test section is the main part of the wind tunnel where the experiments are conducted. It features a rectangular cross-section and is equipped with transparent walls for easy visualization of the airflow around the test specimen.
- Computerized Interface: The wind tunnel is equipped with a user-friendly computerized interface that allows users to control various parameters, monitor data in real-time, and adjust experimental conditions. The interface provides intuitive controls and a graphical user interface (GUI) for easy navigation.
- Load Cells: The wind tunnel is equipped with precision load cells that measure the net vertical force acting on the test specimen. These load cells are strategically positioned and provide accurate measurements to assess lift and other forces.
- Barometer Array: The wind tunnel is equipped with a barometer array consisting of multiple pressure sensors located along the test section walls. These sensors measure the pressure distribution and provide valuable data on the airflow characteristics.
- Anemometer: The anemometer measures the airspeed within the wind tunnel, providing crucial data for analyzing the effects of different velocities on the test specimen. It helps in understanding the relationship between airspeed and aerodynamic forces. It also is a data source the computerized interface uses to set an appropriate motor speed.

2.2 Functions and Features of Each Component

- Test Section: The test section creates a controlled and uniform airflow around the test specimen. It allows users to adjust the angle of attack, vary the airspeed, and observe the effects on lift, drag, and other aerodynamic forces.
- Computerized Interface: The computerized interface (WindOS) provides a user-friendly platform for controlling the wind tunnel system. Users can input desired experimental parameters, monitor real-time data, and visualize results through the graphical user interface.
- Load Cells: The load cells accurately measure the net vertical force acting on the test specimen. This data is essential for understanding lift, drag, and the stability of the test specimen under different operating conditions.

- Barometer Array: The barometer array measures the pressure distribution along the test section walls. It helps analyze the flow characteristics and identify areas of high or low pressure, aiding in the assessment of aerodynamic performance.
- Anemometer: The anemometer measures the airspeed within the wind tunnel, providing critical data for understanding the effects of velocity on aerodynamic forces. It helps in determining the correlation between airspeed and lift, drag, and other parameters. It also is a data source the WindOS uses to set an appropriate motor speed.

2.3 Assembly and Installation Instructions

Detailed assembly and installation instructions for the Subsonic Wind Tunnel System are unavailable. Original CAD for the Gale prototype is available at https://github.com/xmutantson and the mechanical design can be altered as you see fit.

In the next section, we will discuss the step-by-step operating instructions for preparing the wind tunnel, powering it on, and adjusting experimental parameters.

Section 3: Operating Instructions

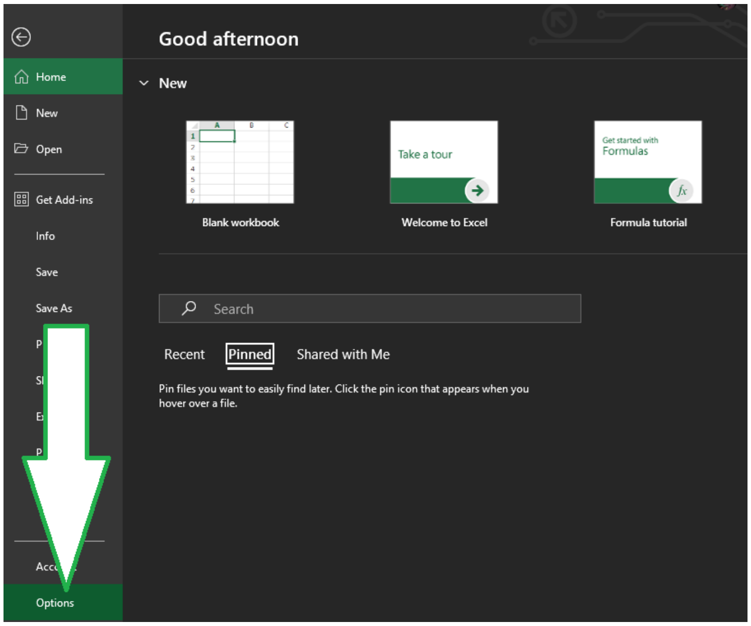
In this section, we will guide you through the step-by-step process of operating the Subsonic Wind Tunnel System. These instructions will help you prepare the wind tunnel for experiments, power it on, and adjust the necessary parameters for conducting aerodynamic tests.

3.1 Preparing the Wind Tunnel for Experiments

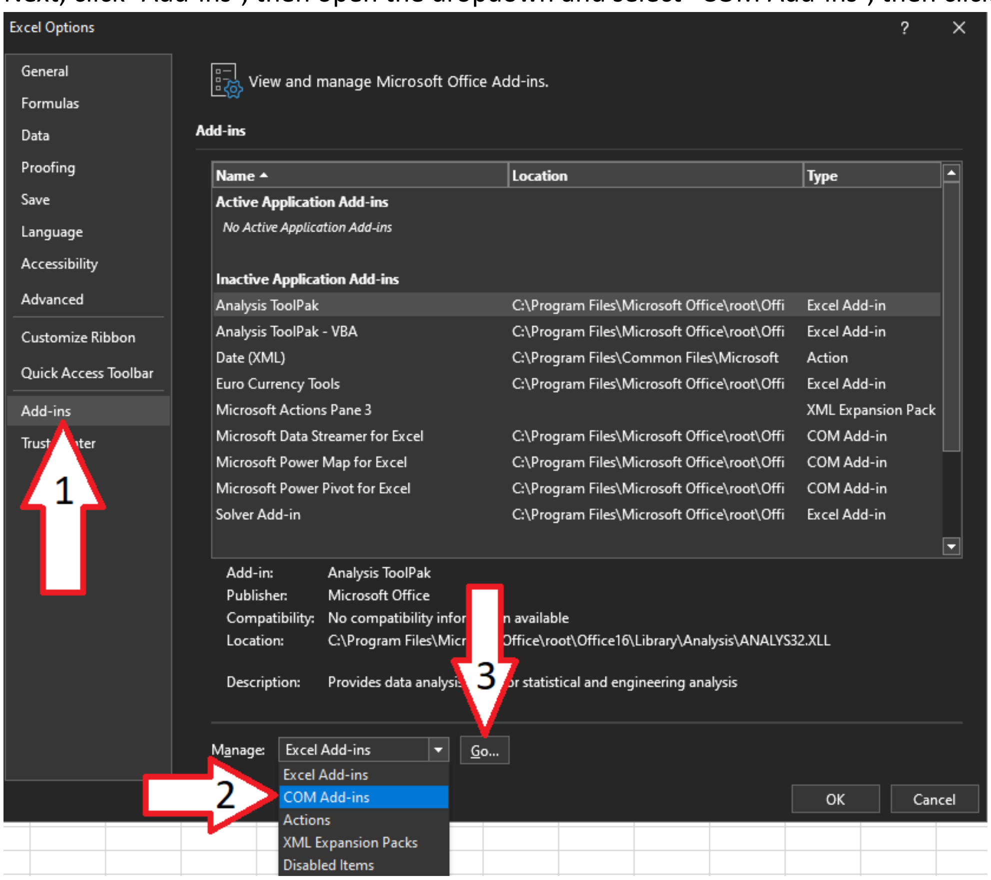
1. Verify that all connections are secure and that there are no loose or damaged parts.
2. Conduct a visual inspection of the test section and ensure that it is clean and free from any debris or obstructions. Clear the surrounding area to ensure a safe and unobstructed workspace.
3. Conduct a visual inspection on the propellor blade, ensure no cracks have formed and no pieces are missing from the blade. Pay specific attention to the leading edge and the hub.
4. Calibrate the load cells by following the calibration procedures outlined in the user manual. This step is crucial for accurate force measurements during the experiments. This step is only needed with a microcontroller which has not previously been used to calibrate the load cells, if the EEPROM bits targeted have failed, or if the EEPROM address has been changed in the code.

3.2 Powering On the Wind Tunnel

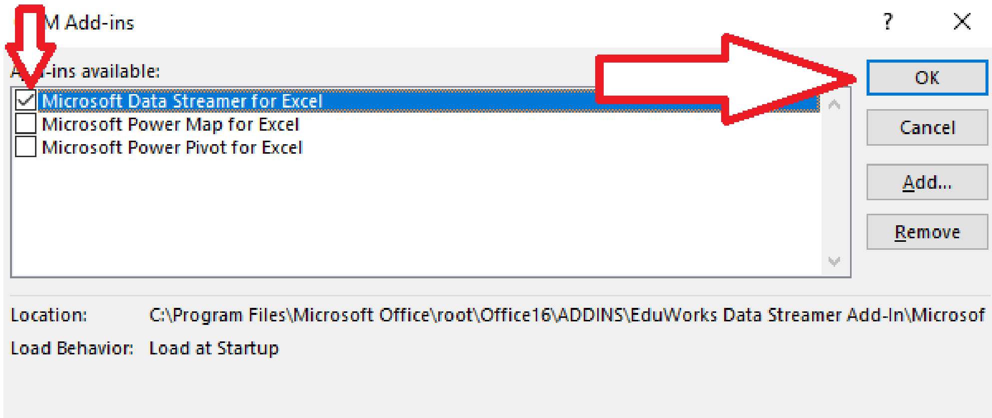
1. Connect the power cable to the designated power outlet, ensuring that it is properly grounded. **This MUST be done first, as there is a back feeding danger when the USB port is attached to the data collection computer. Damage may occur to the attached data computer or the wind tunnel.**
2. Switch on the power supply to the wind tunnel system. Verify that the power panel illuminates the main power LED as well as each of the 4 power rail LEDs. Be sure the computerized interface is operational.
3. Allow the system to initialize and perform any necessary self-tests. This may take a few moments, and the interface will provide status updates during this process.
4. If you will be collecting data, attach a data collection computer (Windows/Mac/Linux laptop) via USB.
5. Use Microsoft Excel and the Microsoft Data Streamer add-in for Excel. If this is your first time setting up Microsoft Data Streamer, open a new/blank workbook. Then, navigate to the options menu:



