High Speed Air Pneumatic Wind Shield Wiping Design

By Moses A. Heyward

Submitted to the Department of Mechanical Engineering
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ABSTRACT

In this creative design process a number of designs were constructed, implemented and tested in order to assess the feasibility of using high speed to create a curtain to repel the rain from the automobile windshield instead of using the traditional wiper blades. The primary two methods tested used a compression system and a blower system that allowed the air to flow upward and parallel to the windshield.

Both of the applications showed potential especially when coupled with a hydrophobic coating covering the windshield. The design using the high-speed squirrel cage blowers was implemented on an actual car in which it revealed positive results, which will be further assessed for patenting potential.

Thesis Supervisor: Ernesto E. Blanco

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Introduction

With the growing use and need of the automobile in the early 1900 came the need for a number of other designs and inventions that would make it practical, convenient, comfortable, and safe. The invention of the windshield wiper is one of such innovations that date back over 100 years. While the activation of the device has seen a number of improvements and advancements through advancing technology over the last 100 years, the methodology of cleaning the windshield is one that has been held fairly constant since the birth of the windshield. The automotive industry and travel has grown tremendously since the days of the model T. With the increasing number of automobiles, highways, and drivers came increasing risk and safety, however, the inclement weather conditions have remained and will remain to be a constant problem. Through this thesis I will prototype a design that will potentially transform the way and condition in which we drive during unpleasant weather.

History

In 1903 on a trip to New York City, Mary Anderson noticed a motor vehicle operator getting out of their car and wiping their windshield clear. This is said to be the inspirational event that would spark the invention of the windshield wiper. She soon developed a system that would allow the operator to manually turn a lever from inside the car that would activate a swinging arm with a rubber blade to swing across the windshield on the outside and return to it's original position. This design would later be further developed into a system that would incorporate automation of this wiping motion and became standard equipment in American cars by 1916, compliments of the inventor Charlotte Bridgwood. From that time until now the design has seen a number of innovations. There have been a wide variety of modifications to the wiper blades. The motor controls have been designed to include variable speeds and intermittent settings. The device has also become used for a windshield cleaning method. A variety of wiper schemes have been used including a tandem scheme, an opposed scheme, and a single arm scheme. Despite the number of efforts to improve the impaired driving conditions there is still much room to dramatically improve these tough driving conditions. I have had my license for over 7 years now and I have been in only one accident and it was in the rain. In my situation I stepped on the brakes, but I could do nothing as my vehicle slide helplessly into the vehicle stopped in front of me. While there may be a number of solutions that can help prevent such accidents one thing is for sure a quicker reaction time would have definitely greatly decreased the probability of my accident as well as many others. There is no denying the fact that visibility factor plays a large roll in the reaction time. Through the use of high-speed air creating a continuous curtain or sheet over the windshield visibility in precipitous conditions could certainly be increased. The work done in this thesis will outline the design process of a prototype design, which incorporates this innovative idea.

Design Process

With this goal in mind of creating a continuous curtain of air over the windshield the design process was initiated with brainstorming an exhaustive amount of options for how to reach this goal through several different ways and several different tradeoffs. A list was made of all the ideas thought possible and research was conducted to see if any previous work had been done that incorporated using air as a means of keeping the windshield obstructions free. The closest design located was the use of compressed air for clearing the windshield of an aircraft. It was stated on internet tech talks and by a Bose employee whose family had done some aviation work to have been an application used on English Electric (BAC) Lightning interceptor and the DC-8, however the patent searches conducted were unable to locate a patent for this design. In attempting to determine a feasible air source the first obvious tradeoff that was realized was that of pressure and volume. The current applications thought of as being feasible to provide the air for the windshield either produced high-pressure air at low volumes or low-pressure air at high volumes. The considerations were between using some type of compression system or some type of blower/fan system. Other properties to decide between focused on deciding the location from which the air would be produced (i.e. the bottom of windshield, top, all around) and whether or not the system would be a static/stationary system or a system that was dynamic with a (single or multiple) moving air source. The process of reciprocity was used, a very powerful design tool, to come up with a design that would provide the results needed through the correct balance of effectiveness, simplicity, magnitude, comfort, and cost. Also many representative sketches of design concepts were made.

