Design and Fabrication of a Low Speed Wind Tunnel.

A Project Report p - 2209

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in partial fulfillment of the requirement in the subject of
(ME1357) Design and Fabrication Project

Under the guidance of
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BONAFIDE CERTIFICATE

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(INTERNAL EXAMINER)

(EXTERNAL EXAMINER)

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SYNOPSIS

DESIGN AND FABRICATION OF A LOW SPEED WIND TUNNEL

Designing for interaction in a fluid medium is the backbone of many diverse engineering fields from automobiles to spacecrafts. We have embarked here in the design of a low speed suction wind tunnel as a first step towards several possible follow up projects that we have planned for. The objective of this project is to,

- Design and fabricate a low speed wind tunnel for simulating the conditions experienced by a automobile at average city speed
- Visualize and study the flow of air over a test samples kept inside the wind tunnel
- Explore opportunities to implement the wind tunnel to achieve design goals in future projects.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

S. No.	ABBREVIATION	EXPANSION
1	a	Cross sectional area of test section
2	C_d	Coefficient of discharge
3	CFD	Computational Fluid Dynamics
4	d_i	Inlet diameter of the diffuser
5	d_o	Outlet diameter of the diffuser
6	h_a	Difference of pressure head of air
7	h_{ci}	Height of the contracting cone (at inlet)
8	h_{co}	Height of the contracting cone (at outlet)
9	h_t	Height of the test section
10	h_w	Difference of pressure head of water
11	l_t	Length of the test section
12	M	Mach number
13	P	Pressure of air
14	PVC	Polyvinyl chloride
15	q	Flow rate of fan
16	R	Gas constant
17	T_a	Temperature of air
18	v_a	Velocity achieved
19	v	Velocity assumed

20	w_{co}	Width of the contracting cone (at outlet)
21	w_{ci}	Width of the contracting cone (at inlet)
22	w_t	Width of the test section
23	ρ_a	Density of air
24	ρ_w	Density of water

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Wind tunnels are without a doubt one of the most important tools in aerodynamic research and design. They are used to help design fuel efficient and aerodynamic cars, trucks, and planes. They are also used to model environmental impact of industries, as well as helping athletes (bicycle racers and skiers) train for international competitions. They can also be used to design ballistic missile re-entry vehicles, and low orbit satellites. Other applications include modeling airflow over and around different objects. These objects could include a simple sphere for educational purposes, or a complex city skyline to model the turbulent flow through and around the different buildings.

1.2 WORKING

A wind tunnel is a research tool developed to assist with studying the effects of air moving over or around solid objects. Air is blown or sucked through a duct equipped with a viewing port and instrumentation where models or geometrical shapes are mounted for study. Typically the air is moved through the tunnel using a series of fans. For very large wind tunnels several meters in diameter, a single large fan is not practical, and so instead an array of multiple fans are used in parallel to provide sufficient airflow. Due to the sheer volume and speed of air movement required, the fans may be powered by stationary turbofan engines rather than electric motors.

The airflow created by the fans that is entering the tunnel is itself highly turbulent due to the fan blade motion, and so is not directly useful for accurate measurements. The air moving through the tunnel needs to be relatively turbulence-free and laminar. To correct this problem, a series of closely-spaced vertical and horizontal air vanes are used to smooth out the turbulent airflow before reaching the subject of the testing.

Due to the effects of viscosity, the cross-section of a wind tunnel is typically circular rather than square, because there will be greater flow constriction in the corners of a square tunnel that can make the flow turbulent. A circular tunnel provides a much smoother flow.

The inside facing of the tunnel is typically very smooth to reduce surface drag and turbulence that could impact the accuracy of the testing. Even smooth walls induce some drag into the airflow, and so the object being tested is usually kept near the center of the tunnel, with an empty buffer zone between the object and the tunnel walls.

Lighting is usually recessed into the circular walls of the tunnel and shines in through windows. If the light were mounted on the inside surface of the tunnel in a conventional manner, the light bulb would generate turbulence as the air blows around it. Similarly, observation is usually done through transparent portholes into the tunnel. Rather than simply being flat discs, these lighting and observation windows may be curved to match the cross-section of the tunnel and further reduce turbulence around the window.

1.3 TYPES OF WINDTUNNEL

Wind tunnels can be described/evaluated in a number of ways.

Based on shape:

- Open return type
- Closed return type

Based on wind speeds:

- Low-Speed wind tunnel
- Transonic wind tunnel
- Supersonic wind tunnel
- Hypersonic wind tunnel
- Hotshot wind tunnel

Based on wind speeds:

- Low-Speed wind tunnel
- Boundary Layer wind tunnel
- Small Scale wind tunnel

For the purpose of simplicity, we will assume there are only two types of wind tunnels: open return and closed return. These two basic designs can accommodate the entire range of air velocities. Additional components may need to be added to reach higher velocities, however the basic design will still resemble an open return wind tunnel or closed return wind tunnel. Listed below are the wind velocity categories for wind tunnels.

Low-Speed Wind Tunnels:

These wind tunnels are those with test sections that can measure wind speeds up to approximately 300 mph. (M=0.4). Air flow is generated by using a propulsion system (usually a large fan) to increase the dynamic pressure to overcome viscous losses. These wind tunnels are the most cost efficient due to the low wind speeds, and simplicity of design as shown in Figure 1.

