Cooling Humidified Hat for Multiple Sclerosis Patients

Team # 6

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BENG 492-001: Senior Advanced Design Project I

Sponsor: Multiple Sclerosis Patients, and Respiratory Problems Patients

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Executive Summary

The problem that must be solved in this project is concerning patients with multiple sclerosis. These patients are unable to leave the house during the summer as warmer temperatures cause respiratory issues and hot flashes. As of currently, the only solution to this problem is placing a cold vapor humidifier in front of the breathing organs. This is a problem as well as all humidifiers are electric and must be plugged into an outlet to function. A portable cold vapor dispenser will allow these patients to leave their houses even on hot days.

Currently, all humidifiers are electric and must be supplied with constant electricity to function. This is ineffective as these forces patients to constantly be near a power source. The main problem is to create a lightweight portable vapor dispensing device that will allow these patients to have more freedom in their daily life. The needs of the patients are for those leaving their house on a hot day. Thus, what should be considered is a way to address the issue of patients having difficulty breathing and staying out in the heat for too long in patients with multiple sclerosis that will allow for these patients to have more opportunity to leave their houses during hot and humid weather.

The different designs brainstormed for this device include a humidifier scarf, an umbrella, a humidifier hat, and a humidifier backpack. All of these designs met the demands of being battery-powered, portable/easy to carry, and releases cold vapor. In addition, all of them contain a water storage unit and enough battery power to function for an hour. The main differentiator between these designs is stability and convenience. The hat and the scarf both contained unstable pieces. For both the tubing that releases the water vapor is floating; in the scarf, it is in front of the patient's face while in the backpack it is over the patient's head. After consideration, it was determined that these can be easily swayed or broken on a windy day. The umbrella included all the demands however there is already a humidified umbrella in the market. In addition, an umbrella requires the patient to have one hand holding the device at all times. This can cause the patient to be inconvenienced as well as strained. In comparison, the hat provides the best results as it includes all the previous mentioned requirements as well as being hands-free and stable.

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Problem Statement

MS affects roughly 400,000 individuals within the United States in 1975 [1]. Since then, it has been reported that the number of individuals with MS more than doubled in the United States from the 1975 data and has been estimated that 2.3 million people are living with MS worldwide [2]. Currently, there is no known cause for how individuals develop MS; however, there has been statistical evidence showing certain demographics and characteristics can increase one's chances of being diagnosed with MS.

The main problem MS patients face is often being home-bound due to the inability to withstand hot weather. Currently, MS patients are constricted during periods of extreme heat. As a consequence of MS patients being exposed to too much heat, they experience nerve pain and muscle weakness [3]. Furthermore, chances of hot flashes and shortness of breath are likely as well. This is linked to how damaged myelinated nerve cells will disperse signals at a slower velocity [4]. As a result, communication issues arise between the brain and the body.

Presently, methods to lessen the pain caused by MS symptoms have been through medication and therapy. However, with medication, there are many side effects that cause many MS patients with milder symptoms to abstain from them [3]. In regards to therapy, it does not target all of the symptoms faced when patients are exposed to too much heat, such as hot flashes, and shortness of breath [3]. Because of this, there needs to be a way to relieve the pain MS patients face in hot, humid temperatures.

To develop a device that may improve the quality of life for the user, understandings of the device requirements, specifications and metrics should be developed. Also, standards that are found to be in similar aspects will be looked upon.

Requirements/Specifications/Metrics/Standards

Requirements

The key requirements for this project are: creating a lightweight, battery-powered, portable/easy to carry, and safe cold vapor dispenser. In addition, the cold vapor dispenser must be cost-effective, contain a water storage unit and function for an hour. Deliverables can be found in Appendix B that states the components that are necessary for the final product after discussion with our advisor and sponsor.

Metrics

The final model of our project should follow metric standards that result in a reliable and an easy-to-use product. For this product, some metrics are:

- Durability test
- Weight test
- Energy consumption test
- Vision test
- Cooling test
- Comfortability
- Volume test
- Motor power test
- Hat size

Specifications

The cooling humidifier device in this project requires a container to store water which provides for vapor dispenser. Apart from the water storage system, tubing and battery are also the main components of this device. The battery is used to transfer water to a dispenser, and tubing is a way to transport them. The calculation of how long the battery last to power the device for at least one hour will be done separately and can be viewed in the preliminary design section. Calculations will be based on Eq. 1- Eq. 3 found in the design alternatives section of the report. The width of the device should be between 20-25 inches, and the length is between 2-5 inches. Moreover, the weight is between 2-5 lbs, so it can be carried around easily. The device should bring the most comfortability to users, so it cannot block their vision, and it should be hands-free. Specifications were based on current solutions and metrics. A breakdown of each specification for its corresponding metrics can be seen bulleted below.

- Durability test: Should withstand five feet fall.
- Weight test: Should weigh no more than 5 pounds.
- Vision test: Should not impair vision during use of the device.
- Energy consumption test: Should at least last an hour without changing of batteries or inputting more water to the storage unit.
- Cooling test: Should provide cooling to the patient five to ten degrees cooler than the surroundings.
- Comfortability: Should be comfortable for the user for at least an hour.
- Volume test: Should be able to store at least 16 ounces of water, the circuitry, atomizer.
- Motor power test: Does not consume no more than 2 dry cell batteries for operating use of an hour.
- Hat size: No smaller than 21 inches and no larger than 23 inches in diameter.

Standards

From looking through a variety of different standards under the ISO webpage, we have concluded two ISOs that can provide possible constraints to our design. These ISOs include: ISO 20789:2018 and ISO 9360-1:2000.

ISO 20789:2018: Anaesthetic and respiratory equipment — Passive humidifiers

There are several conditions for the ISO standard of passive humidifiers. The definition of passive humidifiers is pass-over medical devices that use water to create vapor to moisture the inspired gas at room temperature. Passive humidifiers should have lower humidification output than active humidifiers. Therefore, their humidification chambers should be at room temperature. The temperature of humidification chambers or the breathing tubes should not increase by heat in passive humidifiers [12].

ISO 9360-1:2000: Anaesthetic and respiratory equipment — Heat and moisture exchangers (HMEs) for humidifying respired gases in humans — Part 1: HMEs for use with minimum tidal volumes of 250

HME is a “device intended to retain a portion of the patient's expired moisture and heat, and return it to the respiratory tract during inspiration” [13]. HME contains a machine port, patient port, and accessory port. These ports are used to connect HME to patients’ respiratory tracts, a breathing system, and an accessory device such as a gas sampling line [13].

Based on the metrics, requirements, and specifications created as well as standards found for a humidifier, three design alternatives were designed as well as a preliminary design. For each design, explanations of the design, and the reasoning why the alternatives feel inferior will be discussed as well.

Design Alternatives

General Design Information

General Materials

All designs require a cooling humidifier that will produce cool mist to the user. Because of this, there are certain materials that are included in all designs developed. Such materials include:

- Mist atomizer[1] [Fig. 1]
- Water storage container
- Battery
- Tubing
- Cotton tubing
- Battery holder
- DC Power Plug

Fig 1. Ultrasonic Mist Atomizer [8]:
The ultrasonic mist atomizer uses sound waves or vibrations converted to mechanical energy to generate the mist at a low velocity [10]. Atomizers may vary from producing mist continuously or in intervals [11]. The atomizer presented in the image produces mist continuously [8]. It requires no high-velocity pressure to develop such mist [11].

This ultrasonic mist atomizer is the component that provides the cooling mist itself. Production of mist is a major component of our design and after considering a few other options, we deemed the ultrasonic mist atomizer as the best option. For more information, please refer to the mist option section.

The water storage container will store the water supply which the atomizer will use. Each water storage varies between each design; however, the storage itself is necessary for the atomizer to function.

Batteries will be what power the device. They will provide the necessary voltage to power the atomizer. It has been decided that the battery used will be three energizer max alkaline AA batteries. They will be held in a battery holder that will have a DC power plug connected to it which will be attached to the atomizer circuit. Battery selection has been made based on the criteria of the atomizer's needs and is further discussed in the battery selection section.