Theoretical Analysis

In order to get a better handle on exactly what was needed for the project a number of basic calculations were made that would give me an idea of what kind of forces and power I would need to achieve the goal at hand. One initial calculation made was an estimated speed the water and the air needed to be traveling at to achieve the goal at hand. The speed of air leaving a compressed air tank and the velocity that the air would be traveling when leaving jets that would be possibly pointing almost parallel to the windshield was calculated using e**quation 1**. Using this air speed **equation 2** was then used to calculate the velocity of the air leaving jets or nozzles of a specified area.

$$v = [(2*P_2-P_{atm})/density_{air}]^\wedge(1/2)$$ **Equation 1.**

Where v is the outlet velocity of the air v1 being the velocity of the air in the take which is 0. P_2 is the pressure of the air coming out and P_{atm} is the atmospheric pressure at the opening of the tank. Equation derived from steady flow Bernoulli equation

$$\rho * A_1 * V_1=\rho * A_2 * V_2$$ **Equation 2**

Where 1 would now denote leaving the tank and 2 would denote leaving the pipe jets. The density is denoted by ρ. This is using the property of continuity assuming that the air flowing through the tank opening into the pipe is also flowing out of the jets. (Ignoring viscous losses)

The velocity of the air leaving the tank was calculated to be approximately 753 mph with the air pressure of 20 psi leaving the tank and atmospheric pressure outside the tank. At this velocity with the air flowing through an initial area at the opening of the tank of about 1/4 in. diameter and with 8 total jets each with an area of .03125 (1/16 wide *1/2) square inches the velocity of the air leaving each of the jets would be 147 mph (and almost 8 times that velocity with an .008 wide jet opening). This is ignoring the effects of viscous losses in the hose and in the pipe. If there was a single jet used identical to these 8 individual jets (possibly moving back and forth) an air speed of 1180 mph can be theorized with the same underlying assumptions of neglecting the losses, which will significantly reduce this number. Since a method of using a blower was also postulated calculations were completed to determine the speed of the air that could possibly coming out of a blower that was fitted with a housing having an area of 13 square inches at the opening.

Experimental Apparatus and Procedures

After completing these calculations it was necessary to do some testing that would enable some realism to be put to the calculations in order to see how well they had predicted the behavior of the air and water. To make the testing relevant a test model was created that would simulate the cab of the automobile. This model included the front windshield that was at an angle comparable to that found in an automobile and it also modeled the curved surfaced that would be found on the windshield of the automobile. The one feature that it did not incorporate was that of the glass. The material used for the windshield in the model was lexan. Despite the differences this model was thought to be sufficient to produce some baseline testing and just to get an idea of how the system would work and what it would require. A picture of the test cab can be seen in figure 1 below.

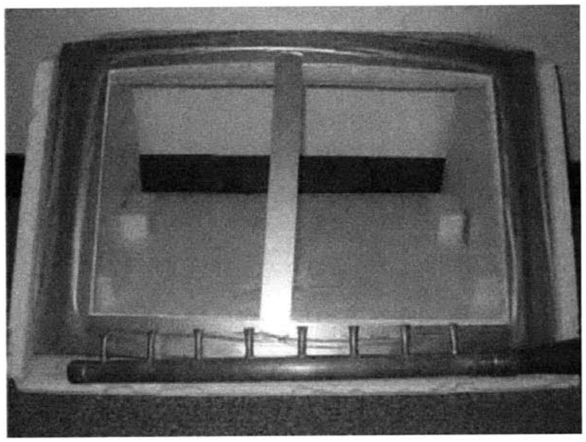


Figure 1. This figure is a picture of the model that was built. The cab was made from styrofoam and the windshield from lexan. The windshield was sealed around the edges using silicone to prevent water from entering the cab. The backside was left open so that the option of adding a camera could be implemented during testing. The size is smaller than that of a car cab for convenience and so that the test model could be placedin the shower if desired.

The first idea that was tried out on the model was that of using compressed air. A very quick but practical test was put in place. In this test a household air compressor was used as the air source. For the test set up a rubber hose was connected to a nozzle with a slim rectangular orifice. The compressor was then connected at the opposite end of the hose and a baseline test was done. The nozzle, a prefabricated design, was used along with the compressor for the opening test. In this particular test the nozzle was simply oriented at the base of the test set up in a position that would allow the air to blow out of the nozzle in a stream slightly parallel (yet impinging) to the windshield. Water was simply sprayed at the windshield above the air stream and the results examined. The air flow coming from the design proved to be not even close to sufficient air source to keep the air from touching the windshield the entire length of the windshield. The length of the nozzle opening was about ½ in and the width was about 1/8 inch. The water was unable to touch the area at the opening of the nozzle up to a distance of approximately 1.5

inches from the opening of the nozzle. The jet produced by the nozzle was a very thin layer such as that produced by a narrow fan spray nozzle. It should be noted that the hose used in the testing connected to the nozzle and connected to the pump via a bicycle connector began to get really warm, which informs us that the viscous effects were very great in this hose. The air compressor used was a Sears's compressor, model number 900.150250. It has been rated for 1.0 SCFM at 30 PSI and 120 Max working pressure. It is often used for inflating athletic equipment such as balls and bicycle tires.

