ECE 445 Project Proposal 2

Electric Paintbrush Cleaner

Luis Bibian (bibian2), John Kriston (jkristo2), Yael Legaria (legaria2)
Team 65
TA: Madison Hedlund
April 3, 2020

1. Introduction

1.1 Objective

When painting, it is commonplace for painters to have a cup or jar of water used to clean their paintbrush when switching between colors. However, after only a handful of times of dipping the paintbrush in the water to clean it, the water becomes heavily stained with residual paint. As the unclean water starts seeping into the brush, this leads to the unwanted mixing of colors on the canvas. This is especially problematic when working with acrylic paints due to their thick consistency compared to other types of paint such as watercolor. In addition to quickly contaminating the painter's rinse water, acrylic paints also require the proper disposal of acrylic paint wastewater due to the plastic particles present in the paint. Although having a designated cup of water to clean the paintbrush is a simple way to combat unwanted color mixing, the overall problem is that it is highly inconvenient for painters to continuously get up to empty and refill their cup, as this ultimately disrupts the painting process.

Our proposed solution is to create a device that allows the user to easily get a fresh supply of clean water while properly handling the disposal of the contaminated rinse water. To achieve this, a clean water receptacle will receive clean water when dictated by the user in bursts of approximately 0.25 liter portions from a clean water storage tank which holds a maximum of 2.5 liters of water. Before a new supply of clean water is routed to the cleaning receptacle, the contaminated rinse water is drained into a filtration system that will filter the acrylic paint particles out of the rinse water when the user is finished painting. Once the filtration process is complete, the user can remove the dried acrylic paint particles and dispose of them in the trash can, and the clean water storage tank will be replenished with the recycled water.

1.2 Background

To mitigate the problem of contaminated rinse water interfering with the quality of a painting, painters will usually either use two separate containers of water to clean their brush (one for getting most of the paint off the brush, and the other for rinsing the brush after the first clean), or a very large tupperware/bucket of water such that any paint that is rinsed into the water will achieve a higher degree of dilution with the larger volume of water. However, neither of these solutions fix the problem of the designated cleaning water getting heavily contaminated with different colors - they instead only serve to slow down the process.

Furthermore, there is a need for a product that can ease the painting process for painters working with acrylic paint. Acrylic paints are popular amongst beginner, intermediate, and advanced painters alike for their longevity once put on a canvas and their “forgiveness of mistakes” [1]. But because of their thicker consistency when compared to watercolor paints, acrylic paints contaminate rinse water at a faster rate, and the plastic particles present in acrylic paint require proper disposal. Acrylic paint particles that contaminate rinse water are harmful to septic systems due to their potential to clog sewage pipes [2], but many painters neglect the treatment of acrylic wastewater because it is a seemingly tedious process. For these reasons, the need for a product that makes the filtration process for painters hassle-free cannot be overstated. In order to properly handle the treatment of acrylic paint wastewater, our solution aims to assist the user in automating the filtration process proposed by Golden Artist Colors Inc. [3], which is essentially a scaled-down version of the treatment process employed in municipal water systems.

The closest product that currently exists on the market for brush cleaning is the STYLPRO makeup brush cleaner [4], which cleans makeup brushes with a motorized-handheld device that spins the makeup brush around in a small bowl of water to get any residual makeup out of it. However, this product does not address our initial problem of the water easily getting stained during the painting process since the STYLPRO is only intended for a single use before the user has to manually refill the bowl. Additionally, the STYLPRO is not designed to handle brushes that are stained with acrylic paint, as brushes that are stained with makeup do not require the filtration of any residual particles that exist in the rinse water.

Our newly proposed solution differs from our previous solution in three major aspects. The first major change for our new design is that we have removed the motorized brush system that was proposed in our initial design entirely. Realistically, we were not sure how effective a rotating cleaning brush would be at cleaning a paintbrush given the flexibility and density of paintbrush bristles. Additionally, the wait time experienced by the user during the deployment of the brush system would require more time for cleaning than if the user was to just swish their paintbrush around in a regular cup of water.

