NAU NORTHERN ARIZONA UNIVERSITY
Mechanical Engineering

**Summer Capstone Team 5**
**Laboratory Fume Hood**

To: Dr. Sarah Oman, Dr. Zachary Lerner

From: Talal Alshammari, Zachary Bell, Bryce Davis, Shirley Hatcher

Date: 26 June 2020

Subject: Progress Memo 1

# Introduction

Dr. Zachary Lerner tasked Team 5 with building a Laboratory Fume Hood for NAU's Biomechatronics Lab. The primary objective of the project is to neutralize the threat of carbon fiber particulates and epoxy fumes. Both are common byproducts of sanding operations necessary to fabricate mobility impairment devices. Dr. Lerner specified the fume hood structure must be compatible with the EBR 50 Exhauster currently in possession of the lab.

The first semester of capstone consisted of research and empirical testing to provide a solid baseline for the structure of the fume hood. Throughout our research the team decided on the optimal material, shape, and filter to be permanently implemented into the design. The material chosen is Polyethylene due to its lightweight, chemically resistant and durable properties. It is a common choice of material for fume hood and it is cost effective making it an effective choice. The shape of the fume hood will be a box shape with a pyramidal hood. This was chosen because the exhauster has a single point of airflow being provided through the system. A flat top to the fume hood would cause points of turbulence and stagnation causing the accumulation of carbon fiber particulates. The pyramidal hood would allow the airflow to filter into the exhauster gradually and consistently creating a safe and efficient work environment. The Levoit Lv-h132 HEPA filter was chosen to be attached at the inlet of the airflow provided by the exhauster. This location was chosen because it will remove the carbon fiber particulates before the airflow exits the system through the exhauster. This will eliminate any threat from the particulates to the exhauster. The CAD Model of the final design is displayed in Figure 1.

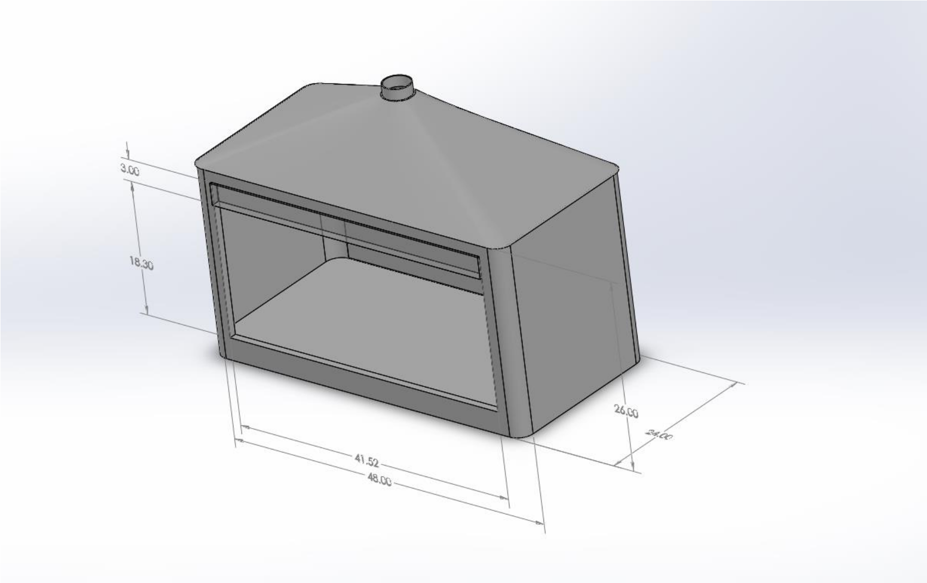


**Figure 1. CAD Model of Current Design**

Research into theoretical testing procedures and numerical calculations to determine the validity of the design are currently in progress. The client feedback changed the team's focus to the pressure differential device which is intended to permanently display the filter capacity as the system is operational. This is done using an Arduino Uno board programmed to read voltages and relate them to the pressure drop. Along with this added device, the manufacturing of the fume hood is being researched to provide clear instructions for fabrication and assembly. The breakdown of the customer and engineering requirements and the relation to the design changes and future goals are outlined below.