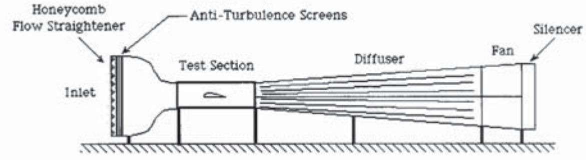

Figure-1

This simple, yet effective design of a low-speed open return wind tunnel can be found in most schools and universities due to the relatively low cost of production. Wind velocity will vary based on the overall size ratio of the intake settling chamber to the test section. This ratio, takes the form of the contraction cone or compressor, and it will act as a nozzle. The greater ratio will produce greater wind velocities. The drive section is where the fan is located. The fan size and fan speed will also influence your wind velocity. This design is great for smoke visualization experiments, due to ventilation.

Closed return wind tunnels (Figure 2) have similar components, however it is a closed and controlled system. This means that airflow will be independent of exterior conditions such as atmospheric effects and temperature. Through the use of corner turning vanes and screens, the quality of airflow can be better controlled. These closed return systems are expensive to produce, and not good with smoke visualization experiments due to the lack of ventilation.

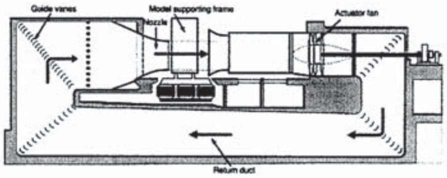

Figure-2

The basic design of the open and closed return wind tunnels are used for low speed wind tunnels. By adding additional components, such as nozzles, and high pressure tanks, higher wind velocities can be reached.

Transonic Wind Tunnels:

High subsonic wind tunnels ($0.4 < M < 0.75$) or transonic wind tunnels ($0.75 < M < 1.2$) are designed on the same principles as the subsonic wind tunnels. Transonic wind tunnels are able to achieve speeds close to the speeds of sound. The highest speed is reached in the test section. The Mach number is approximately one with combined subsonic and supersonic flow regions.

Supersonic Wind Tunnels:

A supersonic wind tunnel is a wind tunnel that produces supersonic speeds ($1.2<M<5$) The Mach number and flow are determined by the nozzle geometry. The Reynolds number is varied changing the density level (pressure in the settling chamber). Therefore a high pressure ratio is required. Apart from that, condensation or liquefaction can occur. This means that a supersonic wind tunnel needs a drying or a pre-heating facility. A supersonic wind tunnel has a large power demand leading to only intermittent operation.

Hypersonic Wind Tunnels:

A hypersonic wind tunnel is designed to generate a hypersonic flow field in the working section. The speeds of these tunnels vary from Mach 5 to 15. As with supersonic wind tunnels, these types of tunnels must run intermittently with very high pressure ratios when initializing. Since the temperature drops with the expanding flow, the air inside has the chance of becoming liquefied. For that reason, preheating is particularly critical (the nozzle may require cooling). High pressure and temperature ratios can be produced with a shock tube.

Hot Shot Wind Tunnels:

These wind tunnels are those with test sections that can measure wind speeds up to Mach 27. These wind tunnels are used to analyze flow past ballistic missiles, space vehicles in atmospheric reentry and plasma physics, heat transfer at high temperatures.

With increasing wind velocities, many obstacles must be overcome. In the Transonic wind tunnels, one must account for the reflection of shock waves from the walls of the test section. The power required for supersonic and higher velocities can be up to 50 MW per square foot of test section. For this reason, high-pressure tanks can be used, however they will only provide a constant flow over a short period of time (1-3 seconds). Other problems are high pressure ratios, a good supply of dry air, wall interference effects and the fact that fast instrumentation must be used to account for the intermittent flow.

1.4 DESCRIPTION OF COMPONENTS

The important components in a commercial wind tunnel are discussed below.

SETTLING CHAMBER:

The purpose of the settling chamber is to straighten the airflow. Uneven turbulent flows can cause unpredictable forces to be experienced and measured in the test section. The less turbulence there is, the better the wind tunnel will simulate actual flying conditions. The settling chamber usually includes a honeycomb flow straightener and wire mesh smoothing screens that produce a smooth airflow. The honeycomb structure of a settling chamber is very effective at reducing swirling currents in the tunnel airflow. It is also used for safety reasons to ensure nothing get sucked into the wind tunnel as shown in figure-3.

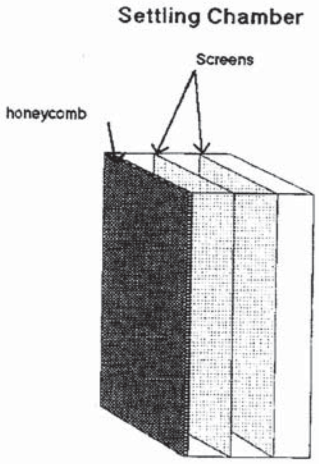

Figure-3

CONTRACTION CONE:

The contraction cone's purpose is to take a large volume of low-velocity air and reduce it to a small volume of high-velocity air without creating any turbulence. It takes the flow from the settling chamber and compresses it as it inters the test section. This compression can increase the average speed by factors up to 20 or more, however they typically increase the flows by factors of 5-10. The principle is that as the size of the opening decreases, the speed of the air increases. Thus it acts like a nozzle or a compressor.