With that said, it is necessary to discuss what other misting options were considered and why the atomizer was the superior option before diving into general equations used and battery selection.

Misting Options

Besides the use of an ultrasonic atomizer for the production of mist, a misting fan and a method to turn water in the atmosphere into liquid water were considered. With regards to the misting fan, water will be outputted in small doses through a mister nozzle as the fan operates [Fig. 2]. As the fan is providing cool air to the user, it would also provide a nice mist to the user's face. However, because of how close the nozzle would be to the user, the mist would most likely not be fine enough. This may cause discomfort to the user by impairing their vision for those who wear glasses. This is due to the water drops building up onto the glasses and there is also a chance, because of this, that the face would be damper than desired. In addition, adjusting the mist rate will be difficult and is necessary to do so as it uses quite some of the water for use. To use the misting nozzle in Figure 2, it takes roughly half a gallon for half an hour [22]. This is not ideal as the user should not feel discomfort from the weight of the device. Thus, the missing nozzle with a fan was debunked.

Fig. 2 Misting Nozzle [22]:
This misting nozzle will produce mist periodically and uses roughly ½ gallons of water for a half an hour of use [22].

Besides the mist nozzle, there was also an idea for developing a way to extract atmospheric water gas and condensing it to make a mist around the user. The problem with this idea is that the scope of developing such an apparatus does not fit the scope of a year-long project. Furthermore, it is uncertain that the device will be light enough for the user to carry without issues. With regards to humidity, if the air is dry, meaning that there is little to no water vapor, such a method would not work as it is dependent on water vapor. Such factors outweigh the advantages it may have with the unnecessary need to carry a water supply.

To conclude, the ultrasonic atomizer would be the best option in comparison to a mist nozzle and a device that condenses water vapor to develop mist. An atomizer can be found in an inch in diameter- excluding the circuit- and can produce cool mist almost regardless of the temperature of the water [8]. Furthermore, the flow rate of the apparatus can be adjusted by changing the voltage input where it should be in a range of 3 volts and 12 volts. By lowering the voltage input, it will also lower the flow rate. Such a design is superior is that it is lightweight and can produce a mist that is on a nanoscale. Unlike the fall found with the mist nozzle, there is a lower chance of the mist hindering the user in close proximity. With regards to the water vapor condenser, the atomizer can be used regardless of humidity as it will need its own water storage like with the mist nozzle. Because it covers the main flaws of both misting alternatives, the ultrasonic atomizer was deemed superior and should be used for our designs.

General Equations

All designs including the preliminary design rely on equations to calculate how much water is necessary for the apparatus to last at least an hour. To calculate the amount of water needed for the design, it relies on the flow rate equation (Eq. 1), and the battery life equation (Eq. 2), [7]. The flow rate can be directly related to the voltage of a circuit [5]. However, in this case, the manufacturer which produces the atomizer we are currently looking at does not provide the information regarding exact current input. From the information provided by the manufacturer, by changing the voltage, it will also change the flow rate of the atomizer [8]. Because of this, the flow rate equation can be experimentally calculated by dividing the volume consumed over how long it took for it to be consumed. For further understanding of the flow rate, a calibration curve will be developed. The calibration curve will pit the time it takes to consume a certain volume with the volume that was consumed. This will be done at a constant voltage value as the flow rate is affected by the voltage input. By doing so, we would have a quicker method to calculate how long it will take to consume a certain amount of volume. Two to three trials will be done for each specified volume and timed each time. The average time will be plotted and a standard deviation will be calculated for precision. We would also most likely make a similar curve for each varying voltage input (x-axis) and the flow rate (for one hour). Again, the average flow rate will be plotted and the standard deviation will be calculated. The voltage input should also be recorded as well as the flow rate will vary with voltage.

Battery life is also relevant for the project as well as it provides us information on how long a battery will last. With this, we will know what battery and how many batteries should be used for the device to last at least an hour span without being turned off. Here, battery life can be calculated by dividing the electric power from its current and multiplying by 70% (Eq. 2), [14]. In this case, the 70% accounts for external factors- including storage life- that may drain battery life [14]. Electric power in this case is the capacity of the battery and its unit is milliampere hours (mAh). Because the units are in mAh for the capacity, the current must also be in milliamps as well. Current in this case is the load current of the circuit where the lower the circuit load, the higher the battery life. For calculating battery life in the preliminary design section, Eq. 3 will be used where it does not include external factors [Eq. 3].

$$\text{Flow Rate} = \text{Volume Consumed} / \text{Consumption Time} \quad (1)$$
$$\text{Battery Life} = (\text{Electric Power} / \text{Current}) * 0.70 \quad (2)$$
$$\text{Battery LIfe} = (\text{Electric Power} / \text{Current}) \quad (3)$$

Battery Selection

The battery chosen for this project was a dry cell Energizer Max Alkaline AA battery. For one, dry cell batteries were considered over wet cell batteries is because they can function in all different directions [16]. They are not sensitive to wet cell batteries where wet cell batteries will cause concerns of leaking [16]. Furthermore, they are found to be very durable compared to wet cell batteries and can hand a long shelf life without losing their charge [16]. AA batteries were chosen as they have a voltage of 1.5 volts. Though this is not a lot, we plan to put three batteries in series having an actual 4.5 volts. We found such a voltage value ideal as we ideally would like to keep the voltage input into the atomizer to be around 3-5 volts. This is due to how a 5-volt input consumed a volume of 15 mL for an hour (flow rate would be found to be 15 mL/hr) despite producing an adequate amount of mist. Furthermore, the mist output was weak enough to soak or provide discomfort to the user. Also, three batteries were chosen over two as we would like to avoid meeting the minimum voltage input in case too little mist is being produced or the actual current load is not enough to power the atomizer.

To conclude, the following designs, including the preliminary designs, will require such basic materials, and equations. The first three designs listed are alternatives and have been rejected based on completing an evaluation matrix and weighing the criteria.

Design #1: Cooling Humidified Scarf

Design Description

A cooling humidified scarf was one of the three alternative designs developed. The scarf will provide mist to the face from below. It is designed where the tubing that mist will contain the mist apparatus may be bendable. By doing so, the angle and direction of the mist may be changed based on user interest. It will be roughly 30 inches in length and contain two pockets that are 10 inches in from each end of the scarf [Fig. 3]. Width-wise, it will be approximately 7 inches. The material of the scarf will be based on cooling towels[2] that are found in the market- specifically the microfiber mesh material-based towels. [Fig. 4]. Such towels provide cooling relief by adding a bit of water and can last at least an hour [6]. This provides direct cooling to the neck area for the user for a long period of time.

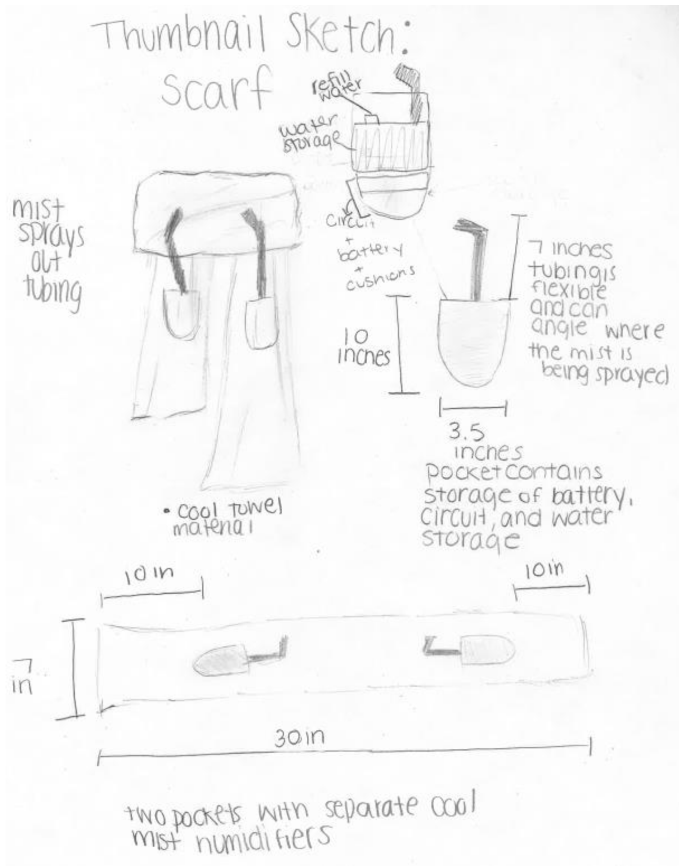

Fig 3. Thumbnail and Multiview Sketch of Cooling Humidified Scarf:
The sketch includes dimensions of the scarf (30 inches long, and 7 inches wide) as well as a brief detail on how the design function.

