Water Purification System

Final Design Report

Messiah College

Department of Engineering

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Abstract

The project that we have chosen is a continuation of the Living Water project from two years ago. The original idea was to produce a marketable water filtration and purification system for a SUV or RV. The previous team was able to prove that this idea works, but were unable to complete a marketable product. The system developed was too costly, bulky and heavy to be sellable. We have created a marketable water purification system that is powered by a DC battery. This system meets market standards of purification, filtration and safety. It is also aesthetically pleasing for the potential customers. Our team consists of Stuart Oberg, Adam Yoder and Nathan Martin, all senior engineers at Messiah College. Stuart is earning his electrical concentration and Adam and Nathan are earning their mechanical concentrations. Our faculty sponsor is Carl Erikson, the Engineering department chair.

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Table of Contents

1 INTRODUCTION

1.1 Description

Our goal for this project was to build a marketable water purification system. We created an affordable, reliable and easily manufactured system. We used the Living Water senior project as a starting place for our project. To accomplish our goal, we have used nearly all commercially available off the shelf parts. This was to reduce the cost and ease the manufacturing. We improved upon several aspects of their original design. The system now has a new controller for the pump and UV light. The new controller turns on the UV light for five seconds before turning on the pump and remains on five seconds after the pump has been turned off. The purpose of this is so that no contaminated water goes through the outlet hose. Our design implements a single on and off switch to be more user friendly. As the filters become clogged, their performance will drop as well as putting unneeded pressure on the pump. To find the flow rate of the current system, the user needs to calculate the fill time of a controlled volume container. We would like to eliminate this amount of user responsibility. The pump on the previous system does not seem to fit the aim of our project. It is a very expensive and heavy custom built component. The pump also had a problem of overheating during long periods of operation of about a half an hour. We would like to see a pump implemented that would overcome these obstacles. After our initial assessment of the system, we felt that it was entirely too heavy and too large to be marketable. Our goal is to reduce both of these specifications. Finally, we feel this system needs to be aesthetically pleasing. This is a consumer want that would need to be determined through market research.

1.2 Purpose/Benefit

The main goal of this project was to produce a marketable product. The profits of which will go to the Engineering Collaboratory. The system will also benefit the missions of Messiah College. Students take many trips to different parts of the world every year. Our hope is to create a product that they could easily transport and have clean drinking water. A need exists for this product in post disaster areas. After hurricanes and floods, fresh water becomes a precious commodity. Our system could be setup to provide a short term solution until a long term solution could be implemented. For areas like Alaska, this system would be put to great use. There are large areas of land that are off the power grid. People living in these areas could benefit greatly from a 12V purification system. The market contains products similar to ours but for a much greater price. We hope to provide our product for nearly 1/3 the closest competitors price.

1.3 Objectives

For this project, we have developed five specific goals we tend to accomplish.

- Our first goal was an electronic controller for the system. This will need to turn on the UV light a few seconds before the pump and keep the UV light on a few seconds after the pump has turned off. It will also need to be completely waterproof to reduce the chance of failure. The controller also needs to be able to handle the fluctuations in voltage and amperage that the pump will produce.

- We replaced the current pump. Our replacement was cheaper, lighter and does not overheat during long periods of operation.
- There is also a need to install a flow meter within the system. This is a safety feature for the performance of the filters. We need a way to show when the filters have become full and need to be replaced.
- The main goal of the project was to produce a marketable system. To do this, we cut down the size and weight of the system by 30%. Our hope is that it could one day get UL approval; we will design with this in mind, knowing this goal will probably not be achievable this year. When building, we will try and use all UL approved parts and meet UL standards of filtration and purification.
- The current case was entirely too large and too expensive. We reduced the cost of the case as well as the size. The case we found is rugged and able to withstand the abuse of outdoor use.

1.4 Literature Review

There are many types of water filtration systems commercially available. A lot of these systems are designed for the camper and hiker and are hand powered. Through our research we have only found one commercially available system that comes close to meeting our design. Noah Water System produces a four stage water filtration system that runs off a 12 V battery. A four stage water filtration system has pre-filtration, sediment filtration, carbon block, and the UV light. The pre-filtration removes large particles such as rocks and other large particles. The next step is the sediment filter where the water is passed through a 5 micron filter where sedimentation is removed. The water then passes through the carbon block where chemicals and other compounds are filtered out as the pass over the activated charcoal. The last stage is the UV light which kills algae, bacteria, fungi, protozoa, and viruses, see Appendix. The system provides 1 GPM and a 99.99% kill rate. The system weighs 26.5 lbs and the dimensions are 17x21x9 inches. The system costs around $1200 this price was the most current we could find.

The Noah's Trekker is close to what we are looking for but we feel the system is too heavy and expensive. Also there is no indicator to warn you if you need to replace the filters in the Trekker. The only way to know is, "When either of these filters begins to reach the end of their useful life, water output will be reduced dramatically, indicating the need for filter replacement." The Trekker has a flow rate of 1 GPM. The system has an on board 12V DC power supply.

The Responder is another system that is close to what we are trying to build. The system has the same problems as the Noah's Trekker as it is too expensive and heavy. The Responder does not have an indicator for when to replace the filters as well. The Responder has an integrated solar panel which allows it run when no external power source is present and also has a portable external battery. The Responder produces purified water at 1 GPM.

Our main objective for this project is to create a similar system with a much nicer price tag. The Noah's Trekker system costs around $1200, we would like to produce a system for nearly 1/3 of that price. We also hope to create a controller that is very user friendly. This will eliminate much of the burden on the user to carefully monitor the system. The controller will incorporate a flow meter and a UV indicator.

2 DESIGN PROCESS

2.1 Specifications

Price:	$350
Weight:	16 lbs.
Dimensions:	18" x 6" x 6"
Flow rate:	.8 – 1 GPM
Purification:	99.9%
Voltage requirement:	12 Volts DC
	120/240 Volts AC
Maximum current draw:	5 amps
Filtration:	1 micron
UV Exposure:	32,000 μW*s/cm^2
Hosing:	3/8" Inlet/outlet diameter
Safety Drop:	No damage caused by 2 foot drop on hard floor
Service life of filters:	750 gallons
Service life of UV lamp:	9,000 hours

2.2 Description of Design

We are creating a water purification system from the design of a previous project. We have been able to make the system smaller and lighter. The system will be housed into a plastic anti-shock briefcase with interior foam padding so that it can be easily portable.

The water filtrations systems is a 3 stage water purifier. The purpose of the first two stages is to reduce the turbidity of the water. Turbidity is a measurement of how "cloudy" the water is. The water needs to have a low turbidity so that the ultraviolet (UV) light can affect as many as the microorganisms as possible. If the turbidity is high the microorganisms will be able to hide behind particles and not be altered by the UV light. The first stage is a sediment filter, this filter out everything silt, sediment and other debris. Then next stage is a carbon block. The carbon block improves the taste of the water as well as filters out sediment, silt and debris that were too small for the sediment filter to filter out. The last stage is the UV light. The UV light's purpose is to alter the microorganism's DNA so that they cannot reproduce, contrary to popular belief the UV light does not kill the microorganisms. We also have added a large sediment screen to the inlet hose of the system to protect the pump from large sediment.

There are two inputs and two outputs to the system: Water coming in and out and electricity coming in and out. The water will flow through 3/8" ID Tygon tubing throughout the system. The tubing is clear so that the user can visually check the water in the system.

When we began to look at pumps, our requirements were the ability to provide 1gpm and run on 12V dc. We had to modify our search after our initial pump could not self prime. Our second pump self primed to four feet and provided 1 GPM under ideal conditions. This pump was small, lightweight and low cost. After running several tests, we learned that filters have a significant pressure drop across them. Our 1 GPM quickly turned to .3 GPM. Our third pump, the Par-Max 1.9, provides 1.9 GPM under ideal conditions and self primes up to 10 feet. The pump that we selected is from Jabsco and it is the Par-Max 2.9 Water Pressure System Pump. The pump provides a maximum flow rate of 1.9 gallons per minute at optimum conditions and requires 12 Volts DC with a maximum draw of 3.5 Amperes. We needed the pump to be able to draw the water into the system. The Par-Max will pull a maximum of 10 feet of vertical head. This is more than twice the vertical we desired. When the pump pulls vertical head and pushes water through the filters, the flow rate drops. Our goal was to be able to purify approximately 0.8 gallons of water per minute. With the losses of pressure in our system, a pump originally providing 1.9 gallons per minute will provide a flow close to our requirements. An additional feature to the pump is an automatic shut off. The pump turns itself off if when the pressure in the system reaches 25 PSI. This pressure rating is below the ratings of our fittings which means the pump will shut off before the fittings would fail. This reduces the chances of failure in our system.

Once the system was complete, we began to do some more flow rate testing. Our tests indicated a flow rate of approximately .5 GPM. This was not what we had desired. We began to wonder if the flow was being restricted by our pump or by our filters. To check this, we tested the system with the old pump. For comparison, we tested our pump with the old filters. Through these tests, we discovered that it was the filters limiting the flow rate. Some phone calls provided our answers. OmniPure claimed that the filters provided approximately 1 GPM in normal use, which was in-line pressure in a building. The pressure that is provided through a house system is around 50 PSI. The Par-Max 1.9 runs at 15 PSI at steady state. The Par-Max 2.9, which is the next size in the Par-Max series, runs at 40 PSI at steady state. The 2.9 is housed in the same casing as the 1.9, we feel that the flow rate problem could be solved by substituting the 1.9 for the 2.9. This switch would require a simple change in two electrical components, the capacitor and a fuse, both of which require minimal work.

The inlet hose has a large sediment screen. This is in place to protect the pump and increase the life of the filters. The screen blocks sticks and larger particles from entering the rest of the system. Connected to the outlet of the pump is the 1st stage of filtration. This is a sediment filter which filters out the mud and dirt, down to 10 microns. The 2nd stage filter is the carbon block filter that filters out minerals and other small particle that pass through down to 1 micron. The carbon block filter will also help improve the taste of the water.

The 3rd stage of the system is the UV light. The UV light runs on 12 Volt DC and has a maximum current requirement of .85 Amperes. This current runs the ballast which then powers the light. In this stage, the DNA of the living organisms in the water is altered so that they cannot reproduce. Our UV light provides 30,000 µW*s/cm^2 at a flow rate of 1 GPM. The flow rate of our system is slightly lower and therefore will provide more exposure to the UV light. Exposure levels for organisms are shown in the Appendix. The light also inactivates 99.9% of viruses in the water. The purified water then flows out of the UV light through Tygon tubing.

Our design has several safety features integrated into it. The key to these safety features is to eliminate the possibility of contaminated water flowing out the exit hose. The control board is protected from power surges and water damage. The controller is the most complex and innovative part of our project and needs the most protection. The controller will not allow the pump to be activated if the ballast ceases to require power. The UV light has a visual indicator for the user to determine if the light is working. The controller also creates a delay between the powering of the pump and the UV light. This delay will eliminate the danger of contaminated water being pushed through the UV light. The pump itself has an automatic shut off switch. This switch is activated by too much pressure in the system. If a hose becomes clogged or the filters become unusable, the pump will cease to turn on.