The second major change for our new design is that paintbrushes will now be inserted vertically into a cleaning receptacle for cleaning instead of horizontally into a cleaning compartment where a spray valve directs water onto the paintbrushes. While our previous solution was not equipped to handle brushes of various sizes due to the constraints of directing water from a spray valve, our new solution is designed to work with any paintbrush that can have its bristles dipped into the circumference of a regular mug. Replacing the spray valve with a cleaning receptacle also allows for a more efficient use of cleaning water compared to the previous design.

Finally, the most significant change for our new solution is that its use is now focused around the implementation of a filtration system. Because our previous design had no way of filtering or recycling the contaminated rinse water, it was intended for use among painters working with watercolor paints. However, since the new design filters the rinse water, allowing water to be recycled and acrylic particles to be disposed of, this product is targeted towards painters working with acrylic paints, as this market has an intrinsically higher need/demand compared to watercolor paints due to reasons previously mentioned.

1.3 Physical Design

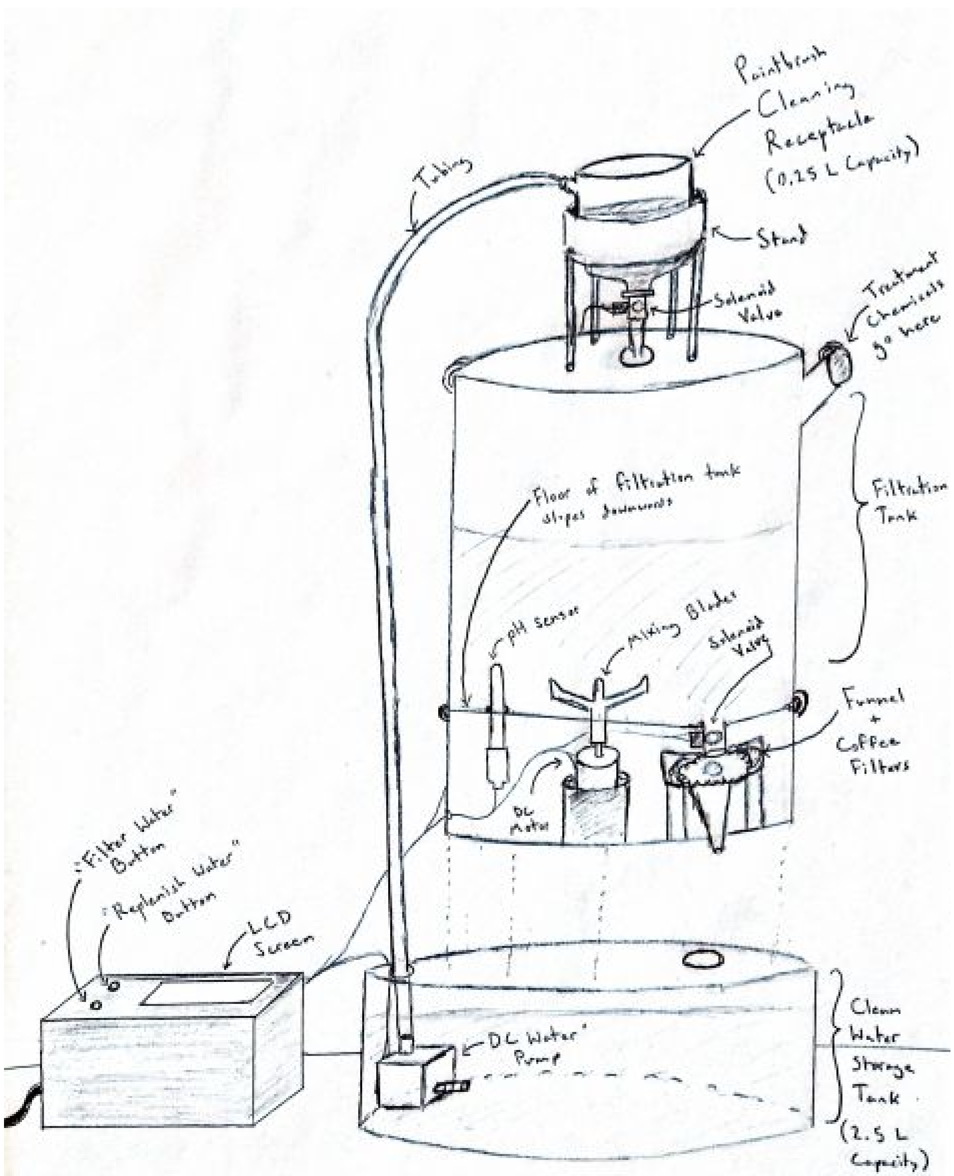

Figure 1: Physical Design of Electric Paintbrush Cleaner

Figure 1 illustrates the physical design of our proposed solution. The paintbrush cleaning receptacle sits over the filtration system, which is positioned on top of the clean water storage tank. The overall device is designed such that gravity will naturally direct the contaminated wastewater downwards, as this enables the solenoid valves to open and close off the flow of water on command. Adjacent to the water distribution and treatment system is the user interface, which allows the user to choose when to receive refills of clean water and when to start the filtering process.

1.4 High-Level Requirements

- The user can replenish the paintbrush cleaning receptacle with clean water at least eight times for a water storage tank filled with 2.5 liters of water.

- The treated water's pH at the end of the filtration cycle must sit between a pH of 6.5 and 8.5 to be considered acceptable for recycling.

- The filtration system must demonstrate the ability to remove acrylic paint particles from the treated wastewater, indicated by the transition of the wastewater from opaque to transparent.