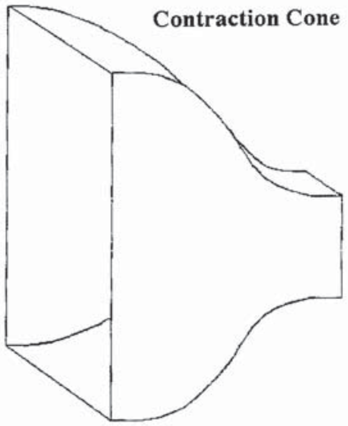

Figure-4

TEST SECTION:

The test section is where the test article and sensors are placed. Models of wings or planes are placed in the test section. As airflow is brought to the desired velocity, sensors measure forces, such as lift and drag, on the test article. Test sections can be of any size and shape, however the bigger the test section, the bigger the wind tunnel to support it. Also, as the test section size increases, the energy required to support it also increases.

Lift is the force on the wing opposite the force of gravity. Lift holds a plane in the air. Drag is the force on the wing in the direction of the airflow. Drag is what an engine must overcome to move a plane through the air.

Based on the measurements of these forces and the known relationships between the test environment and actual flying conditions, accurate predictions of real-world performance can be made. The test section is usually made out of a smooth surface material, such as glass in order to minimize the energy loss due to surface friction.

Test Section

Figure-5

DIFFUSER:

The diffuser slows the speed of airflow in the wind tunnel. The diffuser is where the air coming out of the test section slows down prior to exhausting or re-circulating. The air slows down due to the shape of the diffuser.

This is an important process in the wind tunnel because it saves money. The only place where high airspeed is needed is the test section. By reducing power, the operating costs are reduced. The diffuser extends downstream of the test section, and extends to the exhaust. It is desirable to reduce speeds in the shortest possible distances, without incurring flow separation. Higher wind speeds will require larger contraction cone and diffuser.

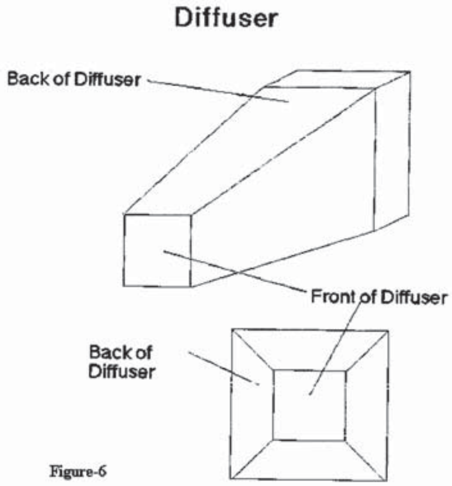

Figure-6

DRIVE SECTION:

The drive section is usually located either in or just outside of the diffuser. This section consists of the power source used to create airflow through the wind tunnel. For low speed wind tunnels, this power source is usually a high-powered fan. In some cases, arrays of multiple fans are used in parallel to provide sufficient airflow. Blowers and high-pressure tanks may also be used to drive the flow. Blowers are located just outside the diffuser, and high-pressure tanks are located at the front of the wind tunnel just prior to the compressor and settling chamber. Very high-speed wind tunnels can produce winds that exceed the speed of sound by using pressurized gases or vacuum cylinders.

Drive Section

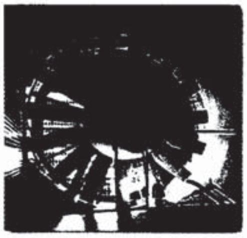

Figure-7

VISUALIZATION OF FLOW:

Because air is transparent it is difficult to directly observe the air movement itself. In order to visualize the flow, a smoke particulate or a fine mist of liquid is sprayed into the tunnel just ahead of the device being tested. The particulate is sufficiently low mass to stay suspended in the air without falling to the floor of the tunnel, and is light enough to easily move with the airflow.

If the air movement in the tunnel is sufficiently non-turbulent, a particle stream released into the airflow will not break up as the air moves along, but stays together as a sharp thin line. Multiple particle streams released from a grid of many nozzles can provide a dynamic three-dimensional shape of the airflow around the object being tested. As with the force balance, these injection pipes and nozzles need to be shaped in a manner that minimizes the introduction of turbulent airflow into the air stream.

Visualization of flow

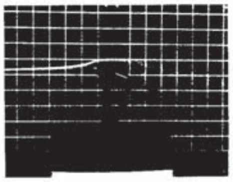

Figure-8

MEASUREMENT PROBES:

Measurement probes are sensors or instruments used to measure the pressure, drag, moment and other forces acting on the model. Generally, a force balance is used in a wind tunnel. With the model mounted on a force balance, one can measure lift, drag, lateral forces, yaw, roll, and pitching moments over a range of angle of attack. Pressure across the surfaces of the model can be measured if the model includes pressure taps. This can be useful for pressure-dominated phenomena, but this only accounts for normal forces on the body. Nowadays electronic probes are placed at various positions of the wind tunnel and they are connected to a computer and the data's are accessed through CFD software's.

Measurement Probe

Figure-9

CHAPTER 2

WIND TUNNEL SELECTION

We have set out to design a low speed wind tunnel to aid us in visualization experiments and to collect starting data in an economical fashion for air flow related projects. This type of beginning analysis will save a lot of time and effort when performing air-flow based designs analogous to a mechanical "Go-NoGo" gauge. This wind tunnel will help visualize the flow involved in the realm of city driving speeds of around 30 to 40 km/hr. For creating air flow in this speed range, as we can infer from chapter 1.3, the ideal and most cost effective solution is a open type suction based wind tunnel. Hence, we can list our objectives for the wind tunnel project as,

- Design and fabricate a low speed wind tunnel for our required velocity (30 – 40 km/hr)
- Visualize and study the flow of air over a test samples kept inside the wind tunnel
- Explore opportunities to implement the wind tunnel to achieve design goals in future projects.

