Portable Drinking Water Cooler and Dispenser
Senior Project Report

F25
AquaCool

Prepared for
Achieving Resilient Communities (ARC) Project
A collaboration between Roots of Change, Tracking California, and The Public Health Alliance of Southern California
Represented By
Alexander Nikolai
Maureen McGuire
Michael Dimmock

By
Gustavo Hernandez-Lerena
gherna35@calpoly.edu
Terry Leung
tleung@calpoly.edu
Erik Torres
Etorre61@calpoly.edu
Caleb Parham
cfparham@calpoly.edu

Mechanical Engineering Department
California Polytechnic State University
San Luis Obispo
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Abstract

This document serves as the comprehensive report for the testing and building for the Portable Water-Cooling System by team AquaCool. Team AquaCool is comprised of four mechanical engineers with a passion to help the agricultural industry in their efforts to keep the health of the workers at their peak. The four engineers who partook in helping the farm workers are as follows: Caleb F. Parham, Erik Torres, Gustavo Hernandez-Lerena, and Terry Leung. To reduce the risk of heatstroke and other unwanted effects from the harsh working conditions during summer, a small and portable system was built to help in the efforts. With rising temperatures, ensuring workers get a liter of sub-59-degree Fahrenheit water per hour is crucial in aiding the fight for the workers’ health. In creating such a product, initial testing can be done to find the effectiveness of the system and serve as the first step in protecting all farmworkers from conditions far from perfect.
Portable Drinking Water Cooler and Dispenser

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1 Introduction

As climate change leads to rising temperatures in Southern California, ensuring access to cool water for farm workers is becoming increasingly challenging. To address this issue, Achieving Resilient Communities (ARC) has proposed a flexible water-cooling solution. The ARC Project is a joint effort between Roots of Change, Tracking California, and The Public Health Alliance of Southern California under the umbrella of the Public Health Institute. In light of record-breaking heat and Ventura's status as one of the state's largest growers, public health initiatives have prioritized developing a solution to heat stress caused by insufficient cool water access for farm workers in Ventura and Kern County.

Guided by Alexander Nikolai, who represents the ARC project, an inventive and scalable water-cooling solution will be created to address health concerns while minimizing additional costs. The AquaCool team, comprising Gustavo Hernandez-Lerena, Terry Leung, Erik Torres, and Caleb Parham, consists of four senior mechanical engineering students from California Polytechnic State University, San Luis Obispo. A separate group of students, known as Team Water Works, has been assigned a similar objective of developing a cooling solution. AquaCool aims to design a portable cooler adaptable to various environments and farm equipment, powered by a standalone, nonstationary energy source. On the other hand, Team Water Works is focused on creating a more permanent water-cooling solution powered by a power take-off (PTO) shaft generator. Their design has a larger water capacity and will be attached to existing equipment pulled by a small tractor.

This final design report presents the process of how the proposed design was constructed and evaluates how well the design achieved the project’s goals. Additionally, this report highlights the final design changes that were made since the CDR presentation. These changes include the addition of a tiedown point for securing the cooler and the use of a standard five-gallon water jug as an auxiliary water reservoir. Finally, this report discusses the results found and recommended steps to make the verification prototype a marketable product.

2 Design Overview

This chapter describes the final design components for each subsystem of the unit.

2.2 Design Description

The frame subsystem was comprised of stainless-steel members and aluminum members. The aluminum members were arranged in a box shape to provide structure for the system. The stainless-steel panels were primarily bolted to the aluminum members to enclose all components within the system. The panels had vents to allow airflow and holes for things like the plug, display, and power switch to be accessible from the outside.

The refrigeration system was bolted to the bottom of the frame on top of a piece of galvanized steel that was bolted to the aluminum members. The refrigeration loop is a closed loop filled with R-134a. The evaporator coil wraps around the cold-water reservoir and provides a cold refrigerant for the water to transfer heat to. The loop does not have an automated shut-off for when pressures inside the closed loop reach outside of their bounds. The pressure in the system should
not exceed 200psi. The major refrigeration components include compressor, condenser, expansion valve, and a high-pressure receiver tank.

The water distribution subsystem begins at the 5-gallon jug where it then flows to through the lid to the cold-water reservoir. Between these connections is a seal that is created using gaskets and clamping forces generated by latches and straps. These are described in more detail in the manufacturing overview. After the cold-water reservoir the cold-water leaves through a drain and is connected with silicon tubing to the spigot where farm workers can receive their cold water in a cup.

The electronics of the system feature a high voltage system and a low voltage system. The high voltage system is the compressor and fan of the refrigerant system which is turned on/off by an Arduino system. The Arduino system is a low voltage system that has sensors to detect water level and temperature to turn the system on/off as needed to preserve energy. Shown within the appendix, the wiring diagram for the system and how it’s all interconnected is shown. To reduce the high voltage from a typical 110-Volt outlet, a stepdown converter was used to bring a line down to 12v. Once at 12v, an inline glass fuse rated for 3 amps was placed as a safety check before going to the next stepdown. The next stepdown takes the 12v and makes it suitable for the Arduino and sensors.

2.3 Design Changes Since CDR

There have been some design changes since the CDR. We added the requested D-rings and 5-gallon Jug attachment. We also changed some manufacturing methods with the Lid. Originally the Lid was to be welded along the edges. This was going to be too difficult with stainless steel sheet metal. The new method was to be to screw the two pieces of the lid together using rivnuts and bolts. Another change to the lid was the method of securing the 5-gallon jug on top of the unit. Originally, we planned to have 4 members that prevented it from tipping over. This was a bad design idea as it was not aesthetic and would make it hard to insert the jugs to fill the system. Instead, we used a custom formed piece of stainless steel and secured that to the top of the jug using straps that were connected to the lid to create downforce for the water seal below. A more detailed description of this process is described below in the Manufacturing overview.

3 Implementation

Within the implementation chapter, the procurement and manufacturing process for the entire system will be described in detail in the manner that it happened. Through the various challenges and different problems that had to be resolved, it is estimated that the team has spent a collective 400 hours. Each team member has contributed roughly 100 hours to get the device manufactured.

3.2 Procurement process

Before the cooling unit could be manufactured it was important to first procure all major components and stock needed. Beginning with the frame it was important to acquire square aluminum tubing and a sheet of stainless steel. While these could be acquired online, it was much more cost effective to pick the material up from a local metal supply store. Two 1”x1” of twenty-foot tubes of with a 0.065” wall thickness and a 4’x 10’ sheet of 16-gauge stainless steel was purchased from B & B supply in Santa Maria.
For the refrigeration components everything was ordered online as many local HVAC supply stores required a license number to purchase from them. Components that were ordered online include the main ½ Hp condensing unit, copper coil, pressure gauges, refrigeration fittings, an excess refrigerant high pressure receiver tank, and insulation for the lines. The r134-a refrigerant needed to charge the system was provided by Dr. Peuker and the Cal poly HVAC department. Solder for brazing the lines together was not purchased as the brazing was outsourced to Cal Coast Refrigeration in Santa Maria.

For the water system components were sourced online and at local hardware stores. The stainless-steel tank was sourced from a kitchen supply website, Webstaurant, that offers various sized stainless steel serving trays. Other components such as the spout, drain, and food safe hose were ordered online from Amazon. Adapters needed to connect the hose to the spout were purchased locally at Home Depot.

Finally for the electronics system all the parts were ordered online through Amazon. While some components could be purchased locally it was much more cost effective to order parts online. This included components such as relays, LCD displays, buttons, a microcontroller, wire, heat shrink, temperature probes, and water sensors.

3.3 Final budget status

The initial project budget was $2000 from the ARC project, not accounting for the extra $500 provided on behalf of Cal Poly funding for senior design. With initial concerns about the potential manufacturability of the system while staying within budget. The nonstationary power source was dropped to keep the design closer to the original budget. Seeing that the total cost of solar panels and batteries would quickly add up, they were omitted from the final design. Although actions were taken to help minimize the budget being spent, the project has totaled more than $3500. The final amount for the project is estimated to be $3621.64.

During the preorder of refrigeration unit is not completed because of the shipping issue, we have to choose another company to get another refrigeration unit. For the situation, it gets a bit cheaper than the previous version. But there was a large expense for the brazing service because we cannot find any HVAC technician to help us to do the brazing service, so we have to find HVAC industry to help us, that is about $800 unexpected expense. Also, we did not expect the HVAC components for completing the connection, so it is another unexpected expense. Based on the miscounting the HVAC components, it also needs to buy extra fasteners to stable the system. Based on the extra expense, this is the reason why we have about $1500 over budget cost.

3.4 Manufacturing overview

The following section gives an overview of the manufacturing process that took place to get the system put together.

3.5 Welding

The manufacturing process began with welding the frame together. We Tig welded aluminum to create the shape of the frame. The Personal Protective Equipment (PPE) included
welding helmets jackets and gloves, along with pants and close toed shoes. We ended up needing to weld together two additional members so that there was enough support on the bottoms for the condensing unit.

To start, the twenty-foot stock was cut to size using a metal blade on a chop saw. Once all the stock was cut to size the surface was cleaned using a metal brush wheel. Cleaning the surface helps reduce the risk of oxidating the metal while welding. If a professional welder is hired, they can simply put together the system using the drawings found in Appendix H. If a professional is not hired, there is a learning curve to ensure that the stock is properly fused together and burning through the material is avoided. We found that setting the welder to 85 amps with a frequency of 110Hz and a 70% balance worked well. Using too low of an amperage will result in inadequate penetration and therefore structurally insecure welds. The gas flow was kept at around 25 cfm.

Once the settings were figured out and some practice was done on scrap pieces, we then began welding the frame for the water cooler. We found it easiest to divide the frame into sections by first welding the front and back section of the frame. Once the front and back were completed, they were then welded together using the members from either side. This can be seen on Figure 3.1, where the front and back of the frame were initially joined together.
Figure 3.1. Shown in top left and bottom right is the 90-degree clamp used to weld two sides together. This was important to ensure the members remained square as they cannot be adjusted after being welded together. Once members were tacked together the clamp could then be removed to have more clearance for the welding torch as shown on the figure on the top right and bottom left.

While welding the corners, it is recommended to stick out the tungsten more than usual and turn up the gas flow. It is also important to let the aluminum create a puddle before attempting to add filler material. Overall, the welding process was most likely the most time consuming because we needed to learn how to weld aluminum as well as it just being a long tedious task. Next, we needed to mount the refrigeration unit onto the frame.

3.6 Mounting refrigeration unit to the frame

To mount the refrigeration unit, we used galvanized steel sheet metal. We first cut the sheet metal to the correct size using an angle grinder. The PPE for this included a face mask, ear plugs, safety glasses, pants, and close toe shoes. The face mask for this task is essential because there are particulates from the galvanized steel that are harmful to lungs. We had two pieces of sheet metal for the mounting plate and lined them up on the top of the bottom's aluminum frame members. We marked where we needed to drill and took it to the drill press with a ¼” drill bit. Figure 3.2 shows the two plates bolted on the frame. The PPE for this includes pants, close toe shoes, and safety glasses. Once that was drilled through, we lined it back up on the frame and marked on the aluminum frame through the holes we created. We then drilled using a hand drill and a ¼” drill bit through the aluminum frame. We fastened the galvanized steel mounting plate to the aluminum frame using ¼” bolts with washers and nuts. A photo of the intermediate stages for the mounting plate is highlighted below. The holes are drilled with space for fasteners. The condensing units spacing within the frame is shown in Figure 3.3.
We then continued with a similar process to mount the condensing unit to the newly created mounting plate. We lined up the condensing unit on the mounting plate where we wanted it and marked holes through the holes on the mounting plate that the condensing unit came with. We then drilled the hole and fastened them with the same bolts, nuts, and washers as before. When we ordered the condensing unit, we were not aware that there would not be a high-pressure receiver tank included. After finding this out, we ordered a high-pressure receiver tank and found a space for it within our system. We put the condensing unit towards the back of the sheet metal mounting plate and drilled a hole for the high-pressure receiver tank to sit in. The receiver tank had a short-threaded portion on its bottom that we put through the mounting plate and then fastened with a nut purchased at Home Depot. The mounting of the high-pressure receiver tank can be seen in Figure 3.4. Once all the major components were mounted, we bent $\frac{1}{4}$" tubing on the high-pressure side to fit from the service port after the condensing unit to the high-pressure receiver tank. After the tank, we left the filter/dryer for the technicians to put together with compression fittings. We also set up the $\frac{1}{4}$" line that goes from the filter/dryer to the charge port, high-pressure pressure gauge. We connected the gauge and charge port using compression fittings. After the pressure gauge, there was the needle valve that acts as the expansion device to the lower pressure. Once past the needle valve, our refrigerant is cold and is ready to run through the evaporator coil and cool the water. After the evaporator coil, we bent some of the 3/8” pipe to run through the low side pressure gauge and charge port and to connect to the low-pressure service port. A picture with the condensing unit mounted and connection ready for the technicians is highlighted below.
Figure 3.4. Shown here is the frame with the condensing unit mounted and the refrigeration lines bent ready for a technician to braze together.

The condensing unit we purchased also did not come with connections to the lines that are attached with flare fittings. The connection point they did provide needed to be brazed. A picture of the service ports provided in Figure 3.5.
As you can see, the lines connecting to these ports would need to be brazed by first inserting them into this port.

After all the lines were put into place, we dropped off the whole system with the refrigeration company Cal Coast. Their task is to braze all the lines and pressure test the system. The technician ended up getting rid of the compression fittings and brazed all connections, performed the leak test, pressure test, and charged the system with R134a. The leak test can be seen in Figure 3.6. We requested that they braze the evaporator coil to the cold-water reservoir, but they decided this would reduce the strength of the refrigerant line and they used epoxy instead to create a better thermal connection between the cold refrigerant and water that needs to be cooled.
As of our latest update with our technician some of our fittings leaked when the system was pressurized to 200 psi. This will be corrected by brazing the lines where the pressure fittings were used. Once all the refrigeration components were finalized, we wrapped the components in plastic and painted the aluminum frame members with spray paint to protect from deformities due to contact with stainless steel.