# 1. Customer Requirements (CRs)

At the start of the spring 2020 semester the capstone fume hood team met with Dr. Lerner to discuss the requirements and the scope of the project. From this meeting the team was able to get the customer and engineering requirements for the project.

The customer requirements for the device are needing to be safe to operate, reliable, compatible with a blower that Dr.Lerner has, durable, portable, lightweight, be able to indicate the life of the filter, be able to eliminate hazardous material, and within budget. A detailed list about what each customer needs is and more accurately entails is below.

1.Safe to Operate - The final product must meet all OSHA standards and be safe to routinely use in a lab setting.

2.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.

3.Compatible - The fume hood design must be built around the existing exhauster already owned by the Biomechatronics Lab. The team cannot propose changing the exhauster.

4.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.

5.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.

6.Combined Weight - The combined weight of the final product should remain under 60 lbs.

7.Filter Assessment - Filter life readings are available to lab workers to maintain a safe operational level.

8.Eliminate Epoxy Fumes - The fume hood and exhauster should effectively remove the threat of epoxy fumes which can be harmful to human life.

9.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.

10.Within Budget - The budget is flexible but should remain around $400. Client updates and communication will be necessary in determining the final budget.

# 2. Engineering Requirements (ERs)

As a part of our client correspondence with Dr. Lerner he had specified certain aspects of our project that he would like to see in the final submission. His requirements, in terms of engineering requirements, included dimensionality, weight, maneuverability, and usability/compatibility. All other engineering requirements have been established by the fume hood team and are as follows: volumetric flow rate, air velocity, pressure drops, durability, filter assessment, and particulate capture. Our initial engineering requirements have not changed with the exception for dimensionality. With current precautions and circumstances in the world Dr. Lerner has asked us to look into buying a pre-manufactured fume hood in place of designing and manufacturing a fume shell.

## 2.1 ER #1: Fume Hood Dimensionality (Changed)

### 2.1.1 ER #1: Fume hood dimensions 2x4x3 feet Target = 24 square feet (2x4x3 ft)

This engineering requirement is important to the vitality of the project as it is the fume hood shell itself. This is one of the main components to the project. In our research we were able to determine that this size fume hood is compatible with the pre-purchased exhauster fan. Our fan produces 395 cfms and with a fume hood shell this size we are able to use exhausters with up to 400 cfms, recommended.

### 2.1.2 ER #1: Fume hood dimensions 2x4x3 feet Tolerance = +- 0

Dr. Lerner has specified these dimensions for the fume hood shell and therefore we do not require a tolerance for this portion of the project. However, with current circumstances and the desire to purchase a prefabricated fume hood our dimensions could be changed, since we couldn’t find an exact match between our dimensions and current market model fume hoods.

## 2.2 ER #2: Weight < 80lbs

### 2.2.1 ER #2: product weight < 80 lbs. including exhauster - Target = 80 lbs.

One of the main criteria for this project was to provide the Biomechatronics lab at NAU a quality fume hood that was both lightweight and portable. The Biomechatronics lab is currently moving locations and therefore the fume hood would need to be portable until a more permanent location was secured. In our proposed designs, the fume hood shell and the exhauster fan could be transported separately which would reduce the weight of the device at one given time.

### 2.2.2 ER #2: product weight < 80 lbs. - Tolerance = +/- 10 lbs.

Most of the overall combined weight between the exhauster and the shell comes from the exhauster itself. According to the specification sheet the exhauster fan weighs 62 lbs. which equates to roughly 78% of our target weight [1]. With this information we determined that it would be rather difficult to manufacture a fume hood shell that weighed less than 18 lbs. We can reduce shell weight by using lightweight plastic (PVC) however, we were still looking at shell weights of around 25-30 lbs. This left a total combined weight around 90 lbs. As mentioned above, the shell and the exhauster can be separated during transportation and therefore would not be as heavy when transported separately.

