Restated Project Definition and Project Plan/Scope

Team 6

Design of a Less-Deafening Hair Dryer

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ABSTRACT

There is a fundamental problem with the current design of many hair dryers, which is the fact that they produce an unappealing amount of sound during use. This present endeavor will seek to design a hair dryer that is quieter than what is currently in the market and just as effective, while also maintaining low cost of manufacturability. Optimal results to this project will include a working prototype, as well as a business plan for marketing and commercializing the product. In order to reduce the sound produced, Team 6 will target and aim to improve the loudest noise sources that are currently in hair dryers. The significant noise sources are found to be a combination of the fan and its intake, the fan flow over internal components and the motor operation. Many of the project constraints were chosen in order to maintain consistency with the current market for hair dryers. Some design concepts are presented along with a Gantt chart that contains future tasks for the project.

1. Introduction

Hair dryers are an easily found appliance in countless homes across the country. Currently the average hairdryer produces a sound level that is bothersome, invasive and harmful. Some examples include salons where hair dryers are constantly in use producing excessive noise pollution, or the case where someone is sleeping in close proximity of someone needing to dry their hair. The average hair dryer also produces a sound level that can be threatening to one's long term hearing with prolonged use. Being that there is this inherent problem associated with the current hair dryer, it offers a niche in the market for this project to fit a need. A solution that would be deemed fit is to be able to offer the same amount of power output, while reducing the noise that it produces compared to current hair dryers in the market. This project also asks the group to analyze the entrepreneurship aspect and to generate a product that is suitable for the current market by creating a device that meets safety regulations, provides equivalent drying quality, and also is quieter. With this in mind, all design aspects must be made to ensure the product can easily be transferred to the market and be mass-produced inexpensively.

This assessment will begin with some background on the current state of hair dryers, where the current noise sources come from and information on components critical to the design. The needs of the project and design goals will be clearly stated to give an idea of what we would like to accomplish in this project. Major considerations for which the designs will be based off is presented in the form of a house of quality; this shows what is important to the customer as well as what the important engineering characteristics are. Methodology of the design will look to incorporate methods to reduce noise output. Major components of a hair dryer are analyzed, along with technical specifications and a functional analysis. This will transition into the presentation of some concept designs. A Gantt chart is created in order to set the plan for the project moving forward and keeping with the schedule.

2. Restated Project Scope

2.1 Background Research

Hair dryers are one of the most widely used hair-related instruments, seen in both personal and commercial environments with the purpose to style and dry hair quicker. Their primary use is to speed up the time that it takes to dry hair. In order to make hair dryers perform efficiently, their heating elements and air flow rate must be extremely effective. However, this causes one big problem: the level of sound created by the hair dryer. It has been observed that people are unhappy with the noise that is associated with using a hair dryer. The typical hair dryer produces anywhere between 80 - 90 decibels [1]. This not only creates an unpleasant experience for the user of the hair dryer, but also can produce undesired noise to the surroundings of both business and personal settings. Many sources cite that noise-induced hearing-losses begin at the sound level of 85 decibels [2], thus making the average hair dryer detrimental to ones hearing over time. The range of noise levels generated with different hair dryer designs vary greatly based on the design. The causes of the sound come from a plethora of sources. Some of these include the fan intake, vibrations from the motor, and turbulent flow over internals components. The measure that is used to quantify the acoustic power of the sound produced is the decibel (dB).