3.7 Stainless steel panel fabrication

Once all the refrigeration components are in place and ready to operate, we had to install the stainless-steel panels and lid. We needed to create detailed drawings for the panels that need to be cut on the water jet. We submitted the drawings to the shop and put our order in as well as dropped off the material. The panels were optimized to be cut out of a single sheet of stock that was 4ft x 10ft. One of the drawings that we made for the water jet is highlighted below in Figure 3.7.
Figure 3.7. Water jet cutting file for stainless steel 4x10.

Shown here is a screen shot of a DXF file used to ensure the pieces met the excess material requirement to be cut on the water jet. Not that each part had its own DXF file, and the final arrangement was determined by the shop technician operating the water jet.

Once we got the material back, we bent the ends of the metal so that they could fit in the frame. This was done using the finger brake to produce a clean bend. The water jet cut panels can be seen below in Figure 3.8.

Figure 3.8. The side panel that was cut on the water jet before being bent on the finger brake.
The sides, front, and back panels were then attached to the frame using self-drilling screws. The side panels sat beneath the front and back panels and had two screws in at the top. The front and back panels sat above the side panels and had one screw at each side member that held in both the back and front panels along with the side panels. The handles used the same screws and were placed at the top of the side panels. 4 total D rings were mounted on the sides of the side panels. On the right-side panel, the cup holder was installed near the top of the panel so that cups could be easily taken from the mechanism. Below is Figure 3.9 where the side panel final set up is visible.

![Figure 3.9: Side panel set up (right side).](image)

The back panel has a cable for plugging into an electrical power source of 120V. This cord comes from the bottom right of the panel. Originally, we cut the hole with the water jet, however this turned out to be too large. We covered that hole up with a rubber stopper and drilled a new one to the left that was the correct size. This needed to be the correct size so that a feature could be installed that made it so that pulling on the cord could not damage the electrical connections to the compressor. The power switch is at the top right of this panel. To manufacture the rectangular hole for this switch, we began with a small drill size and drilled the perimeter of the shape. We finished the shape with a Dremel. The switch is mounted using epoxy. There were also two latches installed at the top of the back and front panels that compressed all the components in between the lid and frame. This back panel can be seen in Figure 3.10 below.
The front panel has a water distribution spigot which connects to the cold-water reservoir on the inside with a tube. This tube slides over the barb on the drain from the cold-water reservoir. This tube then connects to the spigot with 2 brass fittings bought at Home Depot that include a barb and a size change to fit the spigot. Hose clamps were used to make the tube connections strong. The LCD display will sit at the top right of this panel. And the holes for that and the button were made with the water jet. These components were mounted with epoxy. The latches are also installed on this panel at the top to keep components from falling off and for creating a seal in the water distribution system.

The lid had a lot of changes made in the final weeks of manufacturing as welding it would have likely turned out poorly. With the help of an IME Professor on campus, Kevin Williams, we designed the lid to be manufactured using rivet nuts and bolts. There was a bracket welded to the interior of the top piece of the lid at each corner. There was a hole drilled in the bracket for a rivet nut to be placed. There were also 4 holes drilled in the bottoms lid piece. 4 bolts connected the two lid pieces using the rivet nuts. On the top lid piece there were four more drilled holes where rivnuts sat. Eyebolts were screwed into these rivnuts so that a strap could be attached to the lid at the top. This strap was to connect from each corner of the lid to a manufactured piece of stainless steel that had 4 equally spaced connection points. This piece of metal was shaped so that it could hold the 5-gallon jug on top of the device in place. The piece of metal was two rectangular pieces of stainless steel that were bent 90 degrees at the end and welded together at the center. This can be seen in Figure 3.11 below. Originally, we intended to weld some supports for 4 aluminum members to the top of the lid to hold the bottle in; however, this was a poor design and made it hard for the user to insert to bottle into the device. The support for these members can be seen below in Figure 3.12. The lid was held to the rest of the system using latches connected to the body panels.
Figure 3.11: The manufactured piece of metal intended to keep the jug mounted on the water cooler.

Figure 3.12: The original design turned out to be a poor design choice upon further analysis.
3.8 Electronics fabrication

For the electronics, a PCB was used to create permanent connections between the controller and peripherals (sensors). A microcontroller based on the ATmega 328 chip was chosen as the board to be used to the small size, providing just enough I/O ports, and having enough memory to allocate for the program. A schematic of the wiring on the PCB is shown in Fig. 3.13. Wiring was spaced out more in the second revision of the wiring as grouping them close together lead to dealing with bridging of solder in the wrong direction. All the components were soldered using lead-free solder for the safety of team members and anybody else who may be dealing with the board itself. To mount the board to the interior of the system, a custom enclosure box was created to house the board and a 12v step-down for the board. While the board can accommodate 12v, the step down is used to allow 5v to be used by all the peripherals and not just the board. A secondary PCB board was used to allow for connections to the optical water sensors to allow for less clutter of the main board. The secondary board is not contained within the enclosure but rather is on its own on the outside. The PCB shown in Figure 3.13 shows an in-progress visualization of the process of creating the final circuit.

Rather than designing and using a designated PCB for this project, a breadboard like PCB was used to allow for flexibility, ease of access, and cost. A secondary PCB, as seen in Figure 3.14 was used to wire the water sensors to allow for more flexibility with the position of components.
Due to being large and obtrusive, the water sensor connections were kept as their own PCB with wires coming off to connect to the main PCB. Figure 3.15 shows an example of the splicing done on the wires before covered with electrical tape.

Wires were spliced together for connections such as power and ground as they all share the same source. All the data wires from the probes were connected since they communicate through one singular port due to having identifiable addresses. Shown in Figure 3.16, the almost complete model of the PCB is shown with all the sensors and inputs being tested.
During the last stages of the soldering and finalization of the circuit, testing was performed to make last minute modifications in the case that there was some bridging between pins from too much solder. For the last medication, all the ground and power cables were attached to the PCB before being tested once again. A 12v to 5v step down was used to convert the 12 volts coming into the system to a suitable 5v for all the sensors.

3.9 Water distribution

For the water distribution system, a stainless-steel drain was attached to the internal stainless-steel reservoir. Using the barbed end of the drain we then connected our ½” ID tubing to be routed to our stainless-steel spout. The spout itself was secured to the front panel using the included mounting hardware. Using the adapters purchased from Home Depot a ½” barb connection allowed us to secure the other end of the tubing.

On top of the lid the self-puncturing mount was attached so that the external 5-gallon water jugs can passively refill the internal reservoir. We came to a design flaw near the end of the manufacturing process. Since the jug was well above the cold-water reservoir, we needed to seal all components leading from the jug to the reservoir and have a tube that reached heights above the jug so that no water would leak out of the system. This ended up being found out too late in the build phase and there was no other easy solution. However, there was one other option that may work. This option was a float valve that could sit inside of the cold-water reservoir. This valve would close when the water level reached a certain point in the reservoir. This would not work for our system because the water tube from the jug would need to connect to the valve from the outside of the reservoir, and we already manufactured our system so that that tube was on the inside of the reservoir. To fix our design we would need to analyze our leak point between the water jug and the cold-water reservoir and create pressure seals using the force from the latches to prevent water from leaking. We would also have to drill a hole above the water reservoir where air could enter the jug and where the pressure in the system would push water back to the height of the water jug. The float valve idea can be seen in Figure 3.17 below.

![Figure 3.16. Partially completed PCB being tested](image-url)
Figure 3.17: This is the float valve system that could potentially work. This will not work because the water connection would be on the other side of the reservoir wall.
4  Design Verification
This chapter goes over testing on the system once manufacturing had been completed.

4.2  Specifications
The goal of the design was to meet all the set specifications that were made to ensure that the product meets the needs of the end user. Shown in Table 4.1 below are all the design specifications that were set to be met by the verification prototype.

<table>
<thead>
<tr>
<th>Spec. #</th>
<th>Specification Description</th>
<th>Requirement or target (units)</th>
<th>Tolerance</th>
<th>Risk*</th>
<th>Compliance**</th>
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<tbody>
<tr>
<td>1</td>
<td>Weight</td>
<td>51 lbs</td>
<td>Max</td>
<td>H</td>
<td>T</td>
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<td>2</td>
<td>Cooling Performance</td>
<td>3-4 L/hr</td>
<td>Min</td>
<td>H</td>
<td>T, A</td>
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<tr>
<td>3</td>
<td>Water Temperature</td>
<td>59 °F</td>
<td>Max</td>
<td>H</td>
<td>T</td>
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<tr>
<td>4</td>
<td>Operation Time</td>
<td>8 Hours</td>
<td>Min</td>
<td>M</td>
<td>T</td>
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<tr>
<td>5</td>
<td>Size</td>
<td>27 ft³</td>
<td>Max</td>
<td>M</td>
<td>A, I</td>
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<tr>
<td>6</td>
<td>Noise Levels</td>
<td>90 dB in a 5ft radius</td>
<td>Max</td>
<td>L</td>
<td>T</td>
</tr>
<tr>
<td>7</td>
<td>Low Maintenance</td>
<td>10 minutes of regular maintenance daily</td>
<td>Max</td>
<td>L</td>
<td>A, I</td>
</tr>
<tr>
<td>8</td>
<td>UV Resistance</td>
<td>The system lasts 2 years</td>
<td>Min</td>
<td>M</td>
<td>S</td>
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<tr>
<td>9</td>
<td>Leakage rate</td>
<td>0 mL leak</td>
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<td>M</td>
<td>T</td>
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<td>10</td>
<td>Water Contamination</td>
<td>20 parts per million</td>
<td>Max</td>
<td>L</td>
<td>A</td>
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<tr>
<td>11</td>
<td>Non leaching Material</td>
<td>0 leaching</td>
<td>Max</td>
<td>L</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>No Exposed Hazards</td>
<td>0 exposed moving parts</td>
<td>Max</td>
<td>L</td>
<td>I</td>
</tr>
</tbody>
</table>

*Risk of meeting Specification: (H) High, (M) Medium, (L) Low
**Compliance Methods: (A) Analysis, (I) Inspection, (S) Similar to Existing, (T) Test

Specifications were either pass or fail, with very few requiring the need of calculations to prove the design. For the weight specification its compliance will be verified through testing by weighing the unit. The cooling volumetric flowrate will be verified through testing and by doing heat transfer calculations. Water temperature will be verified by testing it with a thermometer. The operation time will be checked by testing to see if the unit can run for eight hours without any issues. The size specification will be verified through analysis based off the dimensions of the unit. Noise level will be checked for compliance by using a decibel meter. The maintenance time will be estimated by inspection of the unit. The UV resistance will be verified by selecting similar materials with a known high resistance. The leakage specification will be verified by testing the refrigerant lines for leaks using soapy water and observing the system. Water contamination will be verified by inspection of water. Analysis will be done on the only specification that required calculations were those regarding temperature. A summary of the testing results can be found in the Design Verification and Report (DVP&R) in appendix E.
4.3 Testing and Results

To quantify that the design prototype met the specifications that were set in place during the design stage some testing procedures were created to gather data. Since some of the specifications could be verified simply through inspection not all the specifications had testing procedures designed. Table 4.2 shows all the specifications that were tested for compliance. The full testing procedure for each specification can be found in Appendix F. Each test gives information on the location, equipment, safety precautions, and step by step instructions on how the test was conducted.

<table>
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<td>1</td>
<td>Weight</td>
<td>51 lbs</td>
<td>Max</td>
<td>H</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>Cooling Performance</td>
<td>OMP of 1.4 or higher. (On Mode Performance)</td>
<td>Min</td>
<td>H</td>
<td>T, A</td>
</tr>
<tr>
<td>3</td>
<td>Water Temperature</td>
<td>59 °F</td>
<td>Max</td>
<td>H</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>Operation Time</td>
<td>8 Hours</td>
<td>Min</td>
<td>M</td>
<td>T</td>
</tr>
<tr>
<td>6</td>
<td>Noise Levels</td>
<td>90 dB in a 5 ft radius</td>
<td>Max</td>
<td>L</td>
<td>T</td>
</tr>
<tr>
<td>9</td>
<td>Refrigerant Leakage Test</td>
<td>0 mL leak</td>
<td>Max</td>
<td>M</td>
<td>T</td>
</tr>
</tbody>
</table>

The target weight (4.2.1) of the system is 51 lbs. so that one person can carry the system while complying with NIOSH recommendations. The dry weight has exceeded 51 lbs. and will not currently meet that requirement. The system will require two people to carry the entire system. After taking the dry weight if the system it was found to be 135 lbs. The weight of the system was measured using a bathroom scale as the was no larger scale on campus that could give out a more precise reading. Figure 4.1 shows the device being weighed.
Figure 4.1. Dry weight of device being measured using a bathroom scale with a pallet that zeroed out on the scale prior to taking a weight reading.

The main issue when choosing materials was finding materials that could hold up well in extreme weather conditions. While the choice of stainless steel ensures a strong and durable construction the overall weight of the systems suffers as a result. Future iterations should explore lighter material alternatives.

For the cooling performance (4.2.2), the team was aiming for an on-mode performance (OMP) of at least one. Referring to the calculations within Appendix F, the performance of the system refers to the ratio of energy that was drawn during a set amount of time to the amount of energy that was used for the system to complete a cooling cycle. A cycle is complete when the compressor in the unit has shut down after the target temperature has been achieved. Testing was done in a climate-controlled environment to ensure consistent results as seen in Figure 4.2.

Figure 4.2 Picture of test setup for the performance test. Temperature was recorded using a probe and a custom script to record the data. Power was recorded at one second intervals using a power meter.