## 2.3 ER #3 Volumetric flow rate: 395 Cfm

### 2.3.1 ER #3: Flow rate: 395 cfm - Target = 395 cfm

The exhauster fan specification sheet shows that the EBR-50 exhauster runs optimally at 395 cfms. This flow rate decreases between 5-15 cfm with every foot of extra hose (beyond 10 feet) while also decreasing between 15-20 cfm for each 90-degree bend [1]. We expect to maintain flow rate as high as possible by using the provided hose (10 feet in length) and minimizing bends and losses throughout the system. It is important to maintain high levels of cfms to effectively capture and retain these carbon fiber particulates.

### 2.3.2 ER #3: Flow rate: 395 cfm - Tolerance = +/- 20 cfm

The maximum cfms that can be drawn from this exhauster is 395 cfms but decreases rapidly with each bend, loss, and length of hose beyond 10 feet. We will keep the hose length at 10 feet, but we also expect to lose some flow due to a singular bend in the hose.

## 2.4 ER #4 Air Flow Velocity: 4,000 fpm

### 2.4.1 ER #4: Air flow velocity: 4,000 fpm - Target = 4000 fpm

The exhauster fan specification sheet shows that the EBR-50 exhauster runs with an air velocity of 4524 fpm. We don't expect any major changes with this air velocity in the system.

### 2.4.2 ER #4: Air flow velocity: 4,000 fpm - Tolerance = +/- 25 fpm

While we don't expect any major changes in the air velocity, we do expect a minor loss due to the filter position on the front of the hose. The actual air velocity of the system is 4524 fpm, but we are targeting a value of 4000 as a constant for our design once the filter is installed in the system.

## 2.5 ER #5 Pressure Drops: < 2 kPa

### 2.5.1 ER #5: Pressure Drop <2 kPa - Target = < 2 kPa

A part of our project includes the design and implementation of an Arduino Uno system that reads pressure drops across the system as the filter fills with particulates. This Arduino system reads out filter fullness in kPa as a percentage of the total system. We hope to keep the filter clean and operational to the best of our capabilities without losing pressure throughout the system.

### 2.5.2 ER #5: Pressure drop < 2 kPa - Tolerance = +/- 2 kPa

Our Arduino system will adequately show how full the filter is based on pressure drops within the system. we do expect the pressure to drop as the filter captures particulates. We need to conduct further testing to pinpoint exactly how much the pressure drops as the filter approaches 100% capacity.

## 2.6 ER #6 Maneuverability: Transportable, wide opening sash

### 2.6.1 ER #6: Maneuverability: Sash opening - Target = 18” H x 42” wide

This specific engineering requirement is important because it allows for designs that promote maneuverability and ease of transportation. Another part of this requirement is the freedom of movement within the fume hood shell. The opening of the hood or the sash needs to allow for complete freedom while working with materials inside the hood.

### 2.6.2 ER #6: Maneuverability: Sash opening - Tolerance = +/- 1 inch

Our sash design runs optimally with the dimensions listed above, however, we have room to increase the dimensions by an inch on both width and height. If we were to get much bigger than an inch, we would lose suction capability as the vacuum suction would just run out of the front of the shell. If we were to get smaller in dimensional opening, we would lose the valued maneuverability and freedom to work within the system.

## 2.7 ER #7 Shell durability: 200 Kpsi

### 2.7.1 ER #7: Shell durability - Target = 200 Kpsi

We need our design to be rather durable and able to prevent galvanic corrosion that often accompanies working with carbon fiber. Galvanic corrosion is the process in which two incompatible metals come into contact one with another in a corrosive electrolyte [2]. Since carbon fiber is naturally electrically charged it tends to corrode other types of metal rather quickly. Therefore, we chose to have a durable plastic (polyethylene) which is unaffected by this type of corrosion while also being known for its durability.