Another test setup was made that would embody multiple jets protruding from a single tube. This design was created to make jets or nozzle more similar to that which might be used in a possible design. The material used to make this tube was copper pipe. The main pipe was arched as can be seen in **figure 2** so as to allow the jets to fit flush along the base of the windshield model. The jets were made by a fairly crude but repeatable squeezing process followed by a trimming. The pipe was drilled with the proper sized holes and then bent into the curve shape. In order to bend the pipe it was heated in the lab and then to shafts with an O.D. equivalent to that of the pipes I.D. was placed in each end while the metal was soft and the pipe was bent across a mold with the same arch as that of the model. After the pipe was drilled and bent and the jets were made the jets were soldered into place, the pipe was capped on one end and adapter attachments were added that would allow for an air source and a pressure measuring device or flow measuring device to be added.

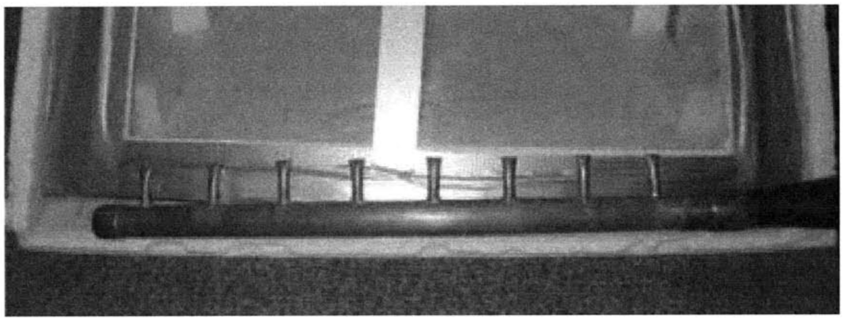


Figure 2. The copper pipe was machined and fitted with jets that would project several flows of air parallel to that of the windshield model.

This model was tested in a very similar fashion to that of the first model in the sense that the water source used was that from a spray bottle onto the windshield. The air source used for this set up was a leaf blower. A Black and Decker leaf blower, seen in **figure 3** was modified with a fitting that would allow it to blow air into the pipe from the end. Although the air was now coming through multiple orifices, the results in this experiment proved to be only slightly better than that of the previous. It was noted that the amount of air coming from the jets in the pipe were not even close to that of the air that could be observed coming from the opening in the blower when removed from the pipe even with the modified fittings. To see how well this type of airflow would perform the blower was tested simply blowing air across the windshield while being bombarded with water spray. The results noted proved to be more promising than the previously observed experiments. From this quick test a larger region where the water was unable to touch the glass was observed. However, even from this source which boast of producing wind speeds of over 200 mph and moving over 400 CFM of air, getting the water to clear the entire windshield appeared elusive. What was observed from this test, however, was that the water that did touch the windshield was immediately blown to and off of the top of the model. This evidence showed promise for a design that could still possibly outperform the traditional windshield wipers in the process of keeping the windshield obstruction free.

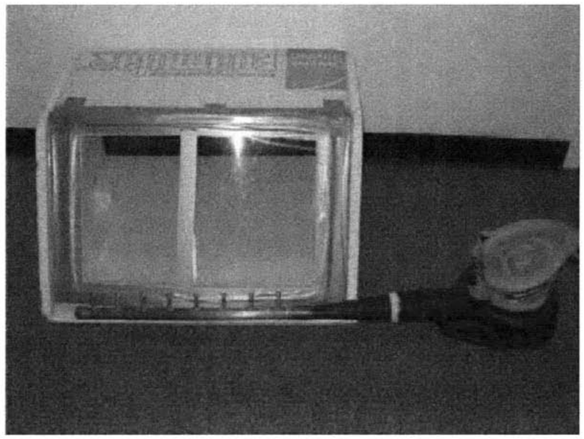


Figure 3. This shows the setup in which the cooper pipe was connected to the leaf blower and a water spray test was conducted.

The promise from this testing led to a pressing forward at the opportunity to produce an innovative design. As the research continued to try and decide what path would be most promising one of the Paparlardo Lab guru's, Steve, suggested that with whatever design used, couple it with the use of Rain-X. Not being completely familiar with the use of this product research was conducted to find out more about exactly how the product work in order to determine how it might be beneficial in my design. After finding out about this product and many other applications that have a similar affect the purpose and use of such a product became lucidly clear. Rain-X along with several other products performs by providing a hydrophobic layer on the windshield. One characteristic of glass is that it has microscopically irregular pores. Products like Rain-X, Rain Clear, Aquapel, and Accuvision seal up these pores providing the user with a windshield that sheds or repels water. The water has a tendency to bead up on such surfaces and slides off rather easily. While some of these products provide this protective barrier much longer than others they all work on a similar principle. When using such products it has been noted that at traveling speeds of over 45 mph the water is simply blown right off the windshield. So while some companies such as Toyota are offering wet weather advancements in the form of rain sensing wipers, Volvo, a company that prides itself on safety is introducing features such as Water Repellent Glass as standard on some models. Similar to the concept of aviation travel the water is blown right off at certain speeds, which are sometimes referred to as aerodynamic run-off. If this concept holds true, then producing a uniform flow of high-speed air in combination with the use of a hydrophobic windshield coating will allow for a cleaner clearer windshield wiping solution.

