NAU Fume Hood

Preliminary Proposal

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DISCLAIMER

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1 BACKGROUND

1.1 Introduction

NAU's Biomechatronics lab would benefit from developing carbon fiber parts in house rather than outsourcing for fabrication. These parts will be vital to creating exoskeletons for people inflicted with mobility impairment. Carbon fiber is hazardous to work with due to the emission of epoxy fumes and fine particles contamination. A previous capstone team has successfully produced an exhauster that we are expected to use as part of our design. A working Lab fume hood would provide a safe and effective environment to cut and sand carbon fiber components while eliminating the threat to human health.

1.2 Project Description

The initial consultation with the client, Dr. Lerner, gave the team initial design parameters and requirements. The fume hood designed should be portable within a building and desktop sized, roughly having dimensions of 4ft wide by 2ft deep by 3 ft long. The flow rate through the hood should be consistent and should not contain any dead zones of stagnant air. Stagnation points could potentially cause a collection of carbon fiber particulates which could present a hazard to those working in the fume hood. A filter was an essential component outlined by the client which will be attached to the exhauster. The filter will collect the carbon fiber particulates, so they are not expelled into the atmosphere by the exhauster. Additional features will be added to the fume hood to increase the safety and effectiveness of the final product. A pressure transducer will be attached to measure the pressure drop across the filter to determine the filter life. A visual display will be mounted to the fume hood to provide operational data to those actively working with the system.

1.3 Original System

The Exhauster already in possession of the Biomechatronics Lab is a 0.5 Hp Baldor Reliance Industrial Motor. This is a single phase with 3450 rpm and a maximum velocity of 395 cfm. The maximum velocity rate is set with 10 ft of hose attached. A neglection of the hose will overload the motor making it un-operational. Airflow will be reduced 5-15 cfm for any feet added to the hose length. A reduction of 15-20 cfm will take place for any 90-degree elbows. The maximum static pressure for this motor is 5.3 inches of water.

1.3.1 Original System Deficiencies

The major deficiency with the current system is the lack of a fume hood attached to the motor. The focus of the project will be to maximize the effectiveness of the motor with the fume hood design. Another system deficiency is the sound at 5 ft from the operating exhauster reaches 72 dBA. The client is not concerned at this time but the team may do additional research to determine if this will present a hazard.

2 REQUIREMENTS

Several consultations with Dr. Lerner provided clear customer requirements which the team was able to relate to engineering requirements. The Biomechatronics Lab needed a portable fume hood to sand and fabricate carbon fiber in a safe manner. There are some safety precautions in place now, but a Lab Fume Hood would be more beneficial and provide greater safety measures. An exhauster was purchased and anything that was to be built must be compatible with existing equipment.

2.1 Customer Requirements (CRs)

- Safe to Operate - The final product must meet all OSHA standards and be safe to routinely use in a lab setting.
- Reliable Design - The design must be efficient and effective. The fume hood will be in regular use and must be in a functioning and reliable state.
- Compatible - The fume hood design must be built around the existing exhauster already owned by the Biomechatronics Lab. The team can not propose changing the exhauster.
- Durable - Materials and filter types must be chosen to be durable, the carbon fiber being removed should not cause severe damage to the fume hood.
- Portable - The fume hood and exhauster should be portable within a lab setting, the design should not be permanently fixed or unable to be moved.
- Combined Weight - The combined weight of the final product should remain under 60 lbs.
- Filter Assessment - Filter life readings should be available to lab workers to maintain a safe operational level.
- Eliminate Epoxy Fumes - The fume hood and exhauster should effectively remove the threat of epoxy fumes which can be harmful to human life.
- Remove Fine Carbon Fiber Particulates - The fume hood and exhauster should eliminate the threat of fine carbon fiber particulates which can be harmful to human life.
- Within Budget - The budget is flexible but should remain around $400. Client updates and communication will be necessary in determining the final budget.

2.2 Engineering Requirements (ERs)

The client clearly specified the dimensionality of the fume hood. The volume, weight, usability and maneuverability of the device were numbers given to us by Dr. Lerner. The volumetric flow rate and air velocity were determined through research of the exhauster given to us. The durability is based on existing fume hood designs and the material strength of plastics used currently. The pressure drop, filter assessment, and particulate capture are all determined experimentally and through independent research of the team. Engineering requirements are tabulated in table 1 below.

Table 1: Engineering Requirements

Engineering Requirements	
Requirement	Units of Measure
Dimensionality	2x4x3 feet
Weight	< 80lbs
Volumetric Flow Rate	300-395 CFM
Air Velocity	4000 FPM
Pressure Drop	< 2 kPa
Maneuverability	Transportable within building
Durability	200 Kpsi
Filter Assessment	Seconds
usability	Compatible with EBR 50 Exhauster
Particulate Capture	0-80% Max capacity (lb/ft^3)

2.3 House of Quality (HoQ)

Our house of quality helped this design team to focus in on the necessary customer needs and engineering requirements that provided the best solution to this project. We were able to determine what customer needs correlated to our engineering requirements. With this data we determined the rank for each category within the design project. From figure 1 we determined that particulate fume capture was the most important customer need as it related to our engineering requirements. This ER alone nearly doubled in absolute technical importance to the other ERs.

FUME HOOD (HoQ) **Customer Needs**	**Weight**	Volumetric Flow Rate (CFM)	Device manuverability/portability	Dimensional area (ft^3)	Weight (Lbs.)	Ventilation velocity (ft/min)	Particulate Fume Capture (lb/ft^3)	Useability	Filter change assessment time (seconds)	Pressure Drops across device (kPa)	Durability/Fracture toughness (ft-lb/in^2)
1. Table Top Fume Hood	5	1	3	5	5	3	5		3	3	3
2. Compatible with Exhauster	5	3				5	5	5	3	3	
3. Hepa Filter	4					1	5	5	3	3	1
4. Particulate Export	4	5	1	1	1	5	3	3		3	3
5. OSHA	5						5		3		
6. Reliability	4						5				
7. Minimize Inlet Pressure Drop	2	1				3	5			5	
8. Filter Light Indicator	1								5		
9. Extended Hose	2	1	1		1	1		1		3	
10. Durability	3										5
Absolute Technical Importance (ATI)		44	21	29	31	72	137	59	62	70	46
Relative Technical Importance (RTI)		7	10	9	8	2	1	5	4	3	6
Target ER values		395	N/A	12	80	4000	0.75	N/A	15	<2kPa	N/A

Figure 1: House of Quality

We also noted that pressure drop across the device, including the length of hose was significant for efficient particulate extraction. We hope to maintain a low level of pressure loss within the system to further increase fume exhaustion efficiency. With this table of information, we were able to derive and design quality ideas for a fume hood exhaustion system as explored further in this report.