### 2.7.2 ER #7: Shell durability - Tolerance = +/- 10 Kpsi

With this design choice we expect the polyethylene to hold up nicely to the harmful effects of the carbon fiber and its particulates. We expect that over time the plastic structure will be susceptible to normal wear and tear from the sharp particulates. This normal wear and tear should only affect the durability of the shell minimally.

## 2.8 ER #8 Filter capacity assessment: 5 seconds

### 2.8.1 ER #8: Filter assessment - Target = 5 seconds

The filter assessment is an important part of the Arduino system in our project. This system helps to determine when the filter needs to be cleaned. We are targeting a value of 5 seconds for the Arduino system to accurately depict filter fullness and then display it on a LED screen.

### 2.8.2 ER #8: Filter Assessment - Tolerance = +/- 1 second

We are allowing for a tolerance of one second in this portion of the system since it will not detrimentally affect the outcome or the usability of the device. We hope that we can get the filter assessment speed to be as quick as possible.

## 2.9 ER #9 Device Compatibility: EBR-50 Fan

### 2.9.1 ER #9: Device Compatibility - Target = 4” hose diameter opening

The hose diameter that accompanies the EBR-50 exhauster fan is 4” therefore we need to have a chimney opening of just under 4”. In our CAD model we built the chimney to have an outside diameter of 3.8” to allow the hose to slide and clamp over the chimney. The chimney is located at the peak of the shell and allows for quick connection between the shell and the exhauster fan. Without this engineering requirement and designation, we would find it difficult to attach the exhauster fan to the fume hood for exceptional particulate capture and extraction.

### 2.9.2 ER #9: Device Compatibility - Tolerance = +/- 0.10 inches

We can accommodate an outside chimney diameter of 3.8 inches with a tolerance of 0.1 inches. The outside diameter of the chimney must be slightly smaller than the 4” hose but must not be too small in the event that we lose air flow from the chimney to the fan. We plan to use a hose clamp on the end of the hose where the two parts connect. Because of this we desire to have the chimney diameter as close to the hose diameter as possible.

## 2.10 ER #10 Particulate Capture: 80% capacity (lb/ft$^3$)

### 2.10.1 ER #10: Particulate Capture - Target = 80% of filter capacity

This engineering requirement typifies the need to monitor and replace the filter when it reaches a capacity of 80%. We chose to have filter replacement at 80% to avoid any overheating or loss of suction at any percentage beyond our nominal value. With the device fully clogged the system would be rendered useless.

### 2.10.2 ER #10: Particulate Capture- Tolerance = +/- 5% of capacity

While we expect the filter to be changed and cleaned at 80% capacity, we understand that it may not happen at that mark every time. We chose to have a simple tolerance of 5% that would still allow for adequate and efficient particulate capture without compromising the effectiveness of the suction.

## 3. Design Changes

The design changes for this project have come from recent client feedback. Once concrete decisions were made in regard to the structure of the fume hood, the client showed interest in a preliminary pressure differential device to display the filter capacity. Currently the team is not in physical possession of this device. However, we have Arduino coding set up to read the differential pressure according to the device provided by Dr. Trevas in the first semester of Capstone. This is demonstrated in Figure 2. The specifications of the device are a 10-bit analog to digital convertor. The device is capable of measuring -2 kPa to 2 kpa pressure difference. Each Volt detected translates into 1 kPa. 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.