2. Design

2.1 Block Diagram

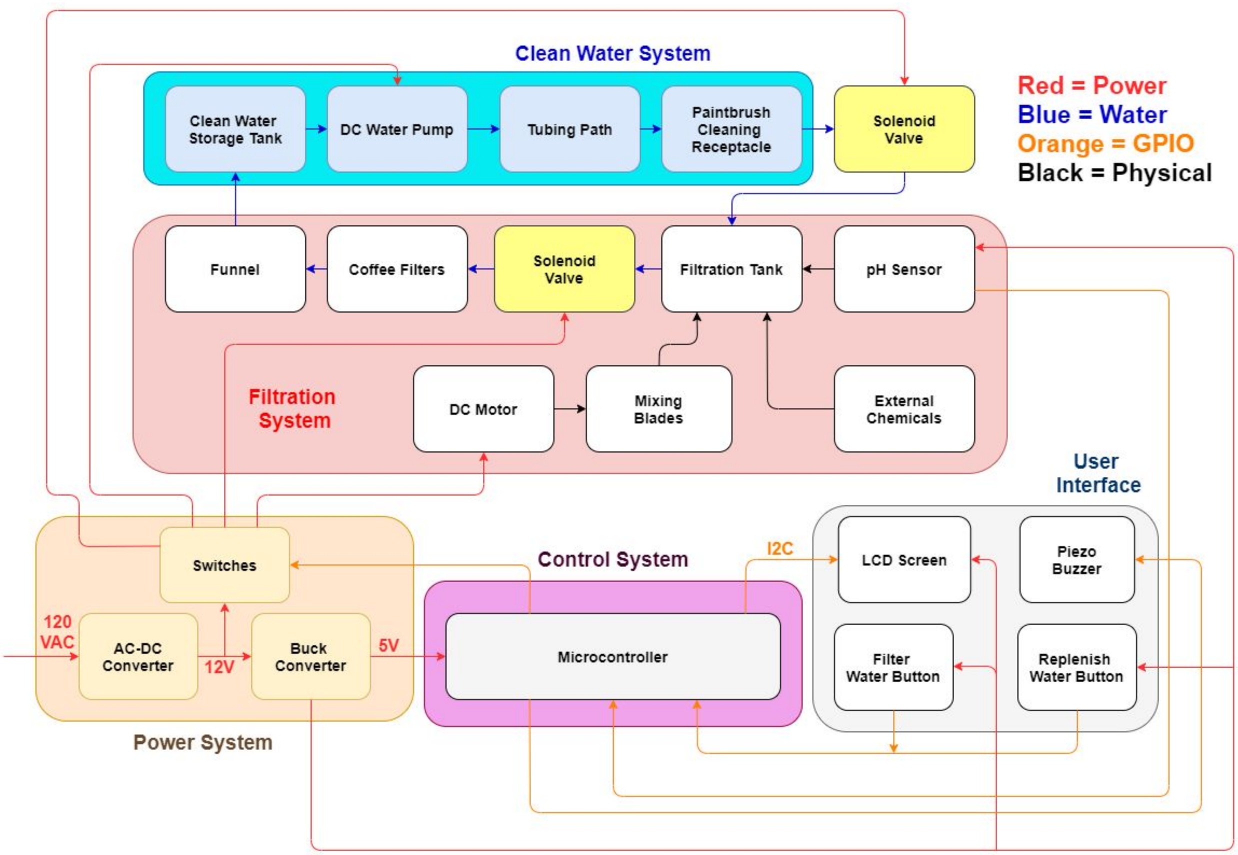

Figure 2: Block Diagram for Electric Paintbrush Cleaner

Figure 2 depicts the functional block diagram of the device. On startup, the user presses the "replenish water" button to fill the cleaning receptacle with fresh water from the clean water storage tank, with the clean water directed up to the cleaning receptacle via a dc water pump and tubing system. When the user wants to get a new supply of water, pressing the "replenish water" button again empties the dirty water from the receptacle into the filtration tank through a solenoid valve before refilling the clean water receptacle with new water. As contaminated water pours into the filtration tank, the microcontroller keeps track of the wastewater's pH using the pH sensor, while also keeping track of the amount of water in the filtration tank based on how many times the user has requested a refill of clean water.

From the pH of the wastewater along with its volume, the microcontroller computes the amount of aluminum sulfate solution the user should add to the contaminated water and displays this value to the LCD screen. To filter the wastewater, the user adds the amount of aluminum sulfate solution specified by the LCD screen to the filtration tank and then presses the "filter water" button, causing the dc motor to turn the mixing blades to begin the flocculation process. Once enough time has passed for the aluminum sulfate to take effect, the piezo buzzer will beep two times to signal the user to add the correct amount of hydrated lime powder as specified by the LCD screen. After adding the hydrated lime powder, the user presses the "filter water" button once again to resume the treatment of the wastewater, causing the dc motor and mixing blades to mix the solution to ensure even distribution of the hydrated lime powder. When sufficient time has passed for the acrylic paint particles to fully separate from the water, the microcontroller switches on a solenoid valve to release the treated water from the filtration tank, allowing the recycled water to fill into the clean water storage tank via a funnel as the flocculated paint particles are collected in the coffee filters. The piezo buzzer will beep three times when the filtration is complete.

2.2 Control System