2.4 Functional Decomposition

The primary purpose of this capstone team is to provide a safe and efficient fume hood exhaustion system for NAU's Biomechatronics lab. This requires the use of a fume hood with compatible exhauster fan which had been pre-purchased in another capstone designation. Our goal for this team is to manufacture and apply prior projects to our current need. We were able to determine the primary functions of the fume hood apparatus to include first containing the toxic fumes and harmful particulates to within the confines of the fume hood, exhausting both the fumes and carbon fiber particulates safely away from the users, and all while maintaining a high level of safety standards which help avoid any possible accident to the user. Figure 2 below depicts our functional decomposition on the overall system level. Our subsystem functional decomposition will be expounded upon further in section 2.4.2.

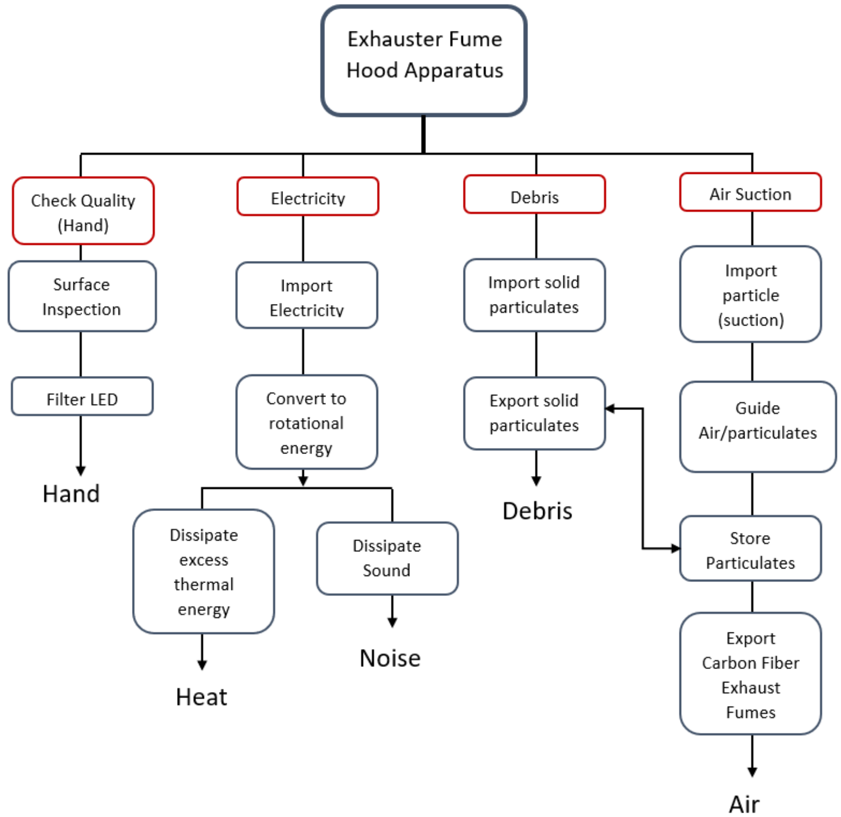

Figure 2: Overall System Functional Decomposition

2.4.1 Black Box Model

Our black box model shows both input and output functions of the fume hood exhaustion system This model relates the functional decomposition inputs and outputs to one another on a simplified basis. It relates the input of materials, energies, and signals to their respective outputs as the system operates. Our signals include a simple on off switch on the exhauster. Energy includes electrical energy provided by the wall outlet. While materials include hands, exhaust fumes, and harmful particulates. This model is visualized in figure 3 below. This model helped the team to visualize the ins and outs of the design project. With this information we were able to further breakdown the system functional decomposition to included subsystems within the apparatus.

Figure 3: Black box model of fume exhaustion system

2.4.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

As mentioned, previously we broke apart our functional decomposition into a full system decomposition and a subsystem decomposition that helped the team better visualize the task at hand. Our subsystem functional analysis model illustrated three different points in the exhaustion system. those points consist of containing harmful fumes and carbon fiber particulates, exporting those harmful particulates, and maintaining an elevated level of safety standards when operating the system. We determined these three subsystems to be vital to the operation and performance of the exhaustion system. Figure 4 typifies our subsystem functional decomposition.

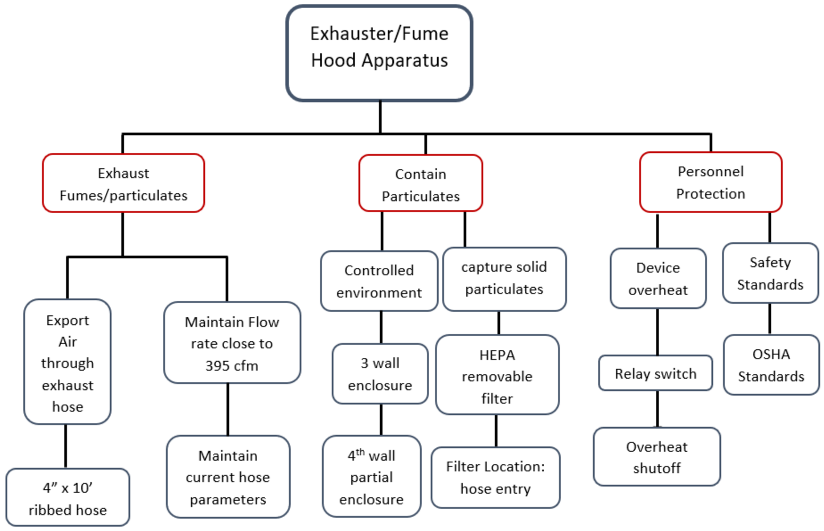

Figure 4: Subsystem functional decomposition of fume hood exhaustion system

3 DESIGN SPACE RESEARCH

[Use this chapter to describe alternative approaches to designing your new or re-engineered system. Sources for this information include existing product descriptions, catalogs, engineering textbooks, the engineering literature, and the internet. Another very important source for some projects, especially (but not exclusively) for process re-engineering projects, is benchmarking or the State of the Art.]

[Put introduction to Ch. 3 here detailing what the chapter contains before leading into Section 3.1.]