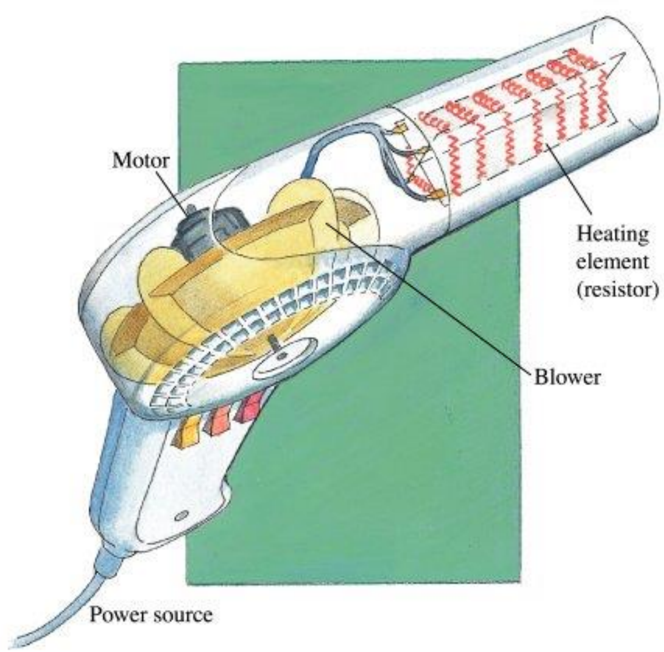

Figure 1: Breakdown of a Simple Hairdryer

A hair dryer is a simple electromechanical device; some basic parts are shown on the left (Figure 1). It begins with a power source that reaches a motor to power a fan device that forces air over hot wiring, thus producing a hot stream of air. The heat is generated by passing a current through the wires where the resistance is high, then subsequently pulled away by the air forced over it. This means of heat transfer is called *forced convection*. The progression of the handheld hair dryer design has been happening since the 1920's when the first of its kind was invented. Over the years, its design has changed to a lighter, safer, and more powerful device. Most of the safety measures include mechanisms that are connected to the circuitry that kill power if something that isn't supposed to happen. These protect against water immersion as well as a sudden fan stoppage; both cases will cut the power to the device.

The main mechanical component of hair dryers are the motors and device that moves the air. Most models use either a DC or an AC motor to rotate the fan component. It is observed that more expensive and quieter designs use an AC motor even though a DC motor weighs less. Typical hair dryers run on 6-24 volts and operate around 6000 rpm. The DC-type motors have two varieties: brushed and brushless. Brushed DC motors typically provide more torque than the brushless counterpart, while both have a higher torque output compared to AC motors. The AC motors have a much longer lifespan compared to DC, making them more desirable to be applied to a consumer product. As for the device that the motor powers which moves the air thru the hair dryer, some common ones seen are axial fans and impellers shown below (Figure 2). All of these designs are protected by an inlet cover to prevent objects from reaching the moving parts. The axial fans are the most common types in hairdryer designs and it works by pulling air thru, parallel to the shaft. The radial impeller on the other hand takes air in, then ejects it in a manner that is perpendicular to the inlet [3][4].

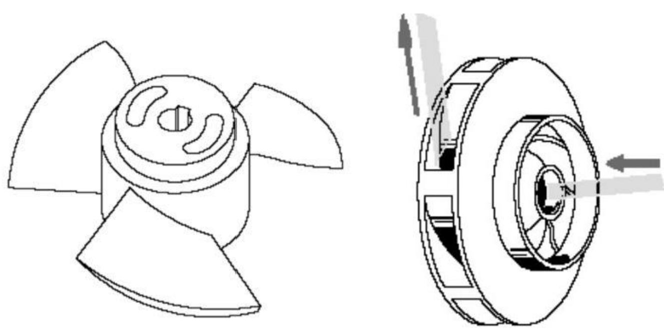

Figure 2: Axial Fan and Radial Impeller

Performing a review of literature of cases where tests were performed to target and improve the noise output of hair drying devices showed helpful in better understanding the problem. Akehmetov et al. [5] examined the noise source ranking of a hair dryer. They focused on using microphone array measurements in a semi-anechoic chamber to record the sound pressure level at distances comparable to those encountered during use. They tested two hair dryers: one normal and one marketed as "quiet". Tests were performed measuring the SPL during operation. They quantified various noise sources by isolating various sound sources by removing components, then measuring again. This included the intake and outlet grill, an air filter and the heating element. Results showed a decreases in SPL for removal of components. An observation they made was for the quieter hair dryer; there was acoustic treatment applied to the interior. Shen et al [6] sought to enhance the performance and the noise of the hair dryer though improved designs to the inlet cover, fan rotor, and stators. They were able to achieve a 9 dBA level of noise reduction while maintaining the same volume flow rate.

This problem of noisy hair dryers has been taken by multiple companies (one of these being Revlon) to produce a “quiet” hair dryer. The “Revlon RVDR5045 Quiet Pro Ionic Dryer” was claimed to be 50% more quiet than the leading brands [7]. Another device is the “Centrix Q-Zone” hair dryer, and it is said to produce roughly 10 less decibels than its competitors [8]. The other is the “Envy + Onyx” made by Velecta-Paramount, which is said to produce only 64 decibels, but with its higher price tag of $300 and its production in Paris, it is not as popular as other models. [9] Both companies suggest that their products utilize advanced noise-cancelling technology. Unfortunately, these companies do not give much more insight into their design improvements as to protect their trade secrets.