The control system is responsible for controlling when the solenoids, motor, and pump are switched on, processing the data from the pH sensor, displaying information to the LCD screen, and handling user input. The control system plays an integral role in governing the flow of water between the separate components of the overall system.

2.2.1 Microcontroller

The microcontroller is powered from the 5V output of the power system's buck converter and awaits high signals from either of the buttons on the user interface before carrying out the designated functions. The microcontroller's GPIO pins are connected to the MOSFETs, the LCD screen, the user interface buttons, and the pH sensor. In addition to sending/receiving signals from the hardware peripherals, the microcontroller also keeps track of how much water the user has used up.

- Requirement 1: The microcontroller can successfully update text on the LCD screen using the I2C protocol.
- Requirement 2: The microcontroller can provide 5V ± 10% to the gate of the MOSFETs via digital output pins for a continuous duration of at least two minutes.
- Requirement 3: The microcontroller's digital inputs can register a voltage of less than 1V as a logical LOW and greater than 4V as a logical HIGH.

2.3 Power System

The power system is responsible for supplying power to each of the device modules, providing outputs of 12 V dc and 5 V dc from a 120 V ac input. The 12 V dc supply will be directly available from an ac-dc converter that plugs into the wall, whereas the 5 V dc supply is obtained from a buck converter that steps the 12 V from the ac-dc converter down to a usable 5 V. In addition to the power converters, the power system also consists of four MOSFETs that are used as switches to switch the motors and solenoids on and off.

2.3.1 AC-DC Converter

The ac-dc converter converts a 120 V ac input to a 12 V dc output, which is used to supply power to the dc motor, dc water pump, and solenoids. The 12 V output is also used as an input to the buck converter.

- Requirement 1: The ac-dc converter must convert the 120V ac input from the wall outlet to a 12V ± 10% output.
- Requirement 2: The ac-dc converter can supply at least 5.5A of current continuously.

2.3.2 Buck Converter

The buck converter steps down the 12 V from the ac-dc converter to a usable 5 V for the microcontroller, pH sensor, LCD screen, and the push buttons for the user interface.