3.1 Literature Review

3.1.1 Student 1 (Talal Alshammari)

Talal was focusing on performance curves, which is one of the critical methods in studying the pressure drop and flow rate. The performance curve is represented by plotting the relationship between Flow rate and Pressure Loss. When flow rate increases, the pressure drop increases with a nonlinear relationship [1]. In addition, the performance curves can be used to distinguish between two different. However, they have different pipe size, which are 1 inch and 1.5 inch. The study of performance curve can help us to determine which design is more efficient and which one to choose to fulfill the project's needs. Several exhauster models are designed by Cincinnati Fan; nevertheless, all models were designed using a nozzle of 10 feet long [2]. The exhauster used in this project is EBR-50 which has a flow rate of 395 CFM and a pressure drop of 5.3 water inch [2]. In addition, the cross-sectional area of the nozzle can be related to both the pressure drop and the flow rate in the performance curve. This relationship is presented by:

$$\text{Flow rate} = \text{Nozzle Area} \times \sqrt{\frac{\Delta \text{p}}{\rho \text{air}}} \; [3] \qquad \text{(Equation 1)}$$

3.1.2 Student 2 (Zachary Bell)

Zachary Focused on the air quality and particulate filtration of the fume hood design. The information that was gathered included testing standards, filtration class types, and testing methods. The filter class system is based off of particulate size and categorization of filters that are found in EN 779 and EN 1822 [4]. For the project the filter is constrained to a HEPA style filter which has an efficiency of 99.97% at removing particulates that are .3μm or larger. In addition to this, the HEPA style air filter is limited to air flow between the ranges of .1 to 1 m^3/sec for a single filter [5]. EN 779 has test standards for various types of filters including coarse filters, medium filters and fine filters. These filters are differentiated based on filter test standards before EN 779:2012 [6]. A standard for counting airborne fibers and asbestos particles is very beneficial for the team as this test can be replicated in the fume hood design to ensure the functionality of the device [7]. The filter selection and testing is heavily regulated and specific as to make sure that the user of the device is not at any risk [8].

3.1.3 Student 3 (Shirley Hatcher)

Shirley focused on researching different materials that could be viable options for this project. The material used must be strong enough to make the overall system durable and able to be moved throughout a building. The material selected must be lightweight and chemically resistant. Three common plastics that are affordable, lightweight, and durable are polyethylene, polypropylene, and polycarbonate. The determining factor for proceeding with a material will most likely be cost and availability of the material. Polyethylene is used across all fields of engineering and should be reliable and readily available [9]. Polypropylene is a thermoplastic polymer also in common application and could be used as the material we proceed with [10]. Polycarbonate is another thermoplastic polymer which is highly transparent [11]. A 1/16th in x 4 ft x 8 ft plastic paneling of polyethylene can be purchased locally for under $30 [12]. This would allow us to stay under budget in construction of the fume hood. A Polycarbonate roofing panel is also available locally for around $30 [13]. Either of these materials would be a viable option for proceeding with fabrication.

3.1.4 Student 4 (Bryce Davis)

Bryce focused on the containment and exhaustion of the fume hood design. Information gathered included the most prominent designs on the market today. The top two designs are ducted ventilation hoods and ductless ventilation hoods. This information was gathered from Labmanager, a website that focuses on lab safety equipment [14]. The third design idea came from a lab study from Singapore that studied diverse types of ventilation hoods in high performance low flow circumstances. Engineers in that report were studying the effects of flow rate on several types of fume hoods with the intent of decreasing the fume velocity vortex within the fume hood. This decrease in the vortex allows for a greater exportation of the harmful toxins and particulates [15]. The third source studied that provided relevant information included the proper placement of fume hood ventilation systems within a lab. Proper or recommended locations include locations away from doors, windows, any type of air diffuser, or in locations where personnel do much of their work [16]. The fourth source studied related the particulate size and density to the overall efficiency of particulate capture. The report showed that as particulate size increased the efficiency of capture decreased rapidly [17]. Figure 5 shows this relationship with two different density materials.

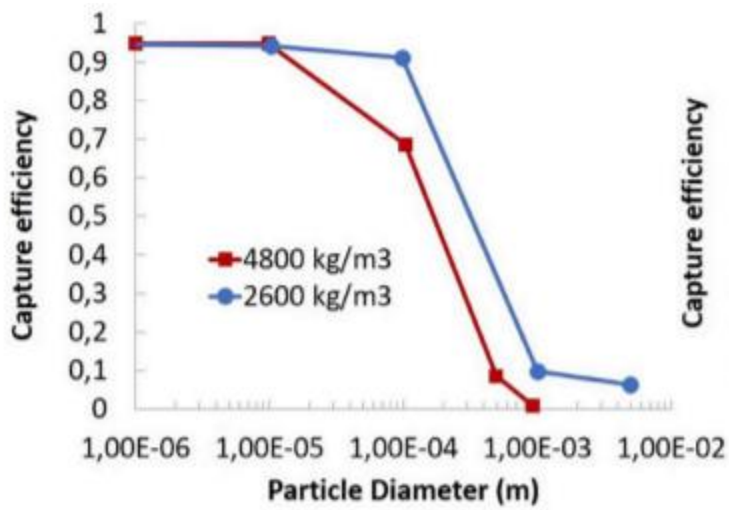

Figure 5: Capture Efficiency for two types of materials [17].

From this experiment the research team determined that particle density had negligible effect on the capture efficiency. The main component of their research explained that particle diameter played the biggest role. Particles with larger diameters fell back to the device floor once suction ceased [17]. Lastly, the fifth source studied on fume hood design focused on fume hood structure and how to avoid re-circulation zones and vortex points within the system. Eliminating these zones, or even reducing them, allows the exhauster to function at a more efficient level and even at a quieter rate [18]. Studies showed that fume hoods with more rounded edges and curves proved more efficient than those with sharp bends. This report also studied the most effective placement of the fume exhauster hose to avoid additional eddied and vortex points [18].

3.2 *State of the Art – Benchmarking*

This Section contains detailed information on the specific aspects of the fume hood design process from a benchmarking standpoint. Our previous literature searches led us to some beneficial information that will be imported into the design process for the most efficient fume hood. We explored benchmarking data with respect to the overall system level and the subsystems that accompany the overall design.