2.2 Needs Statement

Existing hair dryers are too loud. Currently, the average hair dryer on the market operates between 80 and 90 decibels. This type of noise can be damaging to one’s long-term hearing and also cause unwanted disturbances to the user’s environment. Currently, the top-performing and quiet hair dryers on the market are upwards of $200. This creates a need for a hair drying device that is both quiet and effective, while also remaining at an inexpensive price point.

2.3 Goal Statement

The goal of this project is to design and build a working prototype of a hand-held hair drying device that significantly reduces the noise output compared to what is currently available on the market; it must also be roughly equal in its effectiveness of drying hair. Along with designing a quieter device, a business model of the manufacturability and marketability of the current design will be done. Ultimately, the final package submitted will include both a working prototype, as well as this in-depth market study.

2.4 Constraints

Team 6 was set with only two restraints: the device needed to be quieter than current hair-dryers, and that the budget for this project is $1500. The product is also being designed for the market, therefore there will be additional constraints, such as being manufacture-friendly and affordable. Some aspects of a hair-dryer design have become a "norm" in most user's experiences. Although, in this case, the user expects a safe and effective heat output, a light-weight product, and an inclusion of all standard safety measure. These, along with other constraints and needs that Team 6 deems necessary, will be listed below to give an overview of where the design is bounded.

- Noise generated must be less than 70 dBA
- Must weigh between 1.5- 2lbs. or less
- Heat of exposed parts may not exceed 115^{o} F
- Maximum size dimensions of 12 x 12 x 4 inches (length x height x width) or smaller
- Must use between 1400-1500 watts
- Must use a Brushed DC motor
- Must use a Centrifugal style blade
- Must include ground fault switch and bimetallic strip for safety purposes
- Must include grill covers on both intake and outtake

Elaboration on some key constraints/ restraints will be given below.

- Budget – This budget will be used for the prototyping and testing of the device.
- Noise Output –a "quieter" hair-dryer constitutes a sound output of less than 70 dBA.
- Weight – The device should not cause struggle or be uncomfortable to hold during use.
- Temperature Output – The device must be limited on the heat that it can produce so it does not burn the user.
- Size – The size of the design should be similar to current products on the market due to a "norm" associated with current hair dryers.
- Safety – Certain safety measures are required to be incorporated in hair dryers based on regulations from the Consumer Product Safety Commission. This includes a means to prevent electrocution from immersion in water [7].

3. Methodology

Team 6 will aim to produce a device that is effective at drying hair and is not unpleasant nor damaging to ones hearing during use. Starting any project from scratch requires a lot of foundation-work and background research in order to determine the best possible method of moving forward. The team will need to determine the type of technology that is used in current hair-dryers, as well as other plausible technologies that could be integrated. The reverse engineering of hair-dryers will also aid in understanding the intricacies of these devices. Other topics of interest to study that will help in design include air flow using fans, acoustics and circuitry. The main focus in reducing sound from the device is to target the highest source of noise; this will be the most effective means at reducing the overall sound produced.

Team 6 constructed a House of Quality diagram (Figure 3) in order to determine the most important customer requirements for the product, as well as the engineering design characteristics, that are most significant. This is important for the team to effectively design around the things that make for a better product. Research that has been done was incorporated into its conception [10]. The top customer requirements were that it must be quiet, dries effectively, and operates safely. The highest ranking engineering characteristics were the air supply source, the type of motor and the speed of the output flow.

		ENGINEERING CHARACTERISTICS							
Customer Requirements	CI	Air Supply Source	Air Flow Rate	Convert Electricity to Heat	Temp Control	User Protection	Electric Supply	Motor	Material Selection
Quiet	10	10	6	0	0	0	0	6	3
Dries Effectively	10	10	10	10	10	0	3	6	0
Ease of Use	6	0	3	6	3	0	0	0	0
Operates Safely	10	6	0	3	3	10	6	6	0
Lightweight	6	3	0	0	0	0	0	3	10
Ergonomic	3	0	3	0	3	0	0	0	3
Variable Heat Settings	6	0	0	10	10	0	0	0	0
Variable Speed Settings	6	6	10	0	0	0	3	10	0
Affordable	3	6	0	0	0	3	3	6	3
SCORE		332	247	226	217	109	117	294	108
Relative Weight		20%	15%	14%	13%	7%	8%	18%	7%
Rank		1	3	4	5	7	6	2	7

Figure 3: House of Quality

Once sufficient background research is done, the team will progress to testing of the components and creating conceptual designs where multiple ideas will be implemented. A hairdryer that is currently on the market and advertised as a quiet hair dryer was purchased and reverse engineered. The team will look to use parts from the purchased hair-dryers in order to reduce prototyping costs; other needed parts will be ordered once designs are finalized. The main components that will be recycled from the purchased hair dryer are the electrical components. The reason for this is that they are very universal in many hair drying devices and do not contribute to the noise produced.