Fig 4. Image of Cooling Towel [6]:
Cooling towels are generally composed of either polyvinyl acetate (PVA) material or a microfiber mesh. PVA provides a spongy towel when wet and appear stiff when dry. On the other hand, the microfiber mesh will feel soft and light whether it is wet or dry. Both, however, applies the idea of the evaporative cooling whereas water evaporates, the cool feeling on the skin increases [11].

Within each pocket, it contains the battery compartment, water storage, and where the tubing that contains the mister is found [Fig. 5]. Water storage will be found at the above the circuit where there is a small screw-on cap to add or refill water to the storage unit. Water is accessed from the tubing through a different entry point in the water storage where the tubing cannot be removed [Fig. 5]. The tubing itself brings water to the atomizer which is found at the end of the tubing [Fig. 6]. The circuit component is found at the bottom of the pocket encased in a hydrophobic material to prevent damage. The battery is also found with the circuit. To change the battery, the water storage unit can be removed to allow easy access to the battery. Between the circuit-battery component and the water storage system, there is a cushion to reduce the chances of the circuitry breaking [Fig. 5].

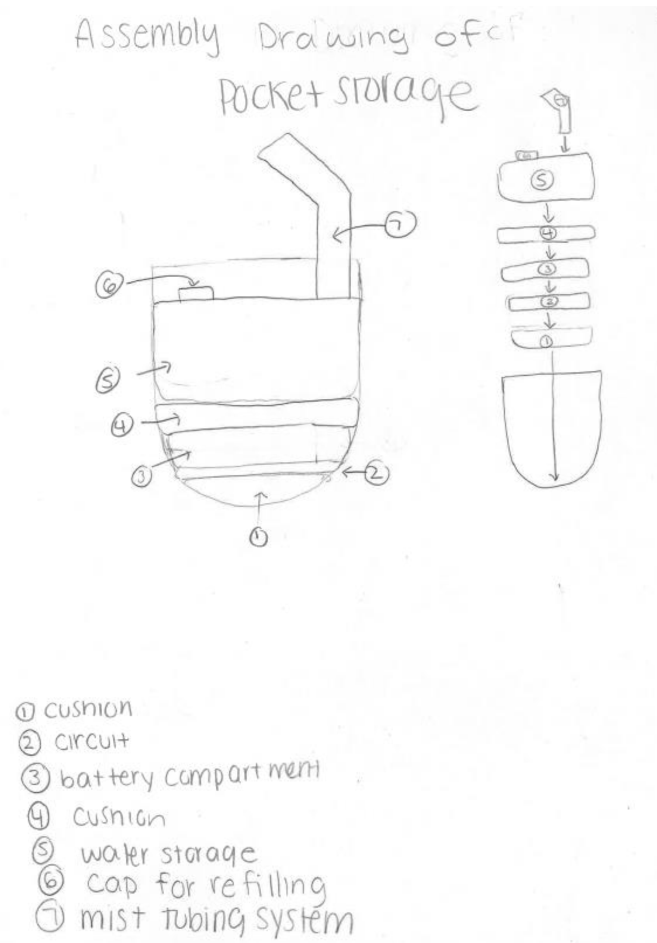

Fig 5. Assembly Drawing of Pocket Storage:
The pocket storage will be having different layers for different components of the system. The pocket will hold the circuit and battery, water storage, cushions, and an entrance for the tubing.

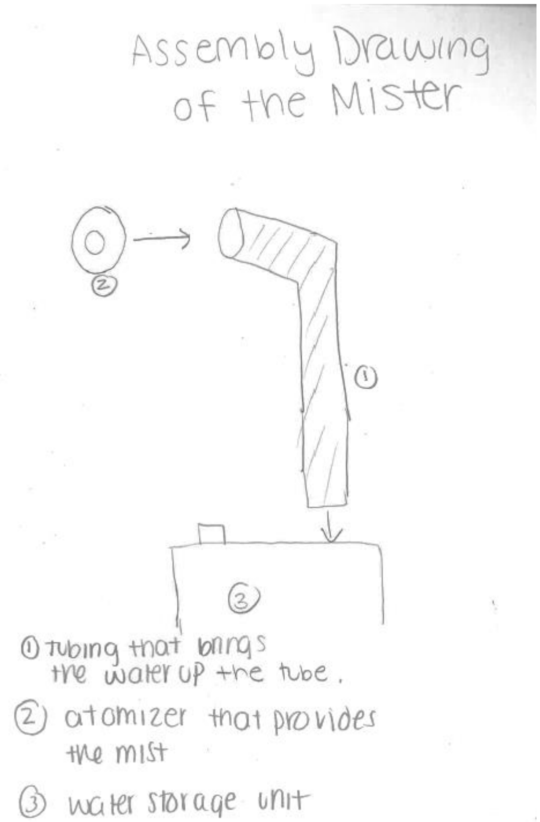

Fig 6. Assembly Drawing of the Mister:
The drawing represents how the tubing apparatus will work. The atomizer will be found at the end of the tubing where the water will go up the tube and reach the atomizer.

Advantages

The cooling humidified scarf is lightweight. With the cooling humidified backpack, the scarf had high compliance and meets the weight demand requirement [Tab. 3, Tab. 5]. The weight distribution is even by having to separate misting units on each end of the scarf and most strain will be found in the shoulder region. However, the strain caused cannot be comparable to the strain caused by the usage of a backpack that carries notebooks, binders, etc. At most, it will be four pounds which is a practical weight an average individual may have on them for at least an hour without too much burden [9]. In addition, it presents a great storage unit where it is compact enough to avoid discomfort for the user but allows all the components to be organized and used appropriately. Lastly, the tubing that is planned to use as a flexible tube that maintains the shape it had been altered to. By doing so, it allows positional and directional changes of the tubing to fit the user's needs or interests.

Disadvantages

The stability of the device is an issue as we cannot control the secureness of the components in the pockets entirely. There is a high chance that component may fall out of place or get damaged in the process. Another disadvantage is that it requires more power to provide mist to the face. This is because the mist would be dispensed from below the face. Because of that, the projection of mist will have to face resistance from both the mesh and gravity. This may pose an issue as the device may not last at least an hour as the voltage input from the battery will need to be increased based on the power equation (Eq. 3).

Design #2: Cooling Humidified Backpack

The second alternative design is the cooling humidifier backpack. This design is similar to a regular backpack except having a cooling device that contains tubing, water storage, and battery inside the backpack. On top of this backpack, there is a small space like a small umbrella in which the cooling mist will be spread out. This space will be considered to be able to fold and put back to the backpack. The general outlook of this backpack will be introduced in Figure 7 and Figure 8.

