Wind Tunnel Testing Device

by

MICHAEL DAVIS

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Signature of Author ______________________
Mechanical Engineering Technology

Certified by ______________________
Janak Dave, PhD,
Thesis Advisor

Accepted by ______________________
Dr. Muthar Al-Ubaidi, Department Head
Mechanical Engineering Technology

WIND TUNNEL WITH WING TESTING DEVICE

Michael Shane Davis

ABSTRACT

Currently no lab study exists to supplement the CAS Fluid Mechanics lecture on Bernoulli's Equation, so students are faced with the challenge of trying to understand Bernoulli's Equation without any supplemental learning tools.Wind tunnels are designed to help people study and understand how air and fluid flow over or around objects in space. Most wind tunnels are very large and are extremely expensive, which means they are often unattainable for students to use.

Surveyed MET students showed a strong interest in using the wind tunnel to test the air velocity over a wing, air pressure at various points, laminar and turbulent flow, and data repeatability. These important aspects are necessary to support the learning process and supplement the theory behind Bernoulli's Equation. .

The projected price range for this new design is projected to be no greater than $2100 dollars at the added 20% maximum, and will be completed for a demonstration on May 1st, 2007. The next important date will be the Tech Expo on May 16th, 2007. The final oral presentation and report for the wind tunnel and testing device will be due on June 6th, 2007.

The Wind Tunnel Testing Device for this project is relatively smaller in size, low cost, and transportable. This device utilizes a wind tunnel built by my partner, Brad Taylor, as well as a system used to collect test data, designed and constructed by myself. This system is very simplified to allow students the ability to run this device with little complication and previous knowledge.

The process began with the presentation to the MET Department during the fall quarter to discuss the need for a wind tunnel with testing capabilities for the MET students. Approval was granted from the MET Department to design and construct a wind tunnel testing device. After this surveys were dispersed throughout the MET students and faculty to determine what characteristics they would like to see on this testing device. The survey data was collected and used to produce a chart that helped determine the desired engineering characteristics that were implemented in the testing device.

The designing of the wind tunnel testing device began with hand sketches that next turned into isometric drawings and then to three-dimensional product drawings. This process took place during winter quarter. A design freeze was placed on the design phase in mid quarter to allow enough time to order the necessary materials for the building phase of the project so the project could be completed in time for Tech Expo.

Construction, assembly, and testing phases began at the start of spring quarter. Once construction and assembly phases were complete, a test run was conducted with our advisor present in order to meet proof of design. After passing proof of design, more testing was done and all minor glitches were worked out in order to ensure that the device met customers' requirements as well as having the best possible prototype for show at the Tech Expo. All phases were completed when the wind tunnel testing device was displayed for the critics at tech expo.

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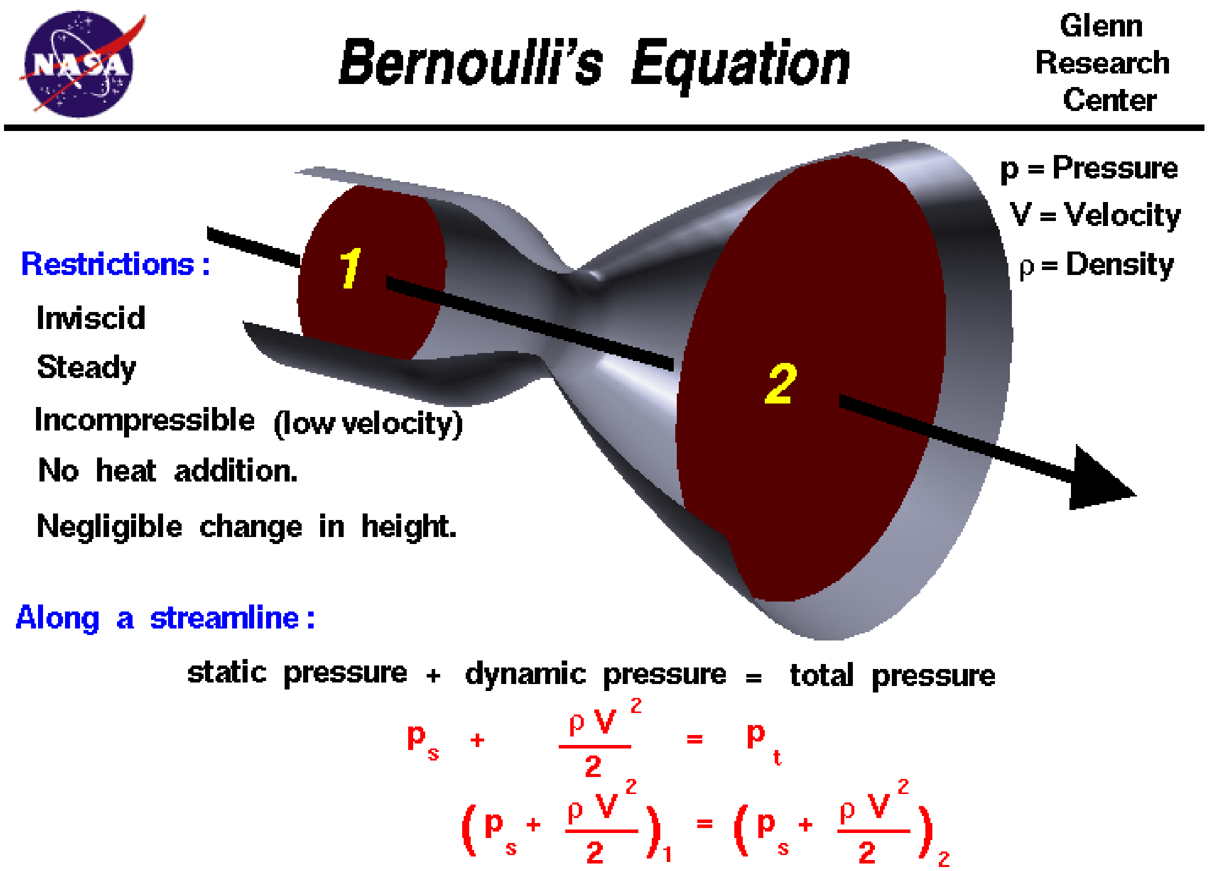
INTRODUCTION

At this time there is no laboratory experiment to supplement the CAS Fluid Mechanics lecture where MET students learn the basics of Bernoulli's Equation, laminar and turbulent flow, and the forces and pressures acting on a wing. Students are constantly faced with the trial of understanding Bernoulli's Equation without any supplemental learning tools.

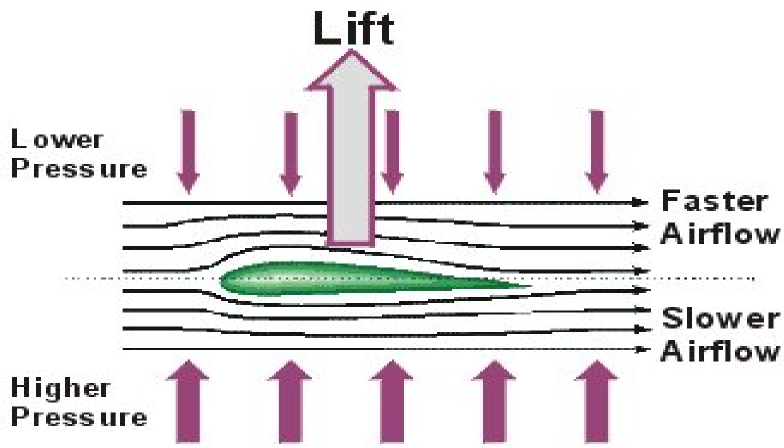
This project is designed to elaborate on the teachings of Bernoulli's Equation that are learned in fluid mechanics along with the relationship between pressure, velocity and density. This is because there is currently no primary lab experiment to accompany the lecture in this subject. This allows students to better understand the basic principles of the pressure vs. velocity relationship as well as the lift force vs. angle of attack relationship.