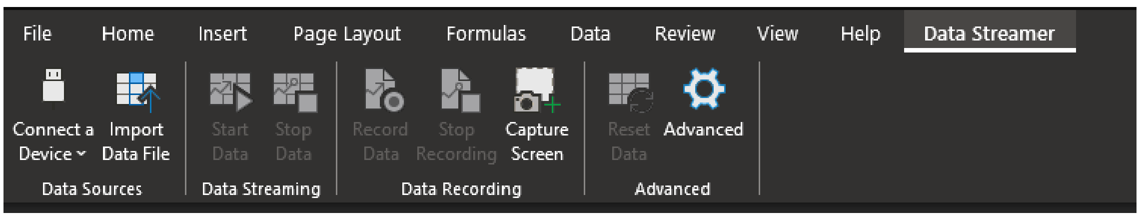
Next, click “Add-ins”, then open the dropdown and select “COM Add-ins”, then click “Go…”:



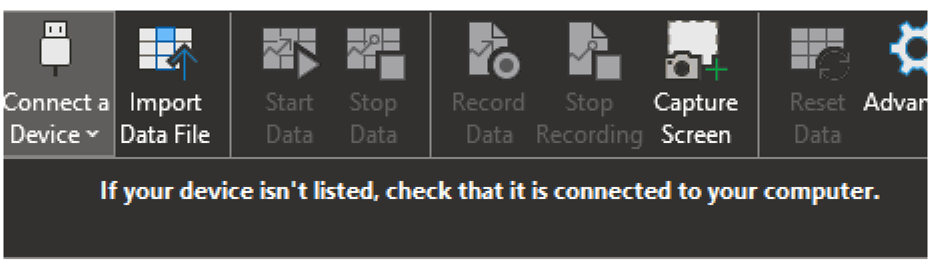
In the new window, check “Microsoft Data Streamer for Excel”, then click “Ok”:



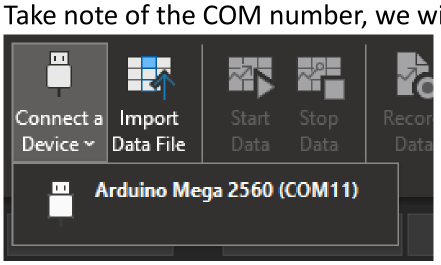
A new tab has appeared in Excel, called “Data Streamer”. Select it:



Then Connect a Device. The wind tunnel should be powered on, and the computer should be plugged into it via USB. If the wind tunnel is not yet plugged in, you should see something like the following:

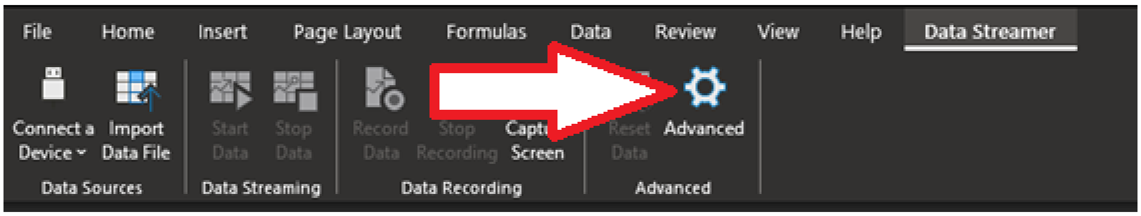


Once there is a valid serial port connection, “Connect a Device” will look similar to the following. It’s ok if the COM number is different, but the device should appear as an Arduino Mega 2560. Take note of the COM number, we will need it later.

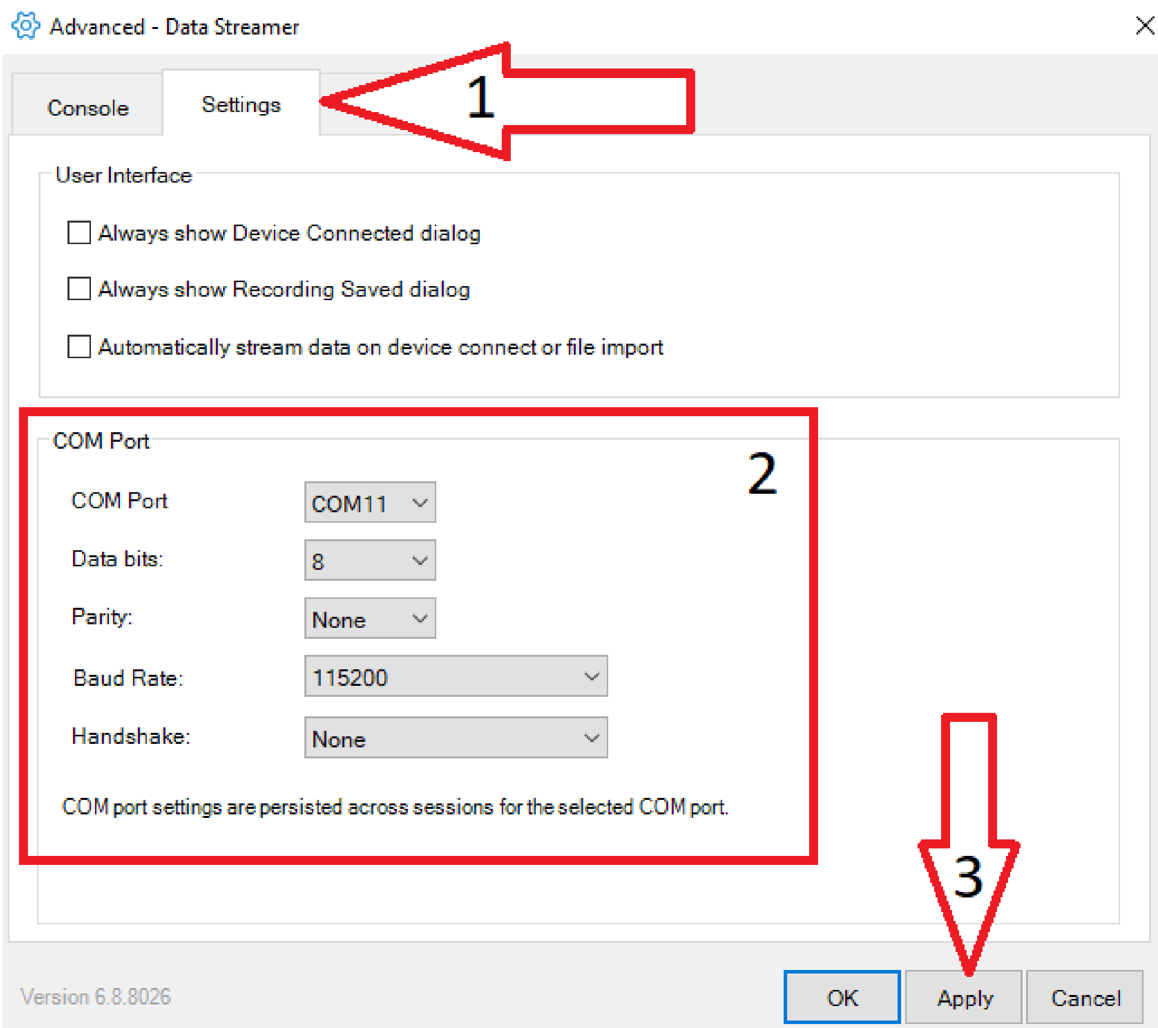


Click on the detected device to connect to it. Excel will create several special tabs to prepare data capture.