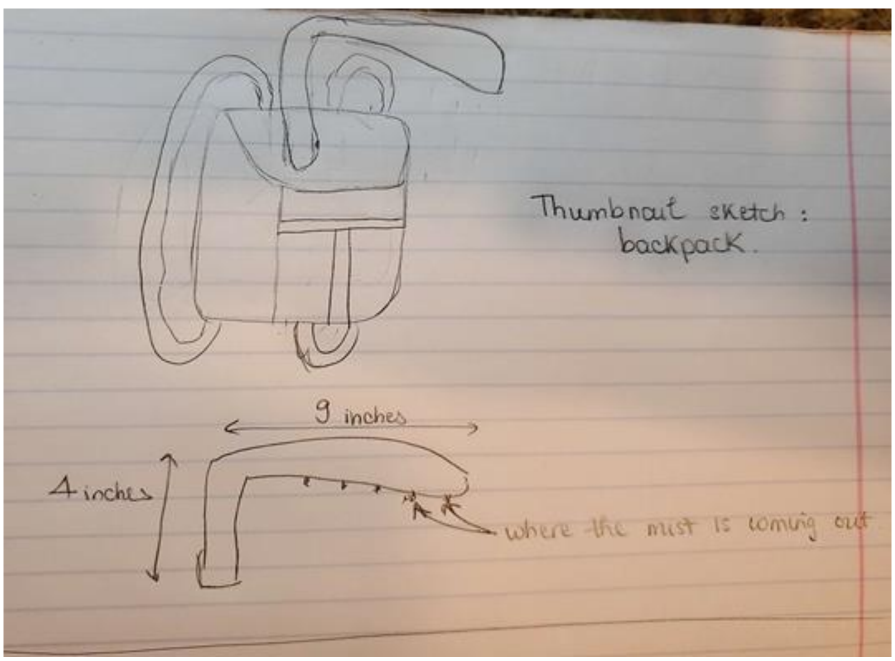

Fig 7. Thumbnail sketch backpack

The figure shows the front and side view of the backpack, and also the location and an overlook of the open space.

The open space on the top of the backpack is around 4 inches height and 9 inches width. Its shape would be a small umbrella so that the mist could be spread out from the top, and cover all the area around people's faces. Underneath it, there would be some vapor holes so the mist can go out nicely and continuously.

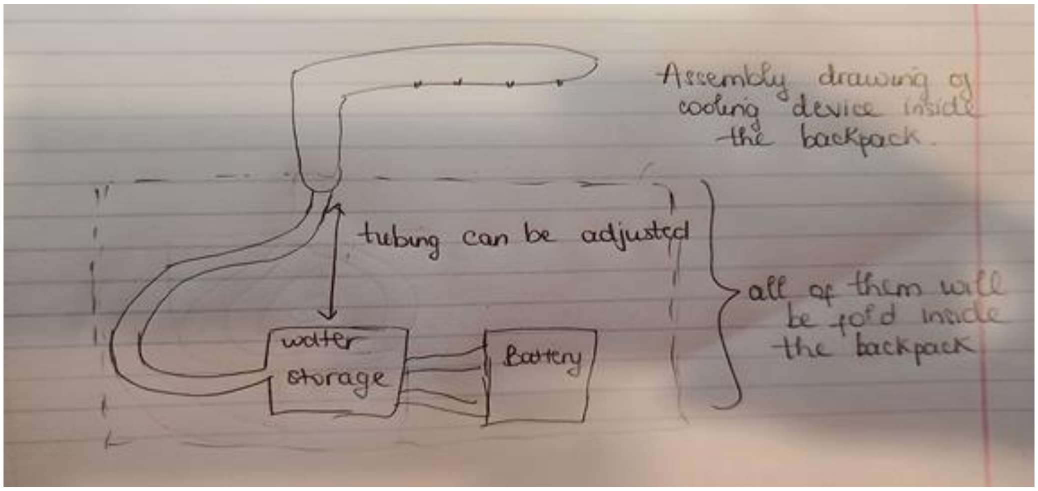

Fig 8. Assembly drawing of cooling device inside the backpack:

The figure shows the arrangement of components of the cooling device: the water storage, tubing, and the battery.

The cooling device inside the backpack will contain tubing, water storage, and battery. It should connect with the open space on top of the backpack. The length of the tubing depends on how big the backpack is because it should long enough to lead the water from storage inside the backpack to the open space. The mechanism of this device is pretty simple. There will be a power button to activate the battery. The battery is used to pump the water from the storage to the open space on top of the backpack through tubing. From the open space, the mist will be spread out through vapor holes underneath it.

Advantages:

The storage of water will be easy to put inside the backpack, and the whole design easy to carry around. There will a separate compartment that will provide storage for the circuitry, and water storage allowing personal use of the bag. Moreover, the device can be transferred to another backpack. If the user is not in need of using the extension, it can be folded back into the backpack. Furthermore, the backpack will be lightweight and any additional weight added into the backpack will depend on the user.

Disadvantages:

When the top is opened, there will be not convenient for customers for going around with this. Moreover, like with the scarf, it will take a large amount of motor power to create the mist. This is due to the water having to be pumped upwards which is going against gravity and as such, increases energy consumption. Because of this, the backpack design is not ideal as the probability of providing enough power to run for at least an hour is low in comparison with other designs.

Design #3: Cooling Humidified Umbrella

The idea behind this product is that, while walking outside the patient can have this product with them which can be used whenever needed. This umbrella will provide a cool environment around them with the help of 8 mist makers spread around the umbrella edges [Fig. 9]. The cool mist will act as a cool environment around the face and the upper chest area. This will help the patients to ease the discomfort caused due to hot flashes and provide cool air for breathing.

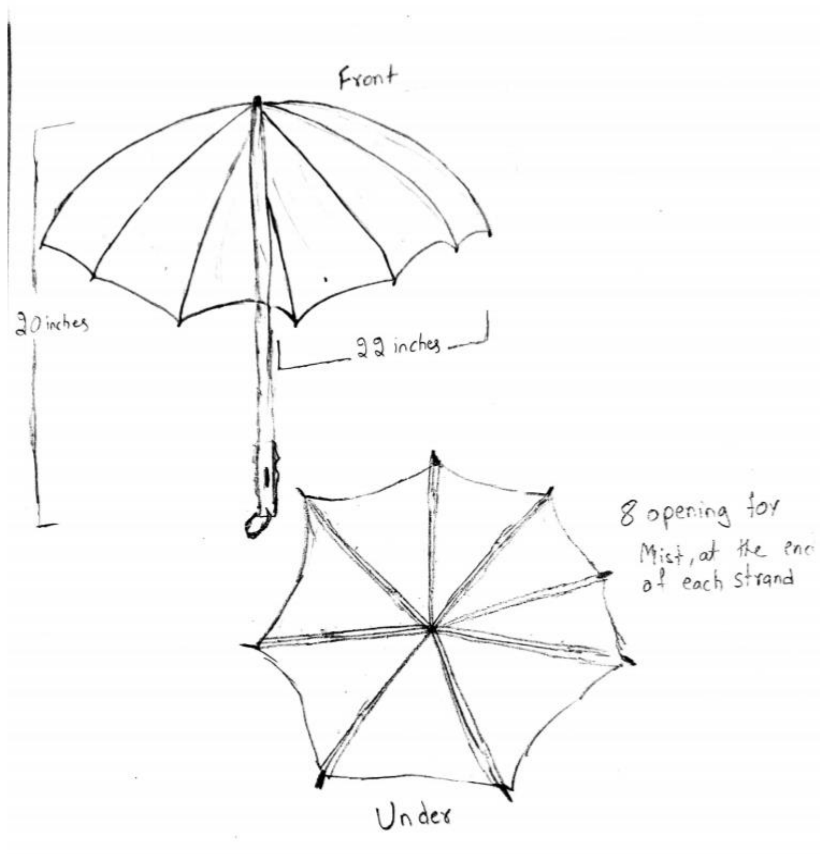

Fig 9. Thumbnail sketch of Cooling Humidified Umbrella:
This figure shows the front and under view of the design.

This umbrella has two main compartments, one the overhead covering and the handle. These components will carry different weights. The overhead will have tubes that will be connecting water storage in the handle to the mist maker at the edges of the umbrella. The mist makers will be set in a direction as shown in Figure 10 so that the cool mist can surround the patient [Fig. 10]. The overhead material will have a waterproof and dark in color cloth with the ability to keep heat out and maintain the cool under the umbrella. This will allow the patients to have shade along with the cool mist.