At this point the design goals were a little more focused although the concept was still only theoretical and had not yet been proved a single affective method for windshield wiping. The leaf blower produced a high volume high-speed flow, but not one that would cover the entire windshield. The leaf blower was also a really noisy way of moving such large volumes of air and has been plagued with a history of complaints do to the noise level. Through searching the library and internet a very common way of moving high volumes of air through small spaces was through the use of blowers. Squirrel cage blowers seem to be a particularly common application for doing such jobs. It consists of a rotating wheel, hollow in the center with a large number of blades at the periphery. Air is drawn into the blower axially through an inlet channel and is spun radially outward by the action of the rotating wheel. The air exits through a side opening after circulating through around the spiraling blower casing. After searching to find the best blower for the job, a blower produced by SPAL USA shown in **figure 4** was settled on. It was the most superior found blower in it's class, boasting quiet operation at top speed, 12 VDC operation, rotating at speeds up to 1670 RPM and moving over 436 CFM. It was also one of most expensive blowers in its class. The surplus center, however, had a rather large stock of this equipment and was selling them for below half of the retail cost.

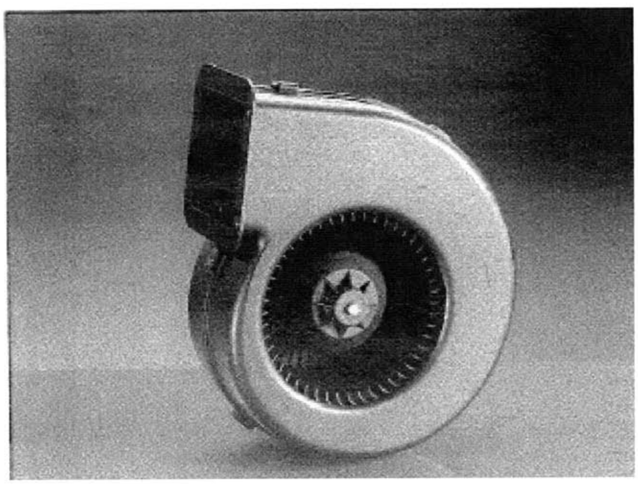


Figure 4. SPAL 3-speed blower. A 7 lb blower moving 436 CFM @ open flow and 100 CFM @ 2.6 in water (max pressure). Overall dimensions 9" x 5-7/8" x 10-1/2"

The blower output unmodified is 436 CFM at open flow out of a rectangular outlet with the dimensions 3-7/16" x 3-15-16". To make the project as successful as possible it would be necessary to produce even higher outlet air speeds and the air would need to be uniformly discharged in a much wider range. In order to solve both of those problems several solutions were considered. The first and most important was how to spread the air out across the windshield. It would be necessary to build an attachment for the blower that would cause the air to be uniformly dispersed. Due to the boundary layer that forms on flow in a pipe or enclosure this would be a particularly hard factor to overcome. The options that were available to spread the air out were to really spread the air out wide through the use of a single outlet or spread it out in stages using multiple outlays that would form overlapping layers. One design concept for a possible way to do this is illustrated by the mold and model shown in **figure 5.** The other option to consider would be to use multiple outlets but such a decision would cause even more concerns with space consumption. In order to make the test more valid the system was going to be added to 1991 Acura Integra and constraints on size and power had to be considered, which was especially good if the application was desired to be adopted in the automotive world. Some mock up molds shown in figure 7 illustrates possible options to be adopted for the multiple openings design.