Figure 1-Bernoulli's Equation



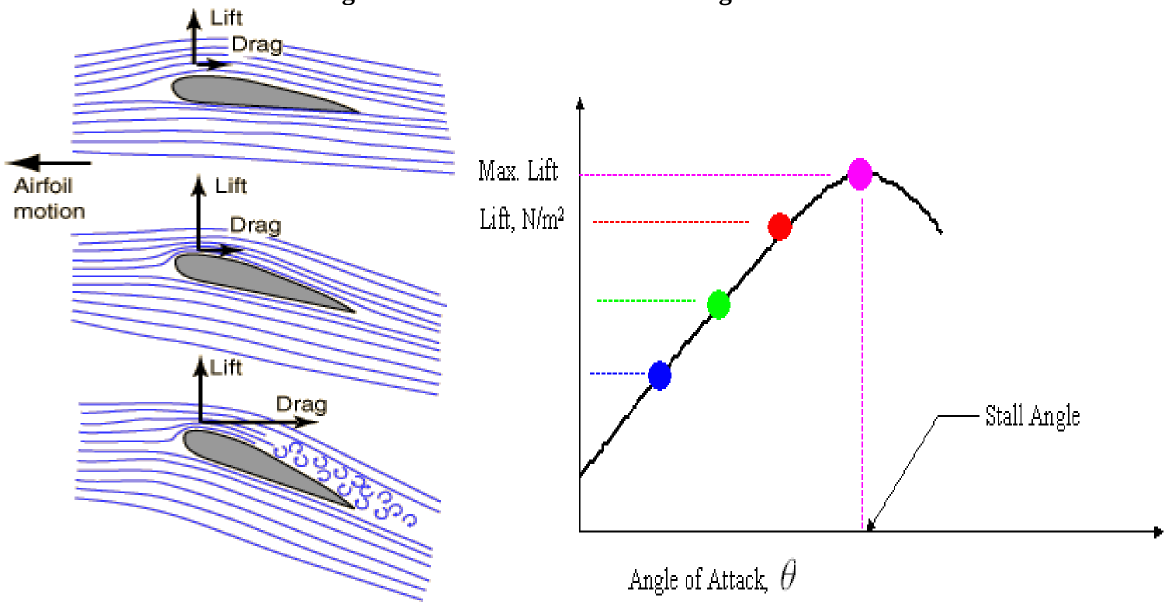
Bernoulli's equation is relatively simple. As the area in the tunnel decreases the velocity increases. When the velocity increases the pressure decreases. This is shown in the equation illustrated in the figure above. It may be better understood when referring to an airfoil. The increased velocity causes the pressure to drop on the top of the wing profile resulting in lift force. By referring to figure 2 below, you will see how lift occurs based on the pressure/velocity difference on the top and bottom of the airfoil. Students are able to measure the pressure with a manometer and the velocity with a velocity flow meter. Given the density of air they are able to relate these values and principles to Bernoulli's equation and how lift on a wing is caused.

Figure 2- Lift and Drag Force on a wing



As seen in the Figure 3 below, the airfoil is able to be turned to different angles of attack. As the angle of the wing increases, the lift will also increase. When the angle of the wing increases, this is what causes the higher velocity air on the top of the wing and the lower velocity air on the bottom of the wing. This results in different pressures and lift forces. This only works until the stall angle is reached. Once this point is reached the lift will begin to decrease again. The lift force cause by these changes is measured with a strain gages

Figure 3 – Lift Force Related to Angle of Attack



This wind tunnel is easy to operate as well as serving as a reliable test fixture. This fixture will help the students in their quest to demonstrate correct theory and use it to supplement their lecture material. This is accomplished by providing accurate and reliable experimental data. This piece of equipment is also easy for the students and instructors to maintain, operate, and calibrate.

WIND TUNNELS AND TESTING DEVICES

There are wind tunnels on the market that are fully able to complete these tests, but they are unattainable due to cost and size. The following discusses other products on the market and some of the pros and cons associated with these models. With this information it will help you understand the concept behind this design and why it was chosen for this application.

OPEN LOOP WIND TUNNELS

"OMEGA's state-of-the-art wind tunnel is designed to give a highly uniform flow rate over a 6" test section. A powerful 12 amp motor varying from 0 to 10,000 RPM is adjusted to give a particular flow rate by a precise motor control unit. Each wind tunnel is supplied with an NIST traceable certificate. The uniform flow rate is determined by monitoring a highly repeatable differential pressure sensor which has been calibrated to an individual wind tunnel as a system. Each wind tunnel is supplied with two restrictive plates for achieving optimum low flow rates. The established differential pressure measurements versus flow rates are listed from 25 to 9000 FPM. Calibration sheets are included which make calibrating different flow sensors simple [7]." This tunnel costs $11,700. Shown in figure 4.

Figure 4 - WT4401- Laboratory Grade Benchtop Wind-Tunnel with Instrumentation from OMEGA®

"The new WTM-1000 mini wind tunnel from OMEGA® gives a highly uniform flow rate at 4 selectable fixed air speeds, yet it costs less than competitive brands. The fixed air speeds range from 2.5 m/s (492 fpm) to 15 m/s (2953 fpm). With the remote option, the user can control and vary the wind tunnel air speed externally by connecting a potentiometer. The internal 10 cm (4") diameter test chamber is large enough to accommodate either hot-wire or vane-type anemometers. The unit is powered by 90 to 250 Vac. Each WTM-1000 comes with an NIST calibration certificate for the 4 fixed air speeds [7]." This model costs $2,995. Shown in figure 5.

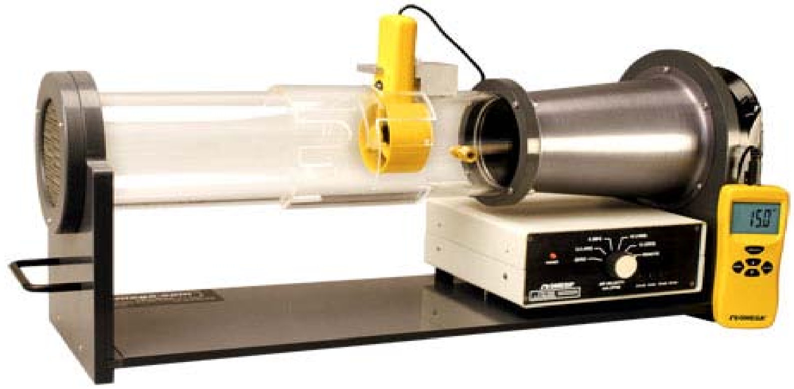


Figure 5 - WTM-1000 mini wind tunnel from OMEGA®

CUSTOMER SURVEY AND ENGINEERING CHARACTERISTICS

CUSTOMER SURVEY AND RESULTS

A customer survey was created and issued to students for this proposed to help us better understand what a student may be looking for in a testing device like ours. The survey asked students to rate the importance level of Design characteristics, as well as what they would like to be able to learn from using the testing apparatus as well. A copy of the customer survey can be found in Appendix B. Questions were asked on the following qualities:

- Safe operation of device
- Operators Manual
- Ease of use
- Adjustability of fan
- Portability
- Low Cost

Post completion of the surveys provided us with the results of what the students would like to see in this device. Ranging from greatest importance to least importance attributes desired were as follows: Data supplements theory, Adjustability of the fan, Ease of use, and Instruction manual.