- Requirement 1: The buck converter must regulate the 12V input from the ac-dc converter to a 5V ± 10% output.
- Requirement 2: The buck converter can supply at least 1.5A of current continuously.

2.3.3 MOSFETs (Switches)

The MOSFETs are used as simple switching mechanisms that allow the microcontroller to switch the dc motor, dc water pump, and solenoid valves on and off at set times. Because the microcontroller can only source a limited amount of current, the MOSFETs are used to drive the electromechanical components directly from the 12 V ac-dc converter to meet the current demands.

- Requirement 1: MOSFET drain-source channel must conduct upon the application of 5V ± 10% to the gate via the microcontroller.
- Requirement 2: MOSFET operates at a temperature no greater than 70° C when driving its corresponding electromechanical component.
- Requirement 3: The voltage drop across the MOSFET drain-source terminals must remain less than 0.2V when conducting.

2.4 Clean Water System

The clean water system is responsible for controlling the flow of clean water throughout the system. This system consists of a clean water storage tank, a paint brush cleaning receptacle, and a dc water pump. The main purpose of this system is to deliver clean water to the user in a timely manner, and plays an essential role in providing the user with an uninterrupted painting experience.

2.4.1 Clean Water Storage Tank

The clean water storage tank holds the clean water used for rinsing paintbrushes and sits at the bottom of the device. Before using the device, the user can separately fill the clean water storage tank to a maximum capacity of 2.5 liters.

- Requirement 1: The clean water storage tank should be able to securely hold up to 2.5 liters of water to avoid any accidental leaking onto the system or surrounding appliances.

2.4.1 Paint Brush Cleaning Receptacle

The paintbrush cleaning receptacle is the designated station for the rinsing of paintbrushes. Tubing is connected to the top of the cleaning receptacle to deliver new water, while a solenoid is positioned at the bottom of the cleaning receptacle to empty dirty water.

- Requirement 1: The paintbrush cleaning receptacle can hold up to 0.25 liters of water without any water spilling from the top during the user's normal rinsing motion.

2.4.3 DC Water Pump

The dc water pump is responsible for delivering water from the clean water storage tank to the cleaning receptacle. The dc water pump is powered from the 12 V output of the ac-dc converter and sits within the clean water tank.

- Requirement 1: The dc water pump can deliver 0.25L from the clean water storage tank to the cleaning receptacle within five seconds of the microcontroller's digital output pins going HIGH.

2.5 Filtration System

The filtration system is used to take the wastewater from the paintbrush cleaning receptacle and remove the acrylic paint particles from the water, allowing the user to both recycle the same water for multiple uses, and efficiently separate and safely dispose of the acrylic paint waste. This is a very environmentally conscious addition to our system because it promotes the saving of clean water as well as impedes the pollution of the community's water system.

2.5.1 Solenoid Valves

The solenoid valves open and close when triggered by the microcontroller to control the flow of water from the cleaning receptacle to the filtration tank, and from the filtration tank into the funnel and coffee filter.

- Requirement 1: The solenoid valves open and close within two seconds of the microcontroller's digital output pins going HIGH.

2.5.2 DC Motor

The dc motor is used to turn the mixing blades in the filtration tank to mix the aluminum sulfate and hydrated lime powder into the wastewater, ensuring a thorough distribution of the treatment chemicals. The shaft of the dc motor locks into an insert at the bottom of the filtration tank, similar to a blender, which allows it to turn the mixing blades without getting wet.

- Requirement 1: The dc motor can maintain a speed of at least 100 RPM when the filtration tank is at maximum capacity.

2.5.3 pH Sensor

The pH sensor is a very important feature in the filtration process. After measuring the pH of the wastewater being collected, this data will be used to calculate exactly how much chemical agent must be added for a successful filtration. This will ensure no chemical is wasted due to excessive use, saving the consumer money in the long term.

- Requirement 1: The pH sensor must return a pH reading to the microcontroller that indicates a measurement accurate to within ± 0.5 pH of actual values (as measured using separate pH strips to confirm).
- Requirement 2: The pH sensor must be positioned within the filtration tank such that it can get an accurate reading for wastewater volumes between 1L and 2.5L.

2.5.4 Coffee Filters

The coffee filters are placed within the funnel and used to capture the flocculated acrylic paint particles. After each use, the user must dispose of the coffee filters and replace them.