Data that was collected included the average temperature at the exit of the cooling device and the average temperature of the refill water entering the system. Additionally, the power drawn by the system was collected at every second for each trial. There was a total of three trials done, one at 60 seconds, 90 seconds, 120 seconds. The performance can be found using equation 4.3, where \(Q_{\text{draw}}\) is a calculated value found using equation 4.4. For more information on how the experiment was conducted please refer to Appendix F.
\[ \text{Performance of Cooler} = \frac{Q_{\text{draw}}}{Q_{\text{Replenish Adjusted}}} \]  
\[ Q_{\text{draw}} = m \cdot c_p \cdot (T_f_{-\text{avg}} - T_o_{-\text{avg}}) \]

After conducting three trails it was found that the OMP of the cooling system did not meet the set specification as shown in Table 4.3.

| Table 4.3. Summary of on-mode performance for each trial. Note that the cooling unit did not meet the specification goal that was set. |
|---|---|---|---|
| Trail # | time (sec) | \( Q_{\text{Draw}} \) (BTU) | \( Q_{\text{Replenish}} \) (BTU) | OMP (%) |
| Trial 1 | 40 | 2.37±5.78 | 16.66±1 | 14%±36% |
| Trial 2 | 60 | 2.46±5.80 | 53.62±1 | 5%±11% |
| Trial 3 | 120 | 2.78±5.75 | 12.22±1 | 23%±49% |

There are many reasons why the performance of the system did meet the goal. One reason is that the evaporator coil that is responsible for the cooling of the internal reservoir had poor thermal conductivity with the tank. This was due to the difficulty of matching the taper on the cold-water reservoir. Additionally stainless steel is a poor thermal conductor so there is less heat transfer happening between the coil and the water. Finally, while the coil reaches below freezing temperatures the expansion valve needed some adjusting to maximize the performance.

The operation time (4.2.4) specification was designed originally to make sure the system would be powered throughout the workday using the nonstationary power source. Now that the nonstationary power source is outside of the scope of this project, this specification will be used to verify the powered systems will not overheat. A test to determine if the system would be able to operate for 8 hours, the length of a typical workday, was conducted with the system operating and compressor always on. With all the components of the system running continuously for 8 hours without stopping, proper performance on the jobsite can be guaranteed. The device is predicted to have the compressor on for about 4 hours per day, enough to cool about 3-4 refills of water within the 9-liter tank.

One of the biggest challenges when testing was performing the operation time. With a lot of tests relying on the system running, such as the water-cooling performance and efficiency, it seemed reasonable to allocate an 8-hour time slot to complete all those tests. The first day that tests were supposed to occur, some manufacturing took place which shortened the available time within that day. Tests were rescheduled and rescheduled due to the large time block required. A testing period that seemed easy to complete managed to turn itself into its own issue to deal with. The system was tested in a state as shown below in Figure 4.3.
The size of the unit was also an important consideration during the design stage, this a specification was set in place to prevent the unit from getting too big. The product is compact in size, only fitting the essential internals within the enclosure. This meets the specification for 27 $ft^3$. This specification was created so that the product is not awkward to carry. All parts for the building have been chosen due to their durability, their nonleaking behavior when in contact with water, and their ability to survive daily usage. The noise level test results are highlighted in Table 4.4.

A large concern for the device when running was the noise will over the 90dB which means that it will damage the hearing ability. According to Occupational Safety and Health Administration (OSHA) policy when noise levels over 85 dB are harmful. For a simple example, 90 dB sounds like a hair dryer with maximum speed. As workers might work close to the system, if the system reaches 90 dB that they will get their hearing damage. By our measurement, it is measuring noise level (4.2.6) by difference distance from 1 to 5 feet with 1 foot increment. During the measurement, we are using mobile apps to test the noise level in the empty room. We measure the level from closet distance to 5 feet with 1 foot increment. Fortunately, the noise level is lower than the limitation what we set 1 foot away from the system. The highest noise level of the system is 60 dB, so field workers are safe to work with the system even though they are next to the system. For noise level measurement, we have not met any challenge because this is the simplest test in the list of tests. The system is quieter than we expected.
To pass the refrigerant leakage test (4.2.9) from the specification sheet it was important to not have any leaks in the refrigerant line. While R134-a is relatively harmless to humans, it is bad for the environment and would cause an inconvenience if the refrigerant leaked during normal operations. Since nobody on the team is certified to work with refrigerant, the unit was sent to Cal Coast refrigeration where a technician reviewed and tested the pressure fittings and loops, we designed. After pressurizing the lines to 200 psi the technician found that the system did not hold pressure as shown in Figure 4.4.

![Figure 4.4](image)

Figure 4.4. Refrigerant leakage test performed by Alex at Cal Coast refrigeration. The pressure fitting was found to leak.

After consulting with the refrigeration technician, we decided it would be best to just solder the lines to prevent the system from leaking. After implementing this change the pressure of the system did not drop and it was approved to be filled with refrigerant.

Another large challenge that was encountered during testing was getting the water to reach as close as possible to our target temperature as previously planned. This was found during the water temperature test (4.2.3) There were moments in the testing in which the temperature plateaued and the system had to be slightly adjusted to see if it would help with the results. The system can run in two modes, low and medium pressure modes. With the two modes being available, pressure modes were changed to see if the target temperature could be reached. While there was no test to see how cold the water could get, we only tested to see if the water was able to cool down to the target temperature within the hour. This was not something that was able to be done regardless of how much the system was adjusted. If some fine tuning was to be done to ensure a high but safe level of energy consumption when running, it may be able to compensate for the lack of thermal conductivity of the coils and water.
Other tests such as UV resistance, no leaching materials, no water contamination, and no exposed hazards were all verified through inspection. Stainless steel is highly resistant to multiple weather conditions and the team took care not to overheat or stress the metal to prevent rust from forming. For the reservoir the material of choice was stainless steel since it is commonly used in the food industry thanks to its food safe properties that do not leach metals. Since the system is a closed loop with seals it was determined that water contamination was not an issue. Finally, the fan, the only moving component, is protected by a guard and panels so there are no exposed hazards. A summary table of all the tests can be found in Appendix E. For future testing we would recommend running more temperature tests with each attempt using a different setting on the expansion valve until optimal cooling for the water is dialed in.

5 Discussion & Recommendations

In this section we talk about the next steps and feasibility of our design and how well this system satisfies its requirements.

5.2 Discussion

The system designed did not meet the full specifications that were outlined at the beginning of the project. Our initial aims, also located with Table 4.2, were to create a device that was able to cool multiple liters of water per hour to provide farm workers with water below 59 °F. The system was to be a small form factor cooling device that was easily transportable due to its size and weight. A lot of these specifications were not met due to the choices of materials and manufacturing issues that arose during build weeks.

The system was expected to run without any supervision, being left unattended to cool water while workers were to resume their regular duties, only interacting with the system when they desired a cup of cold water. Late into the project, new information regarding safe operation of the device surfaced. The system would be unable to run without supervision since the system did not have a device that would shut the system off if the refrigerant lines were to exceed 200 psi. Due to this restriction, the system can only be operated while another is nearby and inspecting the device for any potential issues in the pressures of the lines. For this reason, the pressure gauges were rotated to face the vent holes to allow for proper reading.

The weight and size of the system was vital to allow for safe transportation under NIOSH’s recommended loading rules. A single person may carry up to 51 pounds under optimal loading conditions. The weight is changed depending on the action or method of loading upon the person. Seeing that the system has reached a dry weight of 135 pounds, it may be too heavy and pose a threat to the well-being of individuals if proper caution isn’t taken.

The water temperature, a very important factor in this project, was not 59 by the end of the hour. The lowest that the system reached was approximately 65. The temperature had plateaued 3 times throughout the testing and required some modification to the throttle to fine-tune the cooling rate of the system. Since a slow, deep-freeze was not required, running more refrigerant per minute proved to be more useful. Although this solution aided in dropping our temperatures, potential issues can arise from such an action if done without caution.
5.3 Recommendations and Next Steps

To help mitigate some of the things discussed in section 5.2, recommendations are given to help fix or make matters better for each possible issue. Aside from the issues mentioned in testing, there are some steps that can be taken to make the system fully functional as wanted and improve upon the current design of the system. The potential fixes and implementations span from minor, quick-to-do fixes to a total renovation of the system to equip it with some more technology, such as the high-pressure sensor previously mentioned. When dealing with any electrical or refrigerant, it is important that each is done by someone who is qualified to mitigate any risk associated with inadequate care when handling the system.

One of the possible next steps to make the system more efficient is to optimize the evaporator coil and the throttle valve. Shortly mentioned in the prior section, the system was unable to reach the desired temperature albeit having a system rated for more than initially planned. With lackluster heat transfer, the temperature of the water was not able to drop below the desired temperature of 59 °F. To possibly fix the issue without creating a new unit or changing the coil/reservoir out, more brazing can be done on the lines to increase the contact area between the coils and the reservoir. With stainless steel having a thermal conductivity much lower than aluminum, contact area is very important to allow for the maximum amount of heat removal from the system. If brazing is not the desired option, thermal putty/paste exists to fill in the gaps between the coils and tank. This should increase the point of contact to have better distribution.

If the absolute best performance is wanted, acquiring a new container and copper coil is a must. The new reservoir must feature cladding or should be clad using tools. Like that of cooking pots and pans, a multi-ply interface is the most efficient to add/remove heat from any control volume. An outer aluminum surface or copper surface would allow for quick heat transfer. Following up with layers of steel and aluminum/copper, the evenness of the distribution can be regulated to avoid cold spots. When redoing the coil, it is important that the new reservoir has a shape that does differ as location in height is changed. Due to the tapered nature of our reservoir, perfect contact was not realized. Shapes such as cylinders or low-taper rectangular prisms would have the best chance of having optimal contact.

The next course of action, if the user determines that they need the system to run unsupervised, is to implement a high-pressure sensor for the refrigeration system. This change would require a licensed HVAC technician who is willing to do the work on the system. If this course of action is one that is wished for, it is advised that it is coupled with other fixes such as the re-brazing of the system to a new reservoir. The high-pressure sensor would have to be placed near the high-pressure gauge and then connected to the wiring to automatically shut off. The high pressure would act as an on/off switch, not that much different from the switches already present on the system. The live wire may be cut into two, with either end being soldered to an end of the high-pressure switch.
A flaw with the current system is that the system is required to be near a source of power that is not integrated into the system. Initially, this was part of the scope but was later dropped with the agreement that options for it could be mentioned. The recommended course of action is to implement solar panels that would allow for the system to operate when the sun is out. A quick schematic of such an implementation can be seen in Fig 5.1. This would be the easiest solution, allowing for the potential of a battery as well. The solar panels are connected to a charge controller which regulates the fluctuation in voltage/current. The charge controller is then directly connected to a battery or an inverter, depending on the configuration that is wished to be achieved. The battery can be 12/24v but also ensure that the inverter/controller can handle the wattage that is produced at max by the solar panels. The system runs at about 190 watts when the pressure relief valve is nearly closed and at about 480 watts when the valve is open to the safest extent. The safest extent is when the motor does not begin to freeze over and is still warm/hot.

Figure 5.1. Solar panel configuration

Another important matter to consider is the pressure of the water bottle. To maintain a self-refill of the reservoir from the bottle, it is important that the bottle be well seated and strapped down to the system. An airtight seal should be formed allowing no air to enter from the outside. To achieve this, it is recommended that the cooler lid be checked with a filled water bottle. Seat the lid on a table to allow for proper flow of water coming from the bottom nozzle. Place the water bottle on top and plug the hole. Check for any locations of possible leaks. While water is a thicker molecule than those that make up the ratio of air, it gives an insight into possible locations. Extra gasket material can be added to the system to create an airtight seal once the latches are fully latched. The gasket material should be able to create a seal with the lid and surface, as well as the small openings located in-between the top plate and reservoir.
Another potential issue to fix is the sanding or grinding of edges. Due to being stainless steel, a lot of the methods for grinding down the steel to remove the burrs leftover from cutting were difficult to remove. Quick and simple options for this is to cover the edges with a sort of bumper such as silicone, rubber, or any other liner that is synthetic. The permanent fix and recommended course of action is to take an angle grinder and quickly make passes over all the edges. While the sharp edges may not be a large concern when stationary, it is important to remove them in case the systems happens to fall over, potentially putting someone in further danger.

6 Conclusion

The system, although functional, was not a true success. There were multiple points where things could have been better. Functionality and user design could have greatly benefited from more time to work on the project to ensure that every base was covered. While the system is not fully a success, it did manage to meet multiple criteria and expectations that the team had set out to complete. A fully designed and rugged water-cooling system was created to help the workers of Ventura, and hopefully all of California's farm workers, survive the difficult conditions that the summer heat brings to all. Serving as the initial prototype and the basis as a solution for the health of all farmworkers in relation to the heat, team AquaCool presents this comprehensive documentation that outlines the initial goals, major milestones achieved, and the finished product for ARC (Achieving Resilient Communities).

This product can serve as the initial grounds for further development upon user testing. All wiring, code, functionality, and manufacturing has been laid out. Each challenge described with its own possible fixes have been presented for future iterations of the system before making it to the market.
Operation and User Manual: Portable Water Cooler

By Team F25 Aquacool
Caleb Parham, Terry Leung, Gustavo Hernandez, and Erik Torres
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CAUTION ADVISORY

• The system is above 51 lbs. When transporting the system, 2 people must carry the system. Ensure proper safety has been taken prior to lift-off such as carrying straps, using the attached handles, and/or wearing carrying harnesses.

• This system is a high voltage system. When doing any sort of work with the internal wiring, ensure the system is fully unplugged.

• The system may produce an excess of noise during normal operation. To mitigate potential hearing loss, distance oneself approximately two feet or more during operation. Avoid prolonged proximity to the system when running unless proper PPE is being worn.

• When full, the system becomes a great falling hazard as the weight nearly doubles. If the system is tipping over or falling, DO NOT try to cushion or save the system. Ensure all tightening down of the system is done correctly to avoid this issue.

• The refrigeration system within the device uses high pressure lines. Ensure that there are no leaks during operation of the device. While R-134a is neither fatal nor carcinogenic, unwanted symptoms can arise from inhalation of the vapors. Possible bursting or deterioration of the pipes can also arise from a leak that goes without being resolved. Always monitor high pressure gauge to ensure pressures do not exceed 200 PSI

• If the metering device on the expansion valve is adjusted ensure that it is not closed all the way. Having the metering device all the way open can also affect performance.

• Beware of sharp corners located on the device. File them down, add bumpers to the system, or be cautious when maneuvering around the device.
New User

These instructions are for the first-time use of the device. Ensure that the steps are fully followed through to ensure that the device works optimally and no imparted taste to the water of the system.