Through continued work, we are going to integrate a visual flow meter. This is another safety feature. As the filters absorb sediment, the flow through them will decrease. The flow meter will allow the user to know when it is time to replace the filters.

The system is controlled by an electronic controller that requires 12 Volts DC from either a car cigarette lighter or through an AC adapter into a 120 VAC or 240 VAC wall outlets. The AC adapter will be plugged into the wall and will have a female end of a cigarette lighter so that the male end from the system can be plugged into it. The power source of the system is therefore 12 Volts DC and a maximum current of 4 Amperes. The heart of the controller is a PIC (Programmable Integrated Chip) microcontroller. This is a low cost, space saving alternative rather than a fully analog controller which uses large capacitors for timing. The microcontroller turns the UV light on and delays the power to the pump. When the system is shut down, the microprocessor turns off the pump first before running a delay to the UV light. Each of the two delays is 5 seconds long.

The voltage from the car battery or the wall enters the circuit and immediately flows into a 3 Amp slow-blow fuse that handles initial start-up current spikes and then continues to flow into the voltage regulator. The regulator drops the 12V input down to 5V, so the rest of the circuit is not overpowered and is fed with the needed voltage. There are three capacitors connected to the voltage regulator. One is for the input 12V and two are for the output 5V. The capacitor that has significant effect is the electrolytic one on the output. Its function is to keep the voltage level from dropping when the UV light and pump turn on. Since the pump needs so much power to start, this capacitor was needed to charge and hold the voltage around 5V. The 5V from the voltage regulator then runs to the microcontroller. The microcontroller runs the timing sequence for the circuit and basically tells what the relays should do when the switch is activated or deactivated. The switch runs off of a resistor that is connected to the microchip. Two more resistors run from the microchip to two LED's. One LED is for the pump and the other LED is for the UV light. On each of these two traces there is a Darlington pair of bipolar transistors. These are used to increase the amount of current running to the two relays to ensure that there is enough current to activate the relay. The two relays activate and deactivate the pump and UV light. They are essentially a switch. The pump and UV light require a lot of power by only using the small amount provided in the circuit. These relays are rated for handling power for what is required to the UV light and pump. Connected at each coil of the relay is a zener diode. The purpose of the zener diode is to control the current and keep it flowing in the forward direction. The rated voltage for the zener diode is larger than the relay voltage that it is used on. This is so that current does not flow in the opposite direction. There are also one zener connected across each of the outputs to the UV light and pump so that current flows in the forward direction, this protects the circuitry. Before the outputs there is a 5 Amp slow-blow fuse for the pump and a 1 Amp slow-blow fuse for the UV light. This also provides circuit protection from components being damaged and handles initial start-up current spikes. It also prevents from too much current being pulled from either output. See Appendices for pictures.

2.3 Analysis and Experimental Work

In order to find the required flow rate of our project we needed to make some assumptions on the amount of water consumed by each person a day and for how many people. The previous group estimated that maximum number of people would be 8. They made this assumption based on the system being run from a vehicle. Then they assumed that the amount of water one person will consume in drinking, cooking and cleaning would be 3 gallons a day. Therefore our system needs to supply 24 gallons a day. The previous group decided they needed to have a minimum of 0.8 GPM, and only run the pump for 30 minutes at a time. They also stated that if the system ran for 30 minutes only 4 Amp hours would be consumed. Using a standard 50 Amp hour car battery and running at maximum capacity you could run the system for 6 days.

We tested our pump in Frey 45 and found that through the filters from the old system we were getting around 0.6 GPM. Using 0.6 GPM and only running at 30 minutes every 8 hours you could produce 144 gallons of purified water a day. We feel that even though we are not getting 0.8 GPM that the weight and money saved with our pump is worth the loss in flow rate. We have not been able to test our system with the new filters we have purchased.

We tested our new UV light with the ballast from the old system. The ballast supplied the correct power to the UV light. The only problem is that we cannot use the ballast that it comes with because it requires a 120 VAC input. We need a 12 VDC input. When we tested the OmniPure UV light with its original ballast (120VAC input), the output voltage with the UV light as the load was 44 VAC. The current was .182 Amps. Therefore, taking the voltage multiplied by the current you come up with power. The power is approximately 8 Watts provided to the UV light. We then tried to use an oscilloscope to identify the output waveform of the ballast. For three consecutive tries, we experienced failure in hooking up the oscilloscope correctly to read the ballast output. It seems as though that it was the grounding that was causing the problem; meaning that the ballast must not be isolated. If the oscilloscope ground probe is connected to hot on the ballast, it will short out and trip the workbench. Even if the ground on the oscilloscope is connected to neutral on the ballast, sometimes a ground loop will occur which trips the GFI, which is the Ground Fault Interrupter (although this is not as common). One way to get around that is to just float the ground clip and connect only the positive probe clip. The signal will not be as clean, but it will prevent a short of any sort from being able to occur. With those sorts of voltages we have to make sure we use a x10 probe as well, just to keep things attenuated, which makes the signal thin with little or no distortion.

When we tested the OmniPure UV light with the 12 VDC input ballast, the outputs were less than with the 120 VAC ballast. The voltage was 35 VAC with the UV light as the load. The current was .086 Amps and the approximate power was 3.01 Watts. This initially told us that this ballast was not going to work. We then used an oscilloscope to identify the output waveform of the ballast. The waveform was a square function with a peak to peak voltage of 45 Volts. The period was 58 µs and the mean was 20 Volts. The frequency of the waveform was 18.6 kHz. This tells us that the ballast does have a stable output sinusoid. The only problem is that it does not produce enough power. Until we placed one of our arms onto the metal box of the ballast (when we were testing the output waveform of the system using the oscilloscope) by an accident was when we then found that a little bit of current was flowing. We then assumed that the ballast had gone bad. So we ordered a new one and received it for free.

After we assembled the main parts of our system which included the pump, two filters, UV light, and controller, we then tested the approximations of currents and voltages being pulled by our system. The approximations of currents through our system with a load are as follows:

UV Light:	2 Amps at Start-up
	.86 Amps at Steady-state
Pump:	2.54 Amps at Start-up
	1.2 Amps at Steady-state
Together:	3.4 Amps at Start-up
	2.06 Amps at Steady-state

The approximations of voltages through our system with a load when the UV light is at steady-state and the pump is at start-up are as follows:

Together:	11.46 Volts at Start-up
	11.54 Volts at Steady-state

As you can see, the pump requires much more power than the UV light. Therefore, this testing information provided important information in how we should design the circuitry to properly protect and drive enough power in the circuit.

2.4 Difficulties

The main difficulty in our project was the controller. The controller must be able to handle the harsh environments that the system may encounter. It must also have a long operating life. Much of the past semesters work has been product research. We have had to make difficult choices on products which we have very little information about. Our choices have been based on price, size and reliability. Often, one of these criteria has had to be relaxed in order to provide an excellent product. We have found that as size and reliability get better, price rises.

The vendors that we have dealt with have at times become a problem as well. The information provided on a website about a product sometimes does not accurately describe the actual product. This has occurred on several occasions with our parts. Another problem with the vendors, that we have encountered, is communication. Two parts that we ordered have taken a very long time to arrive. The companies did not communicate with us that these parts needed to be special ordered. These caused delays in our schedule.

Another stumbling block we have encountered is the cost of testing. The simple water tests we have found cost several hundred dollars to run. If we want to get our product UL listed, it will cost us thousands of dollars. Purchasing copies of the UL standards for filtration and purification has also proved to be very costly.

The most difficult area we encountered involved the flow meter. For the final prototype, we decided to go without an analog flow meter. Our original intent was to have a visual flow meter for the operator to know when it was time to change the filters. Our research provided several different options for this indicator. Some of these flow meters were small and accurate but quite expensive. Others were small and inaccurate but low cost. We concluded, due to our other objectives, that this flow meter could be eliminated from our system. It was not possible for us to fit both the objectives of low cost and accurate when it came to the flow meter. Consideration was also given to a home made flow meter. With this option, we would have been able to create a small and low cost flow meter. It would have been very challenging to keep a custom built flow meter accurate to the specifications we required. One of our overall objectives was to use commercially available off the shelf parts. A custom flow meter did not fit this objective. For these reasons, we decided to eliminate this part of our system.

The pump for our system was decided on after several tests. Our first pump worked well, it pushed water with four feet of head. The problem we encountered was that the pump was not self priming; it could not draw water into the system. Our second pump fit exactly our needs of 1gpm and the ability to self prime to four feet. We began running tests on this pump and realized that 1gpm flows only under ideal conditions of no resistance. Our system has significant resistance. The third pump, also the pump in our current system, has the ability to push 1.9 GPM under ideal conditions. This larger pump created several problems. The entire system now has to run on 1/2" tubing, an 1/8" larger than we had hoped. The pump is also slightly larger and heavier than we had originally planned. The pump also draws more amps than the controller was originally designed for. Components on the control board had to be modified to accommodate this larger amp draw. Overall, this pump fits our objectives closer than other alternatives.

We encountered problems with our UV light as well. The light we chose originally had several flaws. It could not be purchased with a matching 12Volt ballast, we had to try and match the output of the 120V ballast to the output of a 12V ballast. We did not feel completely confident in our calculations. The UV light inlets and outlets were 1/8" openings; this is a huge reduction in diameter from our 3/8" hose. There was too much of a flow rate drop to be feasible. We chose a different, slightly more expensive UV light to circumvent these problems.

As for the controller part of our system, we encountered many difficulties. We found the PICFlash2 programming device to be significantly difficult in downloading the program onto the PIC12F675 microchip. It took many weeks in learning all about this device and finding help from the European company that sold it. It also took awhile to learn all about how the microchip works and its usable functions. So Steve Frank helped us by letting us use his programming board that was compatible with our microchip. After testing and learning much, we successfully programmed the microchip and got it to function properly.

Another difficulty that we encountered was driving enough current to the pump. Every time our system would turn on, the UV light would turn on as planned, but the pump would not turn on because the 5V supply from the microchip would drop to 0V because the pump required too much current. Therefore, the microchip would cycle the same sequence of trying to start the pump over and over again, but it would never successfully start it up. In solving this problem, we placed an electrolytic capacitor with a ceramic capacitor across the output of the voltage regulator so that it would charge the voltage and keep it at 5V and prevent it from dropping to 0V. After this modification, the pump successfully turned on as planned. See Figure 1.