4. Project Updates

4.1 New Data

For any product to be successful, it must outperform its competition in some aspect of design. The goal of the group's hair dryer design is to make it as quiet as possible, with focus directed toward making it quieter than the current top-selling low-noise hair dryers. In order to determine the noise output of current designs, some form of sound testing is required. This was performed by using a microphone in an anechoic chamber. The use of an anechoic chamber is a means to reduce the reflections of noise in the surrounding environment in order to isolate the noise coming from the hair dryer. The current measurements used a microphone from Bruel & Kjaer designed to be used in this free-field environment.

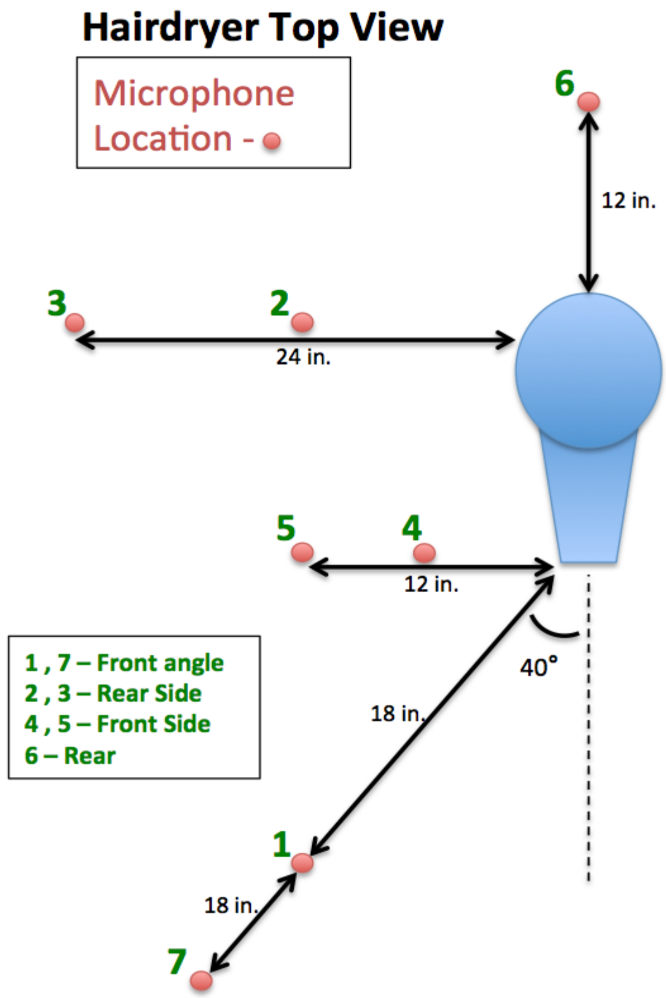

Figure 4: Diagram of microphone testing locations

The experimental setup is shown in the adjacent figure (Figure 4) and shows the position of the measurements that were recorded. All measurements were in the same horizontal plane, at a vertical height that passes thru the barrel of the hair dryer and taken on one side of the device. Measurements were taken at four different locations around the hair dryer; some locations were double the distance. Two different hair dryers were also tested and analyzed. The first was the Centrix Q-Zone brand hair dryer; it uses a forward-curved centrifugal blade design, while the other was made by Revlon, which employed an axial-blade design. The microphone recorded the noise spectrum based on frequency as shown in the figure ahead (Figure 5). The data shows what frequencies are the most dominant in contributing to the overall noise output of the hair dryer. From this information, the group can design a means to remove these noises and reduce the overall sound.