- When the portable water cooler is received, fully inspect the device for any possible damage or loose wires. If problems are present, reach out to a member of AquaCool for assistance on the matter. Depending on the severity, the solution may be a simple fix that can be done by anybody or maybe an issue for a more qualified member of the team such as an electrician or building technician.
- Once inspected, thoroughly clean the device with a solution of water and soap. Ensure that all the exposed surfaces of the device when the lid is off have been thoroughly cleaned. Run water through the tank until it runs clean and clear to avoid having soap residue being present in the water dispensing lines.
- Wipe down the system to avoid air drying the system. Allowing to air dry increases the chances of possible oxidation/rust. Avoid contact with any sort of salt.
Operation of the System

This section will cover normal usage of the system such as how the device works, how to operate it, and how to keep it in optimal working order.

The system features a moderately sized water tank that is lined with 3 optical water sensors and 3 temperature probes. To give a good estimate of the temperature of the water within the tank, the probes take an estimate based off the water level. As the water level decreases within the system, the amount of temperature probes that are being used decrease to only measure the water and avoid possible measurement of the dead air. With water being more conductive and larger heat capacity than air, the probes in water give a far better and faster reading for the current temperature.

The temperature probes within the system allow for the device to turn on and off as needed. There is some allowance for the device before the system turns on again. This is to avoid the system from turning off and on rapidly. The system must reach a degree below the designated set temperature. Once the temperature has been reached, the device must go up approximately 8 degrees from the target temperature before the device starts again.

In the following pages, various instructions on how to change parameters of the system, as well as navigate will be introduced.
Enabling/Disabling Auto-On of Device

The system allows the user to change whether the device turns off or not once the target temperature has been reached. When the target temperature is set to “On”, this allows for the system to turn on and off as described in the previous page. When the system is set to “Off”, this allows the system to keep running, allowing for the water to reach colder temperatures before being disconnected from the power source or being switched back to auto-on. In the figure below, the “Auto Update” is easily discernable.

| Water Temp: | 70.25°F |
| Water Level: | >50% |
| Auto Update: | OFF |
| Change Temp: | Button3 |

Auto Update of the system is set to “OFF”

| Water Temp: | 70.25°F |
| Water Level: | >50% |
| Auto Update: | ON |
| Change Temp: | Button3 |

Auto Update of the system is set to “ON”

Described on the next page are the steps on how to go about changing the settings on the device to configure to the user’s liking or needs at a given time.
Enabling/Disabling Auto-On - Continued

The first button located on the device from left to right at the bottom of the screen must be held down for 1 second. After having held down the button for about 1 second, wait to see the transition of the “On” to “Off” or vice-versa. There is no other action necessary on the user’s end other than to ensure that the temperature has been set correctly.

To change the target temperature of the system, change the target temperature using the information on the next page titled “Changing Target Temperature of System”.

Portable Drinking Water Cooler and Dispenser
Changing Target Temperature of System

The system features the possibility to change the target temperature of the system. By changing the target temperature, the system changes the temperature of which it compares the current temperature to determine whether to turn the system on or off. This feature is implemented to allow the user to have the water to their desired temperature. A representative screen of the temperature changing screen is shown below.

![Screen showcasing the target temperature change.](image)

To change the temperature of the system, hold down button three, the right most button located under the screen. After having held down the button for approximately 1 second, the screen will change to the screen featured above.

Once on the new screen, the first and second buttons allow for the user to change the target temperature of the system. The button pressing is slightly delayed preventing the temperature changing too fast. Press the buttons at a slow pace, ensuring that the temperature changes on the screen.

Once the desired target temperature has been set, press down button 3 and hold down for about a second to transition back to the main screen.
Maintaining the System

The system features parts and locations that must be vigilantly maintained to provide the best user experience. To fully maintain the system, listed will be parts that require replacements, the acquisition source, replacement interval, how to replace, and cleaning methods for the system.

<table>
<thead>
<tr>
<th>Item/Part</th>
<th>Source of Acquisition</th>
<th>Interval of replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone Tubing (1/2”)</td>
<td>Home Depot</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>5-Gallon Jug</td>
<td>Water Supplier</td>
<td>On empty</td>
</tr>
<tr>
<td>Gaskets (Neoprene)</td>
<td>McMaster</td>
<td>When deteriorated</td>
</tr>
<tr>
<td>Bolts</td>
<td>Home Depot</td>
<td>Upon stripped bolts</td>
</tr>
<tr>
<td>Glass Fuse (Arduino System)</td>
<td></td>
<td>When blown</td>
</tr>
</tbody>
</table>

To replace the parts, follow the steps as listed for each part to make efficient change of the parts.

**Silicone Tubing**: Ensure that the tank is fully empty with no water running down to the spigot. Unbolt the front panel where the spigot is located. Once the front panel has been removed, unscrew the clamp that holds down the tube to the spigot. With the tube still in hand, point it to the floor to ensure that every drop of water falls onto the ground as opposed to the system. Once dripping stopped or is very intermittent, pull the other end off of the reservoir. Use it as template to cut the new tube. Follow in reverse order to reassemble the unit.
5-Gallon Jug: Loosen up the straps holding down the 5-gallon. To loosen the straps, press down on the silver lever on the middle of the straps and tug. Once the straps have been loosened, remove the hooks holding down the bottle. Remove the bottle and prepare a new one to be placed on top of the system. Once the new bottle has been placed, place the metal guard on top. Attach the hooks and strap the bottle back down. Ensure that the bottle is securely fastened to hold pressure and prevent leakage.

Gaskets: Scrape the gasket off with a sharp knife or similar tool. Once most of the gasket material has been removed, one can either further grind it down to the bare metal or simply reapply new gasket on top. Using the gasket roll, measure out pieces to thoroughly cover the edges. Glue them down with super glue or a glue of similar properties.

Bolts: Simply replace the bolts by unscrewing them with the preferred tool of choice.

Glass Fuse: Remove the back panel that is opposite of the spigot. Locate the black box with the AquaCool logo and follow the pair of wires that extrude out, not to be confused with the large bunch of wires that extrude and go to the sensors. Locate a black tube on the red wire and unscrew. Once unscrewed, replace it with a new fuse and close it. Reattach the panel.

To keep the system in operating order and safe for everybody who is drinking the water, proper maintenance of the device must be done. The proper maintenance includes cleaning out the tank and the lid. Cleaner is up to the discretion of the operator, but it is advised to use normal dish soap. Create a ratio of 3:1 dish soap to lather and clean the interior of the reservoir. Run water through rinse it out while the spigot remains open. Keep running water until it runs clear. Using the same concoction, wipe down the lid that touches the reservoir and the top surface of the tank surface. Rinse off and hand dry with a microfiber towel.
Appendix B – Risk Assessment
## Appendix C – Final Project Budget

### Materials List

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Vendor</th>
<th>Vendor Part Number</th>
<th>Model</th>
<th>Project Cost</th>
<th>Procurement and Transportation</th>
<th>Shipping</th>
<th>Tax</th>
<th>Total Cost</th>
<th>Site Purchase</th>
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<tbody>
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### Total Costs

- **Total expense:** $5,169.72
- **Rent:** $516.97
- **Utilities:** $624.00
- **Maintenance:** $450.00
- **Total Site:** $1,500.00

### Summary

- **Total budget:** $6,240.72
- **Site purchase:** $5,724.00

---

**Note:** The above budget is subject to change based on final project scope and approvals.
Testing Software

// Include the libraries we need
#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into port 2 on the Arduino
#define ONE_WIRE_BUS 2
#define TEMPERATURE_PRECISION 9

// Setup a oneWire instance to communicate with any OneWire devices (not just
Maxim/Dallas temperature ICs)
OneWire oneWire(ONE_WIRE_BUS);

// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(&oneWire);

// arrays to hold device addresses
DeviceAddress insideThermometer, outsideThermometer;

// Assign address manually. The addresses below will need to be changed
// to valid device addresses on your bus. Device address can be retrieved
// by using either oneWire.search(deviceAddress) or individually via
// sensors.getAddress(deviceAddress, index)
// DeviceAddress insideThermometer = { 0x28, 0x1D, 0x39, 0x31, 0x2, 0x0, 0x0,
0xF0 };
// DeviceAddress outsideThermometer   = { 0x28, 0x3F, 0x1C, 0x31, 0x2, 0x0, 0x0,
0x2 };

void setup(void)
{
    // start serial port
    Serial.begin(9600);
    Serial.println("Dallas Temperature IC Control Library Demo");

    // Start up the library
    sensors.begin();

    // locate devices on the bus
    Serial.print("Locating devices...");
    Serial.print("Found ");
    Serial.print(sensors.getDeviceCount(), DEC);
    Serial.println(" devices.");
// report parasite power requirements
Serial.print("Parasite power is: ");
if (sensors.isParasitePowerMode()) Serial.println("ON");
else Serial.println("OFF");

// Search for devices on the bus and assign based on an index. Ideally,
// you would do this to initially discover addresses on the bus and then
// use those addresses and manually assign them (see above) once you know
// the devices on your bus (and assuming they don't change).
//
// method 1: by index
if (!sensors.getAddress(insideThermometer, 0)) Serial.println("Unable to find address for Device 0");
if (!sensors.getAddress(outsideThermometer, 1)) Serial.println("Unable to find address for Device 1");

// method 2: search()
// search() looks for the next device. Returns 1 if a new address has been
// returned. A zero might mean that the bus is shorted, there are no devices,
// or you have already retrieved all of them. It might be a good idea to
// check the CRC to make sure you didn’t get garbage. The order is
// deterministic. You will always get the same devices in the same order
//
// Must be called before search()
//oneWire.reset_search();
// assigns the first address found to insideThermometer
//if (!oneWire.search(insideThermometer)) Serial.println("Unable to find address for insideThermometer");
// assigns the seconds address found to outsideThermometer
//if (!oneWire.search(outsideThermometer)) Serial.println("Unable to find address for outsideThermometer");

// show the addresses we found on the bus
Serial.print("Device 0 Address: ");
printAddress(insideThermometer);
Serial.println();
Serial.print("Device 1 Address: ");
printAddress(outsideThermometer);
Serial.println();

// set the resolution to 9 bit per device
sensors.setResolution(insideThermometer, TEMPERATURE_PRECISION);
sensors.setResolution(outsideThermometer, TEMPERATURE_PRECISION);
```c
Serial.print("Device 0 Resolution: ");
Serial.print(sensors.getResolution(insideThermometer), DEC);
Serial.println();

Serial.print("Device 1 Resolution: ");
Serial.print(sensors.getResolution(outsideThermometer), DEC);
Serial.println();
}

// function to print a device address
void printAddress(DeviceAddress deviceAddress) {
    for (uint8_t i = 0; i < 8; i++) {
        // zero pad the address if necessary
        if (deviceAddress[i] < 16) Serial.print("0");
        Serial.print(deviceAddress[i], HEX);
    }
}

// function to print the temperature for a device
void printTemperature(DeviceAddress deviceAddress) {
    float tempC = sensors.getTempC(deviceAddress);
    if (tempC == DEVICE_DISCONNECTED_C) {
        Serial.println("Error: Could not read temperature data");
        return;
    }
    Serial.print("Temp C: ");
    Serial.print(tempC);
    Serial.print(" Temp F: ");
    Serial.print(DallasTemperature::toFahrenheit(tempC));
}

// function to print a device's resolution
void printResolution(DeviceAddress deviceAddress) {
    Serial.print("Resolution: ");
    Serial.print(sensors.getResolution(deviceAddress));
    Serial.println();
}
```

Portable Drinking Water Cooler and Dispenser
// main function to print information about a device
void printData(DeviceAddress deviceAddress)
{
    Serial.print("Device Address: ");
    printAddress(deviceAddress);
    Serial.print(" ");
    printTemperature(deviceAddress);
    Serial.println();
}

/*
 * Main function, calls the temperatures in a loop.
 */
void loop(void)
{
    // call sensors.requestTemperatures() to issue a global temperature
    // request to all devices on the bus
    Serial.print("Requesting temperatures...");
    sensors.requestTemperatures();
    Serial.println("DONE");

    // print the device information
    printData(insideThermometer);
    printData(outsideThermometer);
    delay(1000);
}
Operational Software

// This code serves as the basis for operation of the device created by F25 AquaCool
// The code controls the basic operation of the device to allow for monitoring of the water temperature and level
// Through the use of 3 buttons, the desired behavior/temperature of the system can be adjusted

// Pins for the peripherals that are connected to the device

// Importing libraries
#include "HD44780_LCD_PCF8574.h" // This library has routines to operate the PCF8574 I2C port expander connected to a HD44780 LCD
#include <OneWire.h> // This library is in charge of simplying one wire communication
#include <DallasTemperature.h> // This library uses the onewire library to convert the communication from the temperature probes to an output

// Data wire is plugged into digital pin 2 on the Arduino
#define ONE_WIRE_BUS 2
#define TEMPERATURE_PRECISION 9 // This is the precision of the data reading
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

int TempChange=0;
char TempPrint = "323.32";
int Interval_Count=0; // This variable counts the amount of intervals that the system has gone through before outputting a reading

int ThermoCheck=1; // This value indicates how many thermometers to check
const int RelayPin=12; // The pin that controls the relay is the digital pin 12