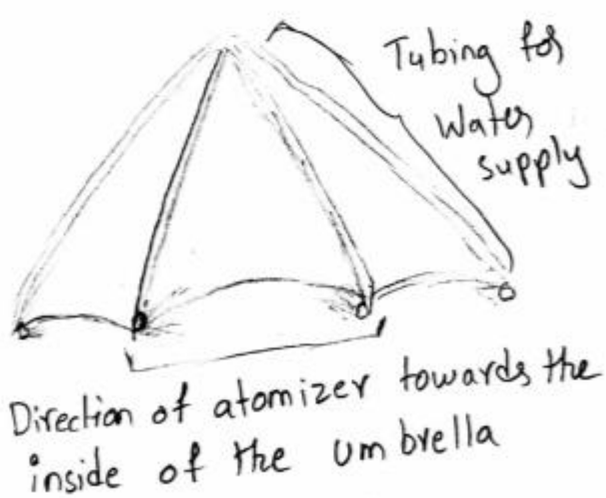

Fig 10. Thumbnail sketch of the humidifier umbrella
This Figure shows the atomizer location on the edges of the umbrella.

The second main compartment is the handle. As shown in Figure 11, the handle is planned to be an empty cylinder made of lightweight metal which will carry both water and power storage [Fig. 11]. The water storage is on the top with a cap to an easy refill for the patients. Here the water storage will have cotton coils that will observe the water, this will reduce the splashing sound that would usually arise from the water storage. A power source is planned to be a rechargeable power bank, which can be charged using a regular USB. The last part of the handle is a button right above the easy-grip, will act as an on-off button for the mist. Once filled and charged the umbrella can work for 45 minutes to an hour.

Advantages

The advantage is that umbrella is planned to be easy to use, with bottle cap opening for the water storage. The removable power bank will allow the patient to easily remove the power bank from the umbrella and charge and replace it back in to the umbrella using the opening in the handle as shown in Figure 11 [Fig. 11]. This umbrella will be cost-efficient by being rechargeable or refillable.

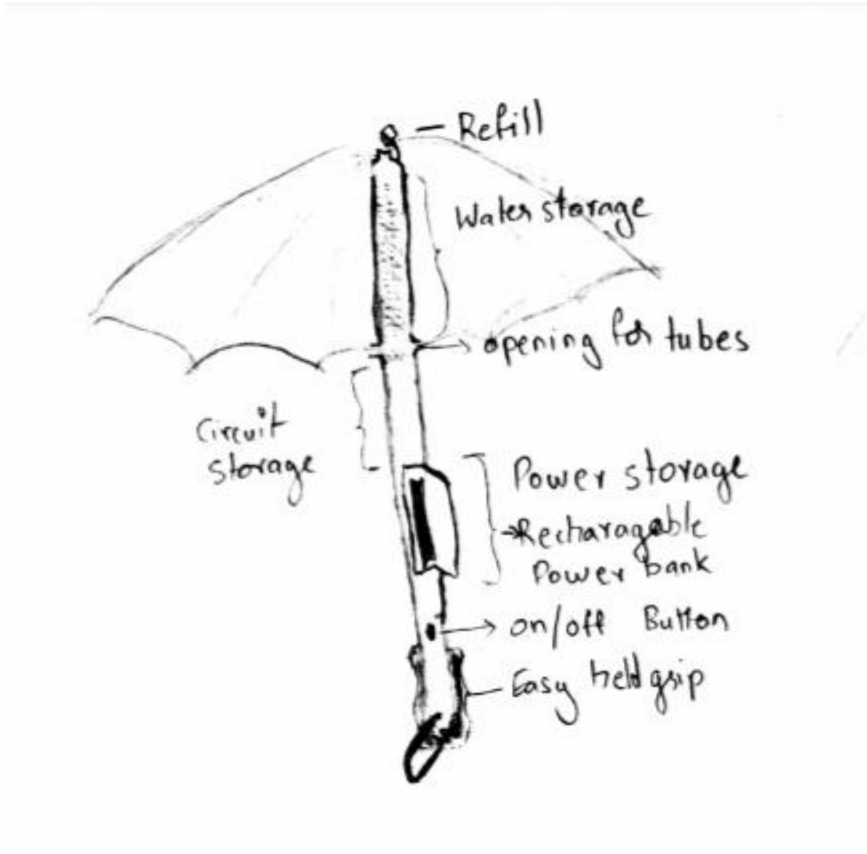

Fig 11. Thumbnail sketch of the humidified umbrella
The sketch illustrates the handle with power and water storage

Disadvantages

Disadvantages of this umbrella are that since it has most of its weight in the handle, the patient will get tried by carrying the umbrella for a long time period. Also, this umbrella will not be able to shrink to an easy to carry size umbrella. The tubing will allow the close but minimize since the umbrella's handle is used as storage. Also, there are many different models of umbrellas with similar function available in market outside the United States.

From these designs, a fourth design was developed and is currently the preliminary design. The design is based off of building a cooling humidified hat where the user would be met with cool mist to the face and receive shade from the hat itself. All four designs were inputted into an evaluation matrix to score and rank the designs based on how well it meets each criterion given.

Evaluation Matrix Breakdown

The evaluation matrix breaks down the decision-making process of the final design. It is broken down into three tables. Table 1 displays the demands evaluation matrix where it determines which device fails the required criteria we had developed. The required criteria include: great storage, unique design, lightweight, stable, and doesn't require a large amount of motor power. Greater storage refers to having enough space to store the circuit, the battery component, the water container, tubing, etc. With regards to a unique design, it refers to the device not having multiple different designs already available to the market. Lightweight refers to the device providing little strain to the patient and stability refers to the unlikeliness the device will have parts or components jostling around. Lastly, the motor-powered amount is important as the design should use minimal motor power to allow the device to last an hour nonstop. What can be seen in Table 1 is an asterisk (*) which indicates that a design may vary in the inability to pass the evaluation based on future design changes to the device. With that said, it can be seen that the cooling humidified scarf has at least two criteria in which it failed to meet [Tab. 1]. The cooling humidified hat is the only design that has a probability to succeed depending on future design changes or enhancements.

Table 1. Preliminary Evaluation Matrix: Demands

Criteria/Device	Cooling Humidified Hat	Cooling Humidified Backpack	Cooling Humidified Umbrella	Cooling Humidified Scarf
D: Great Storage	**x***			
D: Unique Design			**x**	
D: Light Weight				*****
D: Stable		**x**		**x**
D: Doesn't require an abundant amount of motor-powered		**x**		**x**

X = does not meet criteria
***** indicates that depending on design, it may or may not meet criteria

Table 2 indicates the evaluation matrix of the wishes that we hope to have [Tab. 2]. Scoring is based on five being the highest and has a higher chance of the wish being met and one being lowest [Tab. 2]. The two wishes that we hope to see be fulfilled are usability and having the device be cost-effective. Usability refers to the device being used in various situations without issue, including gardening, family events, etc. In other words, it should allow the user to feel comfortable with using it in various events. With regards to cost-effective, the device developed should be marketed and produced at a reasonable price to increase the chances of users to purchase the device. With that said, the cooling humidified hat scored the highest indicating that wishes will most likely be met than with the cooling humidified backpack which scored a three [Tab. 2].

Table 2. Secondary Evaluation Matrix: Wishes

Criteria/Design	Cooling Humidified Hat	Cooling Humidified Backpack	Cooling Humidified Umbrella	Cooling Humidified Scarf
W: Usability	5	2	4	2
W: Cost-Effective	3	1	3	2
Total	8	3	7	4

W = Wish

Criteria scale: Meets Criteria = 5, medium = 3, Barely Meets Criteria = 1

Table 3 indicates a combination of the demand and wish evaluation matrix where the demand has a multiplier of two and the wish has a multiplier of one. Scores listed on each criterion are the scores based on the device matching the criteria scale from one to five. Unweighted scores indicate how well the device fits the criteria where the higher the higher the criteria score, the better fit the device is. The total weighted score listed is based on multiplying each criterion score by the designated multiplier. By summing the score with five being the most compliant and zero being non-compliant, it provides which design is the best fit for this project based on what criteria are deemed with greater importance. Thus, the results are displayed in Table 4 with the cooling humidified hat scoring the highest and the cooling humidified scarf scoring the lowest [Tab. 4].