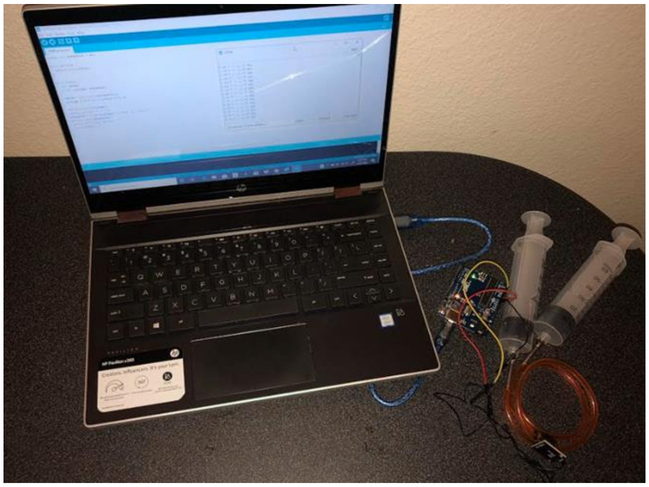


**Figure 2. Pressure Differential with Arduino Uno Board**

Research has gone into expanding this coding and displaying a permanent reading on the pressure drop across the filter. This can be done by using a breadboard and jumper cables to assemble the Arduino Uno board, pressure differential system, and an LCD Display simultaneously. An example of the overall setup is displayed in Figure 3. The client asked for the permanent display to be elegant and effective. A 3D printed cover is currently being discussed by the team as the permanent display shell. This would contain the breadboard and arduino device while showing the LCD display. The entire device would be mounted to the Fume Hood to provide accurate real time readings of the filter capacity.

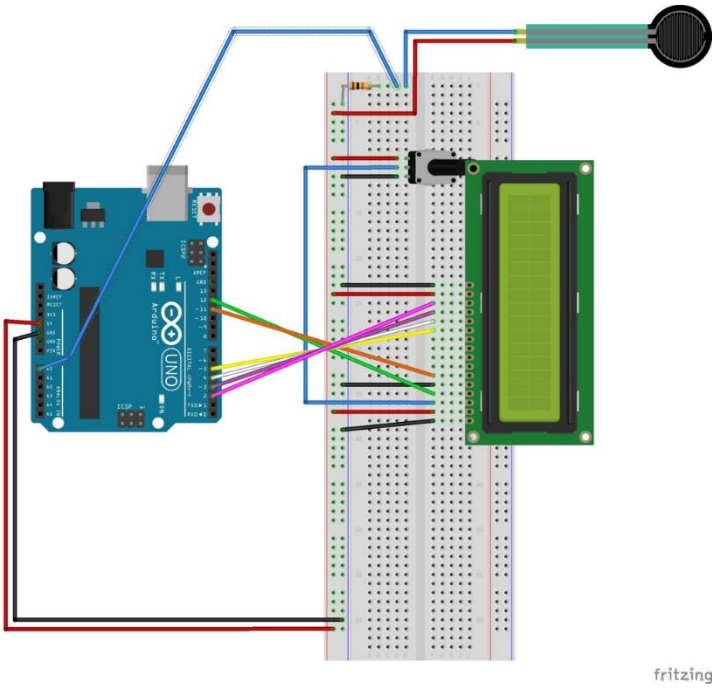


**Figure 3. Arduino LCD Display Example**

## Challenges

There are a few challenges the team is currently experiencing with the design changes. The first is that we no longer have any components to the system described above. The physical system will have to be ordered online and may conflict with the scheduled deadline of the project. The second challenge is the team cannot physically be in the same room to work on or test this addition to the project. One person would have to be entirely responsible for physically assembling, coding, and troubleshooting the system. Once this system is fully functional, testing will have to be done to correlate numerical pressure drop values to the true filter capacity. The system will need to be calibrated and compatible with the specific filter chosen for the project. The team does not have access to the physical filter and will be unable to perform calibration and testing. Once the device is set to the exact specifications of the filter and the numeric values are assigned to the capacity of the filter, the max capacity must be determined and there must be a warning programmed into the Arduino to display on the LCD. The max capacity cannot be determined without testing to determine the minimal adequate air flow that must be achieved at all times through the fume hood. Once all these levels are tested and determined, the pressure drops created by outside variables must be considered as they may cause the LCD to display false information. For example, if the hose on the exhauster is extended or bent it may cause an extra pressure drop the system is not prepared for. Most concerns are specific to this project and must be determined and verified through physical testing. The team can produce a pressure differential system that can read the pressure drops across the filter and assign theoretical numerical values.