For the satisfaction with current market devices, the highest quality out of the nine listed qualities was yet again safe operation of the device, followed by durability of device, ease of setting up, and portability. Ease of use and adjustability were at the bottom of the list for satisfaction. The movability of the fixture was of least importance to the students.

ENGINEERING CHARACTERISTICS

The engineering characteristics were taken from the QFD n order to determine what characteristics the new cost efficient student test version of the wind tunnel needed to include. A copy of the

Engineering Characteristics can be found in Appendix C at the end of the report.

Based on the results of the engineering characteristics portion of the QFD, being able to test the air velocity over the wing profile was very important. Also of great importance to the customer was the ability to test the air pressure at different points of the wing as well as how the fluid flow acts on the wing. Another point of importance was making an affordable test apparatus and being able to operate the test fixture with ease.

PRODUCT OBJECTIVE

PRODUCT OBJECTIVE

Based on the results gathered from the potential customer survey and the QFD, this project was designed to include a simple, mounted test set-up for ease of operation and ease of use. This allows the students understand the relationship between pressure, velocity and density in a less complicated environment. This project was necessary because there was currently no way for the students to be able to relate the material to real life without being able to see touch and experiment with a piece of equipment that will allow them to learn the basic principals of aerodynamics.

PROJECT DESIGN

The process of designing an airfoil was derived from knowledge of the geometry and the pressure distribution over a surface submersed in some type of fluid flow. The goal of an airfoil design varies. Some airfoils are designed to produce low drag (and may not be required to generate lift at all). Some sections may need to produce low drag while producing the given amount of lift. In some cases the drag doesn’t really matter—it is maximum lift that is important. The section may be required to achieve this performance with a constraint of thickness, pitching moment, off design performance, or other unusual constraints. A copy of the Proof of Design Agreement can be found in Appendix F of this report.

One approach to airfoil design was to use a wing profile that has already been published. This “design by authority” method worked well because the design problem coincides with the goals of the original airfoil. This was not the case, although some existing airfoils were good enough for the application. In these cases airfoils could be chosen from catalogs such as Abbott and Von Doenhoff’s Theory of Wing Sections.

When designing the airfoil used in this application, a combination of designing the actual physical wing so it could be used in the environment that it was placed in and using a profile that already existed was utilized. The advantage to this approach was that there was available test data to later compare the test results with for similar airfoil designs. Also when this approach was taken, no unexpected surprises such as early stall are likely. Also other tools are now sufficiently refined that one can be reasonably sure that the desired predicted performance can be achieved. The use of “designer airfoils” specifically tailored to the needs of a given project is now very common. This section deals with the process of custom airfoil design, also incorporating the “design by authority” method.

Wing Profile chosen:

NACA 2415
  At 0degrees of attack CL=0.3
  Cord Length=6”
  Wing Span=6’

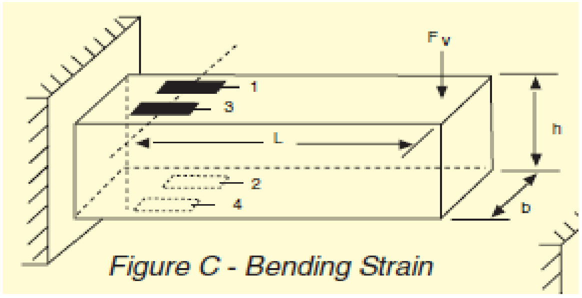
The NACA five-digit series describes more complex airfoil shapes.
The first digit (left most digit), when multiplied by .15, gives the sections lift coefficient, CL.
The second and third digits, when divided y 2, give *p*, the distance of maximum camber from the leading edge (as percent of the cord).
The forth and fifth digits give the maximum thickness of the airfoil (as percent of the cord)

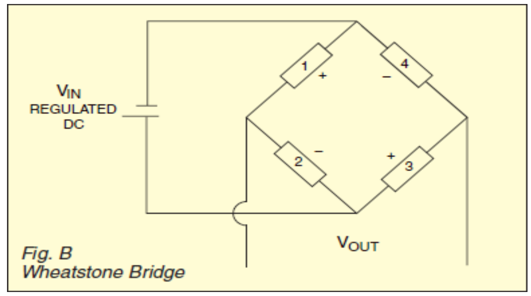
A copy of the Proof of Design Agreement can be found in Appendix F of this report.

MATERIAL SELECTION (WING DESIGN)

For the wing design a lightweight yet sturdy wing was developed. In order to make the wing lightweight, 1/8”x 1/8” balsa wood strips were used to construct the skeleton of the wing. The skeleton was designed following specifications for the shape of a standard NACA 2415 wing profile. First the teardrop shaped ends were formed, and then two more tear drop shapes were formed and spaced two inches apart in parallel to the two ends. These were temporarily held in place by pins stuck through them into the work bench. Next, 8 cross members were cut and space laterally across the tear shaped pieces. These were then pinned and all were glued together with model airplane glue. Once these pieces had dried in the wings shape, a 6”x 6” x 1/16” balsa sheet was applied to both sides to form the complete shape of the wing. This was glued down and left to dry. Once dry ½” tubing was arranged throughout the flat sides of the wing in order to serve as pressure taps. Holes were drilled into the end of the wing where clear plastic tubing was inserted and connected to the pressure taps. This plastic tubing was run through the test section and connected to the manometer in order to read the pressure difference on the wing. Once this was complete the wing was covered with red laminate and ironed on in order to reduce friction and seal off any other holes in the wing besides the pressure taps. The next step was installing a slim aluminum bar into the cross section of the wing so it could be mounted onto the test section. Calculation for the beam were not necessary, it only had to be capable of holding the wing. The final step was installing the strain gages onto the arm so that the lift force could be calculated. These gages had to be installed in a Wheatstone Bridge configuration because that is what is required for an accurate bending application reading. This configuration is shown in figure 6.

Figure 6 – Wheatstone Bridge Configuration





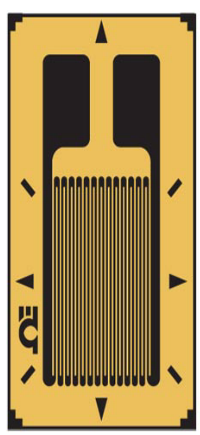
TEST STAND DESIGN

The test stand was originally going to be built from metal but it ended up being too expensive. It ended up being built from 2"x 4"s and plywood that was donated. The frame was cut to 12' in length and 4' wide to accommodate the wind tunnel and to allow enough room for the instrumentation to be mounted. The frame was covered with ¾" plywood for durability. All joints were cut on a 45 degree angle, glued and screwed together for added strength. Next, 6 legs were added in order to support the weight that would be covering the 12' span. The legs were placed in all four corners and two on each side of the middle. The legs were constructed from 2"x 4"s also and were cut on 45 degree angles, glued and screwed for strength. Once this was complete casters were added to the legs on order to make the table mobile. The final step for completing the table was finish sanding and then painting. The table was painted with black acrylic paint.