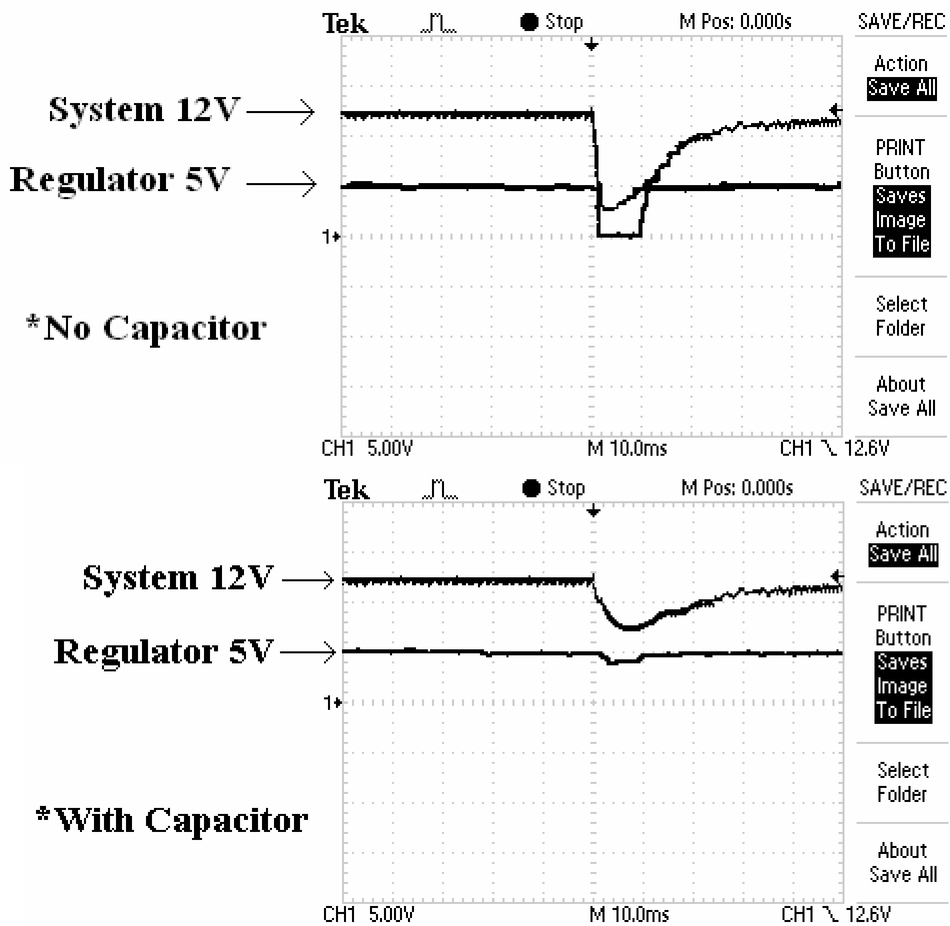


Figure 1 Oscilloscope graphs of controller without and with a capacitor across the output of the voltage regulator.

We encountered a close call with our UV light the day before we gave a presentation to the Engineering Board of Directors. This close call was the wires from the ballast to the UV light touching each other and shorting out, causing more current pull and eventually shutting off the UV light. Thanks to the 1 Amp slow-blow fuse that was blown, the circuitry was saved from being damaged and the UV light was protected from burning out. What we did was dissect the UV light wires and soldered and placed heat shrink on them so that they would not short again.

3 IMPLEMENTATION

3.1 Construction

The main objective of this project is to keep the construction as simple as possible. This means that, as much as possible, the parts will need to be off the shelf and easily obtainable. Our challenge is to find low cost, light weight and durable products that all interface with each other with minimal modifications. The next challenge is arranging our components in such a way as to cut down the size of the case but still maintain efficiency in the flow.

A big area of savings in the construction comes with the case. We have found a case with “pick and pluck” foam. This eliminates the need for cutting and arranging blocks of padding in our case. The tubing will need to be cut to the correct lengths and connected to all of the components.

The only custom part of our design is the controller. In order to manufacture the circuit, we first programmed the microcontroller. In doing this, we used the designated compiler program on our computer and the downloader device for our microchip. After successfully programming the chip, we set up a test simulation on a bread board that used LED’s acting as the pump and UV light. After the chip proved that it performed as needed, we then gathered all of the parts we needed from the room between Frey 254 and 256 to set up a breadboard of our actual circuit; this connected to our UV light and pump outputs. After testing and modifying the circuit to push enough power to the outputs, we were now ready to design our circuit in the program called Ultiboard. This program is on all of the computers in Frey 254. We measured the plastic box so we would know how big to make the circuit. After this was completed, we then started to begin the milling process for our circuit. Using the instructional packet placed above the ProtoMat Milling Machine which is located in the room between Frey 254 and 256, we were able to build a one-sided copper board of our circuit. After our board was finished being milled by the machine, we soldered all of the necessary components on it. Next we tested it to see if it worked as we planned it would. When the test proved to be a success, we drilled the necessary holes in our plastic box and screwed our circuit board into it. All Messiah Students have access to everything that was talked about above.

3.2 Evaluation/Testing

Testing has been a large part of our project during this past semester. In the future, it will become even more important. Our goal is to see this system mass produced and sold to the public. We need to have a reliable product that meets our prescribed specifications.

An important aspect of the system is the flow rate. This is provided by our pump. The pump must be rigorously tested to prove that it can provide our prescribed flow rate. The vertical pull, filters and UV inlet and outlet will all decrease the flow rate. The flow rate will also change over time; this is due to the filters. As the filters fill up with sediment, the flow rate will slowly drop. This will need to be monitored and measured. Our goal for next semester is to provide a sensor that will tell the user when it is time to replace the filters. We have run four tests, a pair without filters and a pair with filters. Each of these was run with and without a vertical draw of 3.5 ft. We have tested three pumps over the course of the year. Our first pump we tested and realized that we needed to find a self-priming pump. Otherwise the user would have to prime the system themselves which would just make the system more of a hassle. We then purchased a 1.1 GPM pump. This pump provided us with our needed 0.8 GPM under no load. The next thing was to test the pump under load with the filters. The filters made the system run at about 0.6 GPM. We still have yet to test the UV light, and adding the UV light dropped the gallons per minute even more down to .45 GPM. We decided to go with the next size up of pump, so that we could maintain a 0.8 GPM flow rate under load and with at least a four foot head.

A big problem that was left us from the previous project was the controller. A big problem from the previous controller was that it could not handle the voltage and amperage spikes from the pump as it started up. We wanted to record the voltage and amperage spikes so that we could properly protect our controller. We hooked up the pump and UV light separate, the results are shown in Figure 2 and Figure 3. Then, we hooked them up together to see that voltage spikes, see Figure 4. Even though the pump and UV light would never start up at the same time, this would be the most current the system would ever see. We used an oscilloscope to show the voltage spikes and placed a fixed resistor, so that we could find the amperage spikes using Voltage = Current * Resistance, see Figure 5 for schematic. We also did an endurance test on the controller. We wanted to make sure that the controller will last multiple uses. It was a success as it still continues to work after we have been turning it on and off for a month now.

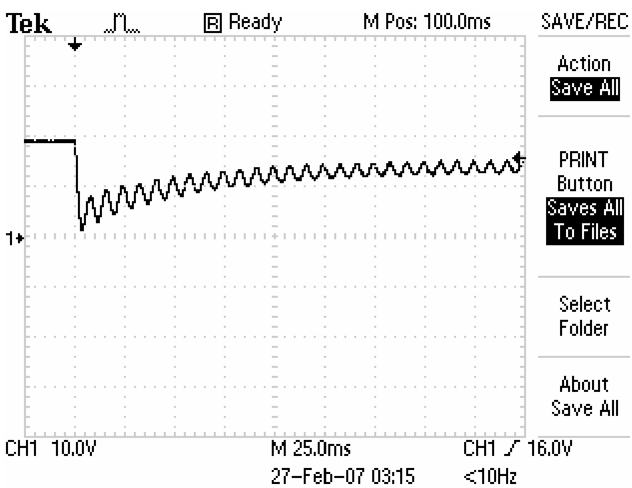


Figure 2 Pump voltage

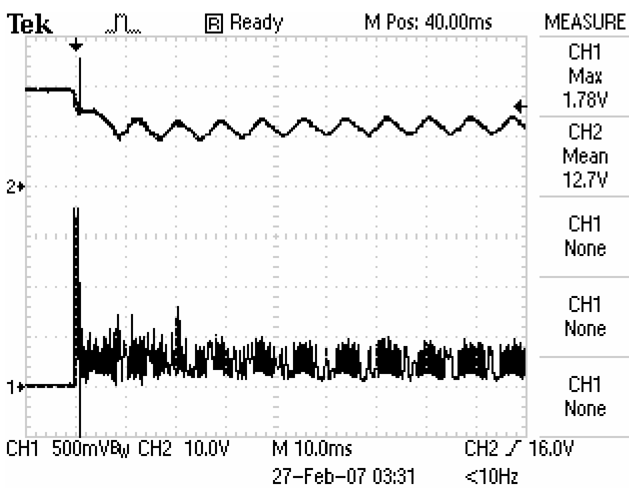


Figure 3 Ballast voltage and amperage

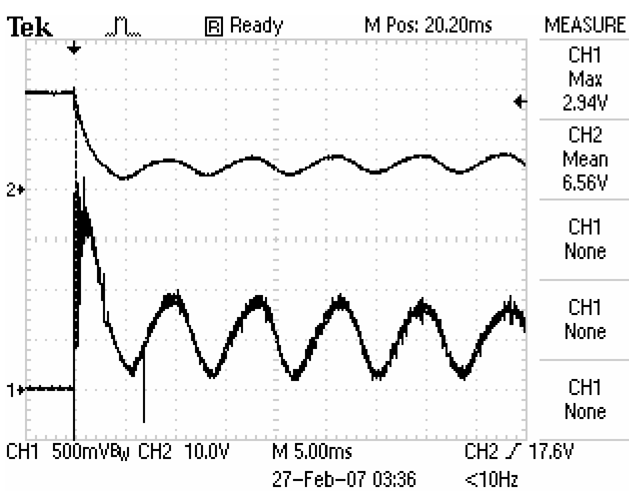


Figure 4 Pump and UV light in series

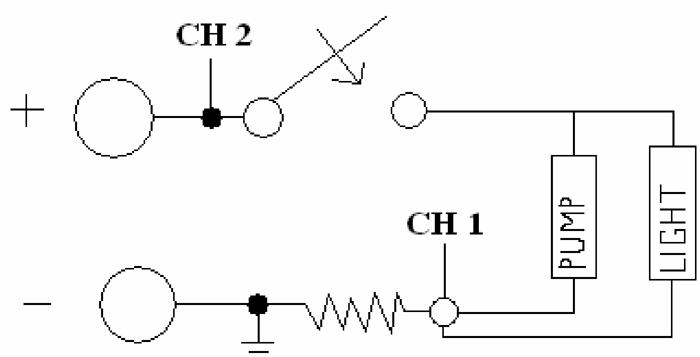


Figure 5 Schematic of voltage and amperage test

When we were finished milling and soldering our circuit, we felt rather unsure whether it would work because the soldering was difficult. It required a steady hand to properly place the solder in condensed places to connect certain components. When we finally tested our finished circuit, it was a success! Our first iteration of our circuit worked!