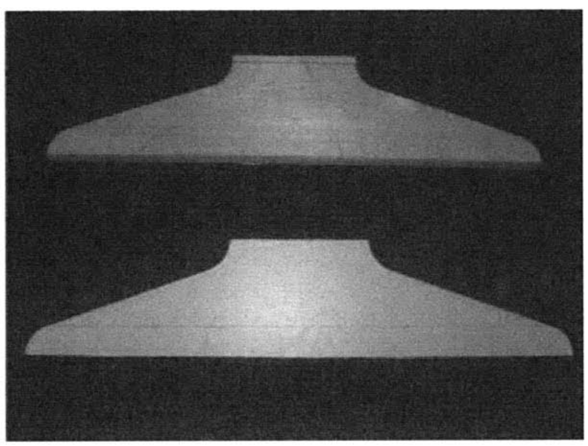


Figure 5. The top mold is a wooden mold that was cut and was going to be used as the single stage mold. The bottoms styrofoam mold is illustrating the same basic top shape but it was cut at an angle to have a thin opening at the end or tip. It was used as part to test the size fit and location possibilities on the car. Figure 7 illustrates two possible molds to be used made out of cardboard for a quick baseline judgment of effectiveness of such a design.

After choosing the design that would use multiple openings and blowers, (in particular 2) because it was viewed as a superior design for dispersing the air, a decision still had to be reached on exactly what shape and size the part would take and how it would be made. In an ideal case we would like to make the opening in the front of blower hood very small so that the velocity of the air would get very large in order for the mass flow rate to stay constant. The problem with building this system this way is the fact that make this area really small causes the pressure to rise and as it rises the blower quickly puts out a much smaller flow rate of air as can been seen by the manufactures testing of the blower in **Chart 1**.

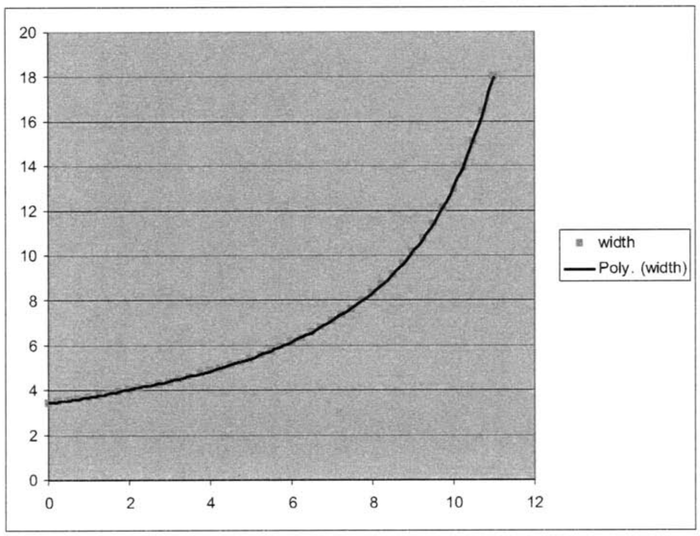
Tensione di prova 13 V cc. - *Test voltage 13 V DC*

Pressione statica / *Static pressure* mm H_2O	Portata / *Airflow* m^3/h	Corrente assorbita / *Current input* A
0	740	22,5
10	650	21
20	590	20
25	550	19
30	510	18
40	430	17
50	350	15
60	240	13
65	170	12
70	-	10

Static pressure: 1 mm H_2O = 0,04 in. H_2O
Airflow: 1 m^3/h = 0,59 cfm

Chart 1. This chart shows manufacturer's measure of flow-rate at specific pressures. The max flow rate is 436 CFM at open flow. At 2.6 in of water the flow is 100 CFM and this is the maximum pressure before stalling the blower.

In order to take advantage of the full blowing capability of the blower the hood was created to have the same cross sectional area at the opening as the blower housing. There were still several possible designs at this point and the schematics in **Graph 1** show these designs. The final design chosen was one that kept this cross sectional area uniform through the entire transition of the air from the front of the blower to the opening in this chamber. Figure 8 shows an excel plot that calculates values which determine what the shape of this chamber should be. The final dimension is characterized by the fact that the opening needed to be a certain length so that the air could be spread out across the windshield and the height was then determined by the constant air calculation.



Graph 1. In this excel plot the calculations take into consideration how far from the opening of the blower housing the air will be and it determines what the width should be at the point taking into consideration the change in height that will be currently in place at this point. The change in height was a uniform linear change that was constant and was the same from the bottom as that from the top.

After getting a drawing of what this shape would embody the mold was then assembled. The mold was made of 3/4 in. MDF as can be seen in **figure 6**. It was created from 5 slices of this material that were cut into the correct shape, glued together and then sanded down to the proper size in order to make the part illustrated by **figure 7**. The mold was made for the vacuum-forming machine and so the bottom plate was drilled with a number of wholes around the base of the main shape of the mold. **figure 8** shows the machine used to produce the part, which was quite a remarkable process.