INSTRUMENTATION SELECTION

In order to test the force on the wing strain gages had to be purchased. These were purchased from Omega Engineering. The factors considered for the purchase of these gages was based on the beam being aluminum and the size of the beam. With this in mind the gages purchased were SGD-1.5/120-LY13. These are made for aluminum and are 1.5mm and rated for 120Ohms.

Figure 7- Strain Gage



The next step was to be able to read the strain. The decision to use the indicator that was use was an easy one because it is the on specifically made for the type of gages that were used in this application. The Strain Gage Indicator was purchased from Omega Engineering.

Figure 8 - Strain Gage Indicator

The next requirement was to be able to read the pressure on the wing. To do this it was necessary to purchase a manometer. Because the fan was producing around 1in/ H_2O the manometer had to have roughly a range of 0-3 in/H_2O. This led to the purchase of an inclined manometer from Dwyer Industries.

Figure 9- Dwyer Manometer

The final piece of the puzzle was the velocity flow meter. The velocity flow meter had to be able to read at least 60mph because that is the speed of the air flowing through the tunnel. This led to the purchase of a velocity flow meter from Kurz Industries.

Figure 10- Velocity Flow Meter

DATA & CALCULATIONS

Lift Force

Wing will was tested at various angle of attack then compared to published values to determine correct lift force

$$L_f = .5 \times \rho \times V^2 \times wingarea \times C_L$$

NACA2415 Lf = .594 lbf

Test Section

Maximum air velocity = 50 MPH
(50 *5280)/3600 sec = 73.3 ft/sec

12” x 12” test section to accommodate airfoil model of 6” * 6”
This will give us enough room for any instrumentation

Maximum flow rate needed is 4500 CFM
Q = V * A = (73.3*60 sec) * 1ft^2 = 4400 CFM

Published Data

Angle	Lift (V)	Drag (V)	Lift (N)	Drag (N)	Lift Coeff.	Drag Coeff.
-5	-0.000315	0.000001	-9.8005	0.0374	-0.21669	0.00083
-4	-0.000234	0.000002	-7.2804	0.0748	-0.16097	0.00165
-3	-0.000151	0.000005	-4.6980	0.1869	-0.10387	0.00413
-2	-0.000059	0.000008	-1.8357	0.2990	-0.04059	0.00661
-1	0.000028	0.000011	0.8712	0.4112	0.01926	0.00909
0	0.000102	0.000015	3.1735	0.5607	0.07017	0.01240
1	0.000197	0.000019	6.1292	0.7102	0.13552	0.01570
2	0.000272	0.000025	8.4627	0.9345	0.18711	0.02066
3	0.000365	0.000032	11.3562	1.1962	0.25109	0.02645
4	0.000448	0.000040	13.9385	1.4952	0.30818	0.03306
5	0.000532	0.000048	16.5520	1.7942	0.36597	0.03967
6	0.000595	0.000055	18.5121	2.0559	0.40930	0.04546
7	0.000680	0.000065	21.1567	2.4297	0.46778	0.05372
8	0.000734	0.000071	22.8368	2.6540	0.50492	0.05868
9	0.000802	0.000080	24.9525	2.9904	0.55170	0.06612
10	0.000826	0.000089	25.6992	3.3268	0.56821	0.07356
11	0.000914	0.000100	28.4371	3.7380	0.62874	0.08265
12	0.000967	0.000109	30.0861	4.0744	0.66520	0.09008
13	0.001001	0.000115	31.1439	4.2987	0.68859	0.09504
14	0.001016	0.000126	31.6106	4.7099	0.69891	0.10413
15	0.001095	0.000157	34.0685	5.8686	0.75326	0.12976
16	0.001112	0.000168	34.5975	6.2798	0.76495	0.13885
17	0.001140	0.000193	35.4686	7.2143	0.78421	0.15951
18	0.001040	0.000270	32.3573	10.0925	0.71542	0.22315
19	0.000955	0.000306	29.7127	11.4382	0.65695	0.25290

Gathered Data

Angle of Attack	Lift (N)
-5	-9.8005
-4	-7.7804
-3	-5.7603
-2	-3.7402
-1	-1.7201
0	0.3
1	2.3201
2	4.3402
3	6.3603
4	8.3804
5	10.4005
6	12.4206
7	14.4407

8	16.4608
9	18.4809
10	20.501
11	22.5211
12	24.5412
13	26.5613
14	28.5814
15	30.6015
16	32.6216
17	34.6417
18	34.6618
19	31.6819

As you can see the gathered data is not exactly the same as that of what is published for the chosen wing profile but it does follow the same trend and is roughly ±5% of the actual values.

ASSEMBLY BILL OF MATERIALS, TIMELINE, AND BUDGET

BILL OF MATERIALS

The Bill of Materials is a listing of the components required to manufacture the desired assembly. For the assistive feeding device, there are approximately 12 major components used to complete the wind tunnel and test section assembly. Other miscellaneous items were also used to complete the final assembly. A final assembly can be found in Appendix H of this report.

Table 1 – Bill of Materials

Final Bill of Materials			
Quantity	Description	Part Number	Cost
1	Hard Board 12' X 8' Sheets	Local Hardware store	$75.00
1	Plexy Glass 3' X 3' sheet	Local Hardware store	$45.00
1	Wood For Movable Cart	Home Depot	$100.00
1	Wood and Laminate	Home Depot	$200.00
1	Fan - 2 HP, 4500 CFM Axial duct Fan	ADI160	$750.00
2	Balsa Wood - and Airfoil parts	Towerhobbies	$20.00
1	Kurtz - Velocity Airflow meter	1400	$63.00
1	Kurtz - Velocity Airflow meter Calibration	Lab Tech Inc.	$20.00
1	aluminum Beam for lift mechinium	Mcmaster Carr	$10.00
1	Screen for Settling Chamber	Mcmaster Carr	$10.00
1	Strain Guage	OMEGA	$300.00
Total			**$1,613.00**

TIMELINE

To complete the design of the wind tunnel, a timeline was developed to follow which includes all important dates and deadlines. The first date on interest is the completion of the proof of design, which was completed on January 12th, 2007. A design freeze was placed on the design phase on February 19thth, 2007. An oral presentation of the project was delivered March 14th, 2007, with the design completed and submitted on March 16th, 2007. The design process came to an end with a demonstration of the working model on May 4th, 2007, and the final presentation of the device at the Tech Expo was on May 16th, 2007 at Duke Energy Center in Cincinnati, Ohio. The Final Oral Presentation was delivered on May 25th, 2007. Final reports are scheduled for completion on June 4th, 2007. On June 4th there will be an electronic copy of the report turned into Professor Cook. An unbound copy will be sent to the library, a bound copy will be sent to Dr. Davé, and an electronic copy will be submitted to the MET Department on a disc. A copy of the timeline can be found in Appendix D of the report.

BUDGET

The current budget for the assistive feeding device is shown in Table 2. The goal of the budget was to be able to project the cost of the assistive feeding device in the prototype stages and then show what the actual prototype cost to manufacture and build. A copy of the budget can be found in Appendix E of the report.