3.2.1 System Level State of the Art – Benchmarking

There are several designs that have been developed for the fume hood, and each design works on a different principle. Comparing the requirements with the existing, design three different existing designs have been found that are related to the current project requirements. These existing designs are operating on three different principles of removing the fumes. It mostly consists of an air inlet system with the pressure nozzle to generate the difference of pressure and will cause the force flow to go out from the exhaust door. In addition, designing on the similar principle which takes air inlet and passes the air out from the exhaust with the toxic fumes is needed in this project. Three existing designs similar to the current project have been presented in the flowing sections.

3.2.1.1 Existing Design #1: In-line Fume Hood

In this fume hood design, all the components are working in a single line to perform the action. It has a bypass with the air foils, and slash pushing from the top side to the bottom side. Then it generates the force in the compartment of the slash with the lower side, which operates at different levels of pressure generator [19]. The design has clearly presented in the following figure.

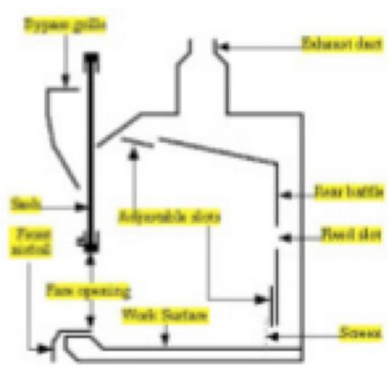

Figure 6: Inline Fume Hood [19]

3.2.1.2 Existing Design #2: Plume Scaling Fume Hood

This is another technique of removing the fumes in which the plume photographic method is used. It has the camera lens which can detect the fumes through the visible surveillance. It starts evacuating the fumes through the air suction method like the normal fume hood, and then it performs the visible emission test to make sure 100% fumes have removed from area [20].The Plume Scaling Fume is presented in figure 7.

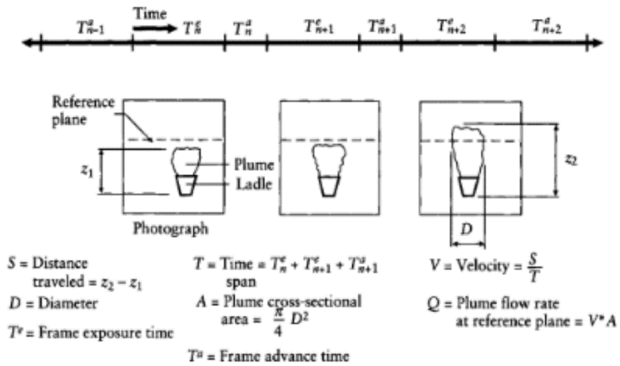

Figure 7: Plume Photography Method

3.2.1.3 Existing Design #3: Low Flow Fume Design

This is another existing design related to the requirement of the project. In this design, the three mixtures have been used are bypass, slash, and baffle airflow [15]. As shown in figure 8, the use of these three cuttings, the design shows a great response, and the resulting area is fully clean in quick time. This existing design has made a short and a high-performance fume hood to be used.

Figure 8: Low Flow Fume Hood Design [15] information and figures.]

3.2.2 Subsystem Level State of the Art Benchmarking

Within the benchmarking data we explored material selection, specifications of air filters, and ways to enclose the fume hood apparatus based on design and efficiency.

3.2.2.1 Subsystem #1: Material Selection

Lab Fume Hoods must be made of durable and effective materials to ensure safe operational standards. While each fume hood can be designed specifically for the hazard being presented, there are some commonalities in methods for choosing a material. Safety is the most important aspect when choosing a material and cost usually determines how safe you can go while staying within budget. The material being utilized in this project is carbon fiber. The following materials are in common practice today and would be effective for our application.

3.2.2.1.1 Existing Design #1: Polyethylene

Polyethylene is a widely used polymer for many reasons. This material is durable, economical, and highly chemically resistant. There are different densities available that can be chosen based on project specification. This is a viable option for the current project as this material would be easily damaged by carbon fiber. For a general density of approximately 955 kg/m^3, the yield strength provided would be roughly 2.7x10^7 Pascals [9]. This would provide a viable option for the fume hood material selection.

3.2.2.1.2 Existing Design #2: Polypropylene

Polypropylene is another common plastic used for fume hoods. This material is available in homopolymer or copolymer composites but the application for the two is essentially the same. Both have a high strength to weight ratio, chemical resistance, and high impact resistance. However, this material is highly flammable. An average density of this material is .9 g/cm^3 with a yield strength of 35 MPa [10]. This material may be applicable to our fume hood.

3.2.2.1.3 Existing Design #3: Polycarbonate

Polycarbonate is a high performance polymer that is lightweight, chemical and heat resistant, and has a high impact strength. The average density is 1.1 g/cm^3 and the yield strength is 65 MPa [11]. Polycarbonate maintains an advantage due to its high fire resistant quality. However, Polycarbonate is vulnerable to hydrocarbon. Testing may need to occur before this material is proceeded with.

3.2.2.2 Subsystem #2: Air Filtration Calculations

Air Filters come in many classifications and each classification has its benefits and downsides for the fume hood project. For the fume hood project the filter class chosen has to be as efficient as possible, be able to remove harmful particulates from the air before being exhausted into the atmosphere, and not create a large pressure drop when a clean filter is present in the device.

3.2.2.2.1 Existing Design #1: Coarse Filters

Coarse filters are a subset of filter classifications that are labeled as having average arrestance in accordance with ashrae dust at final pressure drop of 250 Pa [6]. This type of filter is then further separated down into categories based on the average percentage of arrestance the filter has. These filters are able to capture larger particulates however as the fume needs to be designed with carbon fiber particulates and epoxy fumes in mind a filter that is able to capture smaller particulates.

3.2.2.2.2 Existing Design #2: Fine Filters

Fine Filters are a subset of filter classifications that are categorized as having minimum and average efficiency measurement with an optical particle counter[6]. This type of filter is further categorized in accordance to its average efficiency percent. These filters are able to handle smaller particle sizes but this filter is unable to filter out the epoxy fumes which are dangerous to humans.

3.2.2.2.3 Existing Design #3: High Efficiency Filters

High efficiency filters describe HEPA and ULPA filter types. HEPA filters are able to remove 99.97% of all particulates from air and ULPA filters are able to remove 99.9995% of all particulates from air [5]. These filters are also able to capture extremely small particles with HEPA filters being able to capture particulates sized .3μm or larger and ULPA filters are able to catch particulates sized .12μm or higher [5]. These filter types are what would be best for the fume hood as they are able to catch 99.9% of the particulates from carbon fiber.