// Variables that are constnatly used throughout the code

// Defining the pins for the optical water level sensors
#define Wat1 A0 // For water level sensor 1
#define Wat2 A2 // For water level sensor 2
#define Wat3 A7 // For water level sensor 3
// Defining Variables that correspond to water sensors
int FullSequence=0; // This variable is in charge of determining the order of events
```c
int HelloThere=0;
int WaterLevel=0;
//int WaterSeq1=0;
//int WaterSeq2=0;
//int WaterSeq3=0;
int WaterLevel1=0; //Integer for water level 1 reading
int WaterLevel2=0; //Integer for water level 2 reading
int WaterLevel3=0; //Integer for water level 3 reading
bool Water1=false; //For water level sensor 1
bool Water2=false; //For water level sensor 2
bool Water3=false; //For water level sensor 3
int WaterRead1=0; //Reading the water temperature sensor 20 times to ignore noise
int WaterRead2=0; //Reading the water temperature sensor 20 times to ignore noise
int WaterRead3=0; //Reading the water temperature sensor 20 times to ignore noise
#define WatThresh 200
//Setting the definition for button digital input pins
int IncreaseTemp=0;
int DecreaseTemp=0;

//Defining variables for the temperature sensors
float Temperature; //This variable stores the current temperature of the system

int Target.Temp=59; //This variable stores the target temperature for the system to reach before shutting off
int EnteredTemp; //This variable stores the temperature that is currently being changed before being moved to target temp
int Entered_Value=0; // This variable allows for cross communication of button pressing instead of having returns

int SystemUpdate=0; // This variable signifies whether the system should be turned off or on in regards to temperature

#define button1 4 //Button one is connected to this digital input
#define button2 6 //Button two is connected to this digital input
#define button3 9 //Button three is connected to this digital input
const int Switch1 = 4; //These repeat the above
const int Switch2 = 6;
const int Switch3=9;
```
int ChangeToggle=0;
char PrintTemp[10];
char PrintTarget[10];
char PrintNew[10];
int OUTPUT2_ON=0;
int OUTPUT2_OFF=0;
int OUTPUT1_ON=0;

int Return_Value = 0; //This is the return value for the button pressing to be used
int ButtonReset = 0; //This value determines whether there is a new entry to be entered

float Temp1;
float Temp2;
float Temp3;
// Including the library for the PCF to LCD
#include "HD44780_LCD_PCF8574.h"

// Section: Defines
#define DISPLAY_DELAY_INIT 50 // mS
// **** NOTE :: Comment in If using STM32 bluepill ****
//#define STM32_BLUE_PILL_SETUP

// Section: Globals
#ifdef STM32_BLUE_PILL_SETUP // *** STM32 Blue Pill ***
// Set-up Choice I2C interface 1 or 2 :: pick one and one only
TwoWire Wire2(1,I2C_FAST_MODE); // Use STM32 I2C1
TwoWire Wire2(2,I2C_FAST_MODE); // Use STM32 I2C2
HD44780LCD myLCD(4, 20, 0x27, &Wire2); // LCD object.rows ,cols ,PCF8574 I2C addr, Interface)
#else
// myLCD(rows , cols , PCF8574 I2C address)
HD44780LCD myLCD( 4, 20, 0x27); // instantiate an object
#endif

DeviceAddress Thermo1, Thermo2, Thermo3;
void setup() {
  Serial.begin(115200);
  delay(DISPLAY_DELAY_INIT);
  myLCD.PCF8574_LCDInit(LCDCursorTypeOff);
  myLCD.PCF8574_LCDClearScreen();
  myLCD.PCF8574_LCDBackLightSet(true);

  myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 0);
  myLCD.PCF8574_LCDSendString("   Portable Water   ");
  myLCD.PCF8574_LCDGOTO(LCDLineNumberTwo, 0);
  myLCD.PCF8574_LCDSendString("       Cooler       ");
  myLCD.PCF8574_LCDGOTO(LCDLineNumberThree, 0);
  myLCD.PCF8574_LCDSendString("   By F25AquaCool   ");
  myLCD.PCF8574_LCDGOTO(LCDLineNumberFour, 0);
  myLCD.PCF8574_LCDSendString("                    ");
  delay(3000);
  myLCD.PCF8574_LCDClearScreen();
  // This is the part of the code that sets up the thermometers usings the
  sensors.begin();
  sensors.getDeviceCount();
  if (!sensors.getAddress(Thermo1, 0)) Serial.println("Unable to find address for
  Device 0");
  if (!sensors.getAddress(Thermo2, 1)) Serial.println("Unable to find address for
  Device 1");
  if (!sensors.getAddress(Thermo3, 2)) Serial.println("Unable to find address for
  Device 2");
  sensors.setResolution(Thermo1, TEMPERATURE_PRECISION);
  sensors.setResolution(Thermo2, TEMPERATURE_PRECISION);
  sensors.setResolution(Thermo3, TEMPERATURE_PRECISION);

  pinMode(button1, INPUT_PULLUP);
  pinMode(button2, INPUT_PULLUP);
  pinMode(button3, INPUT_PULLUP);
  pinMode(RelayPin, OUTPUT);
}

// Section: Main Loop

void loop() {

  //delay(100);

  ForeverLoop();
}
void ForeverLoop(){
  // This state contains the forever loops that is checking and monitoring the system
  // It is undecided whether the button should be interrupt or a constant polling nature
  State1(); // State 1 is the button polling of the code
  ButtonMap();
  //Serial.println();
  //Serial.print("Current Status After State 1: ");
  //Serial.println(FullSequence);
  //delay(1000);
  State2(); // State 2 is checking the water level to display an estimated value
  //Serial.println();
  //Serial.print("Current Status After State 2: ");
  //Serial.println(FullSequence);

  State3(); // State 3 checks the temperature of the system
  //Serial.println();
  //Serial.print("Current Status After State 3: ");
  //Serial.println(FullSequence);

  State5(); // State 5 allows for the system to turn off an on depending on the temperature

  State4(); // State 4 updates the LCD
  //Serial.println();
  //Serial.print("Current Status After State 4: ");
  //Serial.println(FullSequence);

  //delay(1000);

  if (FullSequence==1){
    State6(); // State 6 is the temperature change screen that statys within that location
  }
}
//State7(); // State 7 changes the target temperature to be lower
//State8(); // State 8 changes the target temperature to be higher
//State4(); // This state updates the LCD

}  
else if (FullSequence==2){
State9();
}

if(ChangeToggle==1){ChangeToggle=0; State10();}

} 

void State1(){
// This state constantly polls the button for inputs rather than use interrupts
// This state constantly polls for the buttons to see if there has been any changes
// Button Combination Returns
// None : 0
// 1 : 1
// 2 : 2
// 3: 3
// 1 & 2: 12
// 1 & 3: 13
// 2 & 3: 23
// 1, 2, & 3

if(ButtonReset==0){
  if (digitalRead(Switch1)!=HIGH){
    delay(100);
    Return_Value=1;
    if(digitalRead(Switch2)!=HIGH){
      Return_Value=12;
      if(digitalRead(Switch3)!=HIGH){
        Return_Value=123;
      }
    }else if(digitalRead(Switch3)!=HIGH){
      Return_Value=13;
      if(digitalRead(Switch2)!=HIGH){
        Return_Value=123;
      }
    }
    ButtonReset=1;
  }
else if (digitalRead(Switch2)!=HIGH){
    delay(100);
    Return_Value=2;
    if(digitalRead(Switch3)!=HIGH){
        Return_Value=23;
        if(digitalRead(Switch1)!= HIGH){
            Serial.println("122i");
            Return_Value= 123;
        }
    }
    else if(digitalRead(Switch1)!= HIGH){
        Return_Value=12;
        if(digitalRead(Switch3)!= HIGH){
            Serial.println("12");
            Return_Value=123;
        }
    }
    ButtonReset=1;
}
else if (digitalRead(Switch3)!=HIGH){
    delay(100);
    Return_Value=3;
    if(digitalRead(Switch2)!=HIGH){
        Return_Value=23;
        if(digitalRead(Switch1)!= HIGH);
            Serial.println("132");
            Return_Value= 123;
    }
    else if(digitalRead(Switch1)!= HIGH){
        Return_Value=13;
        if(digitalRead(Switch2)!= HIGH){
            Serial.println("122");
            Return_Value=123;
        }
    }
    ButtonReset=1;
}
void State2(){
    // Checking the water level of the system
    WaterLevel1 = analogRead(Wat1); // Getting the value analog output from the first water level sensor
    WaterLevel2 = analogRead(Wat2); // Getting the value analog output from the second water level sensor
    WaterLevel3 = analogRead(Wat3); // Getting the value analog output from the third water level sensor

    if (Interval_Count<20){
        Serial.println(Interval_Count);
        Serial.println(WaterLevel1);
        Serial.println(WaterLevel2);
        Serial.println(WaterLevel3);
        if (WaterLevel1<WatThresh){
            // Additional code here
        }
    }
}
```c
WaterRead1+=1; //Increasing the reading in response to a value above the given threshold

} else if (WaterLevel1>=WatThresh) {
    WaterRead1-=1;
}
if (WaterLevel2<WatThresh) {
    WaterRead2+=1; //Increasing the reading in response to a value above the given threshold
}
else if (WaterLevel2>=WatThresh) {
    WaterRead2-=1;
}
if (WaterLevel3<WatThresh) {
    WaterRead3+=1; //Increasing the reading in response to a value above the given threshold
}
else if (WaterLevel3>=WatThresh) {
    WaterRead3-=1;
}
Interval_Count+=1;
}
else if (Interval_Count >= 20) {
    //Serial.println(WaterRead1);
    //Serial.println(WaterRead2);
    //Serial.println(WaterRead3);
    //delay(3000);
    Interval_Count=0;
    if(WaterRead1>= Interval_Count/2) {
        WaterLevel=1;
        ThermoCheck=1;
        if(WaterRead2>= Interval_Count/2) {
            WaterLevel=2;
            ThermoCheck=2;
            if(WaterRead3>= Interval_Count/2) {
                WaterLevel=3;
                ThermoCheck=3;
            }
        }
    }
```

Portable Drinking Water Cooler and Dispenser
else if (WaterRead1<Interval_Count/2){
    WaterLevel=0;
    ThermoCheck=1;
}
//Serial.print("WaterLevel: ");
//Serial.print(WaterLevel);
//delay(999);
WaterRead1=0;
WaterRead2=0;
WaterRead3=0;

WaterRead1+=1; //Increasing the reading in response to a value above the given threshold
WaterRead2+=1; //Increasing the reading in response to a value above the given threshold
WaterRead3+=1; //Increasing the reading in response to a value above the given threshold

WaterRead1-=1; //Decreasing the reading in response to a value above the given threshold
WaterRead2-=1; //Decreasing the reading in response to a value above the given threshold
WaterRead3-=1; //Decreasing the reading in response to a value above the given threshold

void State3(){
// Checking the temperature of the system

sensors.requestTemperatures();

Temp1= sensors.getTempF(Thermo1); // This is the temperature for the first probe
Temp2= sensors.getTempF(Thermo2); // This is the temperature for the second probe
Temp3 = sensors.getTempF(Thermo3);  //this is the temperature for the third probe

if (ThermoCheck==1){
    Temperature= Temp1;
    //Serial.print("Sensor 1: ");
    //Serial.println(Temp1);
    //Serial.print("Sensor 2: ");
    //Serial.println(Temp2);
    //Serial.print("Sensor 3: ");
    //Serial.println(Temp3);
    //myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 0);
    //myLCD.PCF8574_LCDSendString("Temperature: ");
    dtostrf(Temperature, 5, 2, PrintTemp);
    //myLCD.PCF8574_LCDSendString(PrintTemp);
}

else if(ThermoCheck==2){
    Temperature= (Temp1+Temp2)/2;
    //Serial.print("Sensor 1: ");
    //Serial.println(Temp1);
    //Serial.print("Sensor 2: ");
    //Serial.println(Temp2);
    //Serial.print("Sensor 3: ");
    //Serial.println(Temp3);
    //myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 0);
    //myLCD.PCF8574_LCDSendString("Temperature: ");
    dtostrf(Temperature, 4, 2, PrintTemp);
    //myLCD.PCF8574_LCDSendString(PrintTemp);
}

else if(ThermoCheck==3){
    Temperature=(Temp1+Temp2+Temp3)/3;
    //Serial.print("Sensor 1: ");
    //Serial.println(Temp1);
    //Serial.print("Sensor 2: ");
    //Serial.println(Temp2);
    //Serial.print("Sensor 3: ");
    //Serial.println(Temp3);
void State4(){
  // Updating the LCD Display to display the latest information about the water
  //String TemperatureString = String(Temperature); //This converts the
temperature value into a displayable string
  //String WaterString = String(WaterLevel); //This converts the temperature
  //This section is in charge of printing the temeprature of the system

  if(FullSequence==0){
    myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 0);
    myLCD.PCF8574_LCDSendString("Water Temp: ");
    //myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 12);
    myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 13);
    myLCD.PCF8574_LCDSendString(PrintTemp);
    myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 18);
    myLCD.PCF8574_LCDSendString("F");
  }
  //This part is in charge of printing the water level of the system
  myLCD.PCF8574_LCDGOTO(LCDLineNumberTwo, 0);
  myLCD.PCF8574_LCDSendString("Water Level: ");
  //myLCD.PCF8574_LCDGOTO(LCDLineNumberOne, 11);
  //myLCD.PCF8574_LCDSendString(WaterString);
  if(WaterLevel==0){myLCD.PCF8574_LCDSendString("<25%");}
  else if(WaterLevel==1){myLCD.PCF8574_LCDSendString(">25%");}
  else if(WaterLevel==2){myLCD.PCF8574_LCDSendString(">50");}
  else if(WaterLevel==3){myLCD.PCF8574_LCDSendString(">75");}
  myLCD.PCF8574_LCDGOTO(LCDLineNumberThree, 0);
  myLCD.PCF8574_LCDSendString("Auto Update: ");
  //myLCD.PCF8574_LCDGOTO(LCDLineNumberThree, 13);
  if (SystemUpdate==1){myLCD.PCF8574_LCDSendString("ON");}
  if (SystemUpdate==0){myLCD.PCF8574_LCDSendString("OFF");}
}
void State5(){
  // Turning the system on and off dependent on the temperature
  // If system update is enabled, the system will allow for cycling between on and
  // off state
  if (SystemUpdate==0){
    OUTPUT2_ON=0;
    OUTPUT2_OFF=0;

    if(OUTPUT1_ON==0){digitalWrite(RelayPin, HIGH); OUTPUT1_ON=1;}
    else if(OUTPUT1_ON==1){}
  }
  else if(SystemUpdate==1){
    OUTPUT1_ON=0; // This resets the cycle for the previous to allow for it to flow
    // through
    // If the temperature of the system is below the target temperature and some, the
    // system will turn off
  }
}

void States(){
  // Turning the system on and off dependent on the temperature
  // If system update is enabled, the system will allow for cycling between on and
  // off state
  if (SystemUpdate==0){
    OUTPUT2_ON=0;
    OUTPUT2_OFF=0;

    if(OUTPUT1_ON==0){digitalWrite(RelayPin, HIGH); OUTPUT1_ON=1;}
    else if(OUTPUT1_ON==1){}
  }
  else if(SystemUpdate==1){
    OUTPUT1_ON=0; // This resets the cycle for the previous to allow for it to flow
    // through
    // If the temperature of the system is below the target temperature and some, the
    // system will turn off
  }
}
if(Temperature <= Target_Temp){
    if(OUTPUT2_OFF==0){
        digitalWrite(RelayPin, LOW);
        OUTPUT2_OFF=1;
        OUTPUT2_ON=0;
    }
    else if(OUTPUT2_OFF==1){}
}