# 4. Future Work

This section represents the future team plans for the project design and manufacturing process of the Fume Hood. As the team received new feedback from Dr. Lerner, there are two ways to be considered while we move toward design manufacturing.

## 4.1 Further Design

The manufacturing plans have been changing lately with the client's new feedback. The team now has two different plans to go with toward finishing the manufacturing of the Fume Hood.

### 4.1.1 Purchasing the Fume Hood.

The client's last feedback pointed that the team may buy the fume hood and modify it by focusing on designing an effective mechanism to be attached to the blower and integrating the filter. In addition, he pointed that the team should focus on developing the differential pressure system theoretically and attach this pressure system to the purchased fume hood. The challenges we might face in this path is the fume hood prices. As the budget of this project is $400, it is a huge obstacle to override as the fume hood prices are far expensive.

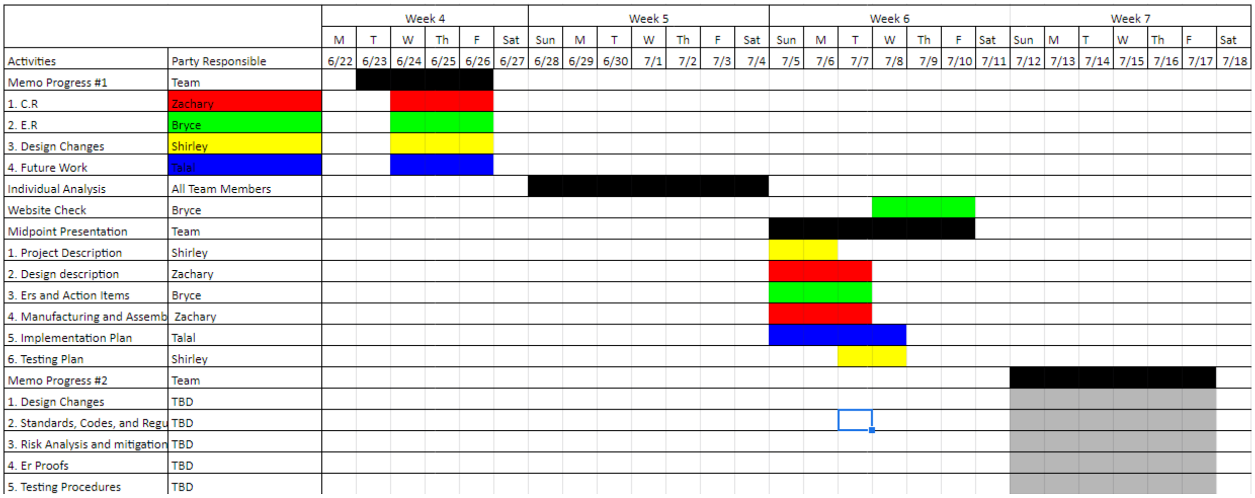
### 4.1.2 Manufacturing the current design.

The team has been working on designing the fume hood structure to be built under the budget provided. The current state of the design shows how the current design is meeting both the engineering requirements and the customer requirements. Proceeding with this design structure is one option to go with if the client proves it.

## 4.2 Schedule Breakdown

The Gantt Chart provided below shows the schedule breakdown for weeks 4-7. The rest of the deliverables need to be assigned and broken down after the client decides one of the two options provided in the manufacturing process. For week 4, memo progress 1 is due on Friday June 26. The team started working on the memo on Wednesday June 24. The work distribution was divided as C.R for Zachary, E.R for Bryce, Design Changes for Shirley, and Future work for Talal. For week 5, Individual Analytical Analysis is due on July 3rd. Each of the team members will do an Analytical analysis related to the Fume Hood project. For week 6, Website check I is due on July 10th. Bryce, who is the website developer, is going to be assigned to finish the task. In the same week, the team will have a midpoint presentation due on Friday July 10th. The work distribution is presented as, project description for Shirley, design description for Zachary, Ers and action items for Bryce, manufacturing and assembly for Zachary, implementation plan for Talal, and testing plan for Shirley. For week 7, memo progress 2 is due on Friday July 17th. The assignment sections are, design changes, standards codes and regulations, risk analysis and mitigations, Er proofs, and testing procedures. Those sections will be distributed as the team moves forward in the manufacturing process.