The last tests we have run are the fecal coli form tests. These tests work by helping any bacteria that is present in fecal matter to grow. If these harmful bacteria are present in the water, the water in the bottles will turn yellow. This means the water is not fit to drink. If the water in the bottles stays purple this means that the water is fit to drink. The test requires to let the water sit out of direct sunlight and at room temperature for 48 hours. We tested water from the Yellow Breeches Creek from behind Messiah College. The first test we did was on March 15, 2007. After the required 48 hours, there was just a small change in the color of the bottles. The bottles were out of date and the water in the Yellow Breeches Creek was very cold which meant the amount of bacteria was low. We decided to test the water again, on April 3, 2007. This test was done with new bottles. This test resulted in a better discolor. We found that our system will remove fecal coli form bacteria from the water.

3.3 Marketing

One idea present in all of our semester goals was to make this system marketable. To accomplish this, we had the help of the Living Water senior project and a group of students from the Appropriate Technologies class. Nathan Geiger and Paula Adams worked very closely with us to create a market plan for their class project. These individuals helped with significant portions of our literature review and helped us refine our goals to gain an edge within this small market. Our objectives were to meet or exceed those market standards. The areas that our group and the marketing group felt we could work on were the size, weight and cost of the system. The areas we are meeting market standards are flow rate, purification and filtration levels. Purification and filtration levels are also current industry standards for consumption.

Nathan and Paula researched potential markets for the sale of the Living Water system. Our market includes any activity near freshwater with a 12 V power supply nearby. This would include small fishing boats, pontoon planes, RV'ers, cabin owners, disaster relief and our original market, short-term missions. Each of these markets requires non-permanent solutions to clean water. The system is small and cheap enough to carry anywhere and be transported in any type of vehicle.

A large market appeared when talking to people from Alaska. There is a need for lightweight, high capacity water purification systems that run off 12 V. Due to the nature of the terrain in Alaska, cabin owners use 12 V. Most of these people also travel by plane to their remote homes. Our system would fit perfectly into the small, lightweight airplanes. The planes are usually outfitted with pontoons for the remote landings. Our purification system is compatible with the plane's electronics and would be a perfect accessory for any backcountry trips. At the cabins, clean water may still be hard to come by. This system is ideal for short-term stays, like for hunting trips, where an expensive, permanent system is not desired.

Recreational vehicle owners could also benefit from this system. An RV owner will have a need for clean water in those "less than perfect" campgrounds. The system would easily hide in a closet until it was needed. Expensive, permanent filtration is offered as an extra in RV's, this would be an inexpensive alternative. There is also a market with off road enthusiasts. Their vehicles can travel just about anywhere and camping from the vehicles is common. This would provide an excellent source of clean water for the groups of drivers.

There is also a small niche market with cabin owners. This market would include people who are seasonal cabin goers and are worried about their drinking water. Our system is not designed for permanent use; it could be used for month long cabin stays. For four people, at 1 gallon per day, the system will last approximately two months. This is perfect for a summer stay at the cabin.

We felt that disaster relief organizations could benefit from this system as well. They would use this when initially entering an area, before permanent solutions for water are set up. This would help protect the workers as well as provide for those who were affected by the disaster. Since the system is low cost, an organization could have several for use by their volunteers. This would be a great way to protect the volunteers while in the initial stages of disaster relief.

The original purification system was designed with Messiah short-term missions in mind. The idea was that groups of students, traveling to underdeveloped countries could carry the system to protect them from water-borne bacteria. Generally, these trips are three-week treks to an underdeveloped country. When flying, weight and space is a definite consideration. This system would meet both of those standards. A group of 10 students, drinking .5 gallons per day, would hardly phase this system. We included an AC adapter in the case so that the system can be plugged directly into a wall socket, both 110 and 220 V AC. The system could be considered semi-permanent for the protection of the students during their stay.

We feel that our system has an edge over the current market of self powered filtration system. We offer a similar flow rate and purification levels. Where our system beats the competition is in the size, weight and cost. Overall, it is approximately one half the volume and weight of competing systems. It is also nearly one-third the cost of the nearest competitor. We feel that our system would do well if marketed properly. The intent when selling this system would be to benefit Messiah Missions.

4 SCHEDULE

The team followed the Gantt Chart religiously in the fall 2006 semester. On the other hand, it wasn't until the end of October when delays in our schedule started to happen. Finding a suitable pump for our system was difficult. We purchased a total of three pumps and tested five. Professor Erikson donated the two other pumps that we tested. Finally, after testing throughout the semester, we decided to use the Jabsco Par-Max 1. As for the ultra-violet light, we purchased one with $1/8^{th}$ inch diameter inlets and outlets. We were yet to discover the problems with this UV light. Another obstacle that affected our schedule was the programming of the microcontroller. The program was written successfully, but the programmer that downloaded the program onto the chip was difficult to use and caused a huge time delay in our project.

In the spring semester there were three delays that affected our Gantt Chart dramatically. First, was the development of the controller. We had difficulties figuring out what the problem was with the programming device for the microchip. It is taking a long time to get a reply from the European company that made the programming device. We have still yet to hear from them. This led to obtain another source of help, Lab Technician

Steve Frank. Steve had a programming board that could troubleshoot and adequately test the microchip that we wanted to program. Steve let us borrow his board and we found out what we needed to do in order to successfully program a working microchip for our project. From then on, things went smoothly with the controller and only one board was milled and soldered to successfully make our circuit control our system the way we wanted it to. The other delay in our schedule was finding a pump suitable to pump around .8 - 1 GPM through our system. We ended up choosing the higher model of the Jabsco Par-Max 1 and it is called the Jabsco Par-Max 1.9. As for the UV light, the inlet and outlet size of 1/8th inch diameter was too small that it reduced the flow rate and increased the pressure, causing a lot of problems with hoses popping off during the pumping process. We ended up using the same UV light as the last Senior Project Group with 1/4th inch diameter inlet and outlets. This worked fine after running tests.

Overall, our predicted and actual Gantt Charts for each semester differ greatly.

4.1 Gantt Chart

See Attached Pages

5 BUDGET

Item	Quantity	Cost
Pump - Alita Industries	1	$43.29
Pump - Jabsco Par-Max 1	1	$49.99
UV Light and Ballast	1	$81.97
12VDC Ballast	1	Free
1 micron Carbon Filter	1	$18.53
5 micron Sediment Filter	1	$11.60
Head for filter	2	$31.35
PIC microprocessors	6	$20.83
PICFlash2 programmer	1	$54.00
Tubing and Fittings		$18.65
Pump - Jabsco Par-Max 1.9	1	$71.18
AC Adapter	1	$34.19
Case	1	$64.64
Circuit Board	1	$9.46
Tubing and Fittings		$21.23
Total (to date)		$530.91
Total (remaining)		-$30.91

6 CONCLUSIONS

We were able to complete a functioning 3 stage water purification system that ran of 12V DC. The controller was a major success for us; we were able to have the controller run a timing sequence with the pump and UV light as well as handle voltage and amperage spikes. We also reduced our weight from 22.4 pounds to 13.2 pounds and reduced the volume by about half. We feel with minor changes to the pump and the controller that our system will provide the necessary 0.8 – 1.0 GPM. We feel that the benefit of a flow meter is not worth the cost to implement it. With more testing for durability of the pump and filters, we feel our product could be marketed. We would also like to see our product certified by UL, we were not able to obtain these standards due to funding.

7 RECOMMENDATIONS FOR FUTURE WORK

Our project has several places on which future work could be done. Our original idea was to have the system UL approved. This plan proved to be too much for a single year's work. We would like to see the system earn the UL stamp of approval. Getting UL approval will be a long and expensive undertaking, it would prove to be worth the work. Having a UL approved, portable filtration system will be a great asset to Messiah College Missions as they travel to underdeveloped countries.

One of our original goals was to implement an automatic flow meter. We were not unable to find a COTS part that fit our needs, nor did we feel that a custom flow meter fit into our other goals. Future groups could implement a flow meter, either custom built or purchased, so the user would know when it is time to change the filters.

The final area we would like to see improved upon is the hose diameter. The flow rate the system provides is not in proportion to the hose diameter that we have implemented. We were unable to find the proper fittings to allow for the use of 3/8" hose. The pump we used works with both 1/2" and 3/8" hose, if the proper fittings are found. We would hope that a future group would be able to find the correct 3/8" fittings to allow for the use of a smaller, lighter hose. Currently, we have retrofitted the system with the 3/8" hose, but would like to see other, lower cost fittings used.

The case we chose for the controller is considered waterproof. This is perfect except that there are holes drilled into it. These holes need to be sealed from the water that may enter the case. The most challenging part of this modification will be finding a waterproof switch. The current switch has two large spaces for water to simply run onto the circuitry.

The LED indicators are currently designed to be in an open loop system. This means that if the UV light or the pump were to not work, the LED's would still emit light. The LED indicators are controlled by the microprocessor; the chip dictates when they should turn on and off. We would like to see these LED's placed into a closed loop with the pump and the UV light. Our desire is that they would be placed so that they only turn on when the pump or UV has turned on, and turned off when either the pump or the UV light was to not work. For this to happen, we would need to place the LED indicators after the fuse so that they will power off when either the UV light or pump fails. We would have to make sure that these LED's are rated to handle the amperage from the pump and UV light. Also, the LED's would need rated resistors before them. This should be a fairly simple design change, as they are not very integral on the circuit board.

As mentioned before in the design portion, the flow rate is not quite what we had desired. We have hopefully found a solution to this problem. Our current pump, the Par-Max 1.9 operates with a pressure of 15 PSI. The filters were designed to filter 1 GPM at a pressure of approximately 50 PSI. The pump we would like to see implemented is the Jabsco Par-Max 2.9. This pump operates at a pressure of 40 PSI. This should drastically increase our flow rate. The 2.9 and the 1.9 utilize the exact same enclosures. This means that there would not have to be any design changes made the interior of our system; it will fit perfectly into the case. The only changes that would have to be made are on the controller. The capacitor that prevents the chip from resetting may need to be increased due to a larger start up amperage draw. Since a capacitor is already designed into our system, it will be a simple switch for a larger capacitor. The 2.9 also will draw more current. It may be necessary to increase the size of the slow blow fuses. Again, since they are already designed into the system, it will not be a problem to swap them out.

The only test we did not complete were longevity tests of the pump and the filters. We are confident in the pumps' abilities due to the nature of its use. Running the pump, with a load, for a long period of time may provide interesting results. The filters need to be run until failure. The operator needs to know at what point to replace the filters. Our hope is that a test could be run to determine a flow rate at which the filters should be replaced. We had neither the funds nor the time to run such a test. The results of this test should then be placed into the operations manual.

Finally, we would like to see this system marketed. It would be great to see a batch of 10 systems built. These would either be sold to benefit Messiah Missions or given to the Agape Center or Collaboratory for use by students traveling abroad. Hopefully, the school could set up distributor accounts with Jabsco and the PFC to help lower the cost of the components. Thanks to the appropriate technologies group, we have a market plan already written and ready to implement.