The primary decisions to be made for the selection and construction of the wind tunnel are three-fold,

- **Flow Source:** The flow source that we have selected is a 14" radiator fan which can be powered off a 12V battery. The flow rates for the fan have been obtained from the manufacturer specifications.

- **Wind tunnel dimensions:** The wind tunnel dimensions are influenced by the flow source and the test speeds that we have selected. This constrains the cross sectional dimensions of the test area. As for the length of the wind tunnel, the settling chamber, contraction cone, test section, diffuser and the drive section dictate the selections. We have selected the overall length based on the above factors and portability to be 50in.
- **Visualization techniques/Measurement probes:** Various visualization techniques can be considered like free floating strings in the flow region, smoke and other electronic means. Also, for pressure measurements across the test sections, we can have pressure probes. For our design, we choose to have a smoke source and a guided stream of smoke delivered close to the test sample.

CHAPTER 3

DESIGN DETAILS

The design details of the essential components of the wind tunnel are explained as follows.

3.1 FAN SPECIFICATION:

The fan details are got from the manufacturers details.

Fan diameter = 355 mm

Fan speed = 1200 rpm

Number of blades = 6

Current = 5.5 amps

Voltage = 12 V

Flow rate $[q] = 1000$ cfm

$= [\,1000 \times (0.3048)^3\,] / 60$

$[q] = 0.4719\ \text{m}^3/\text{s}$

3.2 VELOCITY REQUIRED:

Velocity $[v] = 38$ km/hr

$= (38 \times 1000) / 3600$

$[v] = 10.56$ m/s

3.3 TEST SECTION CALCULATION:

To find the area of test section:

Flow rate [q] = Velocity [v] × cross sectional area [a]

$0.4719 = 10.56 \times [a]$

$[a] = 0.04468\ \text{m}^2$

$= 0.04468 \times (0.217)^2$

$[a] = 69.25414\ \text{inch}^2$

Rounding off to nearest value, we get $[a] = 70\ \text{inch}^2$

To find the width and height of test section:

Since the cross sectional area of test section $[a] = 70\ \text{inch}^2$

Let the height of the test section $[h_t] = 10$ inch

Hence width of the test section $[w_t] = 7$ inch

Let the length of the test section $[l_t] = 12$ inch

(The length of the test section is assumed based on the total length of the wind tunnel)

3.4 CONTRACTION CONE CALCULATION:

OUTLET DIMENSIONS:

The outlet dimensions of the contracting cone are equal to the dimensions of the test section.

Hence, height of the contracting cone (at outlet) $[h_{co}] = 10$ inch

width of the contracting cone (at outlet) $[w_{co}] = 7$ inch

INLET DIMENSIONS:

Due to our design size constrain, we assumed the compression ratio in the contraction cone to be 4. Hence the inlet area of the contraction cone is twice than that of the outlet.

Hence, height of the contracting cone (at inlet) $[h_{ci}] = 20$ inch

width of the contracting cone (at inlet) $[w_{ci}] = 14$ inch

The inlet of contraction was straightened by 2.35 inch to accommodate the settling chamber.

3.5 DIFFUSER CONE CALCULATION:

The diffuser was designed to conical in shape to keep the fabrication process simple.

Hence, inlet diameter of the diffuser $[d_i] = 10$ inch

outlet diameter of the diffuser $[d_o] = 14$ inch

The outlet of diffuser was straightened for 6 in to accommodate the drive section.

CHAPTER 4

MATERIAL SELECTION

The most important part of engineering practice is the choice of the material for our machining requirements, and the development of new ways for using them with greater effectiveness. The selection of the material for the machining is reduced to three broad constraints.

1. Service requirements
2. Fabrication requirements
3. Economic requirements

The service requirements are permanent but the material costs must stand up to service demand. Such demand commonly includes dimensional stability, corrosion resistance, strength, hardness, toughness and heat resistance.

A fabrication requirement includes the possibility to shape the material and to join it with other materials. The assessment of fabrication requirements concerns the question of machinability, ductility, castability and weldability, which are sometimes difficult to assess.

Finally, the economic requirement is essential so that the overall cost of machining and fabrication are maintained to an optimum level without compromising with the quality.

Other factors which are considered for the selection of materials are

1. Availability
2. Economical use (i.e.) Lower initial cost
3. Easy to fabricate
4. Capacity to meet service demands
5. Easy handling
6. Durability
7. Appearance

The materials used for fabrication of various parts of our compressor are:

- Mild steel
- Acrylic glass
- PVC pipes

4.1 Mild Steel:

This is low Carbon steel with no precise control over the composition or mechanical properties. The cost is low in comparison with other steel and it can withstand high pressure. It is easy to cut and bend without any significance deformation. It can also be welded to make joints.

4.2 Acrylic Glass:

Poly(methyl methacrylate) is the synthetic polymer of methyl methacrylate. This thermoplastic and transparent plastic is sold by the trade names Plexiglass, Acrylite, Acrylplast, etc. and is commonly called acrylic glass or simply acrylic. It is preferred for its moderate properties, easy handling, processing, low cost and its brittle nature. It is often used as a substitute for glass due to its relatively inexpensive cost, light weight and shatter-resistant nature.