3.2.2.3 Subsystem #3: Contain harmful carbon fiber particulates and noxious fumes

This subsystem is the overall basis for the project. If we were unable to contain these harmful particulates or exhaustion fumes the entire system would be classified as a failure. The purpose of collection and containment provides a safe and efficient workspace for working with carbon fiber elements in the Biomechatronics lab here at Northern Arizona University. There are various types of fume hoods on the market today, each with their own specific function. We looked at these various models and compared them to our ideas and strategies. Most fume hood systems on the market focus on a design that creates a capture zone within the system which contains the harmful substances that are being worked with in that instance [14].

3.2.2.3.1 Existing Design #1: Ducted Fume Hoods

Traditional ducted fume hoods focus on removing the air within the structure entirely from the room or workspace. These specific type of fume hoods utilize a mounted exhaust fan or blower that pulls the harmful air and particulates up and through the fume hood and then out an exhaust port that leads outside the room or lab space [14]. Any and all harmful particulates/fumes are exported out and away from the workspace without re-circulating back into the workspace. We expect to use this type of exhaust fan in our design. We have been given an exhauster to work with, the Cincinnati Fan model EBR 50.

3.2.2.3.2 Existing Design #2: Ductless Fume Hoods

Ductless fume hoods have comparable properties to the ducted versions with one major difference. These types of exhaustion systems rely on filters to capture and contain the harmful particulates and fumes and then re-circulates that air back into the system to recapture more particulates and fumes [14]. Instead of exporting the air, fumes, and particulates entirely from the room this type of system recycles the air for repeat usage in the system. We will also incorporate this type of fume hood into our system by applying a filter to the front of the exhaustion hose, before the particulates circulate through the motor. Our system will combine both types of fume hood. Ductless by applying a filter to the front of the hose to capture all particulates and harmful fumes but ducted by exporting all remaining air and smaller particulates to the outside air.

3.2.2.3.3 Existing Design #3: Bypass Concept

One other prominent form of exhaustion systems is the Bypass concept. This concept introduces air from a bypass, typically at the top of the fume hood where the operators face is, and then blows that clean air across the length of the fume hood. This design ultimately works but isn’t the most comfortable or logistical used for the fume hood [15].

4 CONCEPT GENERATION

Four designs were created to fulfill the customer needs and engineering requirements for designing a fume hood. In this section, the four designs will be fully explained and shown their beneficial use. This includes the concept generation of one overall system design with three different subfunctions within the system. each design concept will generate at minimum three distinctive design alternatives for each category.

4.1 Full System Concepts

For the full system design concepts, we looked at various filters and how they would react with our current exhauster fan. We made design recommendations for water, HEPA, and carbon-based filters. Those design processes are made available below.

4.1.1 Full System Design #1: Water Based Filter

In this design shown in figure 9 the exhauster is placed on the top of the fume hood. All the sides of the fume hood are fully closed except for the front panel, which is going to be half open for operation purposes. There are several features included in this design, such as, LED indicating large pressure differences and water-based filter. The advantages of those features are to add more filtering tools to the fume hood when adding a water-based filter at the bottom of the hood. Also, it is improving the safety system by adding LEDs to detect the large pressure drop while the experiment is being done. The main disadvantage of this design is having a water-based filter at the bottom of the fume hood. This can cause a mess when operating during an experiment. Indeed, the water-based filter is one of the designs that can be used to fulfill the project's needs.

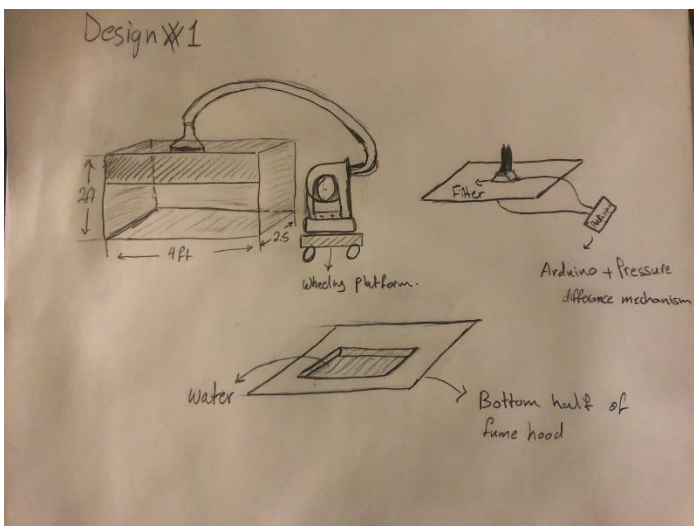

Figure 9: Water Based Filter

4.1.2 Full System Design #2: HEPA Style Filter

As shown in figure 10, the HEPA filter design is similar to the first design structure, since the project's needs are similar in terms of the structure of the fume hood. This design has 3 fully closed sides and one-half open panel for operation purposes. It has LEDs to detect the pressure drop, and also has a pressure difference mechanism. The advantage of using HEPA filter instead of the water-based filter is to prevent some of the mess that the water based filter can do during the experiments on carbon fiber. One of the disadvantages of this design is the cost of the HEPA filter since the project budget is limited to $400.

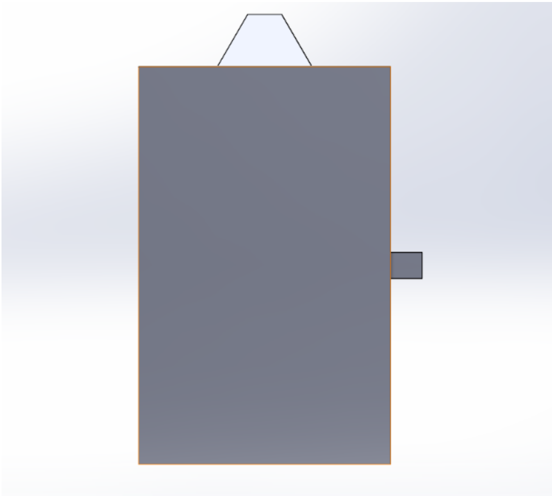

Figure 10: HEPA Style Filter

4.1.3 Full System Design #3: Carbon Based Filter

In figure 11 another fume hood design is presented. This design is using a carbon-based filter. The exhauster is placed on the top of the hood, and it has a full open side of the fume hood. The features added to this design are like the ones before, where it has a pressure difference mechanism, and LEDs to track the large pressure drop during an experiment. The open side is giving an advantage to the workers to have more vision on the working field. On the other hand, having this large open space can be dangerous when exhausting the fumes. Since this project was assigned with a specific exhauster produced by the Biomechanics lab at NAU, the exhausting operation is limited by the performance of this exhauster. therefore, having this open space can affect the safety system of the fume hood that is being designed.