Table 3. Overall Evaluation Matrix

Criteria/Design	Cooling Humidified Hat	Cooling Humidified Backpack	Cooling Humidified Umbrella	Cooling Humidified Scarf
D: Storage	1	5	3	3
D: design	5	3	1	2
W: Usability	5	2	4	2
W: Cost-Effective	3	1	3	2
D: Light-weight	3.5	5	4	5
D: Stable	4	1	3	1
D: Doesn't require an abundant amount of motor-powered	5	1	5	1
Unweighted Total	26.5	18	23	16
Calculations Including Weighted Scale	(1x2) + (5x2) + (5x1) + (3x1) + (3.5x2) + (4x2) + (5x2)	(5x2) + (3x2) + (2x1) + (1x1) + (5x2) + (1x2) + (1x2)	(3x2) + (1x2) + (4x1) + (3x1) + (4x2) + (3x2) + (5x2)	(3x2) + (2x2) + (2x1) + (2x1) + (5x2) + (1x2) + (1x2)
Weighted Total	**45**	33	39	28

W = Wish; D = Demand

Weight scale: Wish = 1x multiplier, Demand = 2x multiplier

Compliance to Criteria Scale: full compliance = 5, non-compliance = 0

Table 4. Final Results

Rank	Medical Device
1.	Cooling Humidified Hat
2.	Cooling Humidified Umbrella
3.	Cooling Humidified Backpack
4.	Cooling Humidified Scarf

Preliminary Design

Using the design matrix, it was shown that a hat with a built-in humidifier is the best design. This design includes all the demands given by the requirements and the client. These features include convenience, stability, battery-powered, and presentable. This hat uses all the same components as the umbrella however the hat can provide a hand free experience. As shown in the diagram, this hat looks like a regular hat with the addition of water pipes on the brim. The vaporizer will be placed under the brim allowing the vapor to be directed to the client's face. This vaporizer will be connected to a soaked cotton stick which is placed around the perimeter of the crown. There will be a control switch on the brim of the hat that will allow the client to control when the water vapor is being released. In addition, there will be a storage pocket on top of the hat which will contain the battery. This battery will be rechargeable and will be fastened to the hat with a Velcro strap.

In order for the vaporizer to function it requires a constant supply of water. The most convenient way to have this water supply is by connecting the vaporizer to a water-soaked cotton filter stick. This allows for the consistent release of water without the risk of spills. When the cotton runs out of water there will be an automatic shut off. This water supply was tested with different temperatures of water and was shown to provide a cool mist even when the provided water was warmed.

For water storage, there will be a small rubber pipes running across the top of the hat to the cotton filter stick which will be placed in a tube on the crown [Fig. 11]. This will allow for the cotton to be constantly wet allowing for the vaporizer to continuously release water vapor. Also, this will disperse the weight of the water throughout the hat allowing the patient to be more comfortable. These pipes will be interconnected and to refill them there will be a screw lid on one of the pipes. As shown in the calculations below, 15 mL of water is necessary for one hour of continuous water vapor for one atomizer. Using this network of tubes, it will not be too difficult to store the water as 15 mL is not a lot.

The cotton filter sticks will need to be replaced every 3 months. To replace the cotton, unscrew the middle pipe and remove the old cotton. Then place the new cotton inside the tube, it should easily slide in. Finally screw the pipe back into place, making sure it is securely tightened in order to prevent leakage.

For this hat, a breathable evaporative fabric will be used and the brim of the hat will be 2.5 inches to allow for sun protection, this will keep the facial area even cooler in addition to the water vapor.

The hat will come in 3 different sizes, small medium and large, depending on the patients head size, ranging from 21 inches to 23 inches. The prototype for this hat will be made to fit our client. Calculations will for battery life and the flow rate can be seen below.

Calculations:

It was shown during testing that running the vaporizer for one hour used up 15 mL of water. This was used to find the flow rate (15 mL / 60 minutes) = 0.25 mL/min and is based on a 5-volt input [Eq. 1].

It is given that the atomizer uses between 3-12 volts and 2.5 watts for max voltage input. During the testing the input voltage to the atomizer was 5 volts. It was decided that this is the best voltage for the product as it provided a constant stream of cooling water mist while also not causing the users face to be wet. For a voltage input of 5 volts, the power would be approximately 1.50 watts. Using this the current was calculated to be (1.5 watts / 4.5 volt) = 0.333 Amps.

Using equation 3 from the design alternative section, battery life was found [Eq. 3]. The battery used for this calculation is an AA Energizer battery and the electric power used by one AA Energizer battery is 1150 mAh. The Battery life is (1150 mAh/ 3330 mA) = 0.34 hours [Eq. 3]. This means that with one atomizer one AA energizer battery will last for 0.34 hours. In addition, one battery is 1.5 volts, for this design we will use 3 batteries to make sure the input voltage is 4.5V. The updated battery life is $0.34\ hours\ *\ 3\ Batteries$ = 1.03 hours.

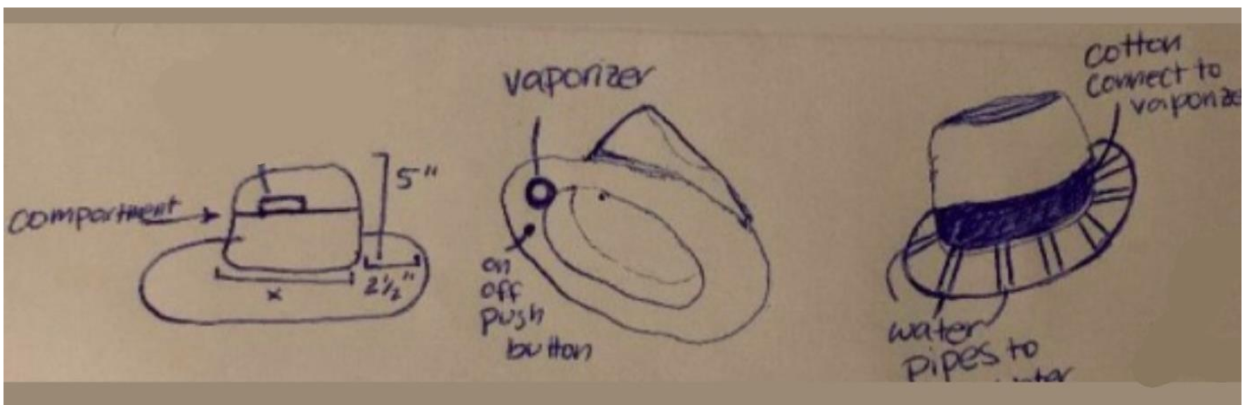

Fig 12. Preliminary Design (cooling humidifying hat):
The design shows measurements and components.

As shown in the design alternative section, the equations necessary for the execution of this device include flow rate, power, energy consumption, and voltage. These equations are used to calculate the necessary sizes of the different components. The flow rate equation shows that in one minute the atomizer uses 0.25 mL of water this means that in one hour, 15 mL of water will be needed [Eq. 1]. The atomizer shows the input voltage needs to be between 3 volts to 12 volts. Picking a middle ground of 4.5 volt it was decided that 3 AA batteries will be used. The battery power equation provides information to find how long the DC battery will function with the current given by the atomizer. 3 AA batteries will be enough to last at least an hour.

From here, a breakdown of future major milestones was developed through Gantt Charts in the following section. This will provide an overview of what steps will be taken to develop the cooling humidified hat.

Gantt Chart

Gantt Charts were created to indicate the major milestones for the senior design project this semester. The major milestones were split into four Gantt charts labeled as: opening, requirements, preliminary and critical. Each Gantt chart displays the range of dates of which each task is worked on as well as the designated individual who will be leading the task. Asterisk (*) represents that everyone will be working on the assignment and the assigned name is the lead for the assignment.