4.3 PVC pipes:

Polyvinyl chloride is a widely used thermoplastic polymer. PVC pipes are cheap, durable, light weight and easy to assemble. It has high strength and low reactivity. It is also easily available in market.

CHAPTER 5

FABRICATION

The fabrication details of the essential components of the wind tunnel are explained as follows.

5.1 CONTRACTION CONE:

The material chosen for the contraction cone is 18 gauge mild steel. The contraction cone has four pieces for the bottom, top, left and right sides respectively. Cut the contraction cone top, bottom and sides using the coordinates from the "Entrance Cone Template" drawings. The sheet metal sheet is cut using tin snips. The curvature of the contraction cone is then bent to their approximate finished shape.

(Refer Appendix I-fig 11,12,13,14)

Once when all the contraction cone sides are bent, they are placed at right angles to each other such that the inlet area is 280 inch^2 and the outlet area is 70inch^2. All the corners are weld using arc welding technique. The type of joint used in this process is corner joint. Care should be taken to ensure that the inlet and outlet of the contraction cone must be parallel to each other.

Now the frames for the contraction cone inlet and outlet are placed at their respective positions. The sides of the frame are spot welded in order to be held in its position and also to be air tight.

5.2 DIFFUSER:

The material chosen for the diffuser is 18gauge mild steel. The shape of the diffuser is cut using the diffuser plan. The sheet metal sheet is cut using tin snips. The sheet metal is now trapezoidal in shape.

(Refer Appendix I-fig 15)

Now the tapered ends of the diffuser section are bent to form a conical shape. The two ends are joined together by arc welding technique. The type of joint used in this process is butt joint. Care should be taken to ensure that the inlet and outlet of the diffuser must be parallel to each other.

The frame for the diffuser inlet is designed using the diffuser frame plan. It is placed at the inlet of the diffuser and lap welded for its full length in order to be air tight. The drive section (fan) is spot welded to the outlet of diffuser. The diffuser outlet is welded to a cylindrical mild steel section of diameter 14inch and length 6inch. This is made to accommodate the drive section inside the diffuser.

5.3 TEST SECTION:

The test section fabrication is divided into three parts, the supporting frame, viewing pane and platform.

5.3.1 THE SUPPORTING FRAME:

The material used for the supporting frame is 18 gauge mild steel. Four hollow rectangular shaped frames of 12inch length and corresponding width, height is used to connect the contracting cone outlet frame and the diffuser inlet frame. The frame is fixed by means of arc welding technique. The type of joint used in this process is edge joint. Before welding it must be ensured that all the frames are at right angle to each other. On the outer sides of the frame, screws are welded in order to place the acrylic glass.

5.3.2 VIEWING PANE:

The viewing pane is made out of acrylic glass. To construct the test section, cut all test section pieces from a 12 x 36 inch piece of 1/4 inch acrylic glass according to the Test Section plan. Cut the top, bottom and sides to exactly fit into the mild steel frame at each end of the test section. Mark each piece of acrylic glass, identifying each piece and its orientation so that there will be no confusion as to what piece goes where during assembly. Drill holes in the acrylic glass with a #32 drill bit only about 1/32 of an inch. Drill each hole with a #43 drill and then tap each hole with a 4-40 tap.

All the viewing panes are attached to the supporting frame using suitable nuts. One of the side viewing panes is used to place the test model inside the test section. This pane is alone tightened using wing nut in order to easily remove and replace the acrylic glass when mounting the test model.

(Refer Appendix I-fig 16,17)

5.3.3 PLATFORM:

The platform is the base required to place the test model inside the test section. It is a flat plate of cross section 6 × 3 inch and is made out of 18 gauge mild steel. It is attached to a steel pillar to support the base. The platform is inserted through the hole in the base of the acrylic glass and it can be attached or detached by using a screw and nut arrangement.

5.4 SETTLING CHAMBER:

The settling chamber is made from 18 gauge mild steel. The shape of the settling chamber is cut using the settling chamber plan. The sheet metal sheet is cut using tin snips. PVC pipes cut to the length of the settling chamber are placed horizontally inside the settling chamber. In order to hold the PVC pipes, a vertical square mesh is welded to both the sides of the settling chamber. The whole setup is welded to the contraction cone inlet frame. The type of joint used in this process is edge joint.

(Refer Appendix I-fig 18)

5.5 FRAME:

The frame is made out of 18 gauge mild steel. The frame is an 'L' shaped structure. The frame was suitably designed to hold all the components together by welding the frame to the components base. Spot weld was used to join the frame and the component.

CHAPTER 6

RESULT AND ANALYSIS

6.1 VELOCITY DETERMINATION:

In order to verify our design, it was required to find the velocity inside the test section. To find this, we needed either an anemometer or a pitot's tube. The pitot's tube apparatus in our college was not compatible with our wind tunnel since the apparatus had a steel base which could not be placed on our wind tunnel test section which was made out of acrylic glass. Hence we had to rent a calibrated pitot's tube apparatus. The pitot's tube apparatus consisted of a U-tube manometer which is connected to the pitot's tube using a rubber hose. The pitot's tube was inserted into the test section through the hole at the top surface of the test section. The pitot's tube is placed in such a way that the opening of the tube is parallel to the flow of the air and the tube is perpendicular to the flow. The fan is made to run at maximum speed and the change in manometer head is measured. The calculation procedure is as follows.