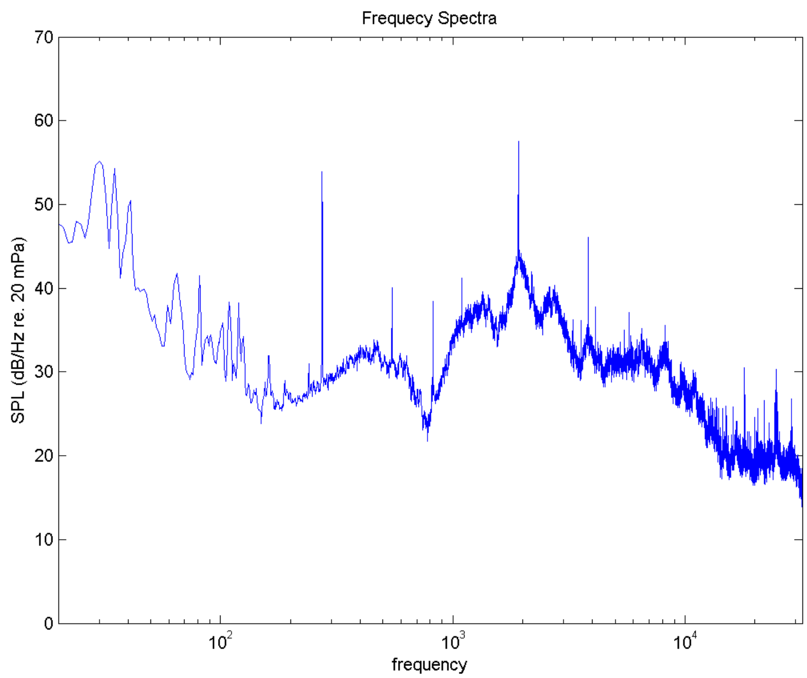

Figure 5: Frequency spectra graph from actual test results

The noise spectra based on frequency can provide insight into where a majority of the noise is coming from, therefore some design considerations can be taken. Observing the noise spectra in the figure, the sharp peaks represent tones where the frequency of noise is very distinct. The left most dominant peak is what is known as the *blade pass frequency* (BPF). The value of the BPF equals the rpm's of the fan, multiplied by the number of blades, which is then divided by 60. This can be interpreted as the frequency where a fan blades pass a certain part of the geometry on this frequency. So knowing the number of blades in the hair dryer it is important with regards to tracking accurate rpm's that the fan is spinning at, depending on whatever speed-setting the dryer is tested on. The other subsequent peaks that occur (towards the right-hand side of the figure) at higher frequencies are *harmonics* of the blade pass frequency that occur at multiples of the BPF. One key discovery in this study was to determine how fast the fans are spinning in the hair dryers. It was then determined that the hair dryer that had the axial-blade fan spun at a much greater speed than that of the forward-curved centrifugal blade fan design.

In conclusion, the axial-blade fan spun at 2,348 rpm, while the forward-curved centrifugal blade fan spun at a mere speed of 534 rpm. This showed an apparent effect on noise production; the centrifugal blade design was, on average, 10 dB lower than that of the axial design. This type of measurement will be used to test our product when ready in the future, and will allow for direct comparison to the other devices.

4.2 New Design of Primary Components

The previous semester's design has been completely modified in order to capture what the team truly desires their prototype to look like. The primary focus for an overall product outlook currently resides with the centrifugal-body style, with the inclusion of an airfoil fan-blade system that is powered by a DC motor; these are the main components which contribute to excessive noise production. By selecting optimal designs for noise reduction, and by altering its geometry, the group was able to construct simple, yet seemingly effective designs.

In the previous semester, the group was able to determine that applying an airfoil fan-blade system would not only provide effective air flow, but also greatly reduce the amount of noise produced by the fan as it rotates at high speeds. Another key point in this selection is that by utilizing this particular fan setup, the motor does not need to operate at a high rotational speed in order to remain effective; therefore, there is a lower amount of noise produced. In the following figure ahead (Figure 6) is the current outlook of the airfoil fan-blade setup with the inclusion of a DC motor and its bracket.

Figure 6: Current airfoil-blade fan design

The other main component that was redesigned was the centrifugal housing that encases the fan and the motor; the fan and motor rests within the center of the housing, and during operation, it rotates in a counterclockwise manner in order to direct the flow from the opening, and out of the nozzle. An image of this arrangement, displayed in solid and hidden-line form, can be seen ahead in the following figures (Figure 7 and 8).