- Requirement 1: The coffee filters must not tear during the filtering of the treated wastewater.

2.6 User Interface

The user interface allows the user to control when a new supply of clean water is directed to the clean water receptacle, as well as when the filtration process should begin. An LCD screen displays information to the user regarding how many refills are left, the current pH of the wastewater, and how much aluminum sulfate or hydrated lime powder is needed to treat the wastewater. Additionally, a buzzer is used to alert the user during the filtration process.

2.6.1 Push Buttons

The device has two push buttons. The first push button allows the user to request a refill of new water for the cleaning receptacle, and the second push button is used to start and resume the filtration process once the proper amounts of chemical treatments have been added.

- Requirement 1: The push buttons connect the digital input pins of the microcontroller with a signal corresponding to a logical HIGH when pressed, and LOW when unpressed.

2.6.2 LCD Screen

The LCD screen is powered from the buck converter's 5 V output and displays information to the user. The LCD screen is connected to the microcontroller via an I2C adapter.

- Requirement 1: The text on the LCD screen should be readable by the user from a distance of up to at least three feet from the device.

2.6.3 Piezo Buzzer

The piezo buzzer is used specifically for alerting the user during the filtration process. Because the aluminum sulfate and hydrated lime powder need time to take effect, having a buzzer allows the user to walk away from the device during these waiting periods.

- Requirement 1: Buzzer should output sounds at a noise level of at least 40dB.
- Requirement 2: Buzzer can produce audible tones from a minimum range of 300kHz to 1000kHz.

2.7 Risk Analysis

The block that poses the greatest risk to successful completion of the project is the filtration subsystem, as this subsystem will determine if our project is of any use to painters who want to properly dispose of wastewater, but are unable to commit to carrying out the entirety of the process themselves. If our system can successfully filter out the acrylic paint particles and recycle the clean water back into the clean water storage tank, then painters can solely focus on painting, and the painter will no longer have to get up multiple times to empty and refill their cleaning jar. However, if this filtration system does not work, then we are no longer providing a unique solution to cleaning paintbrushes for painters. Furthermore, this subsystem is complex because it is a two-level process. This means that if just one of the two levels fails, the overall subsystem will fail. In particular, if the aluminum sulfate and the hydrated lime powder are not properly dispensed and mixed, or if the funnel and coffee filters don't adequately collect the acrylic paint particles, then the filtration will not work. It is also important to note that this subsystem involves multiple valves used to route the water. It is imperative to not allow any water to get on any of the electrical components. This can have catastrophic results, as it could damage the entire system or put an individual's safety at risk.

The main challenge that comes with the implementation of the filtration system is accurately determining the amounts of aluminum sulfate and hydrated lime powder needed to effectively remove the particulates from the water. Because aluminum sulfate is used to decrease the pH of the wastewater, which in turn assists the flocculation process of the acrylic paint particles for a more effective filtration, the hydrated lime powder is used to bring the pH of the wastewater back up, decreasing its acidity. Therefore if the incorrect amounts of either of these chemicals are added to the wastewater, what we will end up with is a solution of treated water that is not fit for recycling, which would automatically cause us to fail our second high-level requirement; this makes the pH range requirement the most difficult one to meet. In order to successfully implement the filtration system, we will need to quantify how much aluminum sulfate and hydrated lime powder are needed to change the pH of a specific volume of liquid to a target value.

3. Ethics and Safety

The first ethical/safety issue we can expect to face is dealing with the separation of water from the electrical components of our system. As cautioned by section 7.8.1 in the IEEE code of ethics, we need to face the possibility of water coming into contact with subsystems such as the power or control subsystem if the proper precautions are not taken [5]. In order to prevent the risk of electric shock to individuals, our team plans on grounding all electrical components and having covers for all the electrical components. This way, water will come in contact with the covers instead of the actual conductive elements. In addition, we plan on making our design durable enough to help prevent any spillage of water from the receptacles.

Our group also acknowledges section 7.87 of the IEEE code of ethics, and realizes there may be flaws to our design, and "we must seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others" [5]. Our main goal is to allow painters to focus on painting itself, instead of having to refill their clean water jar multiple times during the painting process. We know if our system takes too long to refill the water, or if there is not enough clean water at a given time, our solution will not be of any use to painters. This is why our group would like to try out our prototype with painters in the industry right now, and get advice on how we can improve our design. In addition, all outside parts, whether it be the MOSFETs or the ac-dc converter, will be cited as being sourced from outside distributors. Our group will credit contributors to our project in this way.