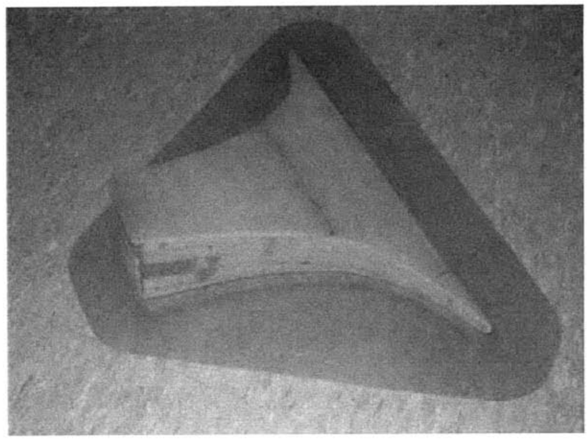


Figure 6. The mold which would be used to make the chamber or hood that would be used to divert the square flow from the blower to a much wider flat flow that would cover a wider area on the hood. A flat board was attached to the bottom in order to get the mold to come out in a design that can be seen in Figure 10.

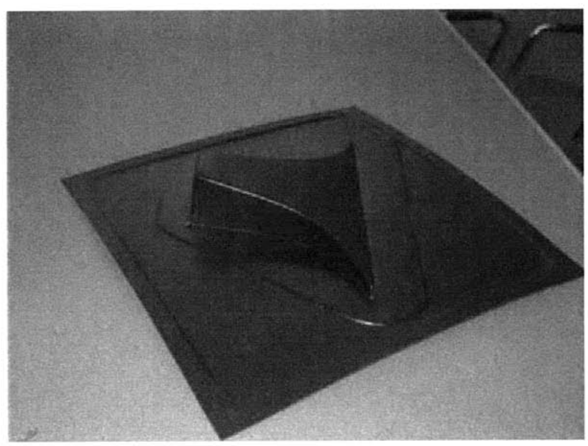


Figure 7. This should the actual part that the mold in figure 9 produced. The parts were made out of ABS plastic and one part was made out of Kydex to experiment produced the more desirable part. ABS produced the cleaner product that was sharper around the edges.

Figure 8. The vacuum-forming machine was used to produce the part. The machine tightly grips the plastic and heats it up evenly. After the plastic begins to heat up and melt, characterized by ripples forming and the plastic sagging, a process of pre-inflating was used to stretch the plastic. The mold was then raised using the handle on the right. The mold stretches into the plastic and the plastic takes shape around the mold. It does not fully take the shape however until the vacuum is initiated, which sucks the plastic tightly around the mold to produce the part shown in figure 10.

While making and designing this part the motors in the blower were being simultaneously upgraded. Because higher flow rates and faster air speeds were desired than that presently being produced by the blower a custom upgrade to the manufactured part was performed. The current motor spun at speeds up to 1670 RPM. This motor of approximately 1/8 hp was removed and a ½ horsepower motor with top speeds of 7800 RPM was implanted in place of the manufacturers motor. The blower dissection and rebuild required some quick and clever modifications. The implant of the motor can be seen in **figure 9**. The motor had to be implanted in a matter that would allow me to still fit the blower housing into the already jammed engine compartment of the Acura. With both time constraints and space constraints in mind and a need for the motor to be firmly held in placed and properly balanced I quickly engineered a design that would allow me to quickly and easily replace the motor in the design.

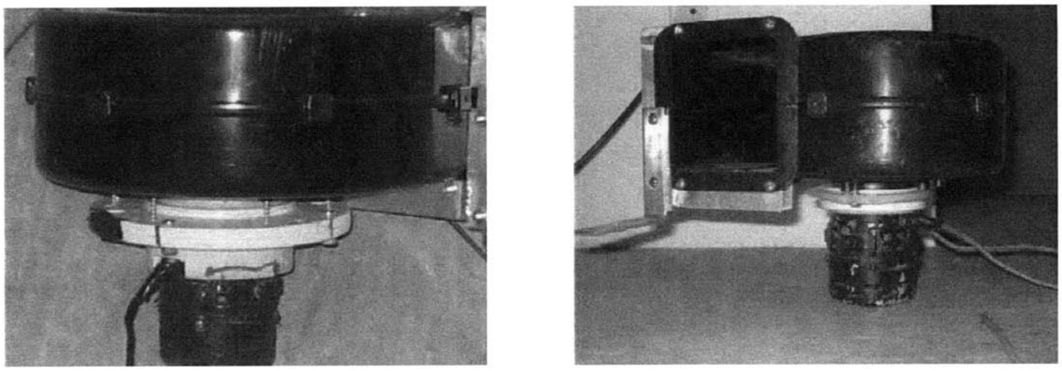


Figure 9. This figure shows two different designs used to mount the motor into the blower housing. The design on the left shows the initial design that was used for the first motor. Because the second motor was being placed in an even smaller space a second-generation design was made that would do just a good of job of holding the motor while taking up a considerably smaller amount of space.