Table 2 – Design Budget

Final Budget			
Quantity	Description	Part Number	Cost
1	Hard Board 12' X 8' Sheets	Local Hardware store	$75.00
1	Plexy Glass 3' X 3' sheet	Local Hardware store	$45.00
1	Wood For Movable Cart	Home Depot	$100.00
1	Wood and Laminate	Home Depot	$200.00
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1	Screen for Settling Chamber	Mcmaster Carr	$10.00
1	Strain Guage	OMEGA	$300.00
Total			$1,613.00

Predicted Budget			
Quanity	Discription	Part Number	Cost
1	Hard Board 12' X 8' Sheets	Local Hardware store	$50.00
1	Plexy Glass 3' X 3' sheet	Local Hardware store	$45.00
1	Wood For Movable Cart	Home Depot	$50.00
1	Wood and Laminate	Cabinet Supply Co	$250.00
1	Fan - 2 HP, 4500 CFM Axial duct Fan	ADI160	$850.00
2	Balsa Wood - and Airfoil parts	Towerhobbies	$10.00
1	Kurtz - Velocity Airflow meter	1400	$63.00
1	Kurtz - Velocity Airflow meter Calibration	Lab Tech Inc.	$20.00
1	aluminum Beam for lfit mechinium	Mcmaster Carr	$10.00
1	Screen for Settling Chamber	Mcmaster Carr	$15.00
1	Strain Guage	Omega	$150.00
Total			$1,533.00

Precent Difference	5.22%

It can be seen in the budget that the largest of the expenses was the purchase of the fan. There was also a good amount of money spent on strain gages and building material. Highlighted in yellow are the areas that didn't match up with what was predicted to be spent. As you can see an additional $100 was spent on the fan as well as an additional $150 on strain gages. $25 more was gained on the hardboard purchase and $50 was saved on the wood and laminate. The predicted budget shows $1,533 being spent. The final budget shows that it took a total of $1,633 to complete the wind tunnel testing device. When compared, this is a 5.22% difference between the actual and predicted budgets, which fell within the given ±10% guideline. A copy of the design budget can be found in Appendix E.

CONCLUSION

SUMMARY

The wind tunnel testing device has a projected cost around $1,600. This device can be easily operated by any student or faculty with the included operator's manual. This apparatus can easily be move around on the provided test stand for easy use and storage after use is complete. The test section is made from plexi glass to allow the operator to easily view the wing and observe what is happening during use. There are 2 switches, one to turn on the fan power and the other to turn on the instruments.

By creating a wind tunnel testing device for the MET Students and the Department, allows the students to more easily learn the principles of fluid flow. A design phase was begun to find out what kind of other wing tunnels are on the market today. The next step was asking the students and faculty what kind of characteristics they would like to see included in the wind tunnel. This allowed us to develop a set of design and engineering characteristics that would be included in the tunnels design. This design was taken and turned into a functioning wind tunnel test apparatus and shown at the Tech Expo.

Future plans for the wind tunnel testing device include completing another wing profile for testing as well as providing suggestions for improvement and devising a lab experiment with Dr. Muthar Al-Ubaidi for his fluids classes.

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APPENDIX A – CURRENT MARKET DEVICES

WT4401

“OMEGA’s state-of-the-art wind tunnel is designed to give a highly uniform flow rate over a 6" test section. A powerful 12 amp motor varying from 0 to 10,000 RPM is adjusted to give a particular flow rate by a precise motor control unit. Each wind tunnel is supplied with an NIST traceable certificate. The uniform flow rate is determined by monitoring a highly repeatable differential pressure sensor which has been calibrated to an individual wind tunnel as a system. Each wind tunnel is supplied with two restrictive plates for achieving optimum low flow rates. The established differential pressure measurements versus flow rates are listed from 25 to 9000 FPM. Calibration sheets are included which make calibrating different flow sensors simple [7].” This tunnel costs $11,700. Shown in figure 11.

Figure 11 - WT4401- Pros vs. Cons

<u>Pros</u>

- Large Test Section
- Variable speed

<u>Cons</u>

- Too large for common laboratory use
- $11,700
- Fixed Location (not easily movable)

WTM-1000

“The new WTM-1000 mini wind tunnel from OMEGA® gives a highly uniform flow rate at 4 selectable fixed air speeds, yet it costs less than competitive brands. The fixed air speeds range from 2.5 m/s (492 fpm) to 15 m/s (2953 fpm). With the remote option, the user can control and vary the wind tunnel air speed externally by connecting a potentiometer. The internal 10 cm (4") diameter test chamber is large enough to accommodate either hot-wire or vane-type anemometers. The unit is powered by 90 to 250 Vac. Each WTM-1000 comes with an NIST calibration certificate for the 4 fixed air speeds [7].” This model costs $2,995. Shown in figure 12.

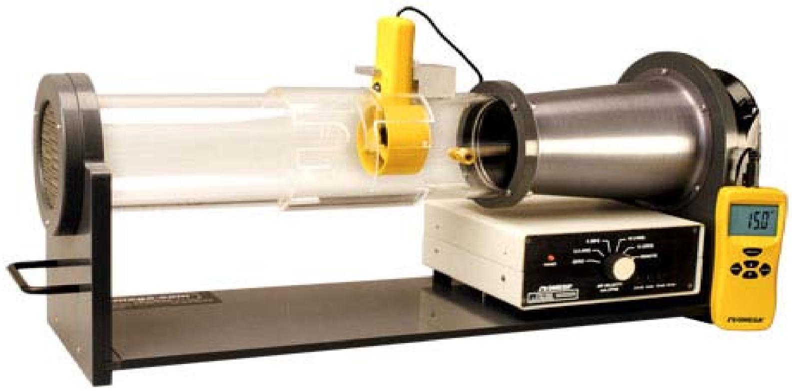


Figure 12 - WTM-1000 Pros vs. Cons

<u>Pros</u>

- Costs less than most competitive brands
- Bench to Model
- Transportable

<u>Cons</u>

- Small test area
- $2,995

APPENDIX B – CUSTOMER SURVEY

Survey Results

Wind Tunnel Testing Device

As students at the University of Cincinnati, we are currently seniors studying Mechanical Engineering Technology. We are designing a test fixture to help future students understand the basic principles of aerodynamics of an air foil. To solve this problem we have decided to create a small wind tunnel. To help with our design decisions we would greatly appreciate it if you would take a few minutes to fill out a short survey.

What concept is most important to you in the design of a wind tunnel for college level students. Please circle the appropriate answer. 1=low importance, 5=High importance

								Score	%
1	Data Repeatability	1 (0)	2 (0)	3 (0)	4 (4)	5 (11)	N/A	71	9.7
2	Cost of Fixture	1 (2)	2 (1)	3 (7)	4 (2)	5(3)	N/A	48	6.6
3	Importance of Data	1 (0)	2 (0)	3 (1)	4 (7)	5(7)	N/A	66	9
4	Ease of Use	1 (0)	2 (2)	3 (3)	4 (3)	5(7)	N/A	60	8.2
5	Instruction Manual	1 (0)	2 (1)	3 (5)	4 (3)	5(6)	N/A	59	8.1
6	Adjustability of fan speed	1 (0)	2 (0)	3 (3)	4 (6)	5(6)	N/A	63	8.6
7	Common power source	1 (1)	2 (0)	3 (8)	4 (0)	5(6)	N/A	55	7.5
8	Movability of fixture	1 (2)	2 (1)	3 (8)	4 (3)	5(1)	N/A	45	6.1
9	Data matches theory	1 (0)	2 (1)	3 (1)	4 (5)	5(8)	N/A	65	8.9
10	Visibility of test object	1 (0)	2 (0)	3 (2)	4 (8)	5(5)	N/A	63	8.6
11	Ease of Maintenance	1 (1)	2 (3)	3 (4)	4 (7)	5(0)	N/A	47	6.4
12	Size of test fixture	1 (3)	2 (0)	3 (8)	4 (3)	5(1)	N/A	44	6
13	Size of test sample	1 (2)	2 (1)	3 (8)	4 (0)	5(3)	N/A	46	6.3
							Total	732	100