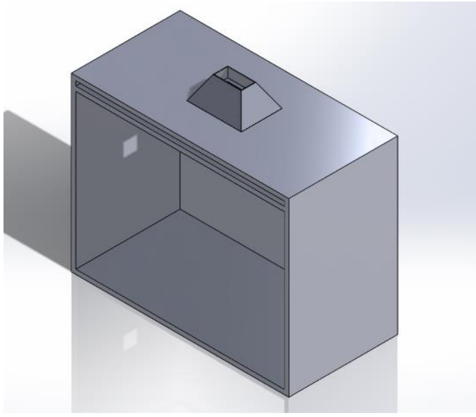

Figure 11: Carbon based filter

4.1.4 Full System Design #4: Carbon Based Filter

In this design, there are four filtered fans attached on the back side of the fume hood as shown in figure 12. The exhauster will be attached at the top of the fume hood. The filters produced in this design are HEPA filters. In addition, LEDs are used in this design to indicate any large drop in pressure. This filtering system is going to produce the best filtering process in the four presented designs. The four fans are going to work to exhaust the fumes in addition to the exhauster used in the other designs. This operation can reduce the danger of the fume produced by the experiment. However, those features are expensive and will be crossing the budget limit of this project.

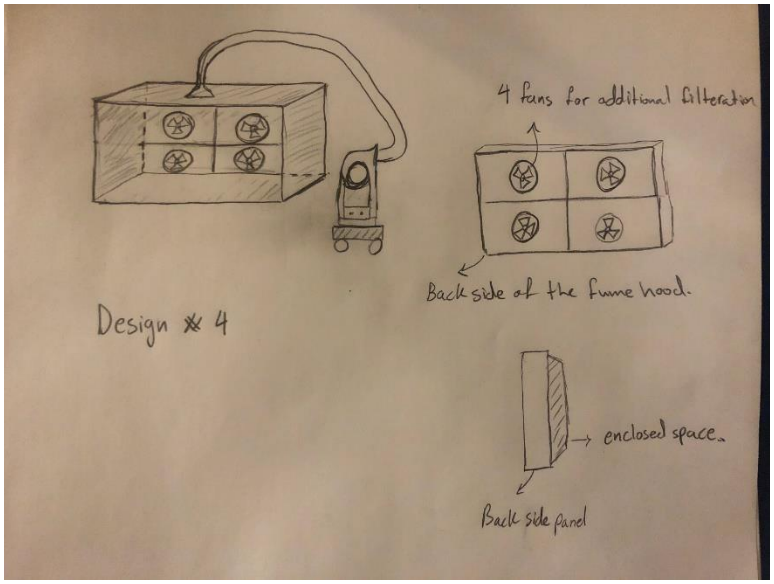

Figure 12: Fan Filtering system

4.2 Subsystem Concepts

Additional system design concepts that are created from expanding upon the varying subsystems and seeing how each subsystem affects the device performance. Each subsystem has 5 additional device designs that are compared to each other.

4.2.1 Subsystem #1: Carbon Fiber Particulate and Epoxy Fume Filtration

The particulates from the carbon fiber and epoxy fumes that are released when shaping carbon fiber is harmful to humans and electrical devices. Because of this a filter that is able to capture the released particulates is necessary as to prevent harm to the exhaust system and the user of the fume hood.

4.2.1.1 Design #1: Coarse Filters

The use of a coarse filter would be able to remove the large particulates from the exhaust. But due to the limitations of this filter type it would cause a majority of the carbon fiber particulates and epoxy fumes to be released affecting the user and other people near the exhaust port. This would result in human harm and a failure of the device function.

4.2.1.2 Design #2: Medium Filters

The use of a medium filter would be better at capturing particulates and epoxy fumes than the coarse filter. Despite these benefits there are still smaller particles that would be released to the user and the atmosphere causing harm. This filter would result in the failure of the function for the device.

4.2.1.3 Design #3: Fine Filters

The use of a fine filter would have the best results of the filters that are not high efficiency filters as it is able to capture the most particulates out of this group of filters. Despite these benefits it is unable to capture the smallest of the particulates which would result in harm for the human user, and particles being released into the atmosphere.

4.2.1.4 Design #4: HEPA Filters

The use of a HEPA filter is the bare minimum for the design as it is able to capture all of the carbon fiber particulates and a majority of the epoxy fumes. However, some epoxy fumes would be released to the operator and the atmosphere in small enough quantities to be considered safe.

4.2.1.5 Design #5: ULPA Filters

The use of an ULPA style filter would be the best for the design as it would be able to capture all of the carbon fiber particulates and the epoxy fumes. The only negative thing about ULPA style filters is that they are really expensive as the cost of a single filter is several times the amount of a HEPA style filter.

4.2.2 Subsystem #2: Remove Carbon Fiber Particulate and Epoxy Fumes

A pressure differential measurement system is being tested and analyzed to use towards the removal of carbon fiber particles and epoxy fumes. The HEPA filter will be attached to the intake of the fume hood flow to collect and neutralize the threat. The filter is being utilized to prevent damage of the exhauster as well as isolate the threat instead of emitting the particles and fumes into the environment. The pressure differential subsystem will provide real time accurate filter readings to maintain a safety standard throughout operation. The following designs are being tested to determine the most effective application.

4.2.2.1 Design #1: 10-bit Analog to Digital Converter

The specifications of the device are a 10-bit analog to digital convertor. The device is capable of measuring -2kPa to 2Kpa pressure difference. Each Volt detected translates into 1 KPa. The Arduino Uno Board will be programmed to read the pressure differences and display an indication light when the filter is becoming full, or adequate airflow is not going through the system. Pros of this set up include accurate real time pressure readings, indication methods, and the cost-effective aspect of this approach. Cons include a permanent display should be purchased to attach to the system and the exact pressure must be determined through experimentation and testing.