We need to prepare the program before starting data capture. Enter the Advanced options menu (make sure the wind tunnel is connected first):

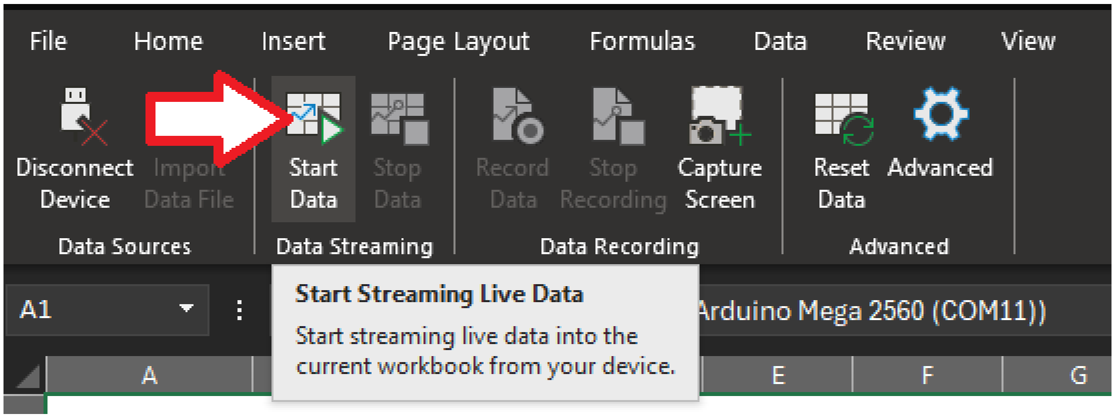


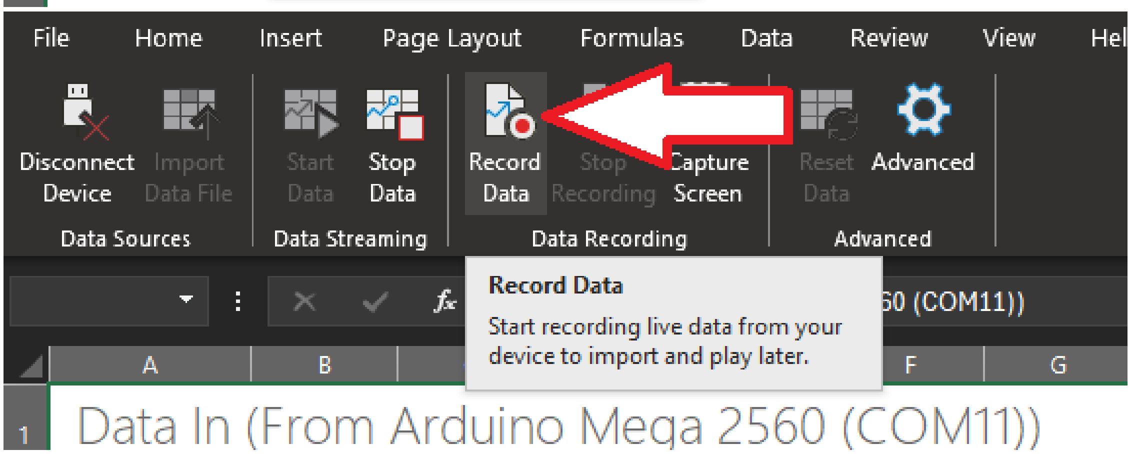
Click the “Settings” Tab, then change the settings as follows (COM## will probably be different, it should be whatever showed up earlier when connecting to the device):



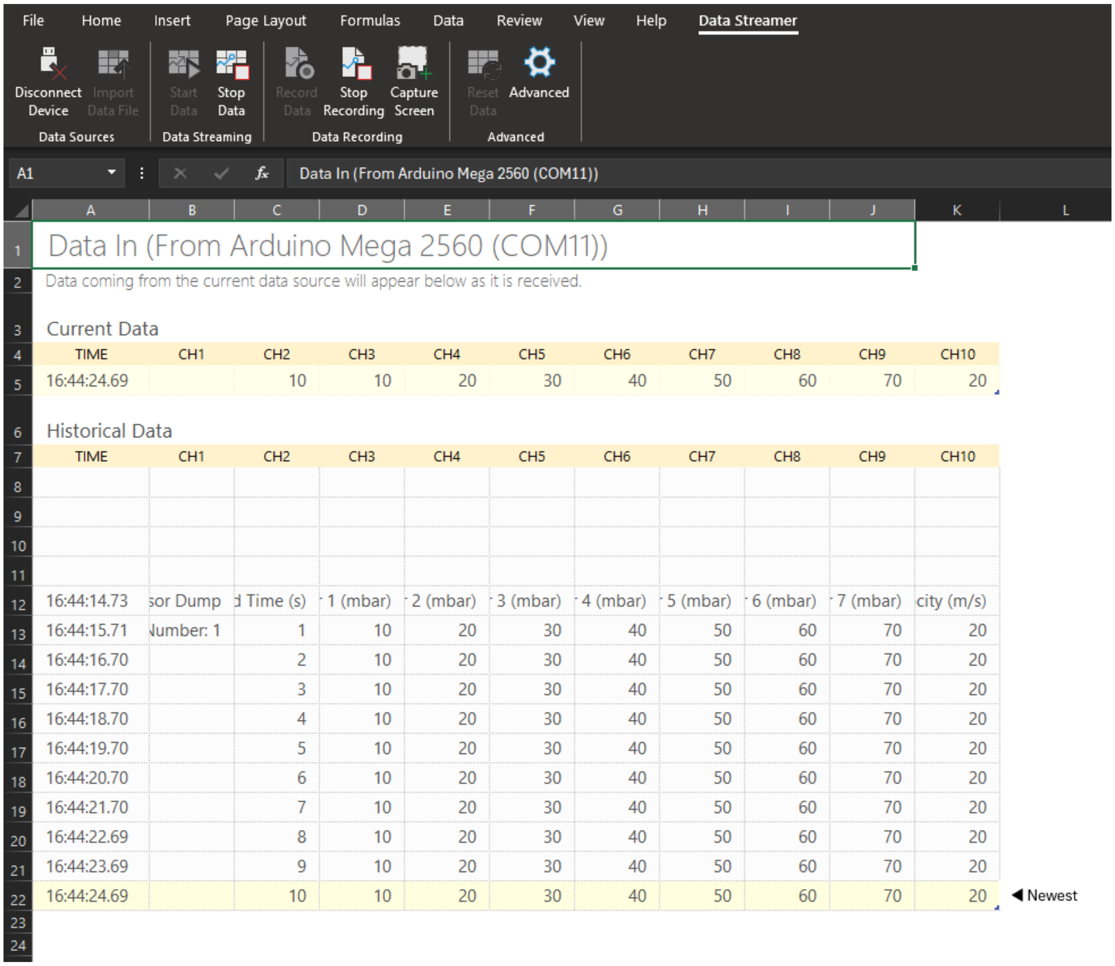
Click “Apply” to save the changes.

Before starting the Wind Tunnel, be sure to click “Start Data”, then “Record Data”:





Once “Start Data” and “Record Data” have been clicked and the wind tunnel is started, excel will gather the data:



Current Data

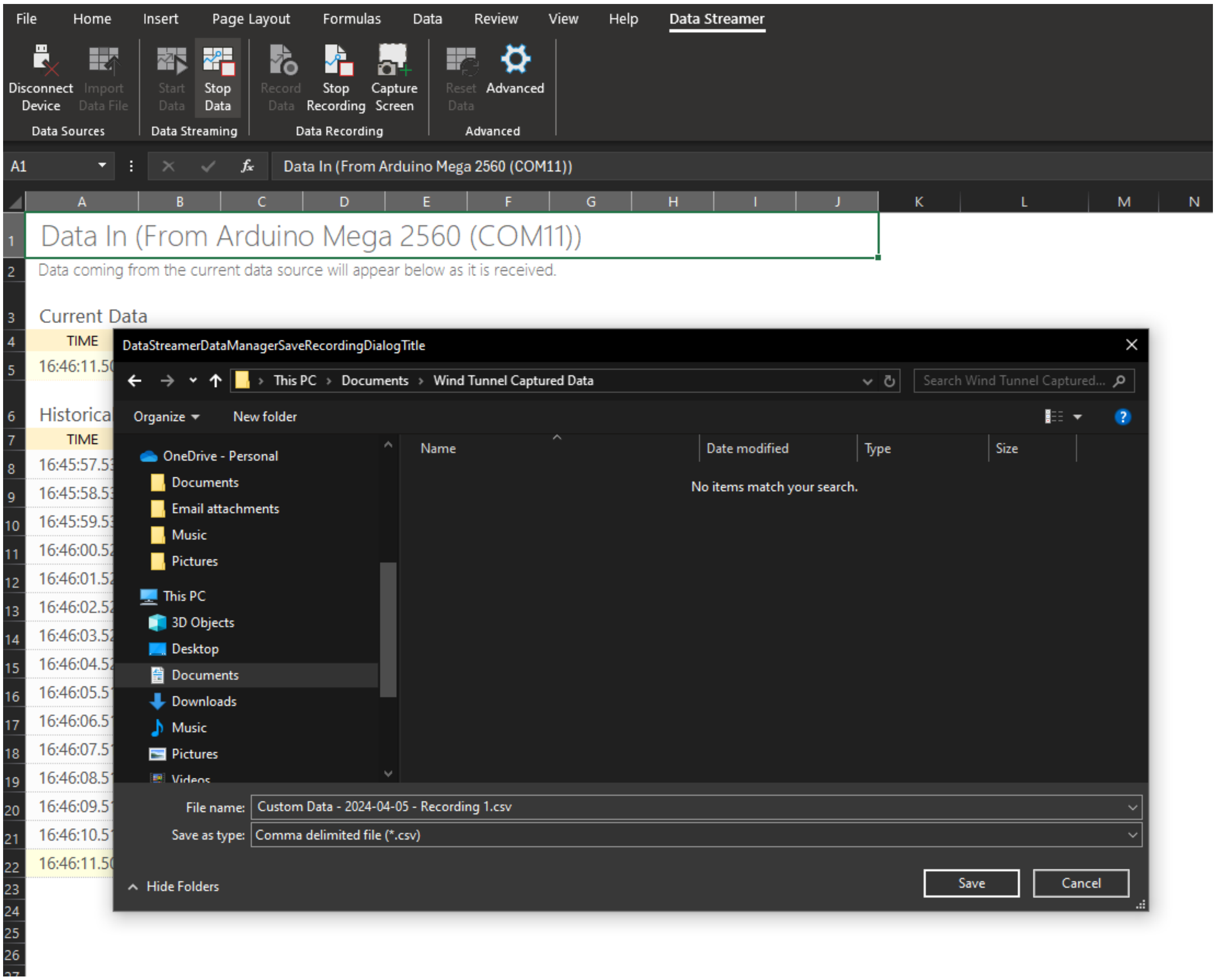
TIME	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10
16:44:24.69		10	10	20	30	40	50	60	70	20