What principles of aerodynamics would you prefer to understand when using the wind tunnel. Please circle the appropriate answer. 1=low importance, 5=High importance

								Score	%
1	Air velocity over the wing	1(0)	2(0)	3(1)	4(5)	5(9)	N/A	68	14.6
2	Laminar and Turbulent flow points	1(0)	2(1)	3(3)	4(5)	5(6)	N/A	61	13.1
3	Fluid flow over the wing	1(0)	2(0)	3(2)	4(7)	5(6)	N/A	64	13.7
4	Reynolds number	1(1)	2(2)	3(4)	4(4)	5(4)	N/A	53	11.4
5	Air temperature	1(2)	2(2)	3(4)	4(6)	5(1)	N/A	47	10.1
6	CFM of the fan	1(2)	2(1)	3(5)	4(6)	5(1)	N/A	48	10.3
7	Actual movement of the wing	1(1)	2(1)	3(2)	4(6)	5(5)	N/A	58	12.4
8	Air pressure at different points	1(0)	2(0)	3(1)	4(6)	5(8)	N/A	67	14.4
								466	100

Thanks for taking the time to fill out the survey, your help is greatly appreciated. Please return survey back to sender.

APPENDIX C – ENGINEERING CHARACTERISTICS

9 = Strong
3 = Moderate
1 = Weak
no relation = blank

	Calibration of Insturments	Lite Design/Casters	instruction manual with pictures	Normal 120 Volts power supply	Keep test fixture small	Velocity meter	CFM sensor	Pressure Sensor	Accurate model represenstation	Clear plexy glass	Thermometer	Adjustable speed fan	cost of supplies	Data Repeatability	Customer importance
Operation															0
1. Data Repeatability	9		1		9	9			3		9		3	9	9.7
2. Movability of fixture		1			2										6.1
3. Ease of Use		1	9	3						3		9			8.2
4. Data matches theory	9					9	9		9	9	9		9		8.9
5. Importance of Data	9													9	9
6. Instruction Manual			9												8.1
Features															0
7. Adjustability of fan speed												9			8.6
8. Common Power Source				9											7.5
9. Visibility of test object										9					8.6
10. Ease of Maintenance			3		9										6.4
11. Size of Test Fixture					9					1					6
12. Size of Test Sample					9										6.3
Cost															0
13. Cost of Fixture	9	9	1	3	1	9	9	9	3	1	9	1	9	9	6.6
Study of Aerodynamics															0
14. Air Velocity over wing						9	9	9			9				14.6
15. Laminar & Turbulent Flow Points		3	1			3	3	9				3			13.1
16. Fluid Flow over Wing								9			9	3		3	13.7
17. Reynolds Number											9			3	11.4
18. Air Temperature															10.1
19. CFM of Fan							9								10.3
20. Actual Movement of the wing					9										4.4
21. Air Pressure at different points						9	9								14.4
Absolute Importance	729	1	243	81	118098	177147	177147	0	0	9	0	9	9		192.00
Relative importance	3.80	0.01	1.27			922.64		0.00	0.00	0.05	0.00	0.05	0.05		

APPENDIX D – PROJECT TIMELINE

TaylorboDavims Wind Tunnel Testing Device																						
Shane's Tasks	Winter Quarter											Spring Break	Spring Quarter									
Dates	1/1-1/7	1/8-1/14	1/15-1/21	1/22-1/28	1/29-2/4	2/5-2/11	2/12-2/18	2/19-2/25	2/26-3/4	3/5-3/11	3/12-3/18	3/19-3/25	3/26-4/1	4/2-4/8	4/9-4/15	4/16-4/22	4/23-4/29	4/30-5/6	5/7-5/13	5/14-5/20	5/21-5/27	5/28-6/3
Tasks:																						
Weighted Objected Method																						
Proof of design	Jan., 12																					
Design of Moveable Chart, Drawings																						
Pick out all sensors and place sensors																						
Review and go over assignments																						
Design Freeze Feb. 19								Feb. 19														
Start Gather information for report																						
Order All Parst Needed- sensors and cart																						
Design Report Due to Advistor										9-Mar												
Work on Oral presentation																						
Exam Week- Oral Presentation											16-Mar											
Spring Break												25-Mar										
Build moveable Cart																						
Gather Sensors and Electronics																						
Final Assembly with Brad																						
Test With Brad																						
Demenstration of Proof of Design - May 1																		May 1st				
Corrections																						
Tech Expo - Thur. May 17																				May 17th		
Finish Final Report																						
Changes proof read Prof. Cook																						
Start Oral Presentation Exam Week																						
Project Report- Report Due June 4																						

APPENDIX E – ESTIMATED AND ACTUAL BUDGET

Final Budget			
Quantity	Description	Part Number	Cost
1	Hard Board 12' X 8' Sheets	Local Hardware store	$75.00
1	Plexy Glass 3' X 3' sheet	Local Hardware store	$45.00
1	Wood For Movable Cart	Home Depot	$100.00
1	Wood and Laminate	Home Depot	$200.00
1	Fan - 2 HP, 4500 CFM Axial duct Fan	ADI160	$750.00
2	Balsa Wood - and Airfoil parts	Towerhobbies	$20.00
1	Kurtz - Velocity Airflow meter	1400	$63.00
1	Kurtz - Velocity Airflow meter Calibration	Lab Tech Inc.	$20.00
1	aluminum Beam for lift mechinium	Mcmaster Carr	$10.00
1	Screen for Settling Chamber	Mcmaster Carr	$10.00
1	Strain Guage	OMEGA	$300.00
Total			$1,613.00

Predicted Budget			
Quanity	Discription	Part Number	Cost
1	Hard Board 12' X 8' Sheets	Local Hardware store	$50.00
1	Plexy Glass 3' X 3' sheet	Local Hardware store	$45.00
1	Wood For Movable Cart	Home Depot	$50.00
1	Wood and Laminate	Cabinet Supply Co	$250.00
1	Fan - 2 HP, 4500 CFM Axial duct Fan	ADI160	$850.00
2	Balsa Wood - and Airfoil parts	Towerhobbies	$10.00
1	Kurtz - Velocity Airflow meter	1400	$63.00
1	Kurtz - Velocity Airflow meter Calibration	Lab Tech Inc.	$20.00
1	aluminum Beam for lfit mechinium	Mcmaster Carr	$10.00
1	Screen for Settling Chamber	Mcmaster Carr	$15.00
1	Strain Guage	Omega	$150.00
Total			$1,533.00

Precent Difference	5.22%

APPENDIX F – PROOF OF DESIGN AGREEMENT

Product Proof of Design
Wind Tunnel Testing Device

The following is a set of objectives agreed on between student and advisor. how they will be obtained or measured to ensure that the goal of the project was met. The product objectives will focus on a manually operated assistive feeding device for handicapped people to use. This device will be functional at the user's home or in public dining areas.

Safety:
1.) Safe to use.
2.) Guards where necessary.

Reliability:
1.) Will have the ability to function for at least 5 years

Movability:
1.) The unit will be mounted to a test stand so it can be transported.