Figure 13: Differential Pressure Transducer, Readings

4.2.2.2 Design #2: 16-bit Analog to Digital Converter

A 16-bit ADS1115 with a gain amplifier would provide an even more accurate pressure reading than the 10-bit A/D converter. The 16-bit A/D converter can measure a larger range of signals. It has the ability to boost smaller differential signals to full range to give more precise and accurate readings. Pros of this configuration include highly precise and accurate pressure readings, the ability to output current operational data, and the cost-effective aspect of this approach. Cons include a permanent display should be purchased and mounted on the system, and the exact pressure readings must be determined through experimentation and testing.

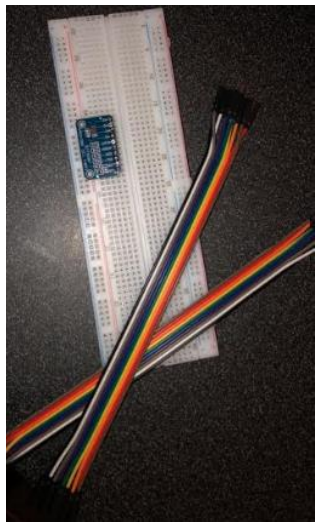

Figure 14: 16-Bit A/D, Breadboard, Jumper Cables

4.2.2.3 Design #3: Dual A/D Chip Converters with Permanent Display

The 16-bit A/D converter can be used along with the 10-bit A/D converter to provide pressure readings more accurately and with more steps. Both devices can be configured with the Arduino Uno board using a breadboard and jumper cables. A permanent pressure gauge can be purchased and mounted to the fume hood for a convenient display of operational safety data. Exact pressure ranges must be determined first through testing and experimentation to choose a specific pressure gauge display. Pros include the prompt and convenient permanent display of the filter functioning and a cost-effective gauge can be chosen. A con of this design is hooking the instrumentation up to the filter correctly after the filter is changed. The team will have to produce a way to conveniently mount all the devices to the fume hood.

4.2.2.4 Design #4: Storage of Fine Carbon Fiber Particles

The Exhauster will provide Airflow through the Fume Hood. The velocity into the exhauster will be sufficient to collect the epoxy fumes and fine carbon fiber particles produced during sanding operations. The outtake airflow can be released back in the environment only if the hazardous materials and by products are being collected and stored safely. A HEPA air filter will be placed at the intake of the exhauster to collect all hazardous materials and by products. If this is done sufficiently, the outtake airflow from the exhauster can be ventilated outside of the building. Pros of this design include the convenience of releasing the outtake airflow outside the building, this is a cost effective and efficient solution, and the exhauster will not be damaged in use if the filter is at the intake. Cons include the exhauster may not be as portable this way, operational safety data should be readily available to avoid emitting hazardous material into the environment, and filter life will be determined experimentally.

4.2.3 Subsystem #3: Particle and Toxic Fume Containment

This subsystem focuses on the overall containment of the carbon fiber particles and noxious fumes that arise when working with the substance. This subsystem directly includes the overall housing and fumigation method for the device and as such requires study and discussion of the EBR 50 exhauster fan and its maximum capacity and efficiency with carbon fiber particulates.

4.2.3.1 Design #1: Pyramidal Fume Hood Shape

As a part of the literature analysis, we were able to determine that the best shapes for a fume hood exhaustion system were those shapes that reduced sharp bends or curves within the apparatus. These sharp bends created vortex eddies and re-circulation points that negated the effects and efficiencies of particulate extraction. We proposed a design that allowed for a smooth transition from all points on the apparatus. This pyramidal shape will allow for a greater suction efficiency by removing most bends in the device. Figure 15 below shows this design idea. Most fume hood design choose to follow this type of design for its extraction properties.

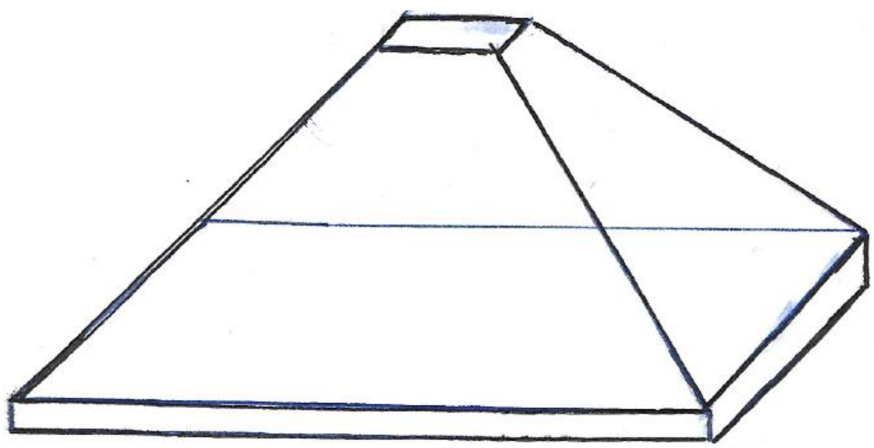

Figure 15: Pyramidal fume hood design shape

4.2.3.2 Design #2: Domed shaped Fume hood exhaustion design

In a similar fashion to the pyramidal shaped fume hood we considered the domed shaped design or figure 16. This design also eliminated the need for bends and sharp curves in the device. However, this design may prove less efficient due to the nature of the curves of the dome as particulates and fumes may be trapped beneath the ceiling of the hood instead of smoothly being extracted away from the workspace. It may also be difficult to bend plastic or sheet metal to a perfect parabolic shape that would increase efficiency in the system.

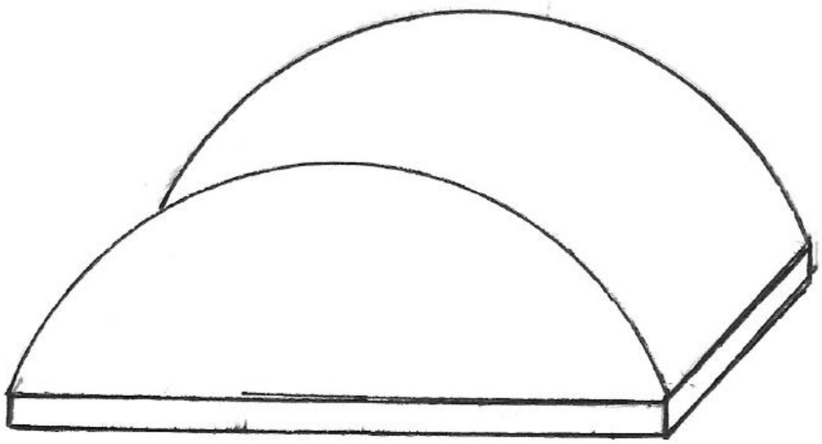

Figure 16: Dome Shaped Design Fume Hood

4.2.3.3 Design #3: Square box with little fume hood extraction point

This square box design seems the least efficient of the proposed design alternatives. This design is a more simplistic design in terms of nature and manufacture. This design takes and enclosure (box) and simply cuts a hole in the top to allow the extraction hose to sit upon. We foresee potential efficiency losses in this design with many of the particulates left uncaptured. We do however intend to use an enclosure with our design, but a flat ceiling may prove less efficient compared to other designs.