In addition to changing the blower design to incorporate the new motors modifications needed to be made to the power source in the car that would operate these motors at their full potential. The manufacturer motors were design to operate at 12 VDC, which is the standard voltage, found in a car produced by the car battery. The new motors could operate at this voltage, but the optimal voltage for them was 24 VDC and lower voltages would mean that the motors would operate at slower speeds. In order to accommodate this preference a batter management system was put into place that would allow these motors to be operated at 24 VDC while still allowing the remaining components in the car to operate at only 12 VDC. The system pictured in **figure 10** incorporated a design that would include a second battery and a control system that would allow this second battery to be switched back and forth from being connected, in parallel or series (series was needed for the 24 volts) to be disconnected. This management system also included a switch that would allow the user to turn the wiping system on and off conveniently from inside the car shown in **figure 11**.

Figure 10. This picture allows the battery system put in place to be viewed. As can be seen there are two batteries located in the right corner of the picture. The second batter has been wired so that it could be switched back and forth from being connected in series, parallel, or not at all. To make room for the second batter the intake system in the car was modified. The manufacturing intake was removed and a performance system replaced it. This performance system was modified. The intake pipe was shorted so that the filter would be located in a position that allowed room for the battery.

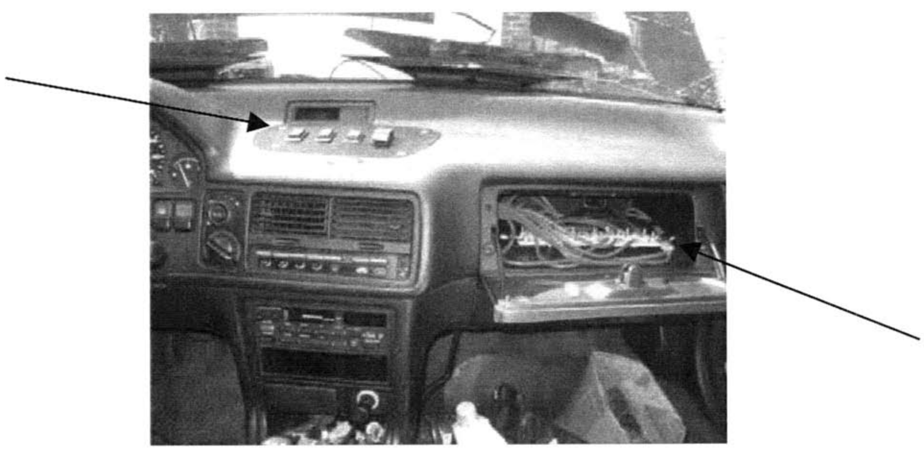


Figure 11. Pictured above is the control system for the blower design. The switches allow for the batter voltage and amps to be changed. The wiring from the outside of the car is run to the inside through the glove box and to the 4 switches on top of the dashboard.

Other modifications were necessary in order to incorporate the design into a car for testing. Because of the method through which these blowers as well as any blower or fan operates the design of this system into the car needed to incorporate an ability for the blower to intake air at the opening at the top. In order for this air to be dry air blowing across the windshield there was a need for a system that would separate the water from the air so that the system would only take in fresh air. Because of the size of the blowers and the desired location of them the system was design so that the opening of the blower would protrude from the hood. The proper cut outs would be put in place over the hood for this to occur. A system was designed to place over this opening so as to cover the blower and to allow the intake of fresh dry/water separated air. The design took on the feel of a custom hood cowl and hood scoop. Underneath this fancy looking design which can be seen in **figure 12** was a system that allowed air to enter from the front of the scoop/cover, which would be particularly good for air intake while driving. Once the air entered the system it had to go through several stages before contacting the blower. The air enters through the front screen, which would automatically stop some of the water from entering. It would have to go down to past the first barrier. The air next has to travel upward to past the second barrier. Not only did the air have to travel upward but it had to travel past a second screening/ filtering system laid perpendicular to these vertical passes. The idea is that if there was any water in the air it would hit the will as it travels in and the air would travel upward while the water would go down and travel into a collection system. At the base of the wall is a downward-sloped opening that would allow the water to drain out

Figure 12. The hood scoop was a custom made part that would allow the blowers to be covered when protruding from the hood, but still allow them to intake fresh dry water free air when it is raining.

As experiments were conducted to get a feel of how the air would flow across the windshield another major concern was encountered. Since it was January if there was any rainfall with the added factor of high-speed air the problem of the air freezing on the windshield was encountered. In order to make the system resistant to such failure a heating element was also added under the scoop. .