The preliminary Gantt chart displays tasks that are composed of setting up groups and project selection process [Fig. 13]. All duties have since been completed and were tasked out to all members. Secondly, the requirements Gantt chart displays the first set of work in relation to client interviews, research, and the writing and presenting of the requirement review draft [Fig. 14]. The third Gantt chart is known as the preliminary Gantt chart where tasks that are related to preliminary designing process is located [Fig. 15]. Lastly, the critical Gantt chart represents the different tasks that are in relation to the critical design as well as the inclusion of material purchasing [Fig. 16]. Each Gantt chart represents the different phases for this semester and are subject to change depending on the situational factors.

Fall 2019

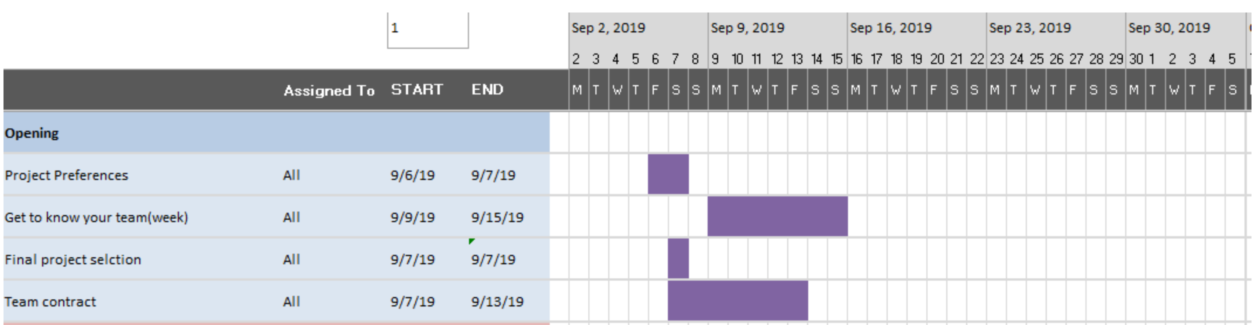

Fig 13. Opening Gantt Chart:

Gantt Chart for project selection and initial team meetings.

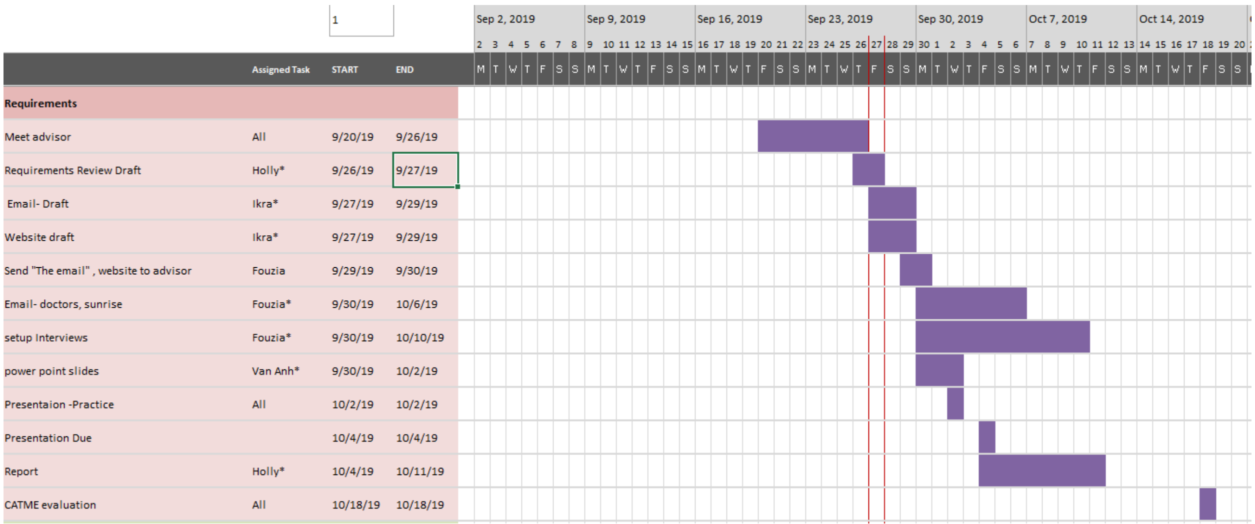

Fig 14. Requirements Gantt Chart:

Gantt Chart for requirement presentation and report.

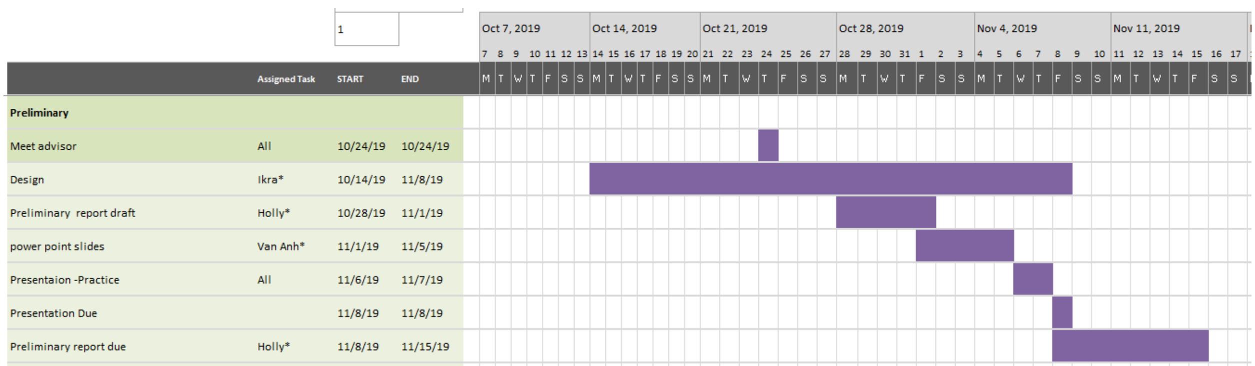

Fig 15. Preliminary Gantt Chart:

Gantt charts for the development of the preliminary design with reports and presentation.

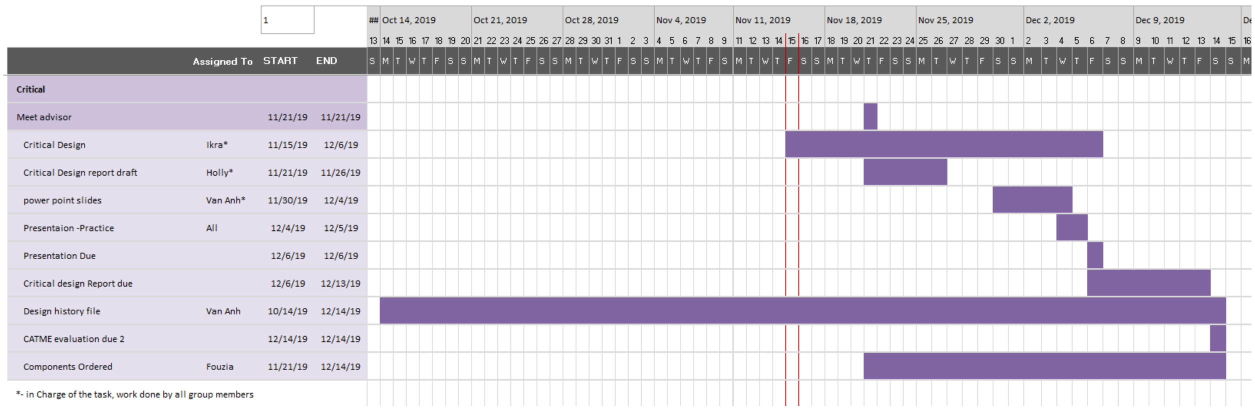

Fig 16. Critical Gantt Chart

Gantt chart for the development of the critical design and the history file.

Similarly, the second part of the project will involve parts gathering and building [Fig 17], implementation of the design [Fig 18], where the design will be implemented, the next stage is testing of the prototype [Fig 19], where the prototype will be tested for durability and maximum load. In this stage the hat will be put under different trails for better understanding its functions and constraints [Fig 19]. Last stage will be delivering the product [Fig 20], where the final product will be shown to the sponsor and final presentation will be held. Final presentation date is currently unknown but will most likely be done in late April or early May.