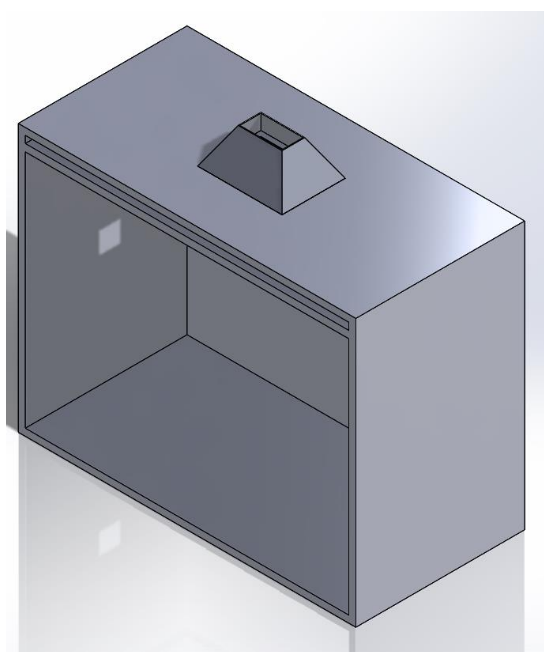

Figure 17: Flat Ceiling fume hood extraction system

4.2.3.4 Design #4: Fully enclosed Fume hood box

The next two design ideas deal more with the enclosure of the fume hood rather than the fume hood itself. We ultimately determined that the best shape for the fume hood would be the pyramidal shape in terms of efficiency and increased suction. For this design idea we took the enclosure design from our CAD model, shown in figure 16, and added a permanent fourth door on the front side of the enclosure. While this design idea keeps all human interaction outside of the fume hood, we considered it to be more of a hassle than not. For this design to work we would need to cut circular holes in the front of the enclosure where hands may be inserted to work with the carbon fiber. This would prove to be more of an inconvenience than a benefit to the system. In the Biomechatronics lab users rely on complete freedom of motion to cut and manipulate tiny pieces of carbon fiber and this proposed design would limit that freedom and maneuverability.

4.2.3.5 Design #5: Partial fourth wall enclosure

Our final design for the fume hood enclosure takes a similar idea from our CAD model and adds a partial enclosure on the front, top half of the open portion of the enclosure. Users would be able to work with complete freedom of motion while also allowing for increased efficiency in particulate capture as most of the enclosure is fully enclosed. The half closure would be of a transparent nature to ensure that visibility is not diminished by the enclosure. The partial enclosure will also be slidable in a vertical nature for increased maneuverability when working within the system.

5 DESIGNS SELECTED – First Semester

This section presents the design selection technique that was done to distinguish the four designs created for this project. It will discuss the criteria used and how it was divided from the most important requirement to the least requirement using a Decision Matrix provided in Table 2. In addition, it will present the top two designs that are possible to build to fulfill the project needs.

5.1 *Technical Selection Criteria*

For design selection, a decision matrix was done to distinguish between the four designs created for this project. The criteria had five main characteristics and requirements that the Fume Hood project need to fulfill. The most critical criterion for this project is filtering system, which has 30% of the total weighting. The filtering system is representing the quality and the quantity of the filters used in each design. The second criterion is safety, which has 25% of the total weighting. Safety is representing the safety features added to each design, such as LEDs for alerting and extra fans. The other three criteria are portability, durability, and cost, which have 15% of the total weighting for each.

Table 2: Decision Matrix of the four-designs created for this project.

		Designs							
		Design #1		Design #2		Design #3		Design #4	
Criteria	Weighting	Score	Total	Score	Total	Score	Total	Score	Total
		1-10		1-10		1-10		1-10	
Filtering System	30%	8	24	8	24	7	21	9	27
Portability	15%	4	6	6	9	6	9	5	7.5
Safety	25%	8	20	9	22.5	7	17.5	9	22.5
Durability	15%	6	9	8	12	8	12	7	10.5
Cost	15%	9	13.5	7	10.5	8	12	6	9
Total	100%		72.5		78		71.5		76.5

5.2 Rationale for Design Selection

From our decision matrix we were able to further derive and design our selected fume hood based on the top two designs. The top two designs selected from the decision matrix shown in table 2 are:

5.2.1 5.2.1 Design #2: HEPA Style Filter

The HEPA filter design has scored 78%. It is the best fit to our project's needs between the four designs presented. This design has scored 8/10 in the filtering system criterion since it is using HEPA style filter and it has only a half open panel in the front side. It also scored 8/10 in the safety since it has LEDs that can indicate any large pressure drop besides the pressure difference mechanism. In the portability, it scored 6/10 since the Fume Hood needs to be hand lifted, and the exhauster is going to be placed on a wheeling platform. Also, it scored 8/10 in the durability criterion since the HEPA filter is the only part that needs to be changed, which has a life time of approximately 5 years [21]. In the cost criterion, it has scored 7/10 since the HEPA filter is the only part that is expensive compared to our budget.

5.2.2 5.2.2 Design #4: Fans Filtering System

The fans filtering design has scored 76.5%, which would be the second-best solution to our project. This design has scored 9/10 in the filtering system, which is the highest score of the four designs. This score was due to the amount of carbon filters used in this design, where there is one on the exhauster side and four more (one for each fan). In the safety criterion, it also has the highest score of 9/10. This high score was due to the features included in this design. In addition to the LEDs and pressure mechanism, there are four fans attached in the back side of the fume hood. Those features have increased the level of safety for the fume hood to get this result. In the portability criterion, it has scored 5/10 due to the weight of the fume hood after adding those fans to it. The durability score for this design is 7/10 since it is using carbon-based filters, which its life time is approximately 2-3 years [21]. In cost criterion, this design has scored 6/10 due to the extra expensive features added into this design, which are LEDs, four fans, five carbon filters.

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