//If the temperature of the system is above the target temperature and some, the
system will turn on
else if(Temperature >= Target_Temp+8){
    if(OUTPUT2_ON==0){
        digitalWrite(RelayPin, HIGH);
        OUTPUT2_ON=1;
        OUTPUT2_OFF=0;
    }
    else if(OUTPUT2_ON==1){}
}

void State6(){
    // Changing the target temperature of the system
    if(TempChange==0){EnteredTemp=Target_Temp; TempChange=1;}
    else if (TempChange==1){
        if(IncreaseTemp==1){EnteredTemp+=1;IncreaseTemp=0;}
        else if(DecreaseTemp==1){EnteredTemp-=1;DecreaseTemp=0;}
    }
}
void State7()
// Decreasing the temperature when the corresponding button is pressed
{
}

void State8()
// Increasing the temperature when the corresponding button is pressed
{
}

void State9()
// Setting the target water temperature
    Target_Temp= EnteredTemp;
    TempChange=0;
    FullSequence=0; //The system will return to operating at the normal function
{
}

void State10()
// Dictates whether the system should auto shut off or not
    //SystemUpdate != SystemUpdate; //Changes the state of the variable
{
    if(SystemUpdate==1){SystemUpdate=0;}
    else if(SystemUpdate==0){SystemUpdate=1;}
}

void ButtonMap()
{
    if(FullSequence==0)
    {
        if(Entered_Value==1){Entered_Value=0; ChangeToggle=1;}//Make this so that this
        else if(Entered_Value==2){Entered_Value=0;}
        else if(Entered_Value==3){FullSequence=1;Entered_Value=0;}
        }/Serial.print("Changed Sequence");
    else if(Entered_Value==12){Entered_Value=0;}
    else if(Entered_Value==13){Entered_Value=0;}
    else if(Entered_Value==123){Entered_Value=0;}
    else if(Entered_Value==23){Entered_Value=0;}
    }

    else if(FullSequence==1)
    {
        if(Entered_Value==1){IncreaseTemp=1;Entered_Value=0;}
    }
else if(Entered_Value==2){DecreaseTemp=1;Entered_Value=0;}
else if(Entered_Value==3){FullSequence=2;Entered_Value=0;}
//Serial.print("Changed Sequence");
else if(Entered_Value==12){Entered_Value=0;}
else if(Entered_Value==13){Entered_Value=0;}
else if(Entered_Value==123){Entered_Value=0;}
else if(Entered_Value==23){Entered_Value=0;}
}
# Appendix E – Design Verification Plan & Report (DVPR)

Table 6. This table shows the design verification plan (and report) to verify that each specification criterion was met. Note that the test results are empty and will be updated as each test is conducted.

<table>
<thead>
<tr>
<th>Test #</th>
<th>Specification</th>
<th>Test Description</th>
<th>Measurements</th>
<th>Assumption Criteria</th>
<th>Required Facilities/Equipment</th>
<th>Parts Needed</th>
<th>Responsibility</th>
<th>Start date</th>
<th>Finish date</th>
<th>Numerical Results</th>
<th>Notes on Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight</td>
<td>Drive all components are installed, system is on a scale and record the weight.</td>
<td>lbs</td>
<td>less than 5 lbs</td>
<td>scale</td>
<td>Full system</td>
<td>Gary</td>
<td>5/25/2023</td>
<td>5/27/2023</td>
<td>The system weighed 155 lbs</td>
<td>The unit was weighed on a bathroom scale with no water in the system. The unit did not meet the target criteria since it weighed more than 5 lbs.</td>
</tr>
<tr>
<td>2</td>
<td>Cooling Performance</td>
<td>The system will cool water through conduction of a refrigerant line to a stainless steel container. For this, you need a difference in temperature, thickness of the walls, and the heat transfer area.</td>
<td>°C (Y)</td>
<td>Coefficient (BTU)</td>
<td>Mass flow rate (m³/hr)</td>
<td>Suction line from condenser</td>
<td>Refrigeration and water sub-systems</td>
<td>Eric</td>
<td>5/27/2023</td>
<td>The performance was found to be below 1.4</td>
<td>The tank seemed to have poor thermoelectricity, with only a couple of cold spots.</td>
</tr>
<tr>
<td>3</td>
<td>Water Temperature</td>
<td>The system will be brought out on a hot day and set up to cool water. After 15 minutes of cooling, the temperature will be checked. If the temperature is below 55°F then the next sample can begin. The water must reach 55°F before 1 hour has passed.</td>
<td>°F</td>
<td>At least 0 °F</td>
<td>Daylight temperature</td>
<td>Refrigeration and water reservoir setup</td>
<td>Eric</td>
<td>5/27/2023</td>
<td>After an hour of cooling the system reached 65.9°F from a starting temp of 86.7°F</td>
<td>While it did not meet the target, we believe adjusting the valve could improve the performance with more testing.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Operation Time</td>
<td>Run the system for 6 hours without overheating components</td>
<td>hour</td>
<td>At least 0 hours</td>
<td>stop watch</td>
<td>Full system</td>
<td>Terry</td>
<td>5/27/2023</td>
<td>After eight hours of cooling the system for operating the system, there were no overheated components and the cooling performance did not do a great job</td>
<td>The unit ran and pressures seemed to be stable.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Noise Levels</td>
<td>When the operation unit is installed and able to be operated, the noise level will be measured by dB meter from 5 feet away.</td>
<td>dB</td>
<td>50 dB</td>
<td>dB meter or sound level</td>
<td>Full system</td>
<td>Casey</td>
<td>5/24/2023</td>
<td>The system ran at a noise level of 50 dB</td>
<td>The unit was measured dB with water in the system for performing cooling. It meets the acceptance criteria.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Leakage Test</td>
<td>Run the system for 60 minutes and look for refrigerant leaks with applying soapy water every 5 mins after the system warms up 10 mins.</td>
<td>minutes</td>
<td>No refrigerant leakage</td>
<td>Dawn's leak spray, spray detection spray, or leak detection dye</td>
<td>Full system</td>
<td>Terry</td>
<td>5/24/2023</td>
<td>The system was pressurized to 200 psi overnight and no leaks were found</td>
<td>This test was performed by our refrigeration technician. Tests from CalCooler Refrigeration.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix F – Test Procedures

Test Title: Noise level

Test Goals: measure the noise level to meet the standard (<90dB in 5ft)

Test Equipment Required:
- Power cord extension (spare)
- Noise Level meter (smartphone)
- Tape
- Tape measurement
- The cooling water system
- Earbuds

Procedure:
1. Place our system in the center of the 5ft coverage.
2. Use tape measurement to find the 4 points for distances from 1ft to 5ft and label 4 points per ft with tape.
3. Find a wall plug location to power up the machine.
4. Will use the extension cord to connect our system and wall plug.
5. Wear earbuds and turn on the system.
6. Use a noise level meter to measure how is the level for each point that we set.

Hazards:
Noise above 70 dB over a prolonged period may start to damage your hearing. Loud noise above 120 dB can cause immediate harm to your ears.

Location for the testing:
Public parking or open area near the mustang 60

<table>
<thead>
<tr>
<th>Noise Level Measurement (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dB</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>dB</td>
</tr>
</tbody>
</table>
Test Title: Weight of the cooling unit.

Purpose: The purpose of this test is to determine the final dry weight of the cooling device.

Scope: This test will verify the weight function of the specification table. The goal of the specification is to create a unit that is close to 51 lb so that one person can handle the device. The final weight of the device will dictate how many users will be needed to lift the unit safely to meet NIOSH guidelines.

Equipment:
- Empty cooling device.
- Platform weighing scale.
- Stable surface

Hazards:
- Dropping the cooling unit while determining the weight of the system is possible if

PPE Requirements:
- Safety glasses
- Closed toes shoes.

Facility: Testing will be done in building 60 using a utility scale if possible, however, the mechanical scale in the HVAC lab can be used if one cannot be found.

Procedure:
1) Begin by zeroing the scale and finding a suitable flat surface.

   ![Utility Scale](image)

   Figure F1. Example of a utility scale that can be used to weigh the cooling unit.

2) Next, ensure that the weighing scale is properly calibrated. This can be done by using a calibration weight.
3) Place the cooling unit on the weighing scale. Make sure that the unit is centered on the scale to get an accurate measurement.
4) Record the weight of the unit that is displayed on the scale.
5) Clean and store the testing equipment after the weight has been taken.
Results:

<table>
<thead>
<tr>
<th>Trial</th>
<th>Weight of the cooling Unit [±0.01 lbf]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135</td>
</tr>
</tbody>
</table>

Once the weight of the cooling unit is found, a pass or fail criteria will be used to determine if the unit meets the specified weight set by NIOSH guidelines. If the weight does not meet the specified weight the operating procedure when lifting the unit will be adjusted to meet guidelines. This will be achieved by requiring two people to lift the unit instead of one. Uncertainty analysis will then be done using the following equations.

\[ u_{weight(w)} = \pm \frac{1}{2} \times 0.02 \text{ lbf} = 0.01 \text{ lbf} \]  

(1)

\[ u_{total} = u_{weight(w)} \]  

(2)

*Note that the resolution of the scale used may differ based on what is found in building 60 or the HVAC lab.*
**Test Title:** Operation Time

**Purpose:** *To make sure that the system can run for a full work day without overheating*

**Scope:** all subsystems (refrigeration, frame, water distribution, and electrical)

**Equipment:** Power Supply from a wall outlet. (List of equipment necessary, diagram of apparatus from Experimental Design Planning Form)

**Hazards:** Parts becoming too hot

**PPE Requirements:** close toed shoes, pants, and safety glasses

**Facility:** outside on a hot day

**Procedure:** (List numbered steps of how to run the test, including steps for calibration, zero/tare, baseline tests, repeat tests. Can include sketches and/or pictures):

1. insert a full 5-gallon jug into the system on a hot day outside
2. plug into an outlet and turn on the system to begin cooling water
3. after each hour dispense 8 liters. If a jug runs out of water replace it.
4. run the system for 2 hours
5. After 20 mins feel around for hot areas. Do not touch things that are radiating a lot of heat. Be careful and don’t move too quickly. Repeat after the next 20 mins two more times until 1 hour has passed. Then check every 30 minutes for the rest of the day.

**Results:** Pass Criteria, Fail Criteria, Number of samples to test, Design analysis equations/spreadsheet with uncertainty. Comment on how Uncertainty Analysis will be completed.

- **Pass criteria:** no parts of the system become too hot. A part is too hot when it is unbearable to be near it.

- **Fail Criteria:** Frame becomes too hot to hold or internal parts are fart too hot to be near. The system shuts down during the day for any reason.

**Sample tests:** 1

**Uncertainty analysis will not be necessary.**

**Test Date(s):** 5/27/23

**Test Results:** Pass

**Performed By:** Terry
**Test Name:** Cooling Performance

**Purpose:** The purpose of this test is to measure the performance of the water cooler using the standards used by Energy Star to test consumer water coolers.

**Scope:** This test will verify whether the portable water cooler is compliant with the Energy STAR program requirements.

**Equipment:**
- Bucket for drawn water
- Power meter with a minimum resolution of 1.0 W
- Cardinal scale from fluids laboratory.
- Warm water (80°F or higher to simulate a warm day)
- Refrigeration unit with cold water reservoir.
- 2 Temperature probes
- Thermometer
- Computer or Arduino board
- Stopwatch with a resolution of at least one second.
- *Standard 5-gallon water jug or 5-gallon bucket.

* Water jug will be used to maintain a consistent water level throughout the experiment. If the lid has not been completed by the test date the reservoir will need to be refilled to a set water level using room temperature water and a 5-gallon bucket.

**Hazards:**
- Freezer burn if the refrigerant unit is left running with no water in the reservoir.
- Use caution to not spill water on exposed electronic devices.

**PPE Requirements:**
- Safety glasses
- Closed toes shoes.
- * Gloves

*Required if side panels are not equipped during testing

**Facility:** Testing will be done in the fluids laboratory.
Procedure:
Begin by ensuring that the test is done in a temperature-controlled environment, this will be accomplished by doing all the testing indoors in the fluids laboratory.

1) Next prepare for the test by suspending the temperature probe about one inch above the drain of the cold-water reservoir.
2) Ensure that the cooling unit is connected to the power meter.
3) If the lid has been finished attach the standard water jug to the lid at room temperature and attach a second temperature probe near the neck of the jug.

If the lid is not available a 5-gallon bucket can be used in place of it. This can be done by resting the bucket above the reservoir and using a short hose to refill the water in the cold water tank. The second temperature probe should be attached near the bottom of the bucket where the water exits into the water reservoir below.