Furthermore, our group plans on creating a safety manual that informs all users of the potential risks associated with using our system, and the precautions they can take to minimize these risks. These precautions include, but are not limited to, not exceeding the max water level of the clean water tank, replacing the coffee filters after each use, always ensuring the water system is working smoothly without any clogging, and making sure there is sufficient aluminum sulfate and hydrated lime powder at all times for the filtration system to work properly. This lab manual is tentative, and subject to change. This safety manually will closely resemble those which are distributed with similar water appliances such as in-home decorative water fountains.

An important addition to this lab manual will be the safety precautions which should be taken when working with the new chemical agents for our filtration process as well as the first-aid measures in case of an emergency. For example, before working with an aluminum sulfate solution, one should always wear the appropriate personal protective equipment. Since aluminum sulfate solutions can cause skin/eye irritation, the user should always use safety goggles and gloves before starting the filtration process. If the solution is accidently exposed to the skin or eyes, one should immediately flush/rinse the exposed area with water for up to 20 minutes. Furthermore, if the solution is accidently ingested, a person should drink a large quantity of water or milk and should not induce vomiting [6]. We understand that children are likely to be around the machine considering painting is a very common children's activity, however, we will make it clear in the manual that the filtration process should only be carried out by a responsible adult, following the important safety guidelines. In addition, the chemical agents should be stored in a cool area out of reach from children to further avoid the possibility of an accident.

Conveniently, working with calcium hydroxide requires the same PPE, goggles and gloves, as our aluminum sulfate solution since it too can cause skin/eye irritation. When exposed to the eyes or skin, the same measures should be followed: flushing the exposed area with water for up to 20 minutes. However, when ingested, unlike with aluminum sulfate, one should at most only drink small sips of water, and instead focus on flushing out their mouth [7]. It will be important to properly distinguish the two in the lab manual considering they are quite opposite. We believe the best course of action is including clearly labeled safety data sheets of both chemical agents into the lab manual thus giving the user all the information he/she needs in case of an emergency. These safety precautions once again are in support of the IEEE guidelines set in place to hold paramount the safety of the consumer [5].

Finally, as stated by the IEEE code of ethics 7.8.3, our group must "be honest and realistic in stating claims or estimates based on available data" [5]. A great example is the amount of water our clean water storage tank will be able to hold. Right now we expect this tank to hold 2.5 liters of clean water at a time, and that a painter can refill his or her cleaning receptacle at least eight times with this original water. However, if this number changes after trial and error, we will need to inform the user of this change. In addition, if we feel the rate of water being pumped through the system is too slow or too fast, this is something that must be addressed immediately. Our system will also not be considered a success unless it is easy to use. Adequate water supply at all times is the main factor for ease of use.

References

[1] Art Passion, “12 Crucial Differences Between Acrylic and Watercolor Paint”, [Online]. Available: https://artpassiononline.com/differences-between-acrylic-and-watercolor-paint/ [Accessed 2-April-2020]

[2] Medium.com, “3 Steps to an Environmentally Sound Art Studio”, [Online]. Available: https://medium.com/@susanlstewart/3-steps-to-an-environmentally-sound-art-studio-d05504d36a22 [Accessed 2-April-2020]

[3] Justpaint.org, “Removing Water-Based Paint Solids from Rinse Water”, [Online]. Available: https://www.justpaint.org/removing-water-based-paint-solids-from-rinse-water/ [Accessed 2-April-2020]

[4] StylTom, “StylPro Original”, [Online]. Available: https://styltom.co.uk/products/stylpro [Accessed: 2-April-2020].

[5] IEEE.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed: 2- April- 2020].

[6] Sawpa.org, “Liquid Alum MSDS”, 2008. [Online]. Available: http://www.sawpa.org/wp-content/uploads/2012/05/Aluminum-Sulfate-General-Chemical.pdf [Accessed: 2-April-2020]

[7] Fishersci.com, “Calcium Hydroxide SDS”, 2014. [Online]. Available:https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-c/S25225.pdf [Accessed: 2-April-2020]