**Prototype III and Customer Feedback**

**Introduction**

In this deliverable, we will be covering the development of our third and last prototype. The third prototype is used to test the overall functionality of our system. To test this prototype we will be measuring how long it takes for water to fill up the reservoir, the time it takes for the water to flow through the system, and how long the growing medium can preserve water. We have received insightful customer feedback from a potential client regarding this prototype. We will be covering an in depth analysis of the responses from our potential clients about this prototype. We will use the information from creating this prototype to re-evaluate our previous schedule and design, and to plan for future iterations.

**Prototype Guidelines**

For this prototype we based our concept on our first prototype. Instead of using straws for the sections where we will grow plants we are using 2 inch PVC pipes. In those pipes we will have holes where little baskets will be inserted to hold the plants. Since we had a limited budget for this prototype we will use smaller sized pipes then what the actual product would be. In the final product it would make more sense to use bigger tubing, approximately 4 inches, to give more room for the plants to grow. Due to the budget we also decided to do only 2 rows of plants for this prototype to cut on cost. The system could have more rows and they could also be longer if there are more funds. The next part is the bottom tank, we will use just a simple water pale as the bottom tank that will hold our water and nutrient solution. We will use the same pump from prototype 2 since after testing the pump we concluded that it would be good enough for our system. On one side we will use ABS pipes and 90‎° elbows to connect the pump to the bottom water tank. On the other side of the pump we will use fittings to be able to connect to a clear plastic 1 inch hose that will connect to the top water tank. The top water tank will be made out of an empty windshield washer fluid jug. We will use that since it is cheap and holds a good amount of water. From the top tank the water will flow in a PVC pipe at the bottom of the tank. Before the section of PVC where the plants will grow there will be a ball valve to stop the flow of the water from the top tank. There will be a manual valve to allow the user to open and close it when the plants need water. The whole system will be held in place by an A shaped frame that will be made out of wood. We plan on making the rear support removable to be able to attach the system against a caravan.

The final part of our system will be the baskets that will hold the plants. We plan on only doing one basket to stay in our budget. The basket will be made out of a metal mesh with holes to allow the roots of the plants to grow out the holes. We will put a small piece of foam at the bottom of the basket with a hole in the middle of it to be able to hold the seed so it doesn’t fall out of the basket. Over the foam there will be wood chips to serve as a growing medium. We decided to use wood chips since they are cheap and they could retain water so the user does not have to water the plants as often compared to using rocks as a growing medium.

**Prototype Test Plan**

Since this is our final prototype it should be a functional prototype representation of our final product. We have decided to build the prototype in the following way because it is more cost effective and resourceful. We decided to build the structure of the system using PVC pipes because they are strong and cheap. We used a plastic tank for the water reservoir because buying a tank would be unnecessary when a plastic tank found at home would serve the same purpose. We have then built an air pump from PVC pipes. The reason we have decided to make a PVC air pump is because primarily it would be more cost effective to only buy the pipes and connectors and then build the pump ourselves. Secondly, we required a manual pump since there is no electricity in the refugee camps to operate the air pump. After having considered these facts, we concluded that a homemade PVC air pump would be the best option. We decided to use a rubber flex pipe to transport the water from the water pail by the air pump to the water reservoir because it allows more freedom when choosing the position of the pipe compared to a PVC pipe and it is more cost effective while performing just as well as a PVC pipe would.

We have made holes in the PVC pipes so we could place a net inside them and growing medium in that net to allow the plants to grow. The water will flow through the holes and moisturize the growing medium allowing the plants to absorb the water. We are using wood chips and a sponge as our growing medium. First of all the wood chips hold the plant’s structure for a long period of time and it is a completely organic growing media. Secondly, the sponge allows the media to retain water for a longer period of time. The growing media was chosen carefully after considering constraints such as cost and availability. Since both materials are cheap and can be easily obtained anywhere.

The testing process will go as followed, we will first build the prototype after having bought all the required material, mentioned in the previous paragraphs, then we will take our prototype outside or in a garage where it does not matter if water spills everywhere. We will setup our prototype as shown in Figure 1 and pour water in the bottom pail. We will then pump water to the top tank with the air pump and another member will measure the time it takes to fill up the tank. We will then let the water flow through the system back down to the bottom pail and measure the time it takes for all the water in the tank to flow through the system. Then we will measure the time it takes for the growing medium to become completely dry. We then repeat the tests 3 more times to make sure our results are consistent and that none of the tests were a fluke. We then record our results in a table and perform simple mathematics to solve the water flow rate through the system.