4) Next dispense water for 20 seconds, and wait for the compressor to power on. This is the point where power data should begin to be collected. Once the compressor is on record the energy consumption, $Q_{\text{cooler}}$, in Wh that is drawn and the amount of time, $t$, it takes for the compressor to shut back down. Also record the power at each second for 40 seconds, then repeat for 60 seconds, 90 seconds, 120 seconds.
5) The temperature at the exit of the reservoir, $T_o$, and the temperature of the water supply tank, $T_f$, should also be recorded in one second intervals when the compressor powers on. This will be done using the microcontroller and the water temperature sensors. For the first trial the temperature data will be collected for 40 seconds, then repeated for 60 seconds, 90 seconds, 120 seconds. Also make a note of the coldest temperature recorded during the time interval.
6) After the time interval record $Q_{\text{replenish}}$ in Wh from the power meter.
7) Next record the mass of the water drawn during the 20 second dispensing period.
8) Take an average of $T_f$ and $T_o$.
9) The adjusted energy consumed can then be calculated using the following equation.

$$Q_{\text{Replenish Adjusted}} = Q_{\text{Replenish}} - Q_{\text{cooler}} \quad (1)$$

10) Finally Calculate the delivered water energy using equation 2 and draw and calculate the performance of the cooler using equation 3.

$$Q_{\text{draw}} = m * c_p * (T_f-\text{avg} - T_o-\text{avg}) \quad (2)$$

$$\text{Performance of Cooler} = \frac{Q_{\text{draw}}}{Q_{\text{Replenish Adjusted}}} \quad (3)$$

Results: Updated

$Q_{\text{draw}} = \text{energy delivered during water draw}$
$Q_{\text{cooler}} = \text{Overall energy consumed by the cooler}$
$Q_{\text{replenish}} = \text{energy consumed to return to natural cycling}$
$Q_{\text{Replenish Adjusted}} = \text{energy consumed to return to natural cycling (Adjusted)}$
$T_f-\text{Average} = \text{The average temperature of the water that is dispensed}$
$T_o-\text{Average} = \text{The average temperature of the water that is located at the source}$
<table>
<thead>
<tr>
<th>Water Draw Time (seconds)</th>
<th>Mass Drawn (lbm)</th>
<th>$T_f$–Average ($^\circ$F)</th>
<th>$T_o$–Average ($^\circ$F)</th>
<th>$Q_{cooler}$ (BTU)</th>
<th>$Q_{replenish}$ (BTU)</th>
<th>$Q_{Draw}$ = $M \cdot C_p \cdot (T_f-avg - T_o-avg)$ (BTU)</th>
<th>$Q_{replenish} = Q_{replenish} - Q_{cooler}$ (BTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>4.5</td>
<td>63.0</td>
<td>62.5</td>
<td>24.3</td>
<td>40.9</td>
<td>2.4</td>
<td>16.7</td>
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<td>4.5</td>
<td>63.4</td>
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<td>Time (t)</td>
<td>Tf (°F)</td>
<td>To (°F)</td>
<td>Power Draw (W)</td>
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Portable Drinking Water Cooler and Dispenser
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**Results:**

Resolution uncertainties

Power meter: \( U_{pm} = \pm \frac{1}{2} (1W) = \pm 0.5 \text{W} \)

Cardinal scale: \( U_W = \pm \frac{1}{2} (0.02 \text{ lbf}) = \pm 0.01 \text{ lbf} \)

Temperature: \( U_T = \pm \frac{1}{2} (1^\circ \text{C}) = \pm 0.5 \text{ °C} \)

Stopwatch: \( U_{SW} = \pm \frac{1}{2} (1 \text{ sec}) = \pm 0.5 \text{ sec} \)

\[
u_{T_f} = \sqrt{u_{stat}^2 + u_{reading}^2}
\]

\[
u_{T_o} = \sqrt{u_{stat}^2 + u_{reading}^2}
\]

\[
s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1}}
\]

Where \( t \) comes from the student t table and \( n \) is the number data points.

\[
U_Q = \sqrt{\left(\frac{\partial Q}{\partial W} u_w\right)^2 + \left(\frac{\partial Q}{\partial T_f} u_{T_f}\right)^2 + \left(\frac{\partial Q}{\partial T_o} u_{T_o}\right)^2}
\]

\[
u_{weight(w),min} = \pm \frac{1}{2} \times 1 \text{ lbf} = 0.5 \text{ lbf}
\]

\[
u_{volume} = \pm \sqrt{\left(\frac{\partial V}{\partial w} * u_w\right)^2 + \left(\frac{\partial V}{\partial \rho} u_{\rho}\right)^2}
\]

---

**Test Date(s):**

5/27/2023

**Test Results:**

PASS/FAIL

Performed By: Erik Torres

Portable Drinking Water Cooler and Dispenser
Test Title: Water Temperature.

Purpose: The purpose of this test is to ensure that the system can cool a minimum of 4 liters of water to 59°F every hour.

Scope: This test will that the system can cool water to 59°F

Equipment:
− Warm water (80°F or higher to simulate a warm day)
− Refrigeration unit with cold water reservoir.
− Temperature probe
− Computer w/ Putty installed and Arduino IDE
− Arduino board

Hazards:
− Freezer burn if the refrigerant unit is left running with no water in the reservoir.
− Use caution to not spill water on exposed electronic devices.

PPE Requirements:
− Safety glasses
− Closed toes shoes.
− * Gloves

*Required if side panels are not equipped during testing

Facility: Testing will be done on campus at Cal Poly

Procedure:
1. Fill cold water reservoir with warm water to simulate water on a hot day
2. Using an external Arduino board with two thermocouples attached to the Arduino system, insert the two thermocouples into the water reservoir
   a. Ensure that each thermocouple is not touching the inner walls of the reservoir to avoid cold spot readings.
3. Once the thermocouples have been inserted, upload a simple thermocouple testing code that outputs to Serial.
4. Once uploaded, close the Arduino IDE and open up putty.
5. Once in Putty, set up Putty to record a new file. Choose a location for the file to be saved and initiate the recording.
6. After recording starts, turn on the system and mark at which point the system started recording for future time offset.
7. Run for one hour and record the time and temperature.
Results:

Test Date(s): 5/27/2023
Test Results: PASS/FAIL
Performed By: Erik Torres
Test Title: Leakage Test
Purpose: The purpose of the test is to ensure that there are no leaks from the refrigeration system
Scope: The test will only be done on the refrigeration subsystem. All piping and connection points will be tested to see if there is any measurable leakage from the system. It does not need to be quantified as this is a pass or fail test.
Equipment: Dawn dish soap, spray bottle/cotton swabs, graduated cylinder or any measuring utensil
Hazards: Inhaling too much R134-a can lead to headaches and nausea in moderate doses
PPE Requirement: Safety glasses that enclose the eyes with gasket seals and a respirator to prevent inhalation of possible R134-a if a leak is present.
Facility: In a well-ventilated area or outside on a day that is not too windy

Procedure:
1. Turn on the system and allow it to get to running specifications.
2. After allowing the system to run continuously for 10 minutes, prepare the mixture.
3. With dawn dish soap and the measurement utensil of choice in hand, create a mixture of 1:10.
4. Mix it until all the dish soap has been fully immersed with the water.
5. Fill a spray bottle with the solution or leave in cylinder/container to be used.
6. With chosen method of application, liberally cover all piping with the solution.
7. Ensure that all points have been covered with it to prevent any missed spots on the tubing.
8. Allow the system to run for 5 minutes before reapplying more.
9. Constantly check the unit to see if there are any bubbles being formed.
10. If there are bubbles being formed, make a note of the location on the refrigeration system.
11. Test the system for an hour with intermittent checks as previously described.

Results: The system will be evaluated under multiple tests each considering of certain criteria to be met before being acknowledged as passing.
Pass Criteria: There are zero leaks throughout the system. Not sort of leak, whether on or off, will be allowed as that is detrimental to the system operation.
Fail Criteria: If any leak is present, the system will automatically fail.
Sample Tests: Testing every 5 minutes for an hour. Initial startup of the device
Uncertainty: No uncertainty is to be performed due to the nature of the test

Test Date(s): 5/16/2023
Test Results: PASS/FAIL
Performed By: ____________________________ Cal Coast ____________________________
Appendix G – Wiring Diagrams
Appendix H – Drawing Package

1000-000 Flexible Water Cooling System

F1100-001 Frame
   F1110-001 20.75 Horizontal Member
   F1110-002 18.5 Short Horizontal Member
   F1110-003 20” Vertical Member
   F1110-004 18” Vertical Support Member
   F1110-005 22.75 X 20.5 Front/Back Panel
   F1110-006 20.50 X 20 Side Panels
   F1110-007 22.75 X 20 Top Panel
   F1110-008 22.75 x 8.75 Base Plate
   F1110-009 Cup Holder
   F1110-0010 Lid
      F1111-001 Top Plate
      F1111-002 Bottom plate
      F1111-003 Stainless Steel Rivet Nuts Kit #8-32#10-24 1/4"-20 5/16"-18 3/8"-16
         ThreadedInsert Nutsert Rivnuts Handle Drawing Sheet
   F1110-0011 Kayak Carry Handles
   F1110-0012 Holding Capacity Adjustable Toggle Latch Clamp Smoker Latch Clamps
   F1111-004 Yufannet Rubber Grommet Kits
   F1111-005 Screw EB Hex Washer Self Drilling 1-1/2
   F1111-006 Mach Screw Zinc comb rnd 1/4 x 1-1/2
   F1111-007 Fasterner (Assorted)

W1100-001 Water Distribution
   W1110-001 Stainless steel Container Product Description/Data Sheet
   W1110-002 0.5” silicone tubing Product Description/Data Sheet
      W1111-001 1 ft
   W1110-003 External water storage Product Description/Data Sheet
   W1110-004 5/8” water dispenser Product Description/Data Sheet
   W1110-005 Valve Product Description/Data Sheet
   W1110-006 5/8” female to ½” barb adapter Product Description/Data Sheet
   W1110-007 Igloo cooler to tubing Product Description/Data Sheet
   W1110-008 ½” Stainless steel container drain connector Product Description/Data
   W1110-009 Gasket Product Description/Data Sheet

E1100-001 Electronics
   E1110-001 Operation/Sensor
      E1111-001 Elegoo Board – Arduino Compatible Product/Data Sheet
      E1111-002 Water Sensor Data Sheet
      E1111-003 20 Gauge Wire Product/Data Sheet
      E1111-004 Temperature Sensors Data Sheet
      E1111-005 Power Switch Product/Data Sheet
      E1111-006 Simple Display Data Sheet

Portable Drinking Water Cooler and Dispenser
Portable Drinking Water Cooler and Dispenser
R1111-0025  1/4" washer x 32
R1111-0026  Power cord
R1111-0027  3/8 hex nuts X4
R1111-0028  4 1/4" hex nut
R1111-0029  1/4" flat washer
R1111-0030  Refrigeration
R1111-0031  Brass adapter
R1111-0032  Brass Reducer
R1110-002   20’ Copper Tubing 1/4”
R1110-003   10’ Copper Tubing 3/8”
R1110-004   R-134a
R1110-005   Insulation
R1111-0033  Walls
R1111-0034  Copper Insulation
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Keeps paper cups in a clean enclosed environment

https://www.amazon.com/San-Jamar-Stainless-Dispenser-Length/dp/B00022WSVC/ref=sxin_search_thematic_asp?content_id=amzn1.sym.f0c5ad8f-clb9-48f0-8868-482b84b2d5eb%n=3Amzn1.sym.f0c5ad8f-clb9-48f0-8868-482b84b2d5eb&cv_ct cx=stainless steel+paper+cup+dispenser&eyewords=stainless steel+paper+cup+dispenser&d_rd_i=B00022W SVC&p d_r c=c29b5469-b33c-40b8-90a4-710fa49fc3&pd rd_r=rc29b5469-b33c-40b8-90a4-710fa49fc3&pd_rd_w=ww63Q&pd rd_w=wJ5L&pf rd p=f0c5a d8f-c1b9-48f0-8868-482b84b2d5eb&pf rd_w=weeFL&pf p_d=p=f0c5a_d8f-c1b9-48f0-8868-482b84b2d5eb&sd p_rd_i=B00022WSVC&sd p_rd_r=rc29b5469-b33c-40b8-90a4-710fa49fc3&sprefix=stainless steel+paper+cup%2Caps%2C171&qid=1675488433&sr=1-3&a73d1c8c-2fd2-4f19-aad1-2d0222bcb241-0&scp c=1&sp La=ZW5jcnlwdG9iUXhbGlmaWVyPuEXmxMxVWJlQUySLMTIEmYy3I5chRRlEIKPU EuMTc3MTYwMjgw1ENWYXZVWzbnMvexKX01ZVR8EiPUeNDuVjNawMIZEEmwQOQ2SUNUUC3aWmXZRO
### Portable Drinking Water Cooler and Dispenser

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<td>W11003</td>
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<td>reuse the existed water container from the field</td>
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<td><a href="https://www.amazon.com/dp/B00RPBQBQ4/ref=sspa_dk_detail_0?pd_rd_i=B00RPBQBQ4&amp;pd_rd_wg=F6isN&amp;pd_rd_r=b9c97bd0-e8ee-4173-b38d-97996e91b53a&amp;sp_csd=p_kg%E7%BB%8F%E8%90%A5%E6%A8%A1%E5%BC%8F:kitchen">https://www.amazon.com/dp/B00RPBQBQ4/ref=sspa_dk_detail_0?pd_rd_i=B00RPBQBQ4&amp;pd_rd_wg=F6isN&amp;pd_rd_r=b9c97bd0-e8ee-4173-b38d-97996e91b53a&amp;sp_csd=p_kg经营模式:kitchen</a></td>
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Professional Grade in-Line Barbed Ball Valve 16mm for 1/2 and 5/8 Inch Tubing