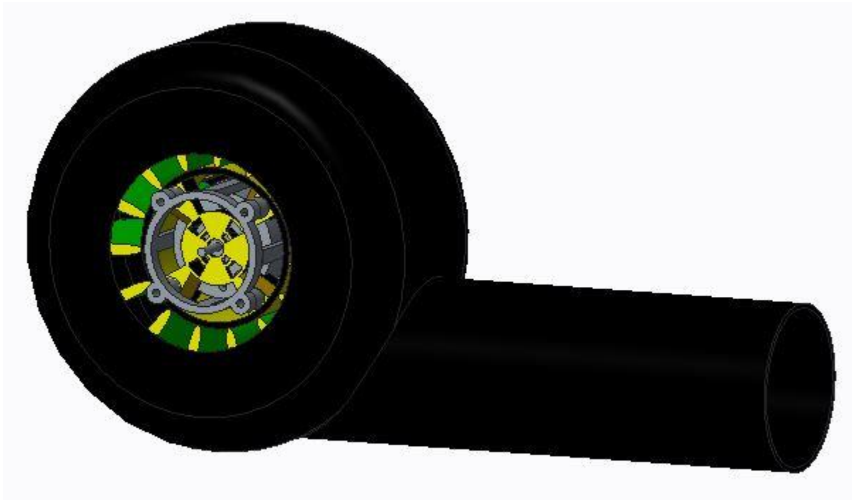

Figure 7: Compiled centrifugal housing with fan and motor in solid form

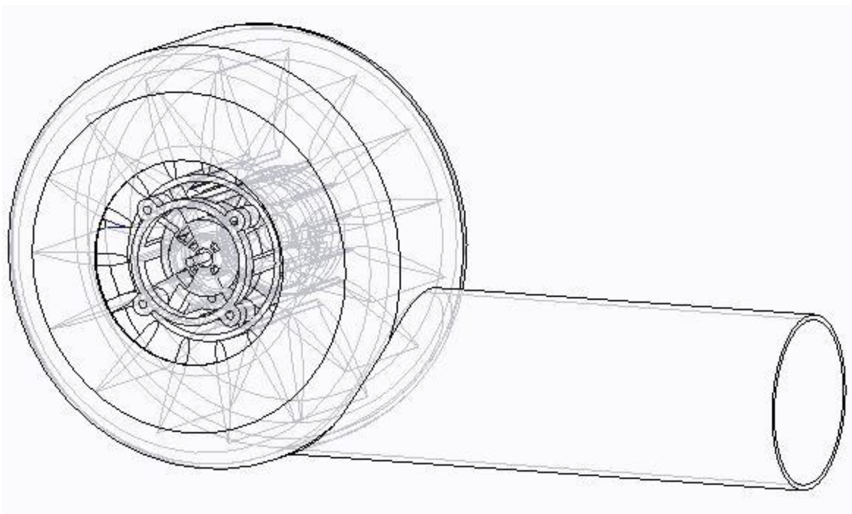

Figure 8: Compiled centrifugal housing with fan and motor in hidden-line form

The previously displayed components need minor refining adjustments, however, those images will closely resemble the physical outcome as the group moves forward into actually creating the physical parts in the following weeks.

5. Entrepreneurial Aspect

This project also acquires the entrepreneurial aspect which serves a purpose, not only to find the solution for the design project, but also to develop a commercialization plan to suit the need for business marketing. Regarding to the problem itself, the main goal is to reduce the noise output that the equipment is producing. The significance of this problem is that the customers were using the product on a daily basis, as it becomes more frequent to them, potentially they will encounter hearing loss or irrecoverable damage to their ears earlier in their lifetime than expected. This raises the concerns which ultimately led engineering students to embark on a task to figure out a satisfactory solution. The idea to encounter this problem is to redesign or alter the components that ranges with the highest of noise that one emits, to the lowest, which should be relatively the least of concern or near redundant. Aside from the in-depth analysis and strategic maneuvering from various logical reasoning to approach closer to the intended solution, fixating on the marketing aspect would be the next goal for the commercialization plan (after the prototype has been fully tested and deemed accomplished). According to the previous senior design group that had performed a statistical analysis of the market (Figure 9), there is no reason to re-analyze the global market, due to the fact that it is steadily increasing by the year, thus leading to more competition between competitors.