We are measuring the time it takes for the air pump to pump water into the reservoir, then we are measuring the time it takes for that water to flow through the system, and then we are measuring how long the growing medium can preserve water. We are measuring the time it takes for the water to go to fill the reservoir then the time it takes to flow through the system because it allows us to determine the time it takes for the water to make one cycle through the system. We are measuring how long the growing medium can preserve water because it allows us to learn how often we need to redistribute water through the system.

We are observing the time it takes for the water to make one cycle through the system and how often the growing mediums need to be re-moistened. We will be recording our results by using a stopwatch to capture the results and recording the results on a table.

Before conducting our test but even before building our prototype we need to do some research and modeling about the different parts of our system such as the type of tubing, the type of pipes, the diameter of the pipes and tubes, diameter of the holes, types of growing mediums, and types of water reservoirs. We need to perform research on which stores carry the required pipes and tubes but also find the store that offers the best price. We made a sketch model of our system and how we will conduct the test but also a simple sketch of our system labeling the different parts.

Before the testing can be made there are a few tasks that must occur before that. Before we are ready to test our prototype, we must first buy all the required material to build our prototype which will take a couple of hours then we must build the prototype which will take the rest of the day and/or half of the following day since it is our final prototype. After having completed the following tasks, we must build a comprehensive testing plan to ensure that we know what we are testing and the success criteria for our test. When all the above tasks are completed, we can test our prototype which will take 1 day to fully complete the test and record our results because the tests require that the growing media to becomes fully dry in order to measure how often it is required to moisten the medium.

For this prototype we had a budget of 70$-80$. Unlike our previous prototype we were able to stay within our budget. Here is a list of all the material we needed and their price:

* 1- 2” PVC pipe of 10’ $17.90
* 3- 2” PVC 90‎° elbow $1.46 x3
* 1- 2” PVC ball valve $12.67
* 1- 2” to 1-½” ABS reducer $2.19
* 3- 1-½” ABS 90° elbow $1.28 x3
* 1- 1-½” ABS thread fitting $1.39
* 1- PVC glue $3.49
* 1- 1-½” to 1” reducer $3.71

In total it comes to $49.57+tax or $56.01. We were able to stay within our budget since a lot of the material we used to build our system support and other components we were able to obtain for free.

The results of the tests are required before the submission date of this deliverable, but it is mainly required before Design Day. The results of this test are required before Design Day because after having tested our system we will have learned whether our system is functional and if there exist any mechanical errors that need to be investigated before our final presentation on Design Day.

We have also created a miniature Gantt Chart using Microsoft Project which allowed us to schedule our tasks for this deliverable and assign tasks to group members. Please refer to Gantt Chart for our deliverable schedule.

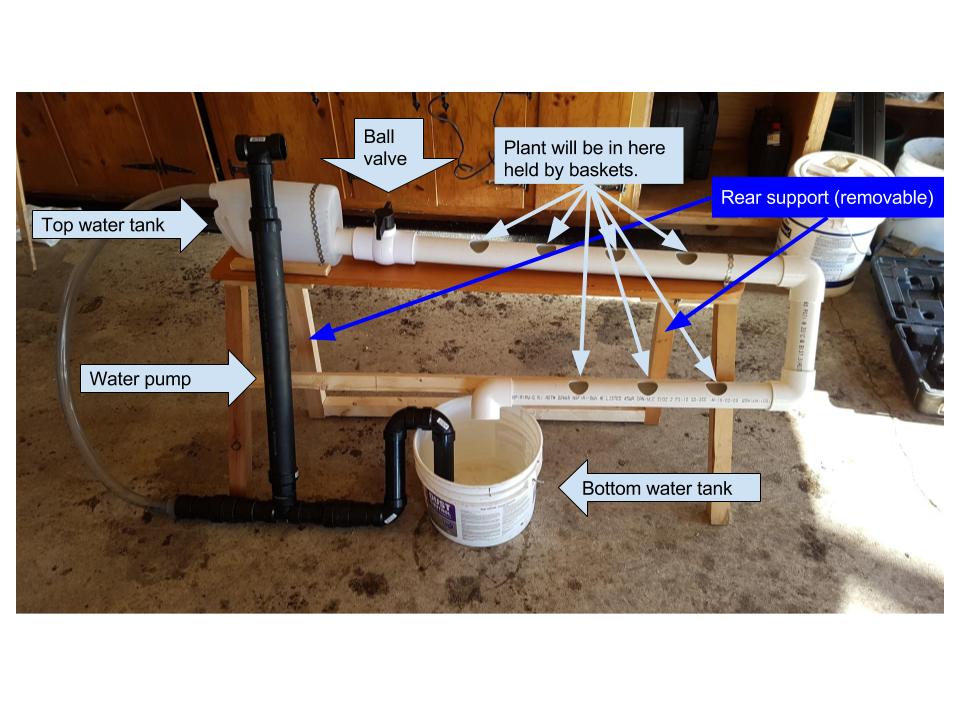
Figure 1. Front View

Figure 2. Isometric View



Figure 3. This is a top view of our hydroponic system which clearly portrays all the holes in our system.