CALCULATION:

Manometer reading,

Height of water column 1 h_1 (cm)	Height of water column 2 h_2 (cm)	Difference is height $h_w = h_1 - h_2$ (cm)
22.6	**21.2**	**1.4**

Table - 1

Difference of pressure head of water (h_w)

$h_w = 1.4$ cm $= 0.014$ m

we know that,

$$\rho_w \times h_w = h_a \times \rho_a$$

Density of water (ρ_w) = 1000 kg/m^3

Difference of pressure head of air (h_a)

Density of air (ρ_a)

Hence,

$$0.014 \times 1000 = h_a \times \rho_a$$

To find the density of air, from gas equation

$$\rho_a = P / (RT_a)$$

Pressure of air (P) = 1.013×10^5 N / m^2

Gas constant (R) = 287 J / kgK

Temperature of air (T_a) = 303K

Hence,

$$\rho_a = 1.013 \times 10^5 / (287 \times 303)$$

$$\rho_a = 1.1648 \text{ kg/m}^3$$

Thus,

$$h_a = (0.014 \times 1000) / 1.1648$$

$$h_a = 12.019 \text{ m}$$

rounding off the above value,

$$h_a = 12.02\text{m}$$

Thus the velocity of air is calculated by

$$v_a = C_d \sqrt{2 \times g \times h_a}$$

assume, coefficient of discharge (C_d) = 0.62

hence,

$$v_a = o.62 \times \sqrt{2} \times 9.81 \times 12.02$$

$$v_a = 9.52\text{m/s}$$

$$v_a = 34.27\text{km/hr}$$

Thus the velocity achieved in the wind tunnel test section is 34km/hr which is nearby to the assumed value of velocity of 38km/hr. The decreases in velocity can be accounted for the various losses due to friction inside the tunnel section.

6.2 FLOW VISUALIZATION:

In order to visualize the flow of air inside the test section, we required to spray a smoke particulate or a fine mist of liquid into the tunnel just ahead of the model to be tested. Commercial wind tunnel's use smoke generator, dry ice, infra red sensors to visualize the air flow. Due to economic constraints, we were forced to search for alternatives. Finally we decided to use incense sticks. We had a delivery system designed using which we collected the incense smoke and delivered it at the base of the test model.

Figure-10

As seen from the figure-10, we have had reasonable success in visualizing the flow around the test sample. We can also see that the vortex that should be seen at the trailing end of the test section is not visible. This is because of the low rate of smoke production. To achieve effective visualization we could use other chemical sources like dry ice.

6.3 MERITS:

Some of the essential merits of this project can be put down as follows

- It is possible to achieve wind speed ranging from 30–40 km/hr
- Low cost effective visualization of air flow
- Easy explanation of hard and complex air flow concepts by direct visualization
- Aerodynamics of scale models can be studied with ease

6.4 FUTURE ENHANCEMENTS:

The essential enhancements which need to be implemented for the project in the near future are

- Pressure probes and anemometer should be placed for easy measurement of pressure and wind velocity
- Calculation of drag and lift values should be implemented
- Dry ice or smoke generator must be used for precise and better flow visualization
- Higher capacity fan should be fixed for increasing the range of wind tunnel
- Adjustable mount for samples should be provided so that the angle of airflow around the sample part can be changed

CHAPTER 7

COST ESTIMATION

PARTS	COST
MS Angle	Rs.1570
Nut and Bolt	Rs.134
Paint and accessories	Rs.280
18 gauge MS sheet metal	Rs.570
Acrylic sheet	Rs.480
MS Mesh	Rs.145
Fan	Rs.800
Thermocole	Rs.20
Total	**Rs.3999**

Table - 2

CHAPTER 8

CONCLUSION

The design and fabrication of the low speed wind tunnel has been successfully completed and overall assembly of the wind tunnel is drawn in this report. Thus the major objectives which were achieved are

- Wind speed ranging from 30-40 km/hr was achieved
- The flow of air over test model kept inside the wind tunnel were studied
- Possible future enhancements were studied