Historical Data

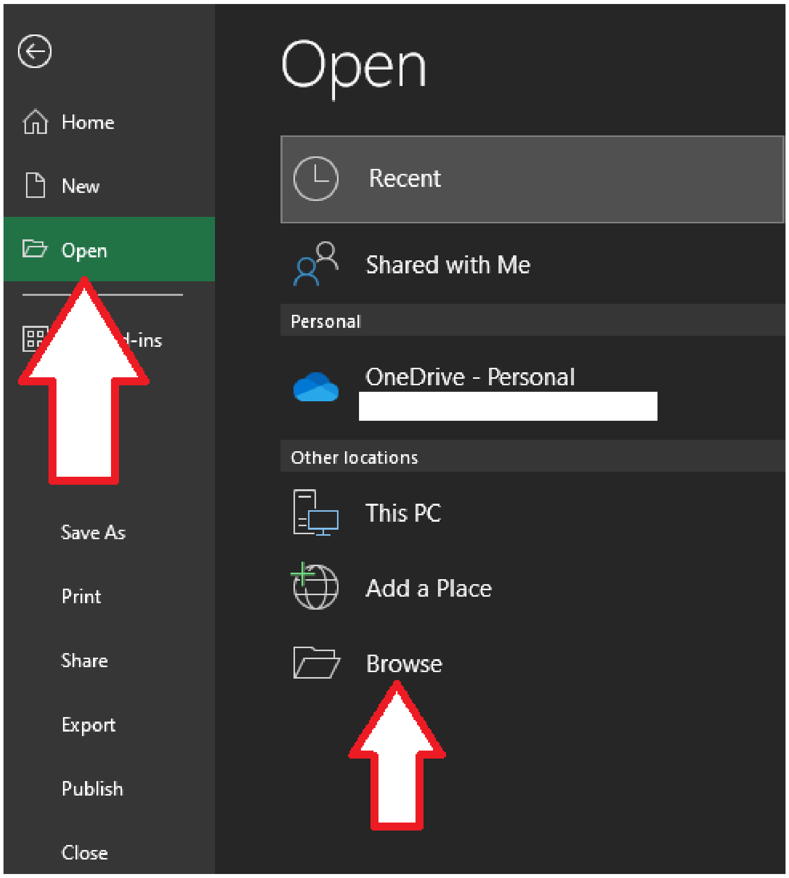
TIME	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10
16:44:14.73	sor Dump	d Time (s)	1 (mbar)	2 (mbar)	3 (mbar)	4 (mbar)	5 (mbar)	6 (mbar)	7 (mbar)	city (m/s)
16:44:15.71	Number: 1	1	10	20	30	40	50	60	70	20
16:44:16.70		2	10	20	30	40	50	60	70	20
16:44:17.70		3	10	20	30	40	50	60	70	20
16:44:18.70		4	10	20	30	40	50	60	70	20
16:44:19.70		5	10	20	30	40	50	60	70	20
16:44:20.70		6	10	20	30	40	50	60	70	20
16:44:21.70		7	10	20	30	40	50	60	70	20
16:44:22.69		8	10	20	30	40	50	60	70	20
16:44:23.69		9	10	20	30	40	50	60	70	20
16:44:24.69		10	10	20	30	40	50	60	70	20

The preview will show a limited history of the incoming data. It will only show 10 columns of data, which is a limitation of the add-in. The wind tunnel uses more than 10 columns of data, and you may notice that some of that data is not available in the “Current Data” or “Historical Data” areas. You may also notice that the historical data area “rolls over” and appears to discard data as new data comes in. Do not worry, all the data are being recorded, and will be available as a CSV shortly.

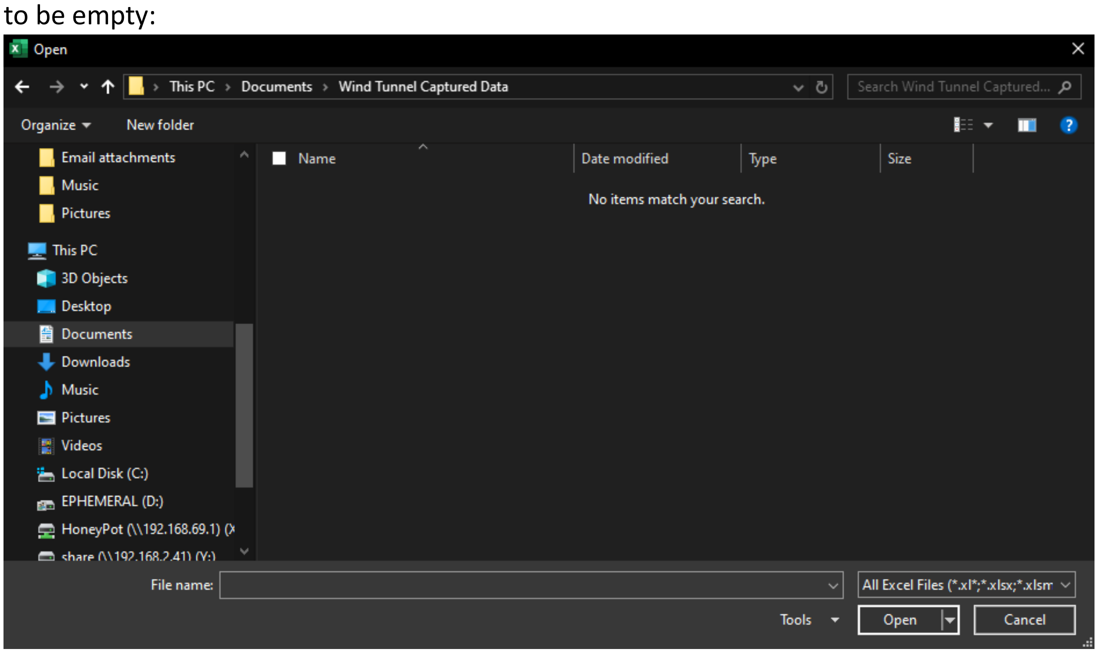
When the total trials have been completed, click “Stop Data”. This will trigger a file save dialog to appear. Name the file, put it where you like, and click “Save”.



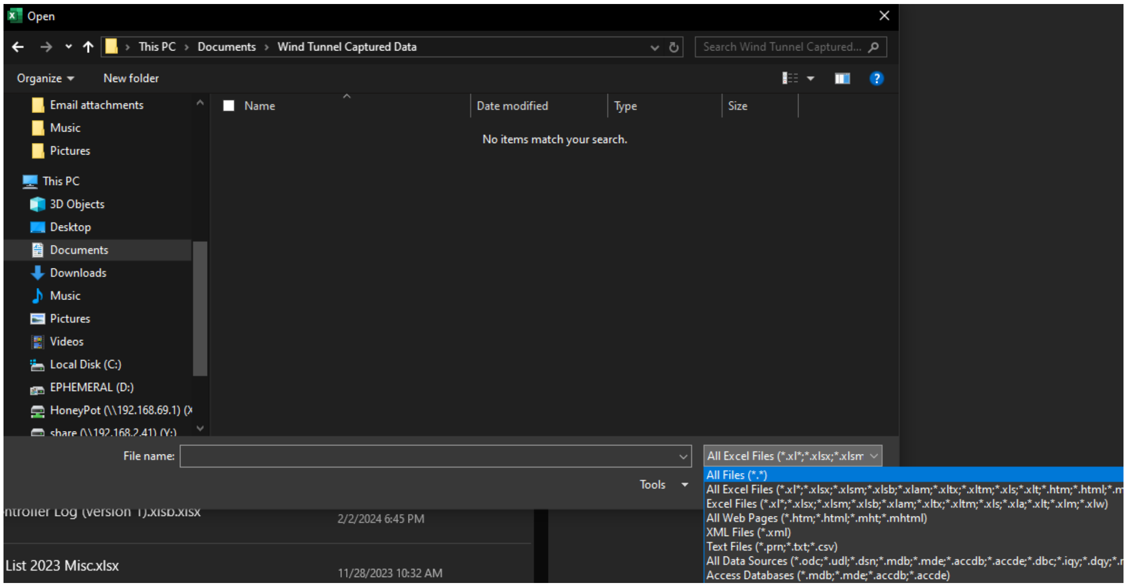
Import the CSV file. Go to “File”, “Open”, and click “Browse”:



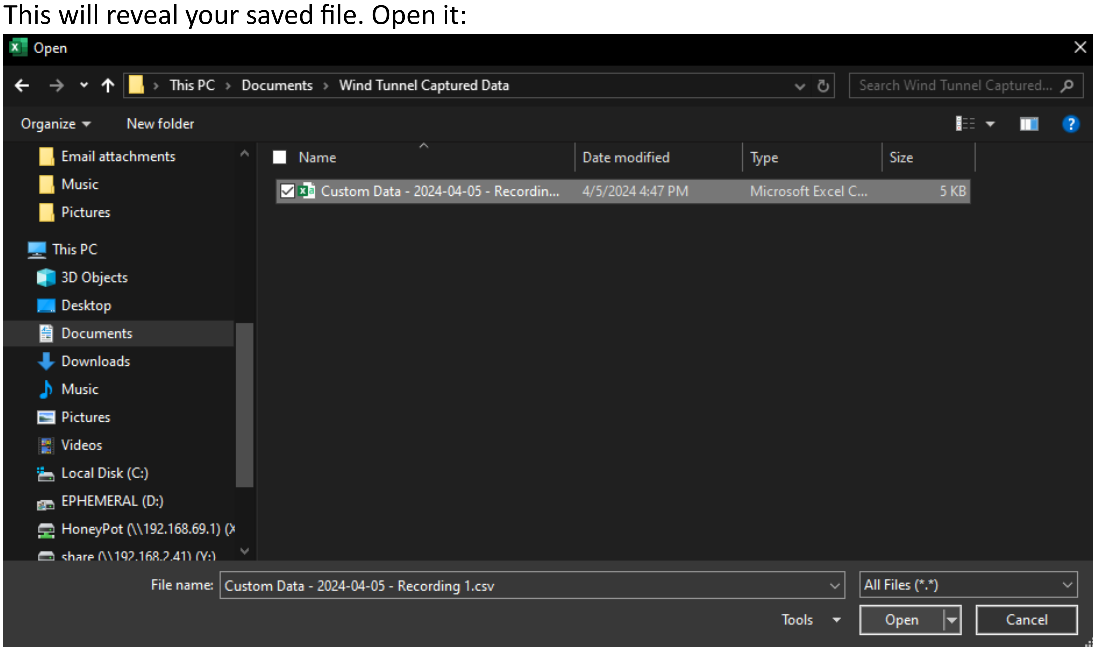
Browse to the location where the CSV was saved earlier. You will notice that the folder appears to be empty:



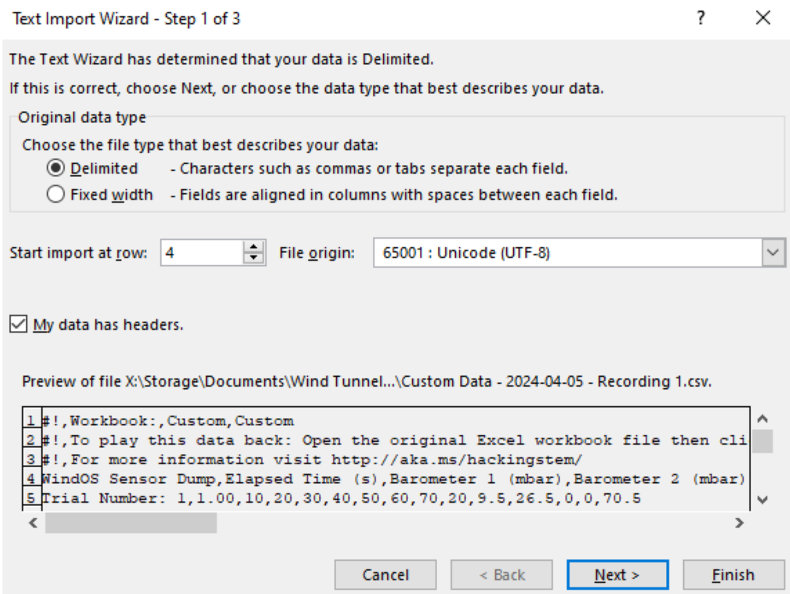
The problem is that excel filters for excel file formats by default, and CSV files are not included in the list of file formats Excel will look for upon trying to open a file. Click the dropdown above “Open”, and change the file format filter list to “All Files”:



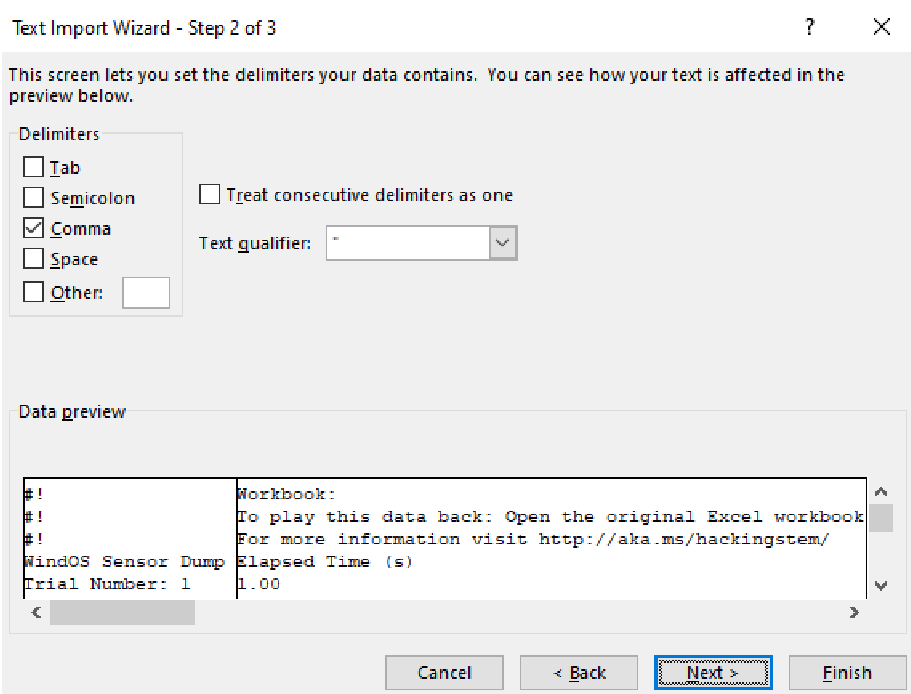
This will reveal your saved file. Open it:

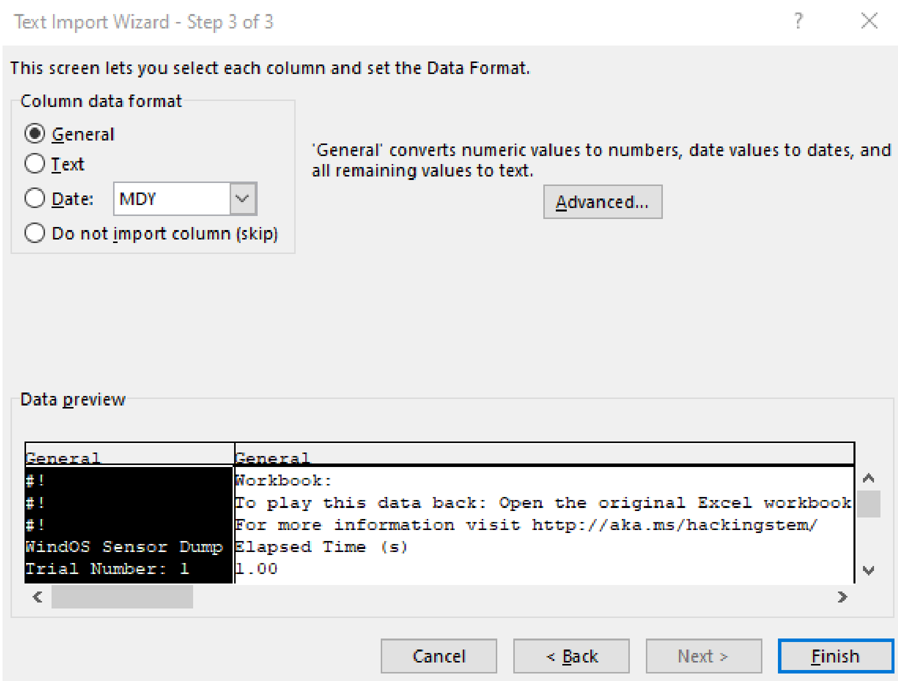


There are several options we must use. First, ensure the use of “Delimited” data type. Start import at Row 4, or whichever row starts with “WindOS Sensor Dump”, as this is the column header row. There is a preview you can use if you need to adjust this. Select that your data has headers. Leave “File Origin” as default:

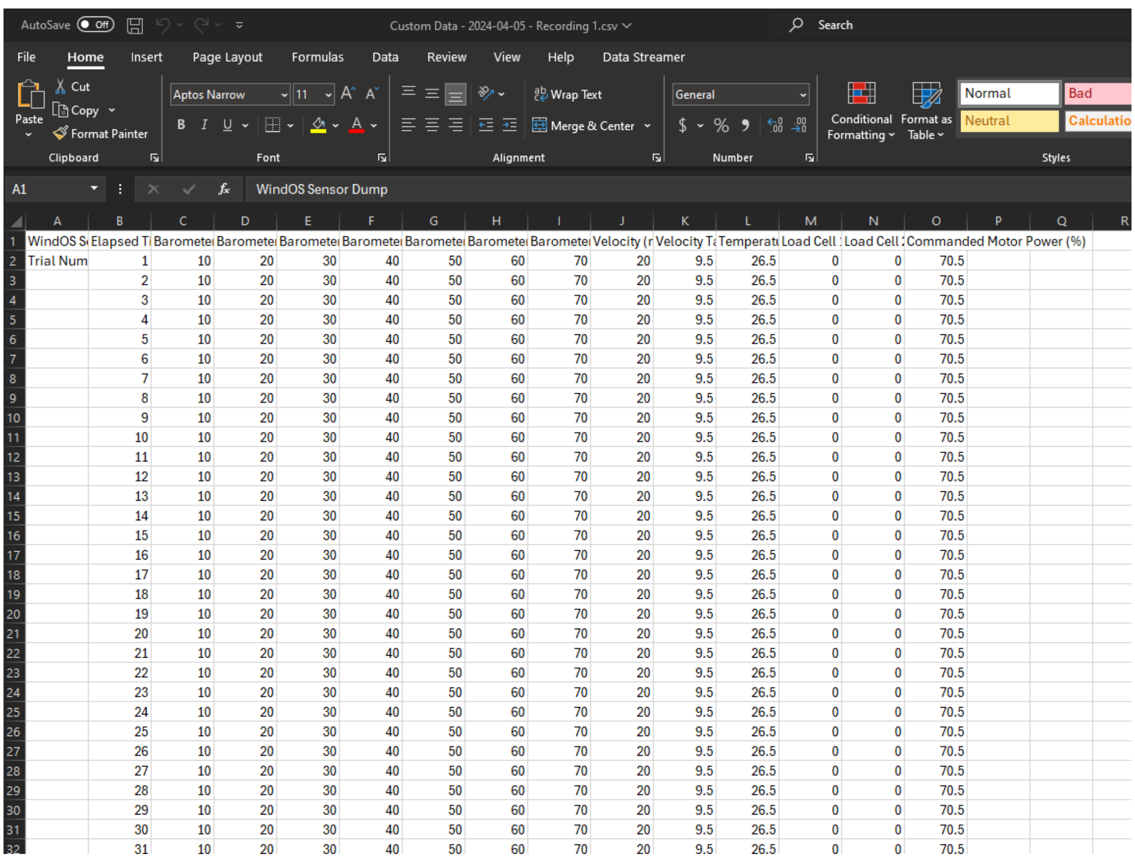


Click “Next”. On page 2, Check “Comma” in the “Delimiter” category, uncheck all other boxes, as set in the following. Don’t worry if the preview is still showing the headers from earlier, the import should start from row 4. Click “Next” when done, don’t change anything on page 3, then click “Finish”:



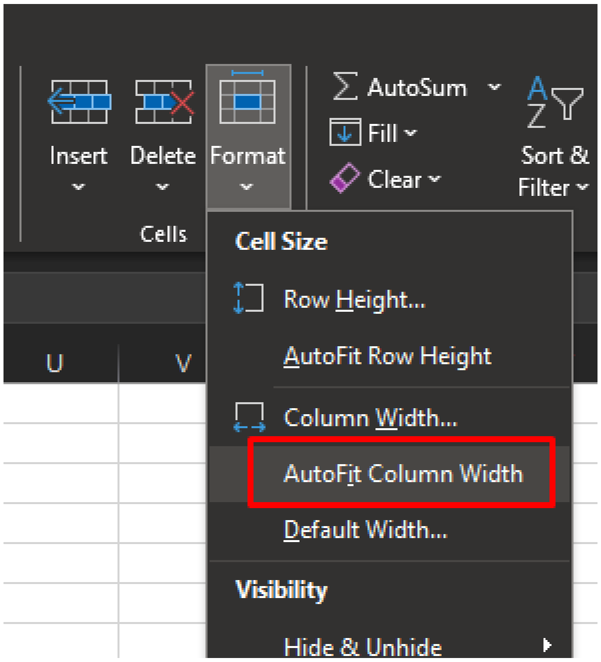


If all has worked well, you should see similar data as the following:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	WindOS S	Elapsed Ti	Baromete	Baromete	Baromete	Baromete	Baromete	Baromete	Baromete	Velocity (r	Velocity T	Temperatu	Load Cell :	Load Cell :	Commanded Motor Power (%)
2	Trial Num	1	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
3		2	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
4		3	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
5		4	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
6		5	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
7		6	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
8		7	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
9		8	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
10		9	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
11		10	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
12		11	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
13		12	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
14		13	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
15		14	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
16		15	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
17		16	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
18		17	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
19		18	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
20		19	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
21		20	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
22		21	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
23		22	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
24		23	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
25		24	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
26		25	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
27		26	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
28		27	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
29		28	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
30		29	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
31		30	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5
32		31	10	20	30	40	50	60	70	20	9.5	26.5	0	0	70.5

The column widths can be AutoFit if desired by first selecting all columns that have data, then going to Home > Cells > Format. Under Cell Size, select AutoFit Column Width:



If the data contains more than one trial, there will be additional header rows for each trial. It is recommended that additional sheets are created for each trial run if there will be further graphing or analysis. This will have to be done manually.

3.3 Adjusting Experimental Parameters

1. Familiarize yourself with the various controls and features of the interface. A quick start guide is in Appendix A, a full explanation of all menus is in Appendix B.
2. Set the desired airspeed and time per trial using the interface controls.
3. Choose desired number of trials and choose whether to disable the barometers or load cells.
4. Monitor the airspeed, load cell readings and barometer data on the interface. These measurements provide crucial information about the forces acting on the test specimen.

3.4 Conducting Experiments and Data Collection

1. Position the test specimen securely in the test section, ensuring proper alignment and attachment to the load cells. Ensure the door is secured.
2. Attach the motor battery. The motor should beep as it comes to life, if you hear no beeps the ESC might be damaged. Before the first run, the motor will continue beeping slowly until the first

trial is initiated. Once the first trial has run there should be no more beeps from the motor unless the computer is resetting at the conclusion of a set of trials.

3. Initiate the tunnel, refer to Appendix A for a step-by-step quick start guide.
4. Monitor the real-time data on the interface, observing the changes in forces, pressures, and other relevant parameters.
5. Record the data obtained during the experiment via the serial terminal for further analysis and interpretation.

3.5 Shutting Down the Wind Tunnel

1. Safely power off the wind tunnel system by **first unplugging the USB connection from the data acquisition computer**, then unplug the motor battery. Finally, unplug the power cord from the wall.
2. Ensure that all components are switched off.
3. Clean the test section and other components as necessary, removing any debris or residue.

By following these operating instructions, you will be able to effectively and safely operate the Subsonic Wind Tunnel System. Always refer to the user manual for detailed instructions and safety guidelines.

In the next section, we will provide troubleshooting tips and common issues that may arise during wind tunnel operation.

Section 4: Troubleshooting and Maintenance

In this section, we will discuss common troubleshooting tips and maintenance procedures for the Subsonic Wind Tunnel System. Proper maintenance and prompt resolution of issues are essential to ensure the optimal performance and longevity of the wind tunnel.

4.1 Troubleshooting Tips

1. Power Issues:
    - Ensure that the power cable is securely connected to the power outlet and that the power supply is switched on.
    - Check for any tripped circuit breakers or blown fuses in the laboratory electrical system.
    - If the issue persists, contact technical support for further assistance.
    - If the wind tunnel suddenly stops the motor and starts a series of **3 fast beeps**, the LVC (low voltage cutoff) mode has been engaged to protect the battery. Change to a fresh battery and recharge the drained battery. **Failure to promptly recharge the battery to at least a storage charge (50% of battery capacity) will result in damage to the drained battery.**
2. Sensor Malfunction:
    - If any of the sensors, such as the barometers or load cells, are not providing accurate readings or are malfunctioning, first check the connections to ensure they are properly secured.
    - Perform sensor calibration procedures as outlined in the user manual.
    - If the issue persists, contact technical support for guidance on sensor troubleshooting or replacement.
3. Interface or Software Issues:
    - If you encounter any issues with the computerized interface or software, try restarting the system. The USB port does scramble the display sometimes when it is attached. A power cycle of the wind tunnel will fix this, but you must do that with the USB disconnected or it will not power cycle. **Also, there is a back feeding danger when the USB port is attached when the main power cord is disconnected. Damage may occur to the attached data computer or the wind tunnel.**
    - Ensure that all software updates and patches are installed. Make sure you're running the latest release of software, available at https://github.com/xmutantson and installable via Arduino IDE.
    - If the issue persists, contact technical support for further assistance.

4.2 Routine Maintenance

1. Regular Cleaning:
    - Clean the test section and other components of the wind tunnel with a lint free cloth after each experiment to remove any debris or residue.
    - Pay special attention to the test section walls, ensuring they are free from any dirt or debris.
2. Calibration Checks:
    - Regularly perform calibration checks on the load cells and sensors to maintain accurate measurements.
    - Follow the calibration procedures provided in the user manual.

4.3 Safety Considerations

1. Always prioritize safety when operating the wind tunnel. Follow all safety guidelines outlined in the user manual.
2. Ensure that the wind tunnel smoke visualization system is operated in a well-ventilated area to prevent accumulation of fumes or gases.
3. Use appropriate personal protective equipment (PPE) when necessary, such as gloves or safety goggles.
4. Regularly inspect the wind tunnel components for signs of wear, damage, or deterioration. Replace any damaged parts promptly to maintain safe operation.