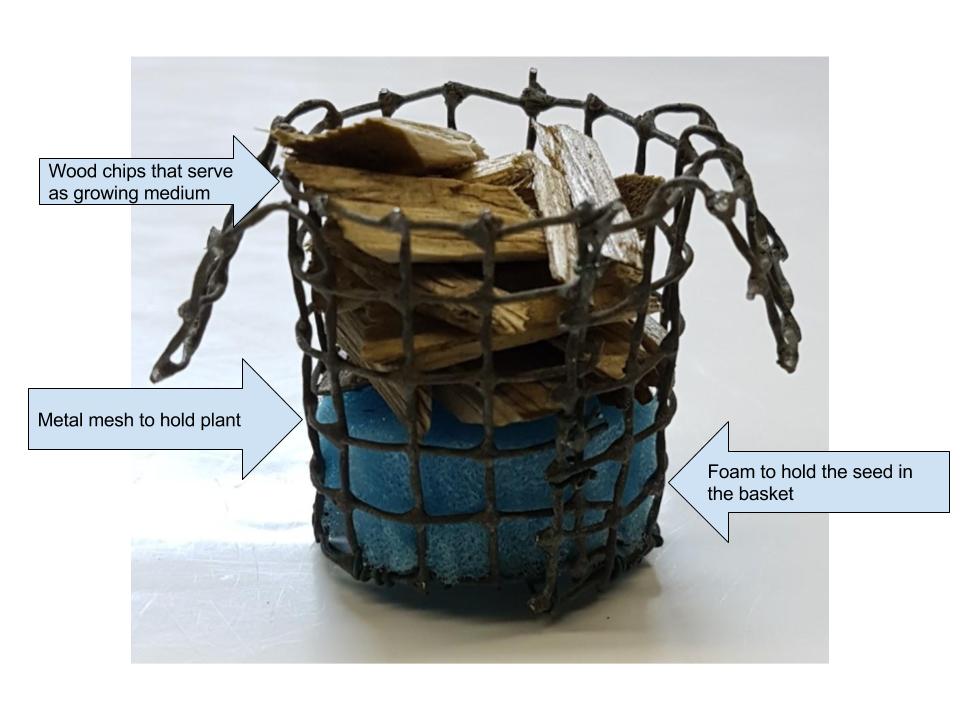


Figure 4. Inside the holes will be baskets to hold the seeds.

**Prototype Results**

Since our tests mainly focused on the current in the pipe, one of the result of how long it takes to fill up the tank could be infinity. That is, the system failed on cycle the water. As mentioned in deliverable II, the reason for the failure could be either leaks in the system or if the force produced by the pressure is less than the gravity force. For the second test, if it takes the water a long time ( more than 2 min ) to flow to the bottom tank, then the system is regarded as a failure as well. The reason for this failure is the low efficiency for each cycle would lead to a super low efficiency on the entire system with multiple cycles. One possible reason for the failure could be the structure of the system prevents the water flowing through the system. Besides, jam in the pipe would prevent the current as well. And the result for this test could be the water flow out of the pipe. The third test is testing how long the pipe can preserve the moisture of the growing medium. Usually, there’s no a certain criterion for this test, but if the moisture of the medium loss too fast, then the material of the medium is not suitable on this part.

As mentioned before, one of the results in test 1 could take an infinite amount of time to fill up the tank, and the corresponding reason could be leaks in the system. When dealing with test 1, if there’s water spilling out from the connection tube, then the tube is leaking and we will need to change the tubing in the system. If there are no leaking problems but the water can not reach the tank, then the problem could be in the valve. If the valve leaks somewhere, the pressure would be reduced due to the leakiness, so the water can’t be pumped up from the bottom tank. In test 2, the reason that causes the failure of the system could be the structure of the system or the pipe is clogged. If the water flows out of the pipe, then test 2 has failed, so we must first check if the inside of the pipe is clean or not. If there’s nothing to prevent the water flow, then we might need to adjust the structure of the system, such as changing the pipe to a different angle. Then repeat test 2 until water can flow through the pipe. If the pipe can’t hold the water in the medium, we first check the leakiness of the pipe, if the pipe is intact, then we should consider another kind of material to work as the medium.