## Table 1: Gantt Chart



| | | Week 4 | | | | | | Week 5 | | | | | | | Week 6 | | | | | | | Week 7 | | | | | | |
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| | | M | T | W | Th | F | Sat | Sun | M | T | W | Th | F | Sat | Sun | M | T | W | Th | F | Sat | Sun | M | T | W | Th | F | Sat |
| Activities | Party Responsible | 6/22 | 6/23 | 6/24 | 6/25 | 6/26 | 6/27 | 6/28 | 6/29 | 6/30 | 7/1 | 7/2 | 7/3 | 7/4 | 7/5 | 7/6 | 7/7 | 7/8 | 7/9 | 7/10 | 7/11 | 7/12 | 7/13 | 7/14 | 7/15 | 7/16 | 7/17 | 7/18 |
| Memo Progress #1 | Team | | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | |
| 1. C.R | Zachary | | | 🟥 | 🟥 | 🟥 | | | | | | | | | | | | | | | | | | | | | | |
| 2. E.R | Bryce | | | 🟩 | 🟩 | 🟩 | | | | | | | | | | | | | | | | | | | | | | |
| 3. Design Changes | Shirley | | | 🟨 | 🟨 | 🟨 | | | | | | | | | | | | | | | | | | | | | | |
| 4. Future Work | Talal | | | 🟦 | 🟦 | 🟦 | | | | | | | | | | | | | | | | | | | | | | |
| Individual Analysis | All Team Members | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | |
| Website Check | Bryce | | | | | | | | | | | | | | | | | 🟩 | 🟩 | 🟩 | | | | | | | | |
| Midpoint Presentation | Team | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| 1. Project Description | Shirley | | | | | | | | | | | | | | 🟨 | 🟨 | | | | | | | | | | | | |
| 2. Design description | Zachary | | | | | | | | | | | | | | 🟥 | 🟥 | 🟥 | | | | | | | | | | | |
| 3. Ers and Action Items | Bryce | | | | | | | | | | | | | | 🟩 | 🟩 | 🟩 | | | | | | | | | | | |
| 4. Manufacturing and Assemb | Zachary | | | | | | | | | | | | | | 🟥 | 🟥 | 🟥 | | | | | | | | | | | |
| 5. Implementation Plan | Talal | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | | | | | |
| 6. Testing Plan | Shirley | | | | | | | | | | | | | | | | 🟨 | 🟨 | | | | | | | | | | |
| Memo Progress #2 | Team | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| 1. Design Changes | TBD | | | | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |
| 2. Standards, Codes, and Regu | TBD | | | | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |
| 3. Risk Analysis and mitigation | TBD | | | | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |
| 4. Er Proofs | TBD | | | | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |
| 5. Testing Procedures | TBD | | | | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |

# 5 References

[1] Cincinnati Fan, "Operating Instructions & Parts List Fume Exhausters Models EBR and EBM," [Online]. Available: https://www.cincinnatifan.com/manuals/PMEB1207manual.pdf. [Accessed 25 June 2020].

[2] Nace International, "Galvanic Corrosion," [Online]. Available: https://www.nace.org/resources/general-resources/corrosion-basics/group-1/galvanic-corrosion. [Accessed 25 June 2020].

[3] Instructables Circuits, “Arduino Sensors,” [Online]. Available: https://randomnerdtutorials.com/arduino-display-the-led-brightness-on-a-lcd-16x2/