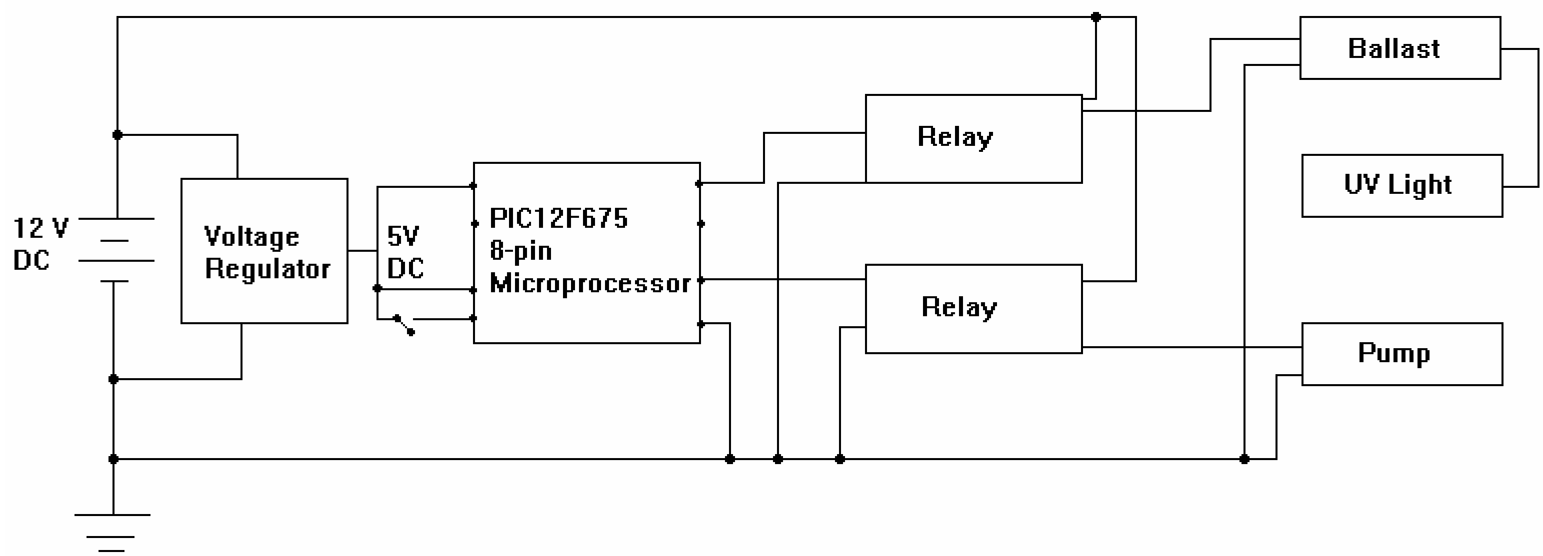
8 REFERENCES AND BIBLIOGRAPHY

The Responder. First Water Inc.
http://www.firstwaterinc.com/

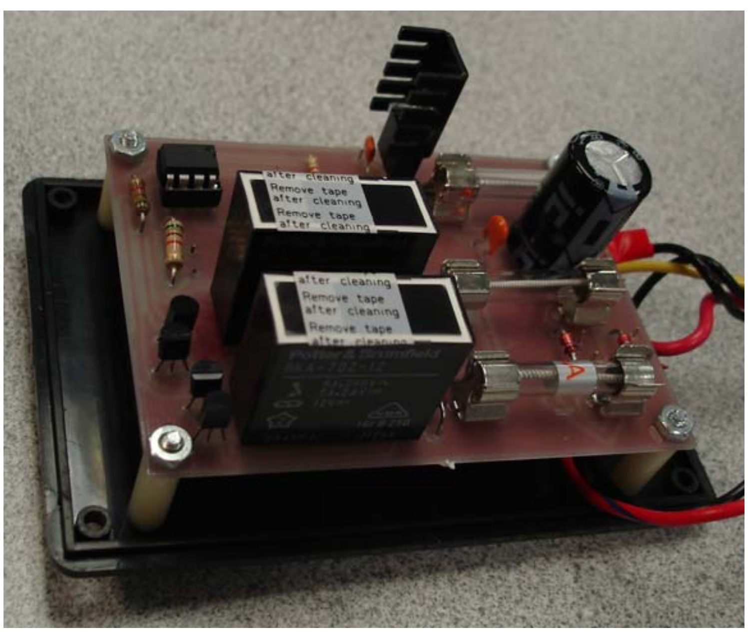
The Trekker. Noah Water Systems.
http://www.noahwater.com/trekker.html