[Amazon Link](https://www.amazon.com/Professional-Grade-Line-Barbed-Tubing/dp/B07Y42PXZD/ref=sr_1_5?crid=307PQB4OAD2UM&keywords=5%2F8%2Bplastic%2Bwater%2Bvalve&qid=1675486293&sr=8-5&th=1)
<p>| W 1 1 0-006 | 5/8&quot; female to 1/2&quot; barb adapter | Fresh water systems | FBA-1008BP | $1.33 | Fresh water systems | FBA-1008BP | Female Barb Adapter - 5/8 barb x 1/2 FNPT - Black Polypropylene | <a href="https://www.freshwatersystems.com/products/female-barb-adapter-5-8-barb-x-1-2-fnpt-black-polypropylene?variant=419453219240">https://www.freshwatersystems.com/products/female-barb-adapter-5-8-barb-x-1-2-fnpt-black-polypropylene?variant=419453219240</a> | 492400 &amp;c1=GAW_SE_NW &amp;source=PLA_USA_PM &amp;cr2=pmax_-<em>nw</em>-<em>shopping&amp;kw=41994532192440 &amp;utm_campaign=pmax</em>-<em>nw</em>-_shopping&amp;utm_source=PLA_USA_PM&amp;utm_medium=cpc&amp;hsa_acc=20141030 &amp;hsa_cam=1183986621&amp;hsa_grp=&amp;hsa_ad= &amp;tgt= &amp;hsa_kw= &amp;hsa_mnt= &amp;hsa_net=adwords&amp;hsa_ver=3&amp;gclid=CjwKCAiAleOeBhBdEiwAfgmXJMyeYrI9HuaPxK2LUt0Q2yS8swjeSV5QSpDc2R pC5isQAvO_BwE |
| W 1 1 0-007 | Igloo cooler to tubing | Amaz on | n/a | $8.54 | Igloo | 00024011 | Replacement Threaded Drain Plug | <a href="https://www.amazon.com/Igloo-Replacement-Threaded-Drain-Plug/dp/B0006FQYP7">https://www.amazon.com/Igloo-Replacement-Threaded-Drain-Plug/dp/B0006FQYP7</a> |</p>
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<th>W1110008</th>
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<td>Gasket</td>
<td>Amazon</td>
<td>n/a</td>
<td>$14.95</td>
<td>Dualplex</td>
<td>n/a</td>
<td>Neoprene Sponge Foam Rubber, Easy Cut Non-Adhesive, Soundproof</td>
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https://www.amazon.com/SHENHUISS-Fittings-Stainless-Straight-Thru-Hull/dp/B09PH87Q2M/ref=dp_lpo_1?pd_rd_w=rvpNM&content_id=amzn1.sym.116f529c-aa4d-4763-b2b6-4d614e7dc00&pf_rd_p=116f529c-aa4d-4763-b2b6-4d614e7dc00&pf_rd_r=116f529c-aa4d-4763-b2b6-4d614e7dc00&pf_rd_s=amzn1助手sym.116f529c-aa4d-4763-b2b6-4d614e7dc00&pd_rd_wg=MAbnV&pd_rd_r=0b3fe6cd-6321-4a85-9e31-eedd9e084f52&pd_rd_i=B0B18GB3X&th=1

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Portable Drinking Water Cooler and Dispenser
<p>| E1111-008 | Barrel Plugs | Amazon | 57101 | $10.89 | MILAPEAK | n/a | 12V 5A DC Power Pigtail Barrel Plug Connector Cable <a href="https://www.amazon.com/43x2pcs-Connectors-Security-Lighting-MILAPEAK/dp/B0728X32YB/ref=pspc_11041121_11_081LVQMV1P">Link</a> |</p>
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**Portable Drinking Water Cooler and Dispenser**
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<td>Copper Wire 14 Gauge</td>
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### Additional Information
- [LLTOP Waterproof AC100-264V Transformer](https://www.amazon.com/LLTOP-Waterproof-AC100-264V-Transformer-Computer/dp/B08BYYNGG/ref=sr_1_1_sspa?keywords=120v%2Bto%2B12v%2Bconverter&qid=1675481527&sr=8-1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzR1QyVjhJQlZJUIjMVuY3J5cHRlZElkPUEwMDYyMDQ5M1VRVkJjJ2Fkb2JlZ29vZ2Fsp249Y2xpY2tSZW5pc3Rvb249Y2xpY2tSZW5pc3Rvb249Y2xpY2tSZW5pc3Rvb249Y2xpY2tSZW5pc3Rvb249)
- [Fermerry Stranded Electrical Silicone Cables](https://www.amazon.com/Fermerry-Stranded-Electrical-Silicone-Cables/dp/B089CRKSNN/ref=asc_df_B089D375K7/?tag=hyprod-20&linkCode=df0&hvadid=459486921002&hvpos=&hvnetw=g&hvrand=17578882146538727243&hvanchor=&hvlocale=&hvptone=&hvptwo=&hyptwo=&hyvmt=&hyde=vrc&hvdcmid=&hvlocint=&hvlocip=1014232&hvtargid=pla-9464488424498&region_id=674469&th=1)
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<td>Magnolian</td>
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[https://www.amazon.com/BOJACK-Inline-Values-Assortment/dp/B0813Q4S6P/ref=sr_1_3?crid=37FNC34XXC8RJ&keywords=120v+inline+fuse&qid=1675487193&sr=1-3](https://www.amazon.com/BOJACK-Inline-Values-Assortment/dp/B0813Q4S6P/ref=sr_1_3?crid=37FNC34XXC8RJ&keywords=120v+inline+fuse&qid=1675487193&sr=1-3)

[https://www.amazon.com/Magnolian-Display-Supply-Converter-Module/dp/B01JJB5508/ref=sr_1_5?crid=1EB9HE2VSC4Y9&keywords=12v%2Bto%2B5v&qid=1675489552&s=electronics&sprex=12v%2Bto%2B5v%2Celectronics%2C150&sr=1-5&th=1](https://www.amazon.com/Magnolian-Display-Supply-Converter-Module/dp/B01JJB5508/ref=sr_1_5?crid=1EB9HE2VSC4Y9&keywords=12v%2Bto%2B5v&qid=1675489552&s=electronics&sprex=12v%2Bto%2B5v%2Celectronics%2C150&sr=1-5&th=1)
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<td>UNEU2140Z1</td>
<td>1/2 HP, 115V, R-134a Condensing Unit</td>
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https://www.hoamelectrical.com/refrigeration-compressors/embraco-embreco-uneu2140z1.1.html?gclid=CjwKCAiA2roOe8hAsEwAHIp7Q9nXRp_mV_MM5SKwWIDtZ-HVV7s3gBmcIikuDioubBpfzv35foKBtCexo5IglQAvD_Qw6

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Portable Drinking Water Cooler and Dispenser
<p>| R 1 1 1 0 0 0 3 | 10' Copper Tubing 3/8&quot; | Home Depot | 1005002286 | $18.94 | Everbilt | n/a | <a href="https://www.homedepot.com/p/Everbilt-3-8-OD-in-x-10-ft-Copper-Soft-Refrigeration-Coil-Pipe-D060IPS100343482?source=shoppingads&amp;locale=en-US&amp;pla&amp;mtc=SHOPPING-BF-CDP-GGL-D26P-026_001_PIPE_FTTING-NA-NA-NA-SMART-NA-NA-NA-NA-NBR-NA-NA-NEW-PMmax&amp;cm_mmc=SHOPPING-BF-CDP-GGL-D26P-026_001_PIPE_FTTING-NA-NA-NA-SMART-NA-NA-NA-NA-NBR-NA-NA-NEW-PMmax-7170000097492030--&amp;gclid=CjwKCAiA5sieBh8NeEwAR9Oh2rbuNWUYUOCAkgN-apxPD2ZL3zoysn8_wyVbYafYmZDNMOoAVoR0Czw0OAeO_BwE">https://www.homedepot.com/p/Everbilt-3-8-OD-in-x-10-ft-Copper-Soft-Refrigeration-Coil-Pipe-D060IPS100343482?source=shoppingads&amp;locale=en-US&amp;pla&amp;mtc=SHOPPING-BF-CDP-GGL-D26P-026_001_PIPE_FTTING-NA-NA-NA-SMART-NA-NA-NA-NA-NBR-NA-NA-NEW-PMmax&amp;cm_mmc=SHOPPING-BF-CDP-GGL-D26P-026_001_PIPE_FTTING-NA-NA-NA-SMART-NA-NA-NA-NA-NBR-NA-NA-NEW-PMmax-7170000097492030--&amp;gclid=CjwKCAiA5sieBh8NeEwAR9Oh2rbuNWUYUOCAkgN-apxPD2ZL3zoysn8_wyVbYafYmZDNMOoAVoR0Czw0OAeO_BwE</a> &amp;gclsrc=aw.ds |
| R 1 1 0 0 0 4 | R-134a | Supplied by Cal Poly | --- | --- | n/a | n/a | most commonly found in refrigerators and automobile air conditioners and it has low acute toxicity levels and presents a low risk to humans exposed to it in small amounts |
| R 1 1 1 0 0 0 5 | Insulation | Amazon | B094D1QSLB | $19.97 | Owens Corning | n/a | Fiberglass Insulation | <a href="https://www.homedepot.com/p/Owens-Corning-R-13-Kraft-Faced-Fiberglass-Insulation-Continuous-Roll-15-in-x-32-ft-RF10/202585857">https://www.homedepot.com/p/Owens-Corning-R-13-Kraft-Faced-Fiberglass-Insulation-Continuous-Roll-15-in-x-32-ft-RF10/202585857</a> |</p>
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<tr>
<th>Material</th>
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<th>R-value</th>
<th>Description</th>
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<tr>
<td>Ceramic Fiber</td>
<td><a href="https://www.amazon.com/Ceramic-Fireproof-Insulation-High-Temperature-Resistance/dp/B094D1Q5LB/ref=sr_1_1_sspa?keywords=cold%20temperature%20insulation&amp;qid=1675491312&amp;sr=8-1&amp;spLa=ZW55jcnlwdGVkUXVhbGlmaWVyPUEsJiGRF2WT1RZMiZQImVuy3J5cHRlEkPUEwMDcDOTlxiyMjhUVVVQVgxMFIRC76mNyEXB0ZWRB2EIkPUEwN1MNjU0MUFJNVzdZMrSWOFFFYMyZ3sWRoZXROYW1PXNwXzF0ZiZhY3Rpb249Y2xpY2tSZWRpcmjdZCkb0SvdExvZ0NsaWNrPXyrdWU&amp;th=1">Link</a></td>
<td>$18.99</td>
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<td>n/a</td>
<td>24&quot; x 12&quot; x 1&quot; (Thick) Ceramic Fiber</td>
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<td>Copper Insulation</td>
<td><a href="https://www.amazon.com/Armaflex-Copper-Insulation-Thick-Nominal/dp/B00E2CKUCK/ref=sr_1_5?crid=O388G13C1R5&amp;keywords=copper+refrigerant+line+insulation&amp;qid=1675491005&amp;sprefix=copper+refrigerant+line%2Caps%2C141&amp;sr=8-5">Link</a></td>
<td>$19.00</td>
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<td>20&quot; Vertical member</td>
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<td>18&quot; Vertical support member</td>
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<td>F1110-005</td>
<td>22.75&quot;x20.5&quot; Front/Back Panel</td>
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<td>6</td>
<td>F1110-006</td>
<td>20.50&quot;x20&quot; Side panels</td>
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<td>7</td>
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<td>22.75&quot;x20&quot; Top panel</td>
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<td>22.75&quot;x8.75&quot; base plates</td>
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<td>9</td>
<td>F1110-009</td>
<td>Cup Holder</td>
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<td>10</td>
<td>F1111-001</td>
<td>top plate</td>
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<td>11</td>
<td>F1111-002</td>
<td>bottom plate</td>
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<td>14</td>
<td>F1111-003</td>
<td>Stainless Steel Rivet Nuts</td>
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<td>Eye Hook 1/4&quot; 20</td>
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<td>ITEM NO.</td>
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<td>DESCRIPTION</td>
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<td>W1110-009</td>
<td>Gasket</td>
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### Frame Cut List

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<thead>
<tr>
<th>Item No.</th>
<th>QTY.</th>
<th>Description</th>
<th>Length</th>
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<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>20&quot; Vertical member</td>
<td>20 inches</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>18.5&quot; Short Horizontal member</td>
<td>18.5 inches</td>
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<tr>
<td>3</td>
<td>4</td>
<td>20.75&quot; Horizontal member</td>
<td>20.75 inches</td>
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<tr>
<td>4</td>
<td>3</td>
<td>18&quot; Vertical support member</td>
<td>18 inches</td>
</tr>
</tbody>
</table>

**Notes:**

- UNLESS OTHERWISE SPECIFIED:
  1. All Stock is 1" 6061 Aluminum Square Rod
  2. TOLERANCES:
      - X.XX=±.01
      - ANGLES=±1°
  3. BREAK ALL SHARP ANGLES
  4. FRAME IS WELDED TOGETHER
  5. ROD THICKNESS IS .065"
Notes:

UNLESS OTHERWISE SPECIFIED:
1. All Stock is 1" 6061 Aluminum Square Rod
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. FRAME IS WELDED TOGETHER
5. ROD THICKNESS IS .065"
Notes:
UNLESS OTHERWISE SPECIFIED:
1. All Stock is 1" 6061 Aluminum Square Rod
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. FRAME IS WELDED TOGETHER
5. ROD THICKNESS IS .065"
Notes:

UNLESS OTHERWISE SPECIFIED:
1. All Stock is 1" 6061 Aluminum Square Rod
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. ASSUME ALL CORNERS HAVE SAME WELDS
5. ROD THICKNESS IS .065"

UNLESS OTHERWISE SPECIFIED:
1. All Stock is 1" 6061 Aluminum Square Rod
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. ASSUME ALL CORNERS HAVE SAME WELDS
5. ROD THICKNESS IS .065"
Notes:

UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet
Notes:
UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet
Notes:

UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet
Notes:
UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet

Φ3.00 Through All

20.74

22.87

.06
Notes:
UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES: X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet
Notes:
UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet
6. Spacing for pattern is repeated
Notes:
UNLESS OTHERWISE SPECIFIED:
1. MADE FROM 16 Ga. 304 STAINLESS STEEL
2. TOLERANCES:
   X.XX=±.01
   ANGLES=±1°
3. BREAK ALL SHARP ANGLES
4. Bend flap on finger brake
5. Cut on water jet
NOTES:
304 STAINLESS STEEL BASE PANEL FOR SHELL
1. PART#: F1111-008
2. Tolerance:
   LENGTH: X.XX ±0.01
   WIDTH: X.XX ±0.01
THE GASKET WILL BE CUT FROM A SHEET.
1. IT WILL BE CUT WITH THE WATER JET OR LASER CUTTER
2. TOLERANCES
   1. LENGTH : X.XX ±0.01
   2. WIDTH : X.XX ±0.01
   3. RADIUS : X.XX ±0.01

4 X R.64
4 X R.39
11.00
13.25
.063