With all of these system design and built the time came to actually put the system in place so that the testing process could begin. In the process of installing the system another problem was encountered. Although the vacuum formed parts had been created with the knowledge of the need to contour to the windshield the proposed solution of incorporating a flexible bottom to the system was not sufficient. The bottom of the part had been attached and a slit was put in it to make it more flexible. However, in order to contour to the full curve of the windshield it required these bonds to be broke. The top part needed more room to flex and had to be re-attached. In addition to this change this also affected the shape of the opening. The opening was now bowed at the top and a larger opening than the original uniform rectangular but contoured shape proposed. At this point in the process the only option was to test the design as is and see how this change would affect the process (correction would be later made). The final design for the system in place and attached to the car can be seen in **figures 13 A and B**.

A B

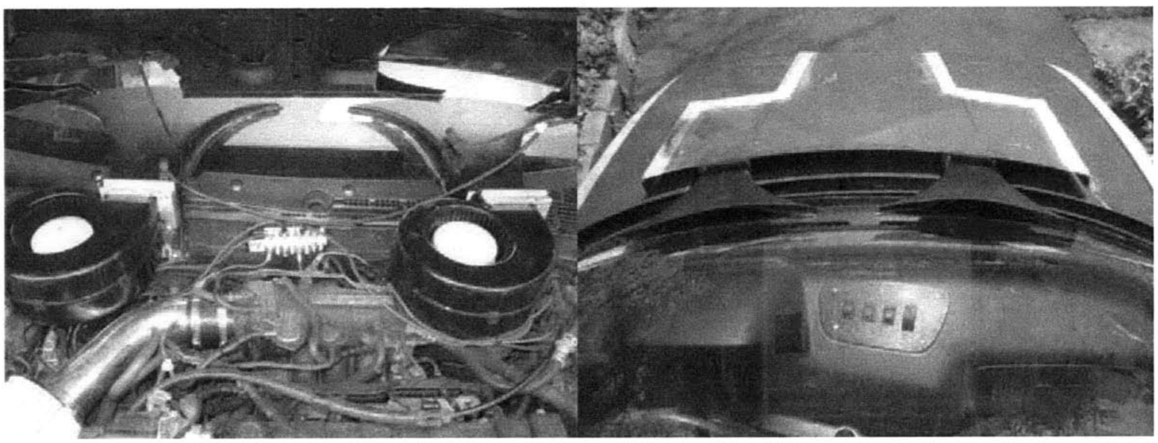


Figure 13 A and B. Here we have a view of the system in place on the car. The figure to the right shows what the system looks like from under the hood of the car. As you can see the scoop is attached to the hood and lifts up separate from the wiping design. The figure on the right allows you to see what the design looks like from over head looking down into the blower openings.

With the system now in place it was time to begin the testing. The windshield was thoroughly cleaned and coated with the proposed temporary hydrophobic coating of Rain-X rain repellent. Another test was put in place as well to compare the results of the different types of flow. In this test the copper pipe was again used. This time however the pipe was being pressurized by a more industrial strength compressor which had a max pressure of 160 psi, a 4.5 gallon tank, and could operate at a flow rate of 6.5 CFM @ 90 psi. In this particular test the openings in the jets on the copper tubing was reduced from about .125 inches wide (1/8 in) to .008 inches.

Results

There was a lot of promise illustrated in each of the design concepts. The design with the copper pipes and the compressor was tested and it did and adequate job of keeping the water from a region of about 6 inches away from the design. It was noticed that the current design would need to have the jets at a slightly closer distance to each other or make sure that the jets were far enough from the region that needed to be clear that at the distance they were not blended and water got in between it would not matter. After the coupling was properly connected to the blower design it was tested on the hydrophobic-coated windshield. When testing this design it had the capability of blowing water poured in the scope of the blower all the way to the roof of the car. The cross path of the two blowers also allowed for coverage that would not allow water to fall between the two blowers and the stream of air. Previous to the blower being modified it was rated at an output of 436 CFM but with the new motor it is estimated that the blower is currently putting out a range of 2 to 4 times as much air.

Conclusion

This really showed promise especially since these results were observed with the car stationary. There were several things that could easily be improved in both the compressor and blower model in an intermediate stage that would probably produce even better results. Things such as reducing the viscous losses by using a much shorter air house and coming up with a process to make much more precise opening would have drastic effects on the test. In the blower phase because the blowers were modified they were not completed balanced which contributed to speed losses in the rotation of the fan, which would decrease the airflow. Also the coupling used could be made significantly lighter and in a manner in which it would not impede as much of the inlet air also allowing for a greater air flow. The next stage for this design will be to input both of the systems and run them together and conduct a test in the rain with the car actually traveling at both city and highway speeds. With the outlook of this project now showing promise further research will be conducted and an outlook at marketing the product will be explored.

References

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