APPENDIX I

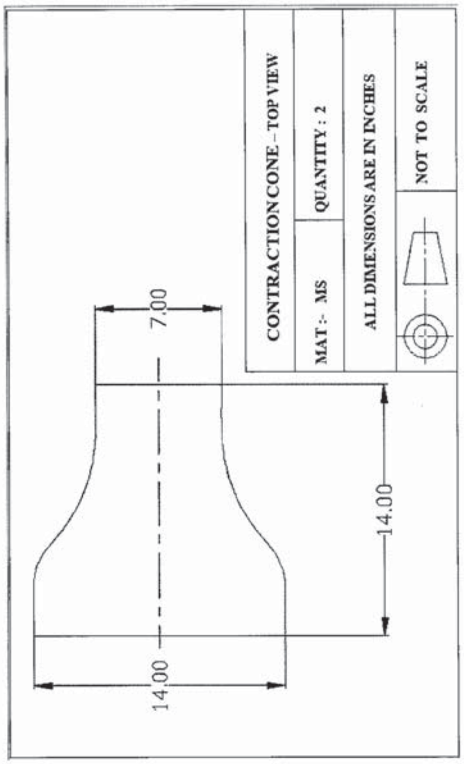

Figure-11 CAD DRAWING OF CONTRACTION CONE – TOP VIEW

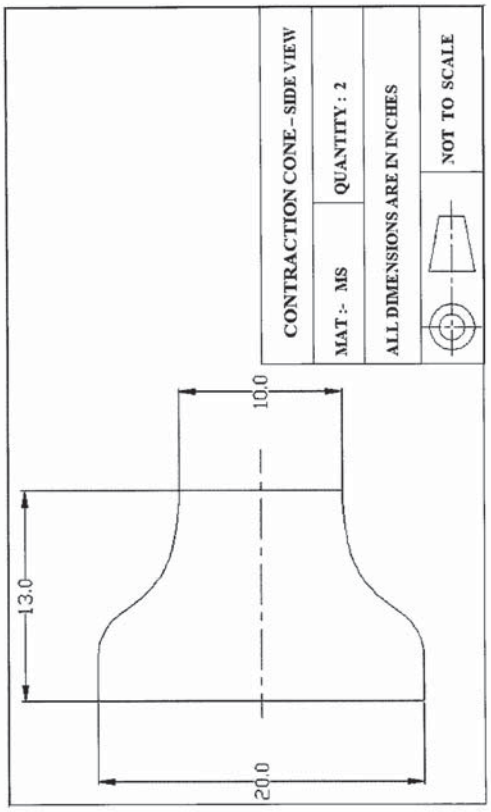

Figure-12 CAD DRAWING OF CONTRACTION CONE – SIDE VIEW

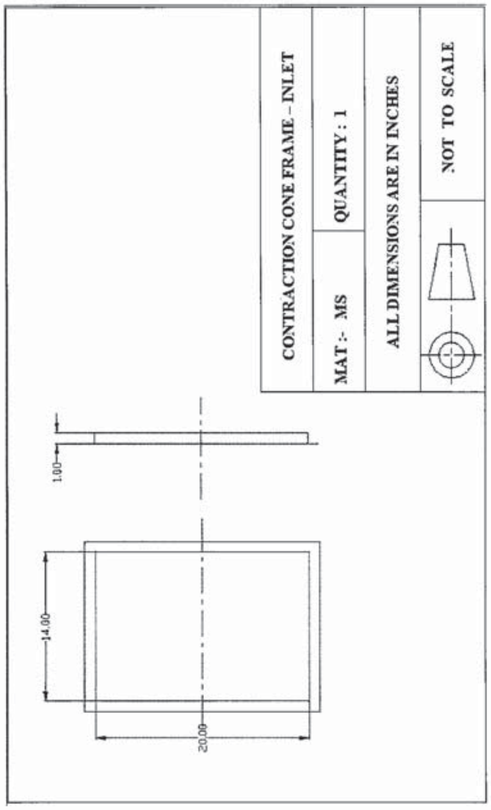

Figure-13 CAD DRAWING OF CONTRACTION CONE FRAME – INLET

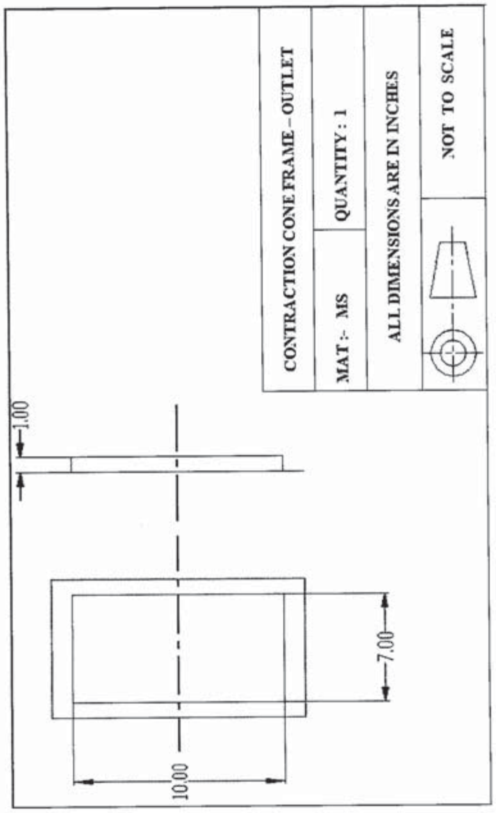

Figure-14 CAD DRAWING OF CONTRACTION CONE FRAME – OUTLET

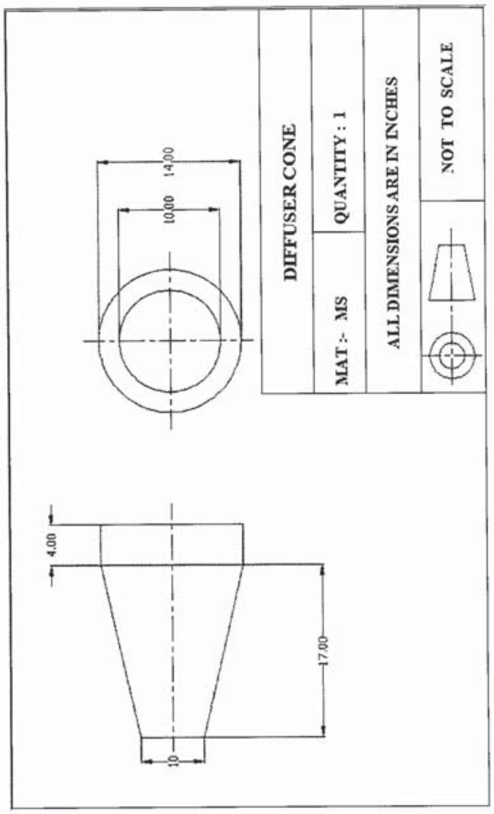