By following these troubleshooting tips and maintenance procedures, you can address common issues and ensure the continued performance and reliability of the Subsonic Wind Tunnel System. Remember to consult the user manual for detailed instructions and contact technical support if you require further assistance or encounter any complex issues.

In the final section, we will provide additional resources and references for further exploration and learning in the field of aerodynamics and wind tunnel testing.

Section 5: Additional Resources and References

In this section, we provide a list of additional resources and references that can further enhance your understanding of aerodynamics, wind tunnel testing, and related topics. These resources offer valuable insights, in-depth knowledge, and practical guidance for individuals interested in exploring the field of aerodynamics and utilizing the Subsonic Wind Tunnel System.

5.1 Recommended Books

1. "Low-Speed Wind Tunnel Testing" by William H. Rae Jr., A. Pope, and Jewel B. Barlow: This comprehensive book serves as a valuable reference for wind tunnel testing techniques, data analysis, and interpretation. It covers various aspects of wind tunnel design, instrumentation, and measurement techniques.

2. "Introduction to Flight" by John D. Anderson Jr.: This book provides a solid introduction to the fundamentals of aerodynamics, flight mechanics, and aircraft design. It offers clear explanations and practical examples that facilitate a deeper understanding of the principles involved.

3. "Aerodynamics for Engineers" by John J. Bertin: This book presents the fundamental concepts of aerodynamics in an engineering context. It covers topics such as airfoil theory, flow visualization, and wind tunnel testing, providing a solid foundation for further exploration.

5.2 Online Resources

1. NASA Glenn Research Center: The official website of NASA's Glenn Research Center offers a wealth of information on aerodynamics, wind tunnel testing, and aerospace research. It provides access to publications, technical reports, and educational resources that can broaden your knowledge.

2. American Institute of Aeronautics and Astronautics (AIAA): The AIAA website offers access to technical papers, journals, and conference proceedings on a wide range of aerospace topics. It is a valuable resource for staying updated with the latest advancements and research in the field.

5.3 Conclusion

In conclusion, the Subsonic Wind Tunnel System user manual, along with these additional resources, equips users with the necessary knowledge and tools to operate the wind tunnel effectively, perform experiments, and gain valuable insights into aerodynamics. By utilizing these resources, you can deepen your understanding, conduct meaningful research, and contribute to the advancement of aerodynamic knowledge and engineering practices.

We encourage users to explore these resources and continue their journey of discovery in the field of aerodynamics.

Appendix A – Quick Start Guide

- Be sure the model you want to test is attached. Use the threaded rods to attach it to the load cells. If you powered up WindOS already, reset it (main menu > Reset) to zero the load cells. You may notice some drift in the load cells. This is normal because the model and affixing hardware has been placed under tension. The tensions will relax over time. Further resets may be needed prior to running an experiment.
- Ensure WindOS is active, check the screen and make sure the main menu is up and updating periodically
- Ensure your data computer is connected, then open a serial session (default 115.2K baudrate)
    - When the data computer initiates a serial connection, usually this automatically triggers a WindOS reset, avoiding the below problem
    - Screen corruption can happen due to electrical noise, if this happens every time, follow these steps to resolve the issue:
        - in the main menu select “Reset” but don’t activate it
        - attach the laptop, then press in on the encoder if the display scrambles
        - n this way you can trigger a software reset safely even if you can no longer see where you are in the menus
- Press in on the white knob (hereafter referred to as “the encoder”) to bring up the main menu
- Rotate the encoder to navigate to the start option, note the “>” character to the left indicates which line you’re on.
    - Clockwise to move down, Counter-Clockwise to move up
    - Don’t spin too fast or the encoder will miss some of your rotations
- Once “Start” has been navigated to, press the encoder to initiate the start menu
- All items here are a “rotate, then click” method. Rotate to adjust a setting, click to move on.
- first input the desired velocity, then the desired time. Velocity is the default adjustment, when it has been entered a “:” character will show up, indicating you must now input a trial duration. When finished entering time, press the encoder to advance to the next screen
- Choose whether you wish to use barometer data
    - Barometer data acquisition is the largest load on the data acquisition part of the program, if you disable the barometers you will get a faster update rate of the other sensors

- Choose whether you are interested in load cell data
- Choose how many trial repetitions you would like. This is useful for if you require statistics that incorporate more than one iteration. Factorial DOE, standard deviation, etc.
    - A standard is 11+ for T-statistics (sample), and 31+ for population (usually you want to get a few more in practice in case some of your trials fail or have abnormalities
    - There is a time estimate in hours and minutes as to how long total trials will take (that way you can decide if you want to run things unattended [not recommended])
    - This is the final screen before the tunnel will initiate, there is no “are you sure” (as of WindOS V1.2), it will just go. Make sure not to confirm your trial repetition selection until you are ready for the wind tunnel to actually start.
- From this point the motor will initialize and the data acquisition will proceed. Data is a CSV format.
- The main screen will update more slowly in RUN mode. This is normal, and saves processing power to increase the frequency of gathered data.
- When finished, the tunnel will reset. To run subsequent tests, start at the beginning of this appendix.

Appendix B - Full WindOS Interface

Menus

When WindOS is powered up, it will do a self test (and force an encoder press to acknowledge any errors). Following that, it will enter into what is known as the **Main Status** display. This display is active in either the "OK" or "ERR" status. This contains live sensor information, and is useful for determining the sensor states "at-a-glance". This screen has a twin, called the **Run Status** display. This is activated in the place of the Main Status display when the wind tunnel is in the "RUN" state.

Both of these menus have menus, which are known as the "Main" and "Run" menus, respectively.

Main Menu:

- Info Screen
    - Will return you to the "Main Status" display. Named differently here to specify that is not supposed to show you any kind of diagnostic data.
- Start
    - Will start the data input sequence. In brief, It will ask for: Velocity > Trial Time > Barometer y/n > Load Cell y/n > Trial Repeat #
- Sensor Statistics -- all sensors update at a higher rate in these menus for diagnostic purposes
    - Go Back
        - Returns you to the Main Menu
    - Barometers
        - Displays barometer status. Scrollable, Barometers 1-7.
            - Barometer 1 is Top-Front (inlet side), 2 Top-Middle, 3 Top-Rear (outlet side)
            - Barometer 4-6 is Bottom-Front thru Bottom Rear
            - Barometer 7 is the atmospheric reference barometer located just above the controls
    - Anemometer
        - Will show you both airspeed and temperature, since they both come from the anemometer
    - Load Cells

        - Shows values for load cell 1 and 2

- Calibrate
    - Go Back
    - Cal LoadCell 1
        - Initiate calibration routine for Load Cell 1. See Appendix C for load cell calibration instructions
    - Cal LoadCell 2
        - Initiate calibration routine for Load Cell 2
- Serial Interface
    - Go Back
    - Current Serial Info
        - Will show you the current serial port configuration. Default is 115.2Kbaud, 8 bit, no flow control, 1 stop bit
    - Change Baud Rate
        - Selectable baud rates from 300 to 115.2Kbaud. Note, slow baud rates will adversely impact wind tunnel data and control loop performance. Set the highest speed your terminal supports.
    - Reset Serial Port
        - Triggers a reset of the serial port (serial flush/release/initialize) from the Arduino side. Changing serial port baud rate will trigger this as well
- About
    - Shows about info, includes WindOS Author (Kameron Markham) as well as the last revision date of the code. Version of the code can be found on the startup splash screen
- Reset
    - Triggers a hard reset of the microcontroller running WindOS. Effectively restarts WindOS.

Run Menu:

- Return
    - Return to the Run Status Screen
- ABORT (Reset)
    - Triggers a hard reset of the microcontroller running WindOS. Effectively restarts WindOS. Named here ABORT to grab attention in case of emergency.
- Sensor Statistics
    - Same exact menus as Main Status
- Live Adjust V
    - Allows the speed target to be updated. Uses a slower control loop for gradual speed shifting.

Appendix C – Load Cell Calibration Guide

This section will walk you through auto calibration of the load cells. This is needed when for some reason the saved data in the EEPROM is inaccurate or unavailable.

Steps:

1. First, ensure the load cells are connected properly. They should be connected to the circuit board and no wires should be loose or broken. Be sure to have proper power and voltage levels for all devices.

2. Ensure that the microcontroller (as of WindOS board Rev 2, an Arduino Mega 2560) is powered on and the latest applicable version of WindOS has been uploaded to the board.

3. Navigate to the load cell calibration menu (Main Menu > Calibrate) and choose Load Cell 1 (this is the forward load cell, closest to the inlet).

4. WindOS will ask you to remove any specimen from the load cell. Remove all fixtures and mass from the load cell, making sure to keep the measuring end away from any part of the tunnel test chamber. Click the menu knob to confirm when complete. The load cell will perform a zeroing operation.

   - The current calibration factor will be displayed (or NaN, if the EEPROM doesn't contain calibration data).

5. Hang a weight from the load cell. This should be in the range of a few hundred grams. The purpose is to establish a reference mass for the calibration routine. Once the weight is attached and hanging below the test section from the load cell, enter the mass into WindOS and confirm. The automatic calibration routine will begin. Please be patient, as it is a process that continuously adjusts the calibration factor and checks the reading against the actual mass. This will continue until the reading agrees with the mass input by the user. It will then store the calibration factor in the microcontroller EEPROM, a type of non-volatile memory which will persist between power cycles of the wind tunnel.