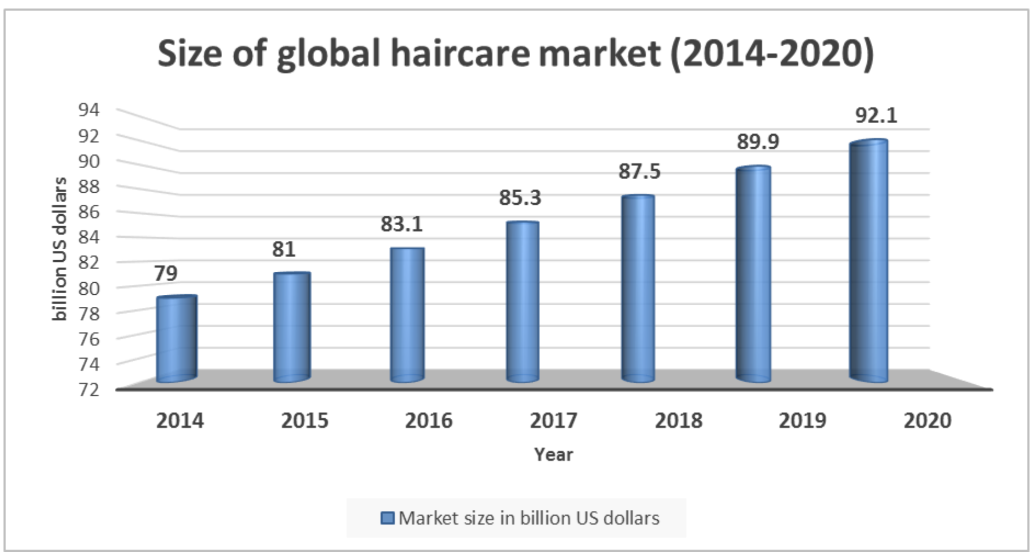

Figure 9: Hair care product market growth prediction by year from multiple major countries

The method that the team will attempt, in order to enter the market, is to ensure their component has attained at least the average efficiency while under the condition of noise reduction. Of course, there are other categories to suit the needs, however the top concerns would be the price range, level of quietness, performance, and power output. The goal in the market is to make the product more successful than the other competitors, varying primarily on the different method and idea that was originally created. It would be preferred to aim for the quiet and inexpensive categories, while being very efficient within the process of hair drying. Determined by the previous business group, the targeted customers are based on: hair salons, individual women, and pet grooming salons. The table listed below (Table 1) reveals the approximate market size varying by population.

Table 1: Targeted customers by the world population

Customers	**World Population**
Hair Salons	307,665
Teens (Female)	402,637,137
Middle Age Women	2,175,918
Elderly women	631,236
Pet Grooming Salons	373,000

To conduct a customer discovery case-scenario, the method would be to survey customers based on the customer list. Though it would not be necessary seeing that it can only be evaluated by the difference between sexes, still the goal is to focus on the customer population. With regards to the population, by advertising and disbursing the group's product would definitely increase a higher chance for customers to consider the group's final product. This stage can also be upgraded by means of online retailing and shipping across continents. Upon waging against competition, there would be the other companies throughout the world that sells a similar product. Based on strengths and weaknesses, the strength would lie more in the region of the main desires rather than main concerns, such as: lightweight, quiet, glamor-level, ergonomic features, power, price, and safety. Considering the weaknesses, often the category would be cheaply designed, expensive, and loud. As for advantages that competitors have on any team that are new in the business, years of experience play a role in the market. Whether as waging with one customer or having a clean and long history with a logo brand, this does not defeat the main purpose, which is to put a product out on the market that is nearly perfect (performance-wise and satisfactory level) with a reasonably low price. Product development is the main source to avoid when dealing with any legal trouble between other competitive companies. Often ideas get stolen or manipulated in a way that had already been done, yet had not been magnified by any social outlet. To avoid these dilemmas, the plan for this team is to gather research data that had been done in the past, and perform background information prior to approaching towards the original goal for this project. Also, the team analysed a few of the top leading competitors' designs so that they can understand the problems more in-depth and construct, test, and compare the newly designed prototype. In order to succeed its first trial, again, the prototype must be designed to be as equally effective yet quieter; later, it can be passed down along the line, such as passing the public safety test and definitely hearing feedback from specific customers. Going into the business with a prototype or finalized design requires precise communication with various dealers when it comes to identity, or any type of business-closure protection. Intellectual property is the heart of every industry, and must remain protected throughout the duration of the company's desire. By submitting a provisional patent, then a non-provisional utility patent to the United States Patent and Trademark Office (USPTO), it will provide the right utility for both domestic and foreign market. The technology involved and the complexity of the invention do greatly affect the quoted price for a patent application. For this reason, examining the possible costs involved in filing a patent would surely benefit the business foundation [11]. Once the main goal of the design project has been accomplished, and is deemed satisfactory by members of the design team, along with advisors, sponsors, and coordinators, this would be the chance to initiate. Diving into business ordeals without protection can result in loss of all working data that was inputted and a total loss for the business.