Figure-15 CAD DRAWING OF DIFFUSER CONE

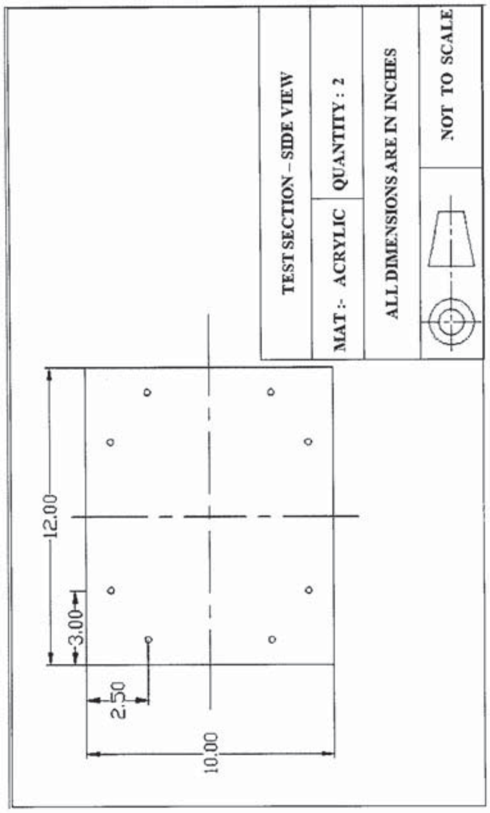

Figure-16 CAD DRAWING OF TEST SECTION – SIDE VIEW

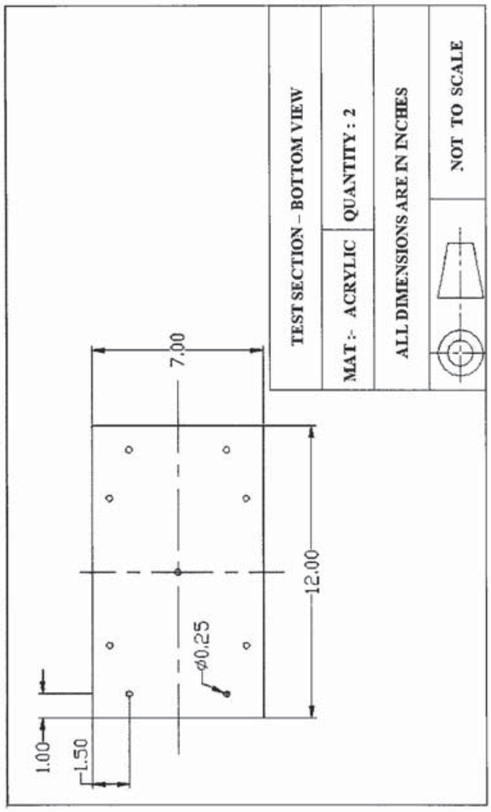

Figure-17 CAD DRAWING OF TEST SECTION – BOTTOM VIEW

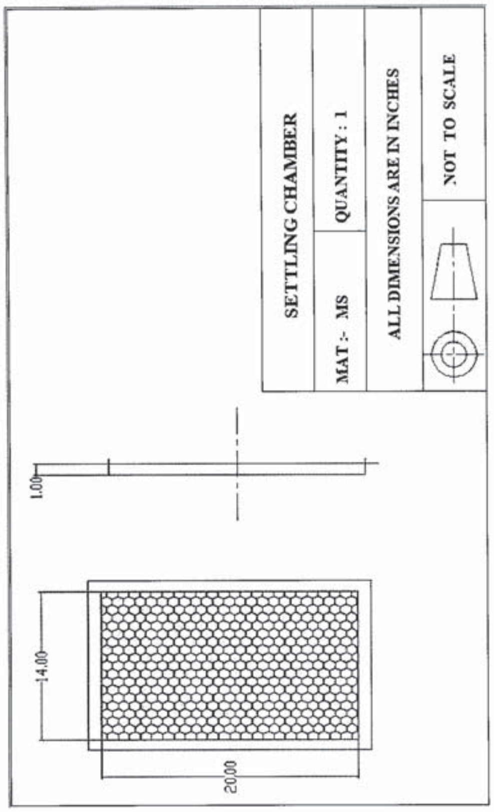

Figure-18 CAD DRAWING OF SETTLING CHAMBER

APPENDIX II

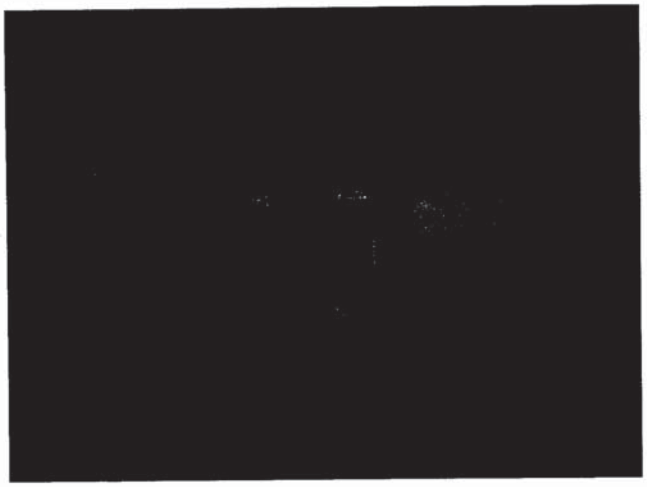

Figure-19 ASSEMBLED VIEW OF WIND TUNNEL

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