6. Repeat steps 3-5 with Load Cell 2. The user-entered mass reading for the weight will already be stored from the first load cell calibration to save time. Adjust if needed.

7. You're done! The load cells are calibrated and will not need further attention unless either the load cells or the microcontroller is changed.

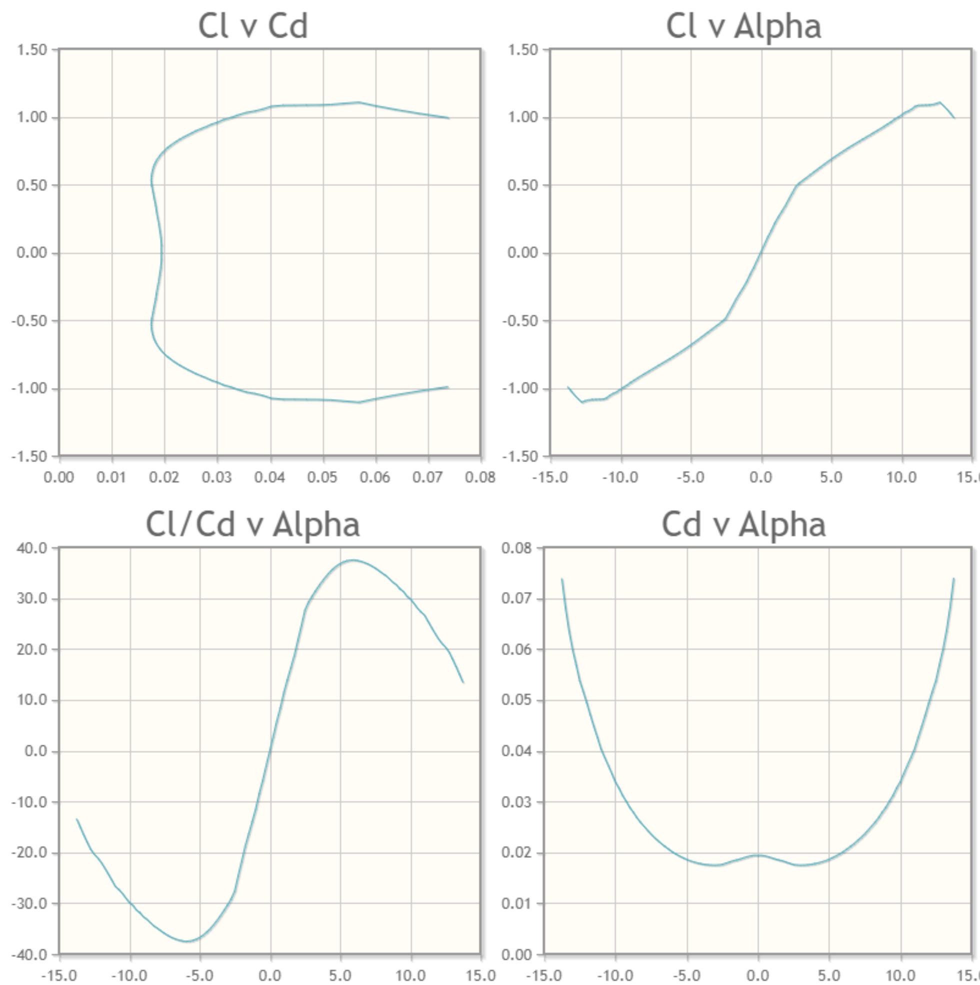
Appendix D – Verification Data

This section is designed to present some example data that will prove that this wind tunnel is comparable to other wind tunnels. The airfoil we are using for reference is a NACA 0015 which has been 3D printed. The layer lines span the wing from tip to tip and there has been no surface processing.

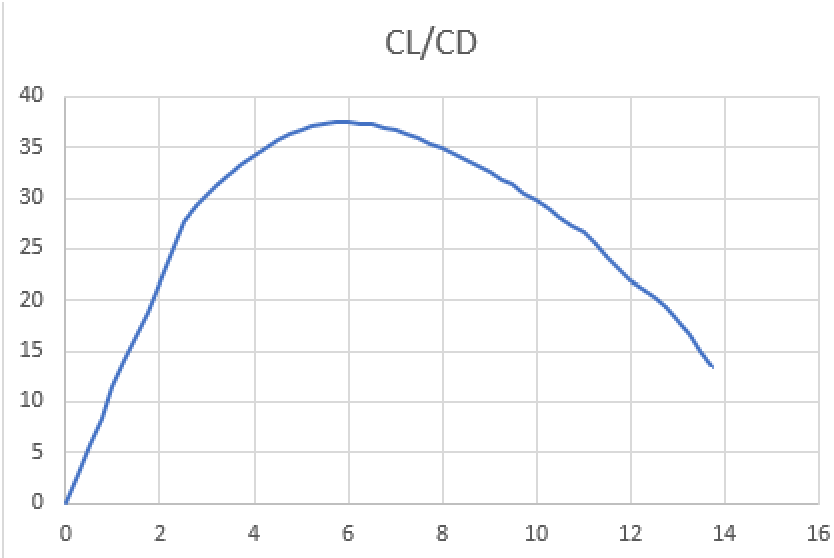
Here is reference data from http://airfoiltools.com/polar/details?polar=xf-naca0015-il-100000

Cl = Coefficient of lift, Cd = Coeff. Of drag, Alpha = Angle of Attack

Sample Data:

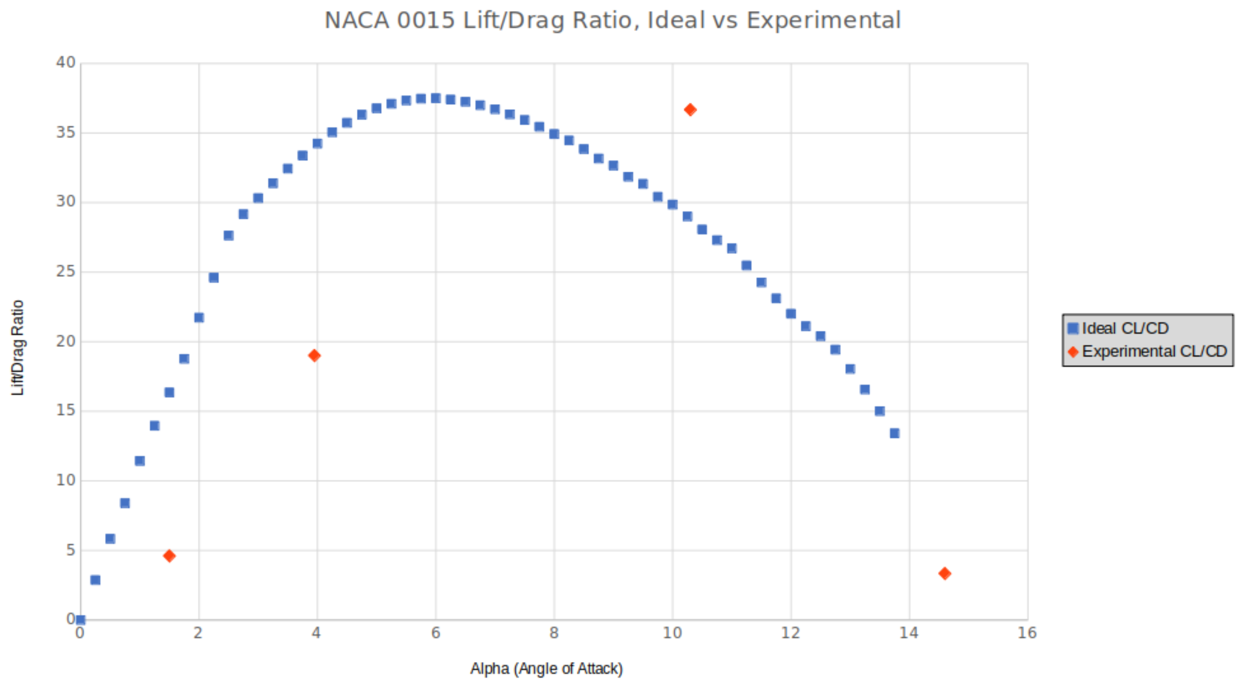


We are going to focus on the bottom left graph for all positive Alpha:



That is the ideal data, I expect that curve to be somewhat flatter near the top due to increased surface friction. The test airfoil has layer lines that are perpendicular to the flow direction, and I expect this to cause some less-than-ideal boundary layer adhesion, which will make a peak lift-to-drag ratio hard to achieve. Note that the angle of attack is x, so we should expect peak performance near 5 degrees.

After performing the tests, this is the ideal data versus the experimental data:



This experimental data is a bit sparse, but does seem to roughly follow the shape of the curve. It seems to be shifted to the right by a few degrees or so, which may be an issue with how I was measuring the airfoil angle. I was doing it by putting graph paper behind the airfoil and illuminating it with a light, then using that to work out the angle of attack. A better way to measure angle would be through use of a differential laser level, for example. The data collected validates that airfoil tests for lift and drag within the wind tunnel are likely to be reasonably accurate. Raw data in support of these tests is available in the WindOS GitHub repository as well.