9 APPENDICES

9.1 Drawings/Diagrams/Pictures



Circuit Block Diagram for Controller

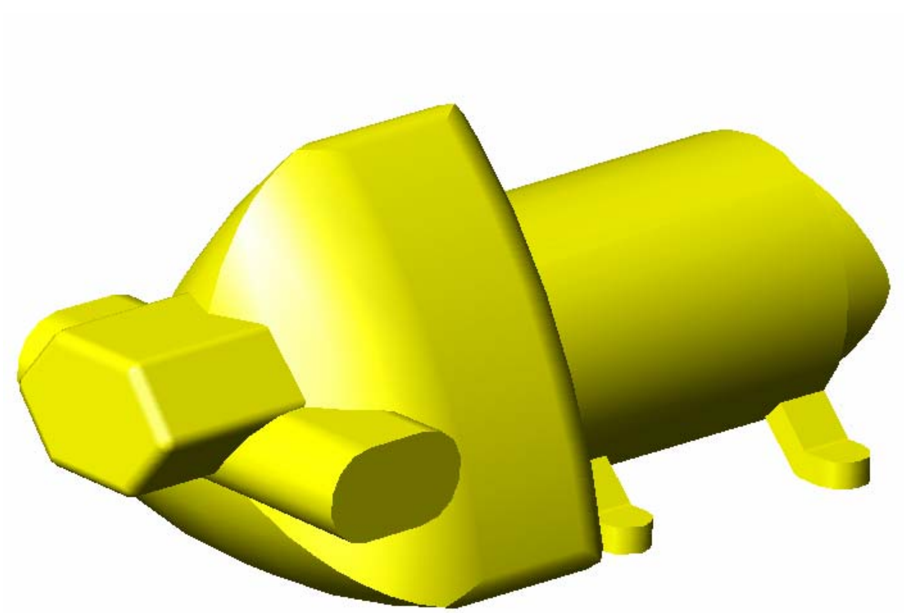


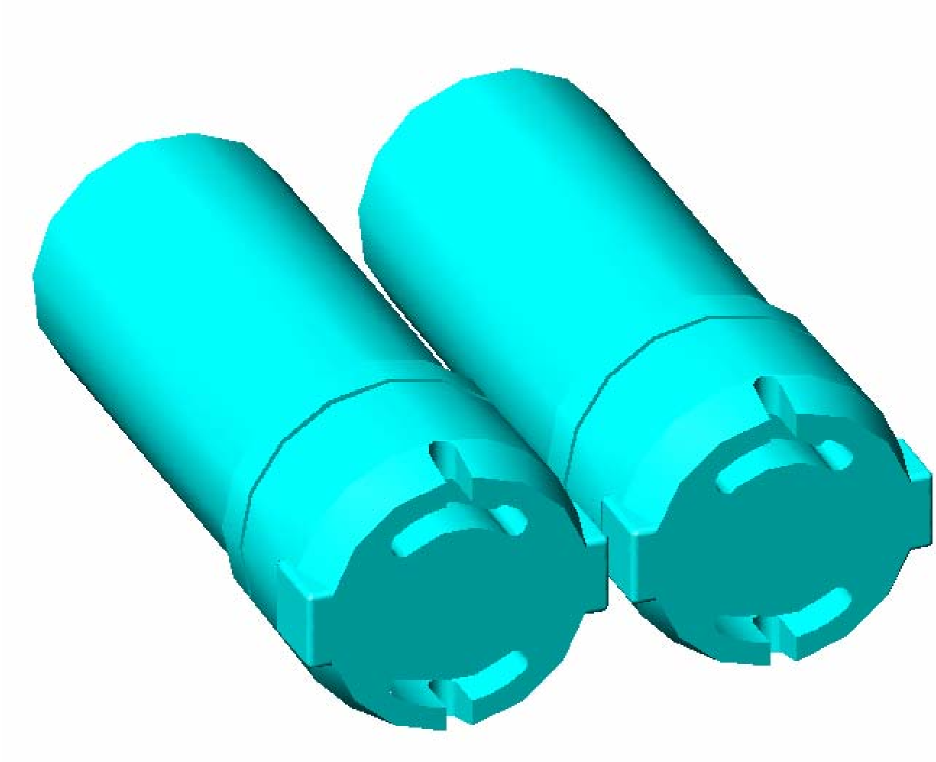
Picture of Circuit

Picture of Controller Box

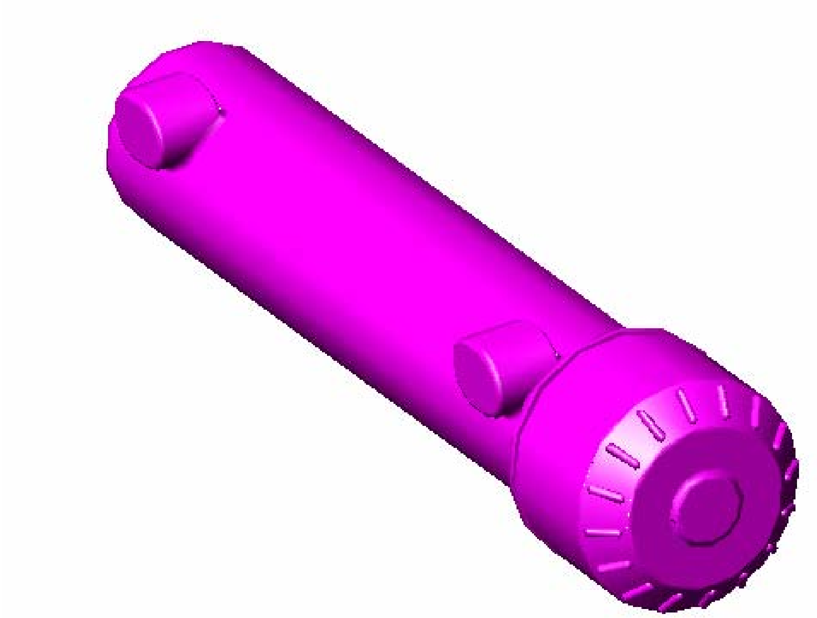
AutoCAD drawing of entire system

Picture of the completed system

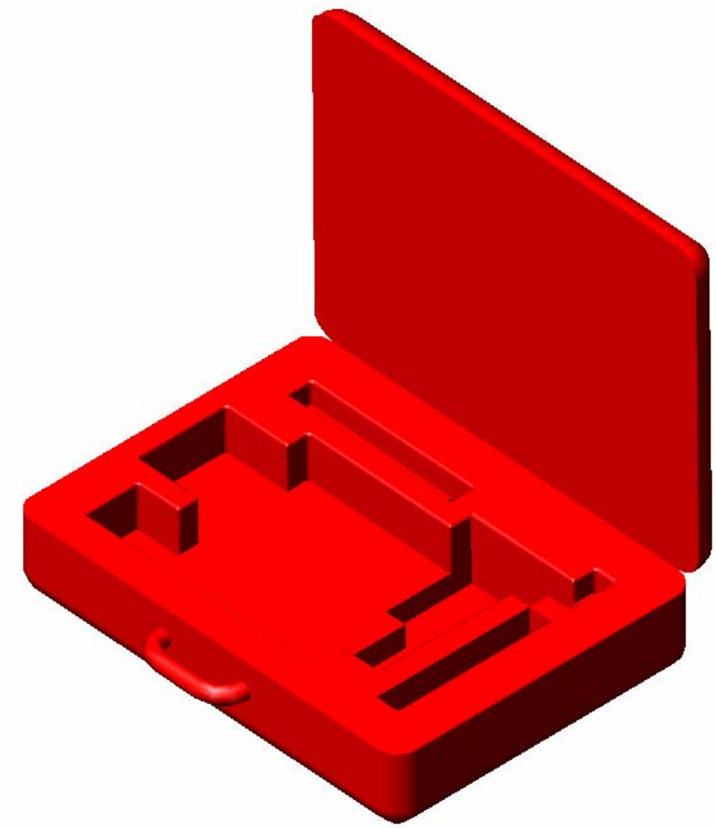

AutoCAD drawing of the pump



AutoCAD drawing of the filters



AutoCAD drawing of the UV light



AutoCAD drawing of the case

9.2 Resumes of Team Members

Nathan D Martin

Messiah College, One College Ave, Box 5898, Grantham, PA 17027 (college) (717) 796-5334
40 Park Street, Akron, PA 17501 (Home) (717) 859-1765
nm1191@messiah.edu

Goals

To obtain an internship in engineering with a focus on the mechanical side of production.

Summary of Qualifications

Self-motivated with interpersonal and communication skills and a background in the following broad-based competencies:

Communication	**Organized**	**Punctual**
Logical	**Self-Starter**	**Diligent**
Attentive	**Leadership**	

- Demonstrated ability to develop a develop an idea and put into a logical plan of action
- Ability to communicate ideas to customers, colleagues, and friends in laymen's terms
- Ability to Organize an event and follow through to conclusion
- Listen carefully to all of those around me, both superiors and colleagues
- Provide leadership with the ability to stay focused on the goal

Software Knowledge

CAD	**IDEAS**	**Excel**
Word	**PowerPoint**	**Novell Network**

Experience

Chad Hurst**,** Realtor**,** *Lancaster, PA* *Summers: 2003-2005*
Subcontracted painting for

- Prepared the rooms to include plaster, sanding, strip wall paper and painting
- Landscaping as needed

Rocky Mountain Mennonite Camp, *Woodland Park, CO* *Summer 2004*
Camp Counselor: Primary duties were to interact with campers. Additional responsibilities included serving as counselor to campers, kitchen duties and maintenance assistance

- Interacted with campers as counselor and friend
- Provided leadership in hikes, mountain biking trips and climbing for campers
- Carried out responsibilities in the kitchen as needed to include: food preparation, clean-up, serving while interacting with campers
- Helped with painting, fence repair, upkeep of trails, roofing cabins

Royer Pharmacy, *Akron, PA* *2000-2003*

Pharmaceutical Technician: Responsible to assist customers requiring prescriptions and assisted pharmacist with dispensing medication. Specifically,

- Logged prescriptions
- Verify insurance data with customer
- Pull medication, fill prescription order with labeling, verifying accuracy with pharmacist
- Received telephone orders from customers needing prescription refills
- Interacted with customers to complete purchase of medications and other purchases

EDUCATION

Messiah College, Grantham, PA, Junior majoring engineering with a mechanical concentration. Graduation scheduled for May, 2007.

CO-CURRICULAR ACTIVITIES

On volleyball team in High School and Messiah College
Member of Ski Club, President 2005-2006
Work at The Climbnasium in Mechanicsburg as Birthday Belayar

PERSONAL INTERESTS

Mountain Biking, Climbing, Racquet Ball, Camping, and Reading

Adam M. Yoder

Campus Address:
Box 6345, One College Ave.
Grantham, PA 17027
(717)-796-5020

Home Address:
11218 Old Town Road
Huntingdon, PA 16652
(814) 667 2534

E-Mail: Ay1155@messiah.edu

OBJECTIVE: To obtain a full time engineering position that will allow for the possibility of further education.

EDUCATION: Bachelor of Science in Engineering / Mechanical Concentration
December 2008
Messiah College, Grantham, PA

SKILLS:I-DEAS, Microsoft Office 2000 and XP**,** MatLab 14, TK Solver, Derive
Works wells in a team setting
Good problem solving skills

RELATED EXPERIENCE: **Genesis II Solar Racing Team**
September 2004-May 2005
Constructed a light weight solar powered race car
- Constructed the haul out of carbon fiber
- Worked on the team to design the drive train

Senior Project
September 2003-present
Designing and constructing a light weight and portable water filtration system

Freshmen Design Project
Drexel University 2003-2004
Designed a system to help emergency vehicles find the most effective route in city traffic to reduce response time.

WORK EXPERIENCE: **Taylor's IGA**
1999-2002
Stocked shelves and cashier
- Learned customer service

Hoss's Steak and Sea House
March 2003-August 2003
Dishwasher

Christopher Stuart Oberg Jr.

Campus Address: Messiah College, One College Avenue, Box 6072, Grantham, PA 17027

Home Address: 214 Pearl Street, Lancaster, PA 17603

E-mail: co1178@messiah.edu

Phone: (717) 779-4338

OBJECTIVE: To obtain an internship in the field of engineering using my experience, education, and well-developed analytical and interpersonal skills to enhance the efforts of a progressive corporation.

EDUCATION:

Bachelor of Science in Engineering, December 2007
Electrical Engineering Concentration
Messiah College, Grantham, PA
Current Cumulative GPA 3.3/4.0

SENIOR PROJECT: Used project management skills to lead a team in the creation of a low cost camping water purification system with an electronic controller to present as a marketable product.

COMPUTER SKILLS: Windows, MSWord, MSPowerPoint, MSExcel, Minitab, Derive, IDEAS, Matlab, Java, Multisim, Ultiboard, Multimeter, Oscilloscope, ProtoMat Milling Machine

RELATED SKILLS:

Excellent organization, planning, and time management
Good analytical thinking and problem solving abilities
Works well with interdisciplinary teams
Strong communication skills

WORK EXPERIENCE:

HVAC Mechanical Assistant Summer 2006
Mr. David Eggelton/Monkton, MD
- Studied drawings to learn the HVAC design process
- Helped in the construction of commercial and residential assignments

Maintenance Technician Summers 2004 and 2005
Dr. Craig Landa/Freeland, MD
- Repaired and maintained grounds to guarantee the appearance and function of a veterinarian's horse farm
- Demonstrated an ability to work independently

Machine Press Operator Summer 2003
Crescent Industries/New Freedom, PA
- Performed the process of manufacturing plastic injected parts during the nightshift
- Analyzed ways to reduce defects in parts

Gas Station Manager June 2001 - May 2003
Glen Rock Getty Mart/Glen Rock, PA

- Learned to take initiative in managing the business

ACTIVITIES: Messiah College Men's Lacrosse Team (Fall 2003 – Spring 2007)
2004-2007 Middle Atlantic Conference All-Academic Team
Recreational Flag Football

9.3 Controller Procedure

Procedure on How to Build the Electronic Controller

1. Programming the microcontroller
    a. Obtain a PIC12F675 (programmable integrated chip)
    b. Install mikroBasic by double-clicking on "mikrobasic_5002_setup" (from supplied CD)
    c. Open "Controller" (from supplied CD), but see notes below first
        i. You will see many files that are named "Controller"
        ii. Make sure the file type is **mikroBasic project file**
            1. Find the file type by right clicking on a file and selecting "Properties"
    d. Once file is loaded, locate "Device," "Clock," and "Build Type"
        i. For "Device," make sure that **P12F675** is selected
        ii. For "Clock," make sure that **4.0 MHz** is entered
        iii. For "Build Type," make sure that **Release** is selected
    e. Go to the "Project" menu and select "Edit Project"
        i. In the "Device Flags" section, make sure that **_WDT_OFF = $3FF7** and **_INTRC_OSC_CLKOUT = $3FFD** are both checked, everything else should be unchecked
    f. Installing the PICFlash2 Programmer
        i. Open "installing_usb_drivers" (from supplied CD) and follow the directions for installing the PICFlash2 Programmer Device
            1. Note: To get to "Device Manager," right-click on "My Computer" and select "Manage"
                a. From here, you can select "Device Manager"
    g. Hardware connections from the PICFlash2 Programmer to the PIC12F675
        i. Open "picflash2_manual" (from supplied CD) and follow the middle diagram on the sixth page to make wire connections from the programmer to your chip using a connection board; you can see that this diagram is for the PIC12F675, as it is labeled on the page
            1. **Note: The diagram of connections for the "PICflash CONNECTOR" is viewed from the back, therefore be careful to match connections correctly**
    h. Building program and downloading program to chip
        i. Make sure that the "Controller" **mikroBasic project file** is open
        ii. Also, make sure that the "PICFlash2 Programmer" is connected to the computer and your chip using a connection board
            1. Note: The green LED light should light-up for power running to the programmer and the yellow LED light should light-up for USB connectivity
        iii. Go to the "Controller" program in mikroBasic and click on the "Build Project" icon, it is the icon with two orange axels with pointing arrows, wait until the program has successfully finished building and then proceed to the next step

iv. Now click on the "PicFlash Programmer" icon, it is the icon with a green arrow pointing to a chip, wait until the PicFLASH screen has disappeared to test the programmed chip