Ease of Use:
1.) Clearly labeled instruments and gages
2.) Include Operators Manual

Overall Design Size:
1.) Small enough to fit into lab/shop area at CAS.

Function:
1.) Can test for pressure difference on top and bottom of wing
2.) Can test velocity of air flow
3.) Can test for lift force

Cost:
1.) Affordable for college laboartories

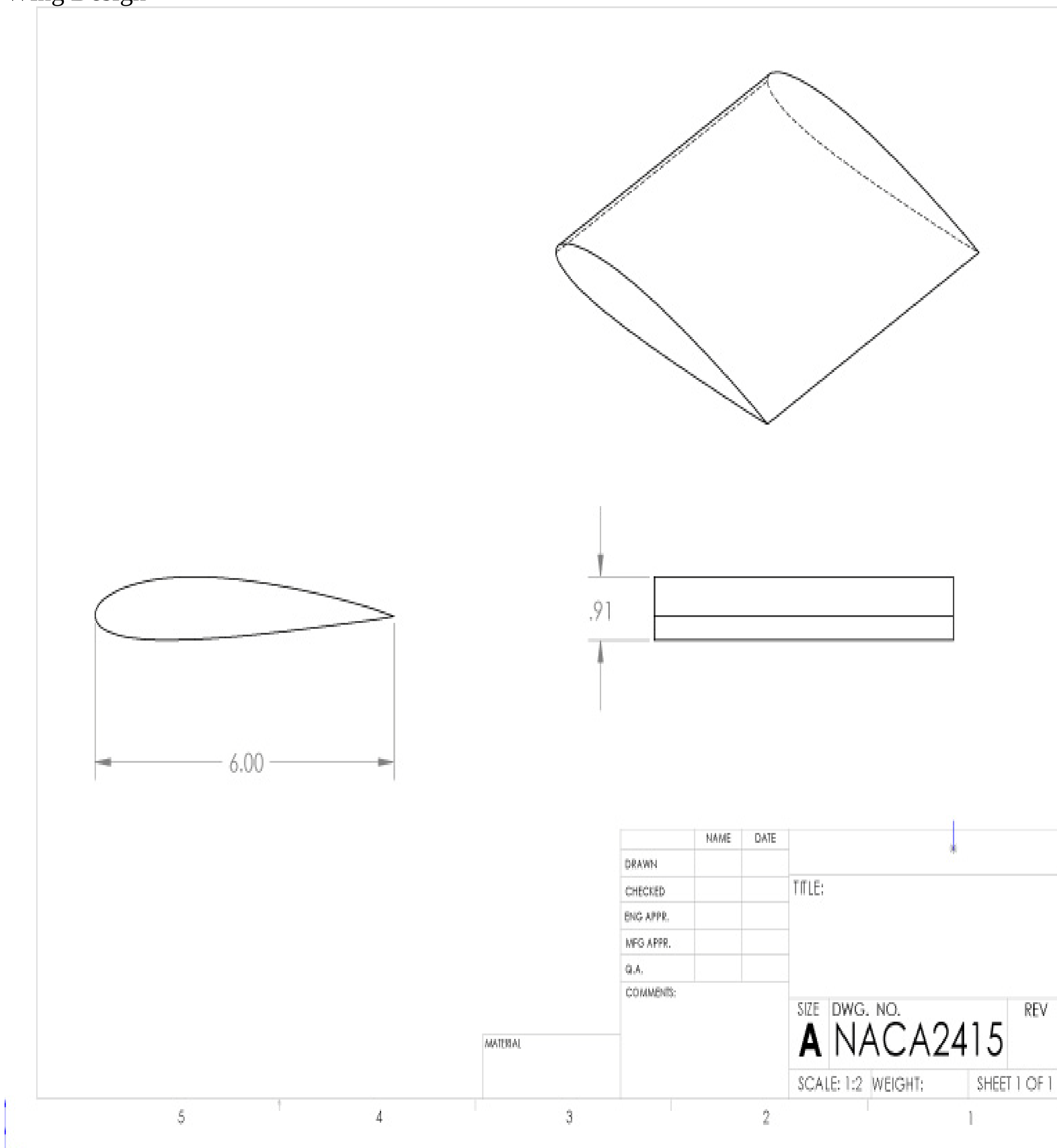
Michael Shane Davis, MET

Dr. Janak Davé, Advisor