6. Assign Resources

There are multiple current resources utilized by the group. The first of which is the internet; the group has used this resource in order to obtain and cite publications that are oriented toward the disassembly/assembly and component-comprehension of the hair dryer. The group's secondary resource is their appointed advisor. This individual provides technical supervision and motivational support for the group; his job is not only to provide assistance with possible issues, but also to point the group in a reasonable direction. A ternary resource would be the use of the anechoic lab in the AME building. This testing location will allow the group to perform necessary sound-quality tests of the hair-dryer in a quiet environment. The final resource (the most viable resource) are the actual group members. Mark Johnson is not only the team leader of the group, but also is the individual who delegates tasks to other members, maintains the quality of the group's overall activity and progress, controls the schedule of events, edits final reports, and provides technical engineering support toward the production of the group's project. Peter Van Brussel is the person in charge of financial expenditures, provision of detailed measurement tools, webpage design leader and assistance in technical fluid-dynamics knowledge. Kiet Ho is responsible for providing expertise as one of the two lead mechanical engineers in computer aided drafts and designs for the hair dryer; he also is responsible for including the mathematical support which correlates to the information created and tested via CAD, Matlab, Mathcad, or any other useful software programs. Shawn Eckert is the other leader in engineering designs, but is not limited to just this task; he is also responsible for maintaining communications between the group and the sponsors/advisors/instructors. Nevertheless, each individual in the group is not limited to their specified tasks; all students will provide assistance to each other as needed.

7. Conclusion

In conclusion, the overall problem statement has been properly addressed and partially revised; hair dryers are simply too loud. There are numerous factors which revolve around the source of noise, however either both the intake and exit of the air through the hair dryer have proven to be the most critical points of observation. Numerous studies have supported the previous statement; therefore, it has caught the group's full attention. These studies have also shown other factors involved, and will not be remised.

By applying certain methods, such as the House of Quality table, has also narrowed down the priorities of engineering characteristics versus customer requirements regarding hairdryer selection, along with critical focal points. Also, with the application of a Gantt Chart, the group is able to stay motivated, prepared, and properly scheduled towards upcoming tasks. The group will be creating physical parts regarding the fan blade system and centrifugal housing within the coming weeks, which will later be tested after the connection of the electrical components. Eventually, the outer cover of the hair dryer will be designed and manufactured via injection molding.

In concurrence to creating physical parts for the hair dryer, the group will make further progress into the entrepreneurial side of the overall, end-of-the-semester report. This process may also be further accelerated with the outcome of the upcoming ACC Innovation Challenge, assuming the group is selected as the university's representative.

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Appendix A – Gantt Chart

Task Name	Start	Finish
Add holes for screws and addtl small parts in current design	Mon 1/18/16	Fri 1/22/16
Prep for for 3-D Printing	Tue 1/19/16	Tue 2/2/16
Initiate backup plan if 3-D printing is not sufficient	Fri 1/22/16	Fri 2/12/16
Setup electrical components from existing hairdryer	Sat 1/23/16	Fri 2/5/16
Purchase addtl screws, sound absorbing material, nuts	Mon 1/25/16	Fri 2/5/16
Test motor with new fan and housing	Mon 2/1/16	Fri 2/12/16
Await group selection process for ACC Innovation Challenge	Mon 2/1/16	Mon 2/29/16
Compare new data with previous testing data	Tue 2/2/16	Sat 2/13/16
Purchase switches	Thu 2/4/16	Fri 2/19/16
Design outer cover of hair dryer	Mon 2/1/16	Mon 2/29/16
Make any necessary changes to main components of hair dryer	Mon 2/1/16	Mon 2/29/16
Locate and get quote from injection molding company for outer cover	Fri 2/5/16	Mon 2/29/16
Purchase outer cover	Mon 2/22/16	Fri 3/4/16
Assemble all components of hair dryer	Mon 2/22/16	Fri 3/4/16
Gather new testing information with fully assembled product	Mon 3/7/16	Mon 3/21/16
If selected for ACC Innovation Challenge, ensure product is ready for show and tell	Tue 3/1/16	Mon 4/4/16