2. Setting up and Testing the Programmed Chip
    a. Setting up a simulation of the UV Light and Pump using LED's
        i. Plug the chip into a connection board
        ii. Open "PIC12F675-DataSheet" (from supplied CD) and locate the PIC12F675 diagram on page 4
        iii. Connect **5 Volts DC to pins 1 and 4**
        iv. Connect **pin 8 to ground**
        v. Connect a **10kOhm resistor from 5 Volts DC to pin 5**
        vi. Connect a **simple "on-off" switch from pin 5 to ground**
        vii. Connect a **1kOhm resistor from pin 2 to the positive end of an LED (longer end)**; choose a color of your choice to represent the UV Light
            1. Connect the **negative end of the LED (shorter end) to ground**
        viii. Connect a **1kOhm resistor from pin 7 to the positive end of an LED (longer end)**; choose a color of your choice to represent the Pump
            1. Connect the **negative end of the LED (shorter end) to ground**
    b. Testing the programmed chip using the simulated setup
        i. Flip the switch to the "on" position and the simulation should run as indicated below
            1. The LED for the UV Light should light-up first and then the LED for the Pump should light-up 5 seconds afterwards
            2. If this does not happen, run through and make sure that your connections are correct for the simulation setup, check for correct connections
            3. If problem persists, then run through downloading the program onto the chip again
        ii. Flip the switch to the "off" position and the simulation should run as indicated below
            1. The LED for the Pump turns off first and then the LED for the UV Light turns off 5 seconds afterwards
            2. If this does not happen, run through and make sure that your connections are correct for the simulation setup
            3. If problem persists, then run through downloading the program onto the chip again, also checking for correct connections
3. Milling the circuit board
    a. Go to the middle room between Frey 254 and Frey 256 (the Electronics Laboratory)
    b. Locate the **ProtoMat Milling Machine** and obtain the typed instructional guide on milling a circuit board and follow the directions it states (this guide

should be somewhere around the machine or computer), but see notes below first

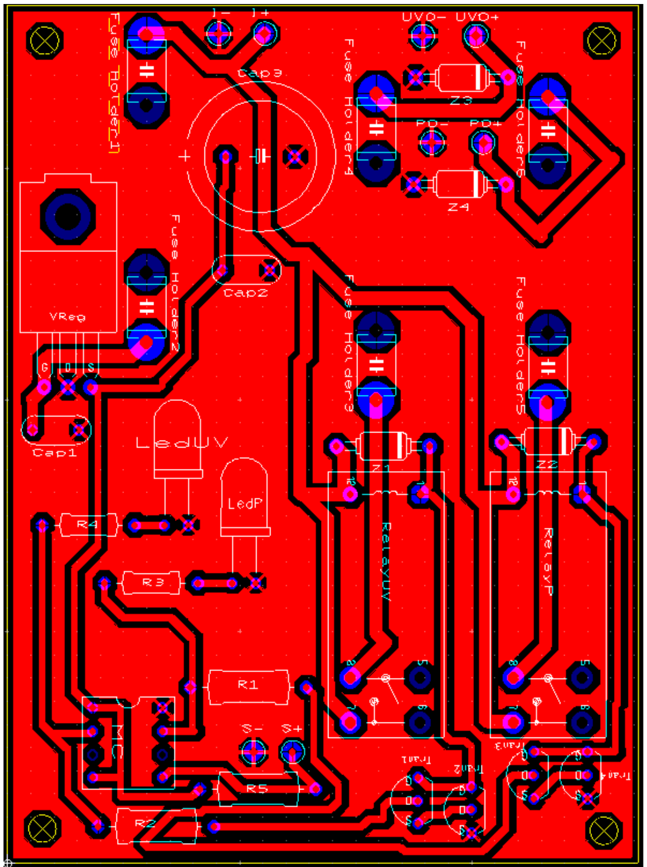
i. You have all of the documents on the supplied CD to mill the circuit board, so you can skip all of the document development in the instructional guide, seek Lab Technician for assistance
ii. Use **1 ounce per square foot** copper board for milling this circuit board

4. Soldering Components to the new board
   a. Gather the following materials and equipment to be soldered to the board
      i. **Materials and Equipment List:**

Part	Part Characteristics	Quantity	Part Manufacturer	Part Number
AC Adapter	12VDC/5A	1		
Cigarette Lighter Adapter	5A Fuse	1		
Pin	Ones that fit inputs and outputs to board	6		
Slow-Blow Fuse	3A	1		
	1A	1		
	5A	1		
Bipolar Junction Transistor		4		PN2222A
DIP Socket	8 pin	1		
Capacitor	Electrolytic/6800µF/10V	1		
	Ceramic/100nF	1		
	Ceramic/100nF/50V	1		
Fuse Clips		6		
Heat Sink	Smallest one that fits LM7805	1		
LED	White	1		
	Green	1		
Microcontroller (previously programmed)	8 pin	1	Microchip	PIC12F675
Relay	12V/5A	2	Potter & Brumfield	RKA-7DZ-12
Resistor	1kΩ	2		
	5kΩ	2		
	10kΩ	1		
Switch	2-state slide	1		
Voltage Regulator	5V	1		LM7805
Zener Diode		4		1N4744
LPKF-Milling Machine	C-Series	1		

Soldering Iron		1		
De-Soldering Iron		1		
Solder	.032diameter/8oz. roll	1		
Wire Cutters		1		
Wire Strippers		1		
Ultiboard Software Program		1		
Electrical Cord	20 feet of two connected wires (20guage each wire)	1		
Electrical Wire	3 feet of 18guage wire	1		
Electrical Tape	1 Black roll	1		
Heat Shrink	1 foot of white 2 feet of red 2 feet of black	1		
Heat Gun		1		

b. Guidelines on Soldering
   i. Go to this website and read everything thoroughly on how to solder: http://www.messiah.edu/departments/engineering/policies/pdf/SolderingHandout.pdf
c. Ultiboard Drawings for component placement are on the next two pages (first is the top view of the board and second is the 3-dimensional drawing):


Fuse Holder1
I-
I+
Cap3
UVO-
UVO+
Fuse Holder4
Fuse Holder6
Z3
PD-
PD+
Z4
VReg
Fuse Holder2
Cap2
Fuse Holder3
Fuse Holder5
Cap1
LedUV
LedP
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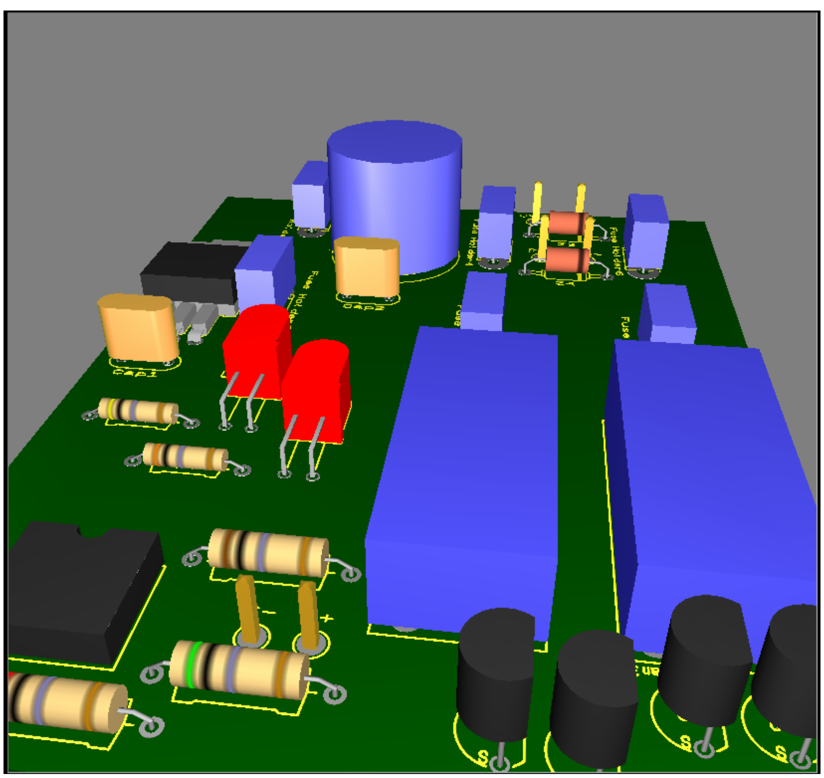
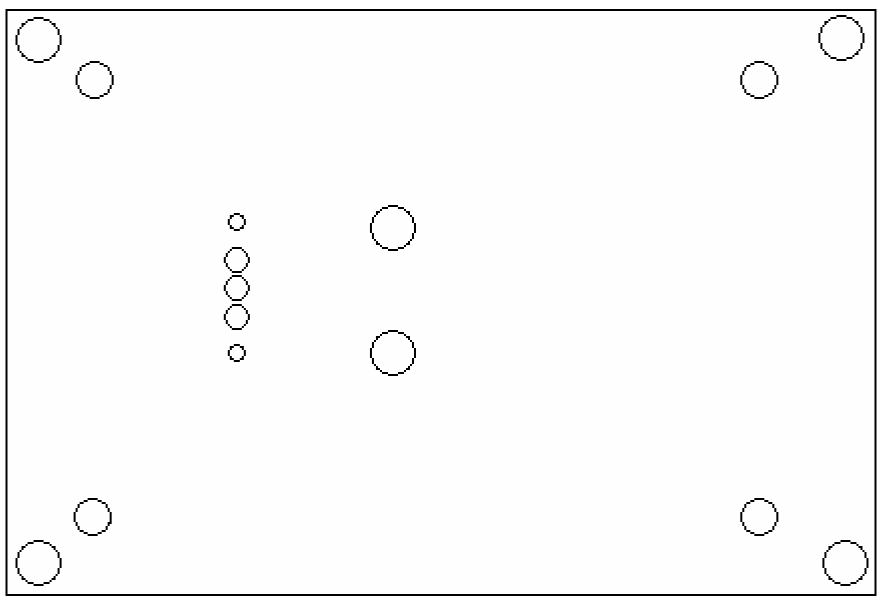
R4
R3
R1
MIC
S-
S+
R5
R2



i. Make note of certain connections that are tricky, be careful to connect the following correctly:
1. Input and output wires with pins (make sure + and – connections are correct)
2. Fuse into fuse holders
3. Microchip into DIP socket
4. Zener diodes (make sure + and – connections are correct)
5. Make sure electrical tape is properly covering 10 specific areas (4 soldering connections to LED's and 6 soldering connections from input and output wires to board)

5. Make appropriate connections (using alligator clips) to the input Car or AC Adapter, and to the output UV Light and Pump, then flip switch to test system with or without water, but see note first
   a. **Note: Make sure there is no power when making connections**
6. Box for controller
   a. Obtain controller box: Hammond Mfg. #1591TSBK
      i. Use the drill press in the shop to drill holes into the back of the lid and the side of the case
      ii. Drill according to the drawing below



      iii. For the switch, drill three holes adjacent to each other and use a small file to square out the corners
      iv. Attach the board using 4 x 4:40 1" bolts and 4 x .25"D, .687"L spacers
      v. Attach the switch using 2 x 2:56 3/8" bolts
      vi. Attach the LED indicators by applying a small amount of superglue to the bottom of the LED
7. Solder appropriate positive and negative connections with heat shrinks to the input Car Adapter, and to the output UV Light and Pump, then flip switch to test system with or without water, but see note first
   a. **Note: Make sure there is no power when soldering connections**

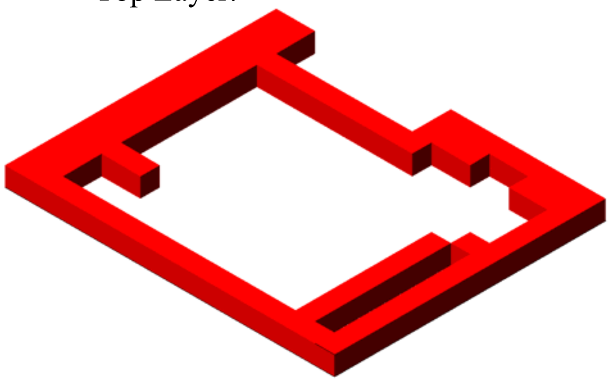
9.4 Construction Manual

Construction Manual:

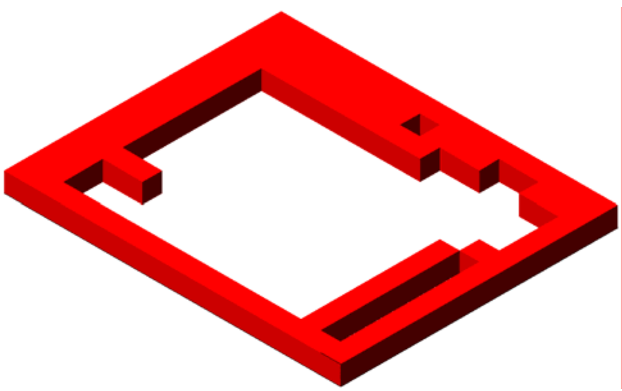
1. Preparing the case:

The case comes pre-filled with pluck and pull foam. You simply need to remove the correct blocks from each layer. These layers are each shown below:

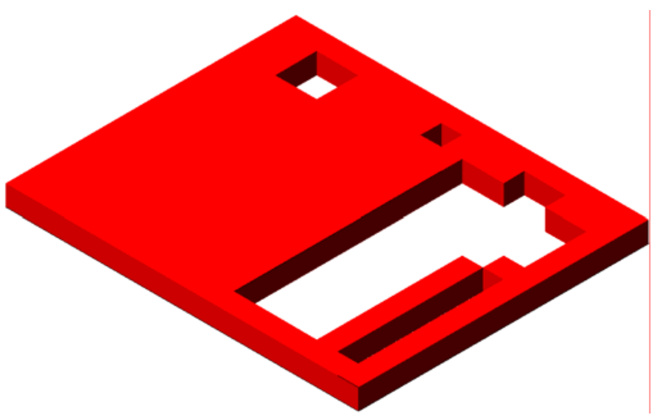
Top Layer:



Middle Layer:



Bottom Layer:



2. Place each of the fittings to the proper places:

Female swivel elbow	Pump inlet
Female straight	Pump outlet
Male elbow	Filter inlet
Male to Male	Between filters
Male to Male	Outlet of filters to UV inlet
Male elbow	Outlet of UV

3. Place the pump into the case. Run the power wires under the foam on the bottom layer and attach them to the controller.

4. Place the ballast into the hidden compartment in the top left corner of the bottom layer. Attach the power to the controller and connect the ballast to the UV light.

5. Place the controller box into the case.

6. Slide the power cord through the corner of its compartment and attach to the controller. Place the cigarette lighter adapter onto the end of the power cable.

6. Cut a 7" piece of hose and place between the inlet of the filters and the outlet of the pump.

7. Place a 4.5' piece of hose on the inlet of the pump. Insert the stem adapter into the inlet of this hose. Screw on the strainer to the threaded side of this fitting.

8. Place a 3' piece of hose on the outlet of the UV light. Insert the plug into the outlet of this hose. Be sure not to push the plug in completely, as it will be difficult to remove.

10. Insert optional AC adapter into the compartment next to the pump.

11. Use superglue to secure the loose edges and cuts in each exposed piece of foam. This will secure the remaining blocks and create a neater looking box.

9.5 Operations and Maintenance Manuals

Operations Manual

1. Make sure both hoses are connected securely to the inlet of the pump and the outlet of the UV light
2. Place the inlet hose in the source of water.
3. Unplug the exit of the outlet hose.
4. Insert the power cord into the cigarette lighter in your car (Note: Car may need to be turned on or the key turned to the Accessories position). If using a receptacle place the power cord into the AC adapter. Then plug the AC adapter in.
5. Turn on the system.
6. Make sure the indicator on the Ultra-Violet light is glowing. If it is not glowing turn off the system and refer to the UV light section of the maintenance manual.
7. Hold the outlet hose above the opening container so that the exterior of the outlet hose does not contact the interior of the container or any purified water. This will reduce the possibility of contamination.
8. When your container is almost full, pull out the inlet hose out of the water, and then let the remaining water in the system fill the rest of your container. This will push the water that is in the filters out of the system.
9. Once no more water is coming out of the system, turn off the system, and replace the plug in the outlet hose.
10. Wrap the cords from the power and AC adapter up and place them in their designated places. Also wrap up the hoses and lay them on top of the filters and pump.
11. Close the case.

Maintenance

Filter Replacement

Every time you run the filtration system you should test the flow rate to see if the filters need changing. If the flow rate drops below (needs to be tested). The filters need changing.

1. Disconnect the quick connect that is going into the filters.
2. Pull the filters out.
3. Unscrew both filters.
4. Screw in new filters.
5. Attach hose to the quick connect.

UV Light Replacement

1. Lift the cap end up the UV light up.
2. Disconnect the white wires.
3. Unscrew the cap.
4. Pull the bulb out of the tube making sure not to touch the glass tube. Getting finger prints on the tube will reduce the effectiveness of the light.

Long Term Storage

1. To purge the system mix 2 gallons of water with Clorox specified on the Clorox bottle.
2. Run the 2 gallons through the system using the steps from the Operations manual.
3. To completely empty the system tilt the case so the exit of the UV light is downward, this will allow the water remaining water in the UV light to escape.
4. If taking the system out of long term storage run 5 gallons of clean water through the system. This will push out any remaining Clorox water.

9.6 Program for Microcontroller

See attached page.

9.7 List of Materials and Suppliers for Controller

Material Component Description	Part Characteristics / Part #	Quantity / Amount	Company	Phone #	Ordering Information
Controller Box	Hammond Mfg. #1591TSBK	1	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
Cigarette Lighter Adapter	5A Fuse	1	Radio Shack	1-800-843-7422	www.radioshack.com Credit card
Pin	Ones that fit inputs and outputs to board	6			
Slow-Blow Fuse with 6 Clips	3A	1			
	1A	1			
	5A	1			
Bipolar Junction Transistor	PN2222A	4	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
DIP Socket	8 pin	1	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
Capacitor	Electrolytic/6800µF/10V	1	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
	Ceramic/100nF	1			
	Ceramic/100nF/50V	1			
Heat Sink	Smallest one that fits LM7805	1	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
LED	White	1	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
	Green	1			
Microcontroller	PIC12F675	1	Microchip	1-480-792-7200	www.microchip.com Credit card
Relay	RKA-7DZ-12	2	Tyco Electronics	1-800-522-6752	www.tycoelectronics.com Credit card
Resistor	1kΩ	2	Mouser Electronics	1-800-346-6873	www.mouser.com Credit card
	5kΩ	2			
	10kΩ	1			
Switch	2-state slide	1	Radio Shack	1-800-843-7422	www.radioshack.com

					Credit card
Material Component Description	**Part Characteristics / Part #**	**Quantity / Amount**	**Company**	**Phone #**	**Ordering Information**
Voltage Regulator	LM7805	1	National Semiconductor	1-800-272-9959	www.newark.com Credit card
Zener Diode	1N4747A	4	National Semiconductor	1-800-272-9959	www.newark.com Credit card
Electrical Cord		20 feet of two connected wires (18guage each wire)	Home Depot		www.homedepot.com Credit card
Electrical Wire		3 feet of 20guage wire	Home Depot		www.homedepot.com Credit card
Electrical Tape		1 Black roll	Home Depot		www.homedepot.com Credit card
Heat Shrink		1 foot of white 2 feet of red 2 feet of black	Home Depot		www.homedepot.com Credit card
Milling Board	3.70 in. x 2.71 in. / 2 layer board	1	PCBexpress	1-503-829-9108 x555	www.pcbexpress.com Credit card
	4 in. x 3 in. / double sided board	1	E-TekNet	1-480-752-7854	www.e-teknet.com Credit card

9.8 Detailed Cost Analysis for Controller

Material Component Description	Part Characteristics / Part #	Quantity / Amount for One System	Single Unit Pricing		
			For 1	For 10	For 100
Controller Box	Hammond Mfg. #1591TSBK	1	\$5.60	\$4.38	\$3.60
Cigarette Lighter Adapter	5A Fuse	1	\$3.49	\$3.14	\$2.79
Pin	Ones that fit inputs and outputs to board	6			
Slow-Blow Fuse with 6 Clips	3A	1			
	1A	1			
	5A	1			
Bipolar Junction Transistor	PN2222A	4	\$0.78	\$0.78	\$0.66
DIP Socket	8 pin	1	\$0.90	\$0.86	\$0.64
Capacitor	Electrolytic/6800 µF/10V	1	\$1.55	\$1.16	\$0.87
	Ceramic/100nF	1	\$0.11	\$0.11	\$0.09
	Ceramic/100nF/50V	1			
Heat Sink	Smallest one that fits LM7805	1			
LED	White	1	\$0.11	\$0.11	\$0.09
	Green	1			
Microcontroller	PIC12F675	1	\$1.86	\$1.86	\$1.26
Relay	RKA-7DZ-12	2	\$3.36	\$3.36	\$2.68
Resistor	1kΩ	2	\$0.56	\$0.56	\$0.48
	5kΩ	2			
	10kΩ	1			
Switch	2-state slide	1	\$0.61	\$0.44	\$0.42
Voltage Regulator	LM7805	1	\$0.72	\$0.72	\$0.43
Zener Diode	1N4747A	4	\$0.08	\$0.08	\$0.05

Material Component Description	**Part Characteristics / Part #**	**Quantity / Amount for One System**	**Single Unit Pricing**		
			For 1	**For 10**	**For 100**
Electrical Cord		20 feet of two connected wires (18guage each wire)	$3.80	$3.80	$3.04
Electrical Wire		3 feet of 20guage wire	$0.25	$0.25	$0.25
Milling Board from PCBexpress	3.70 in. x 2.71 in. = 10.027 sq. in. / 2 layer board	1	**For 2 (next day mail)**	**For 10 (next day mail)**	**For 100 (3 day mail)**
			$90.00*	$16.90*	$9.10*
Milling Board from E-TekNet	3 in. x 4 in. = 12 sq. in. / double sided board	1	**For 25 (2 week mail)**	**For 50 (2 week mail)**	**For 100 (2 week mail)**
			$5.22	$3.52	$2.56
Sub-Total	-	-	**$29.00**	**$25.13**	**$19.91**
15% Shipping and Taxes for Grantham, PA	-	-	$4.35	$3.77	$2.99
Labor ($10/hr.)	-	-	$50.00	$40.00	$20.00
Total	-	-	**$83.35**	**$68.90**	**$42.90**
10% Profit	-	-	$8.34	$6.89	$4.29
Price	-	-	**$91.69**	**$75.79**	**$47.19**

* Not included in total pricing.