Accepted on 1-12-07 by Dr. Davé

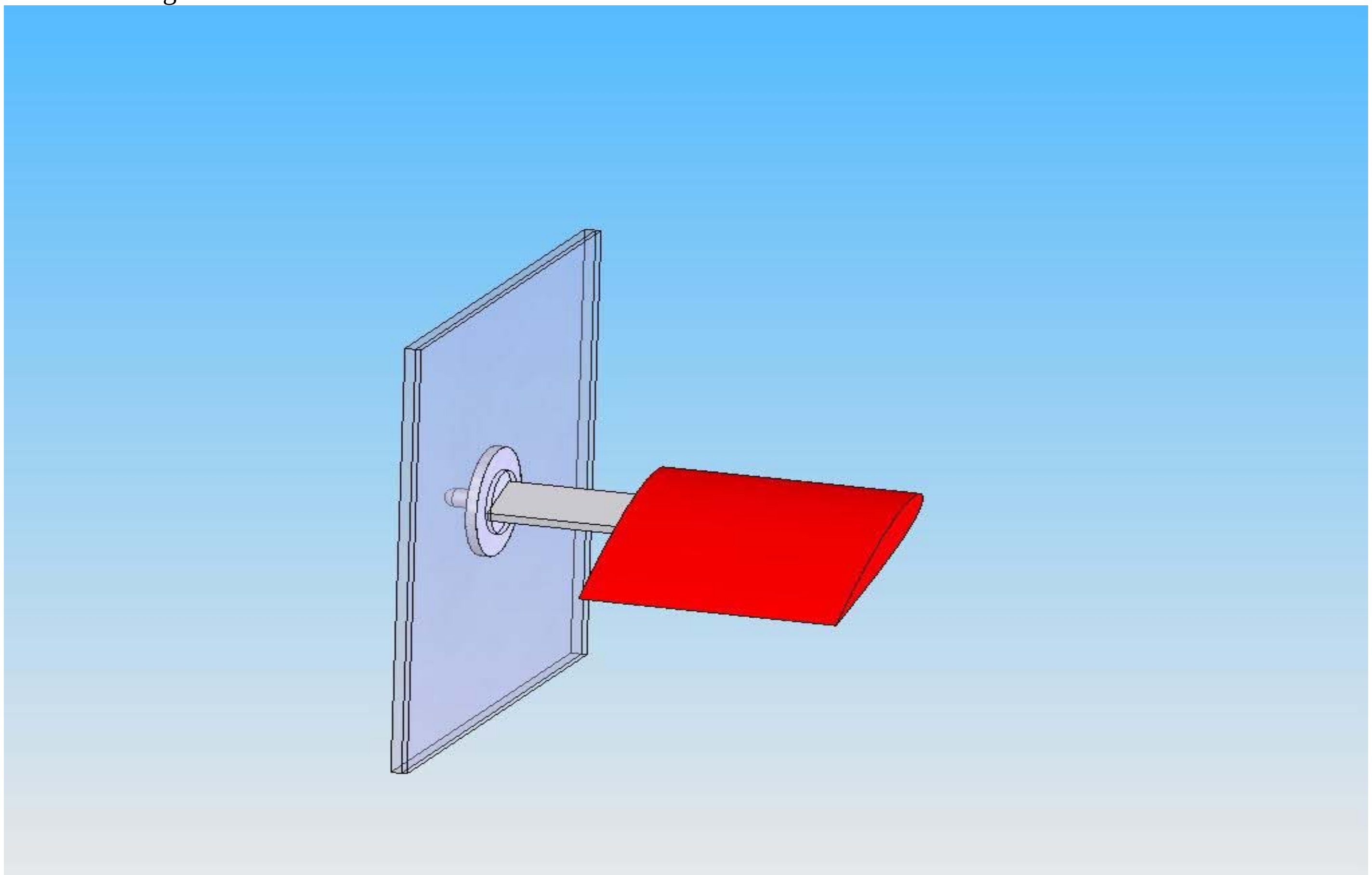
APPENDIX G – PROPOSED COMPONENT DESIGNS

Wing Design

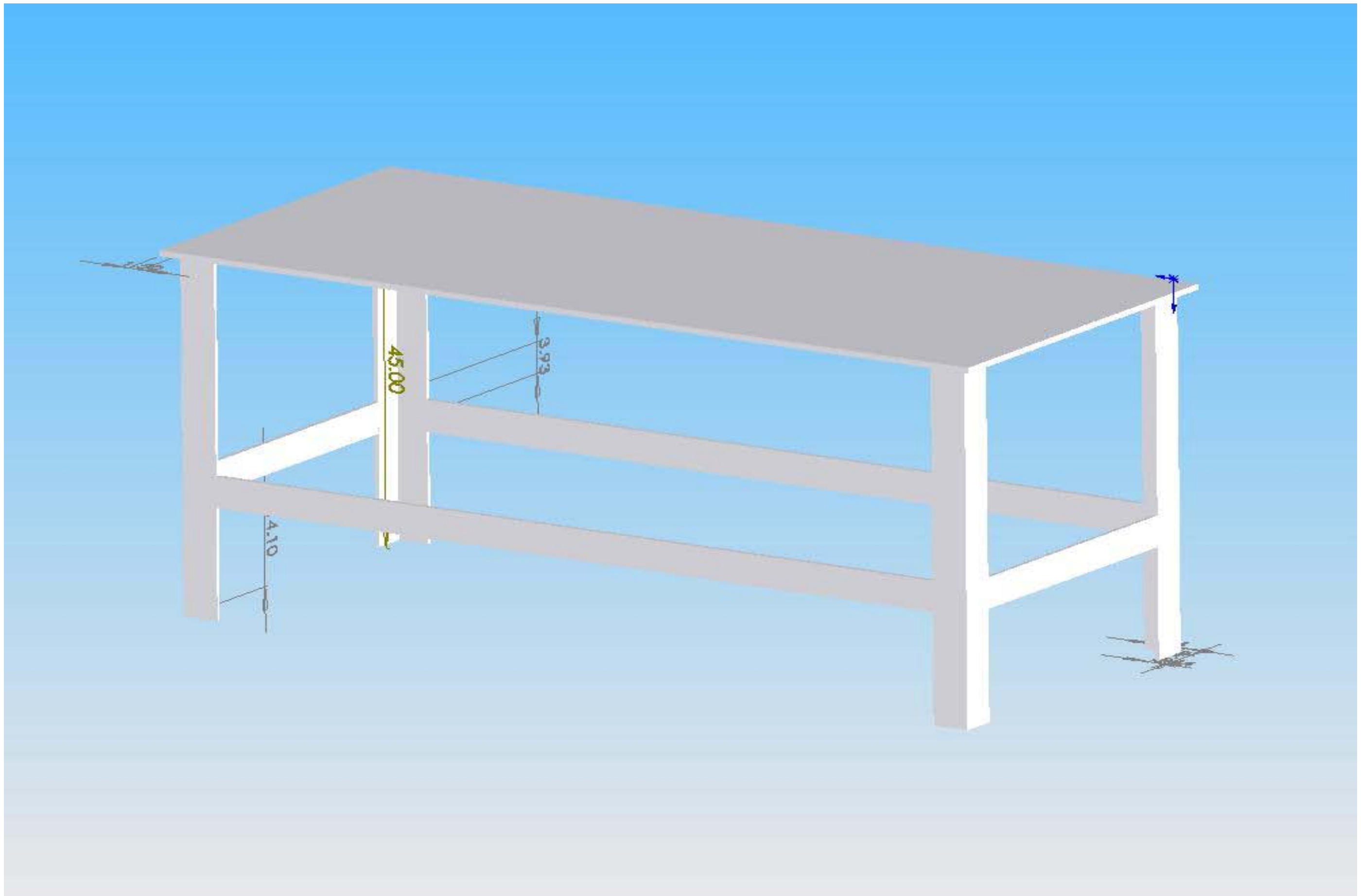


APPENDIX H – 3-DIMENSIONAL DRAWINGS, FINAL COMPONENTS

Mounted Wing Test Section



Test Stand



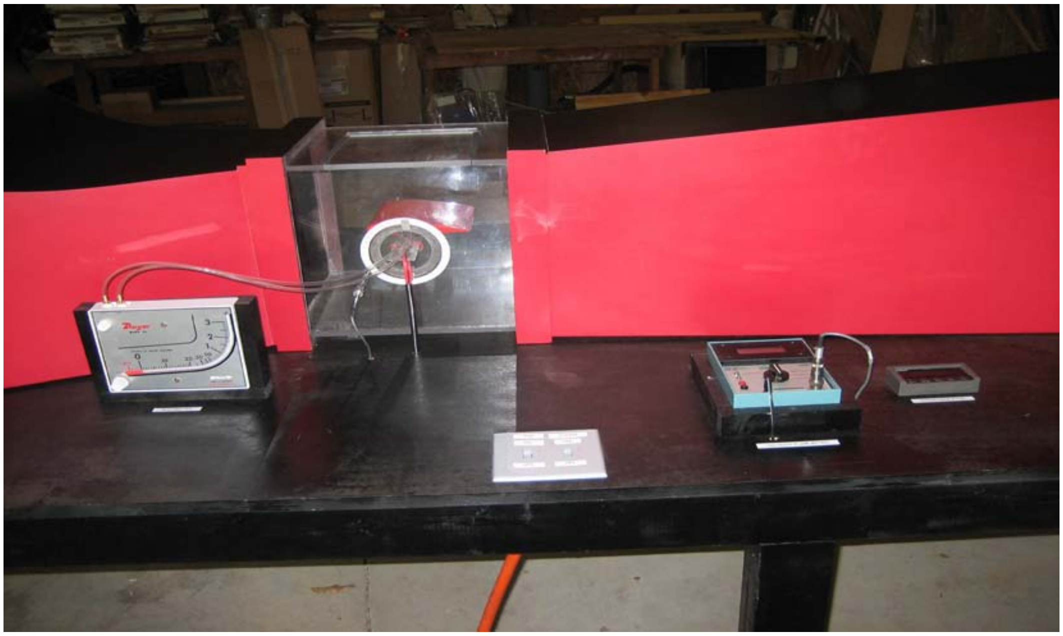
Appendix H2

APPENDIX I – FINAL ASSEMBLY PICTURES

Final Assembly

Manometer Set-up

Instrumentation Set-up



Instrumentation Set-up (Close-up)