A successful criterion for the test is after one cycle of water through the system, the upper tank can hold water, and water can flow from the upper tank to the bottom tank without spilling. Also, another test about the moisture of the medium should be done, and the medium should hold the water for at least several minutes. The criteria for the failure of the tests are when the system leaks somewhere, and water spills out from the pipe. These two problems are attributed in either the design of the system or the problem with the pipe. Additionally, if the growing medium can’t hold water, then the system fails as well, and a new material should be substituted.

**Prototype Analysis**

First we tested how long it would take to fill the top tank:

Table 1. Time to fill up top tank

|  |  |
| --- | --- |
| Test 1 | 17.48 seconds |
| Test 2 | 13.98 seconds |
| Test 3 | 14.73 seconds |
| Test 4 | 17.00 seconds |

Next we tested how long it would take to empty the top tank all the way through the system to the bottom tank while opening the valve at ¼ open, ½ open and fully open.

Table 2. Time to fill bottom tank

|  |  |  |
| --- | --- | --- |
| Test 1 | Fully open | 7.45 seconds |
| Test 2 | Fully open | 6.56 seconds |
| Tes 3 | ½ open | 17:50 seconds |
| Test 4 | ½ open | 19:67 seconds |
| Test 5 | ¼ open | 58.71 seconds |

Finally we tested how long the basket would stay wet once the water has gone through the pipes. We found out that the basket held water up to 4 hours. When we reached the 4 hour mark the wood chips and the sponge was still a little damp. We decided to stop the testing since at that point, the medium is not considered “wet”.

**Customer Feedback**

For our third prototype we were able to get feedback from two different customers. Our first customer, who has profound knowledge of hydroponics liked our product. He suggested that, when we first start to grow the plant from the seed that we do not put any wood chips into the baskets. This will allow the plants to be able to grow freely without having to grow through the wood chips. Once the plant has reached the top of the basket we would add the wood chips to hold the plant in place. The potential customer also noted that our prototype did not have a lid for the bottom tank and without one could deplete our water supply through evaporation.

The second customer we obtained feedback from was a refugee. He was really pleased with what we built but had some minor concerns. What he liked was our pumping system and how it was designed. He also liked the proposed size of our product. One of his concerns was that the size of the holes for the plants might be too small depending on the type of plant. His concern was that the roots would not have enough room in that size of pipe if you are growing tomatoes and other large vegetables. We had explained to our customer that due to our cost restriction we were only able to use 2 inch pipes. He strongly suggested that we should work on a way to reduce the cost of our pump, since it is the most expensive component in the system. If we can reduce the price of the pump we could use spend more resources to increase the diameter of the pipes to allow the user to grow larger sized plants. With all this being said, our customer really liked our design but would like to be able to grow larger plants, which means that we need to reconsider the amount of money we spend on each sub-component.

**Reference To Previous Work**

After completing and acquiring feedback for our third prototype there aren’t any major adjustments that are needed for our design. Our designs and concepts were well received and there weren’t any major issues when testing our system either.

First of all, our prototype was completed within our schedule and was able to stay under budget. We had to adjust our budget due to the expenses of our second prototype. We cut down on costs by using old pails instead of buying a new storage tote for our water tanks. We also had to cut down on costs by using less and smaller piping then intended.

We were able to realize a functional system based on the proof of concept created in prototype 1. Similarly to prototype 2 most of our design criteria has been addressed. Prototype 3 shows that our system is easy to use, requires no electricity, has a large capacity for plants, and is easy to use. However, prototype 3 still doesn’t test for water filtration and if the system is able to withstand harsh conditions.

**What We Need To Do In The Future**

Based on our feedback for prototype 3, our designs and concept were well received with few concerns over final dimensions and criteria of our finished product. These concerns were about the cost and size of our system and instructions for our customer. To move forward to a final product we will need to research ways to cut down on costs while also increasing the size of our system. Prototype 3 was able to stay within budget but this was mainly because of readily available material rather than purchasing new material. To reduce costs for our customers we will have to research cheaper materials that we can buy in bulk, and research lower manufacturing costs. Since prototype 3 was scaled down to remain under our budget we have not finalized dimensions and allocated costs for our final product.

The next step of our project is the final report that summarizes all our work and research based on the deliverables completed.

**Conclusion**

We have identified and prevented any possible errors that could have occurred while testing our prototype. That allowed our prototype to be able to successfully complete its tests. Overall, our prototype was well-received by our client despite some minor concerns. Any concerns have been noted and will be used in researching costs and dimensions for our finalized product. The researched costs and dimensions will be presented in our final report.