Spring 2020

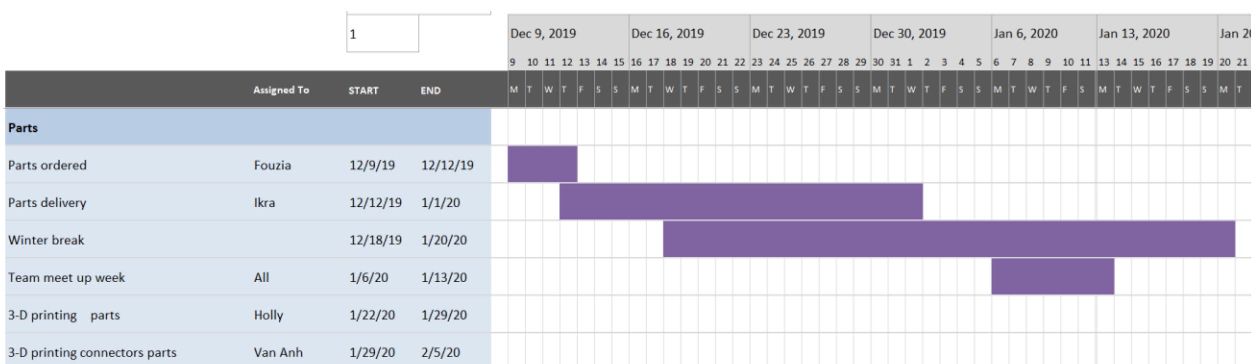

Fig 17. Parts Gantt Chart:

Gantt Chart for the procurement and fabrication of parts for the design

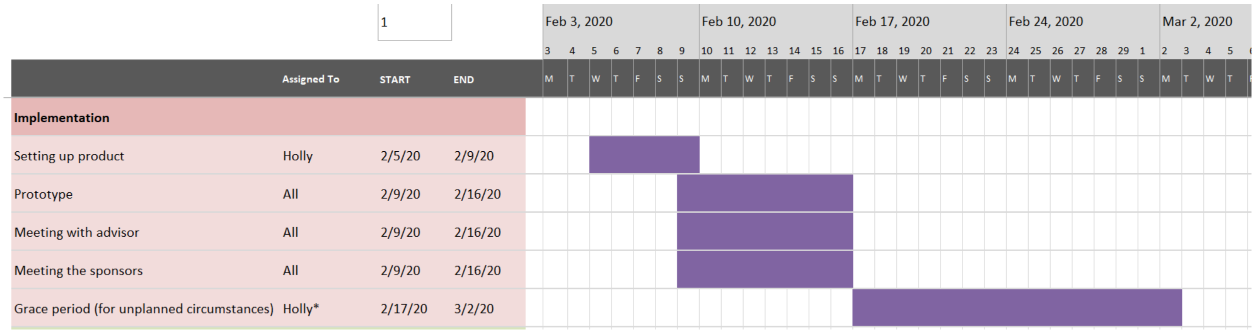

Fig 18. Implementation Gantt Chart:

Gantt chart for the implementation of the design and the making of the final prototype.

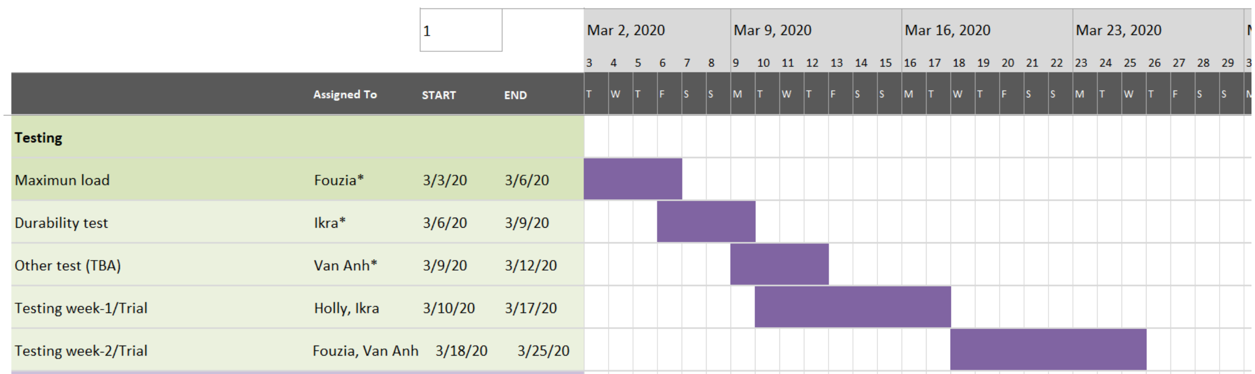

Fig 19. Testing Gantt Chart

Gantt chart for the testing of the prototype and trial period.

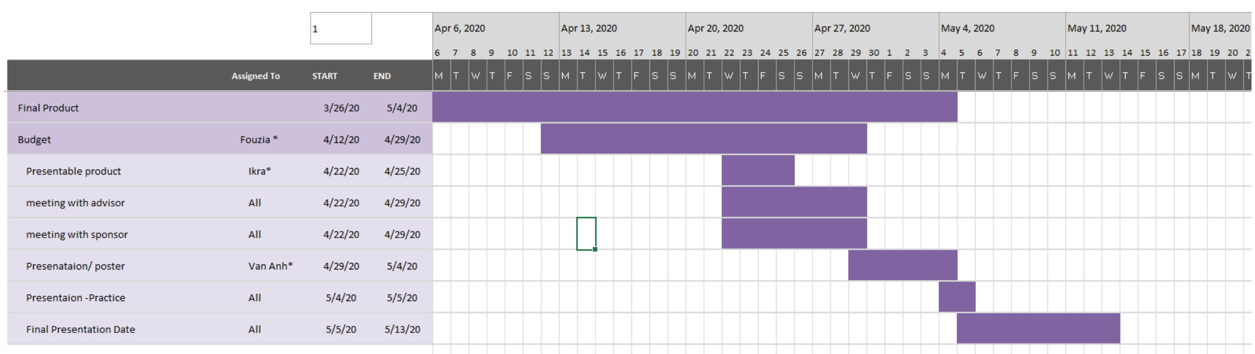

Fig 20. Deliver Gantt Chart:

Gannt charts for the delivery of the final product and final presentation.

Following the discussion of the Gantt Chart, a discussion of the budget of the project will be discussed and the general cost for each material expected to be used will be listed.

Proposed Budget

The proposed budget for this project is $100. However, the budget is subject to change depending on material changes[4]. Proposed materials and their corresponding approximate prices[6] for the cooling humidified hat will include:

- Mist atomizer circuit - $9.99 each [8]
- Hat - $14.95 [17]
- Battery - $12.01 for 20 AA Energizer Max batteries [20]
- Tubing[3] - $14.99 each [19]
- Cotton filter sticks - $6.95 for pack of 10 [19]
- DC connector - $11.45 [18]
- Battery Holder - $8.00 [21]

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Appendix A

1. The atomizer is provided that includes the necessary resistors, transistors, a circuit board, etc. [8]. Modifications will be done accordingly to adhere with each design option. For example, adjustment for designs that require more motor power will be considered. The atomizer is able to be charged with a USB power cord and can be turned on with a button of sorts [8].
2. Cooling towels will vary in size, shape, and quality of material [6]. Furthermore, since the quality of material vary, the cost and how long it keeps the user cools also varies [6].
3. Tubing will most likely be bendable and maintain it shapes.
4. After consulting with our advisor, it has been decided that our budget will be open ending as finalization of materials, supplies and equipment will be done further along. However, the goal is to have the budget being $100 or below matching the proposed budget for the report.
5. Test regarding mist temperature was done in lab. Mist was produced from a beaker filled with room temperature water and a beaker with water that was approximately 100 ᵒF. Both produced cooling mist where it was even cooler than the room temperature water found in the beaker. Temperature measurement of the mist was done qualitatively and for the prototyping process, a quantitative test will be done.
6. Material prices are based on average cost and are subject to change.

Appendix B

After a discussion with our advisor and sponsor, we have concluded that the final product should be a device that has a battery-driven humidifier. This device should work for one hour and does not cause more strain to the user.