GNG 1103

Design Project User and Product Manual

The Heat Control Chamber (THEC)

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Table 1. Acronyms

Acronym	Definition
BOM	Bill of Materials
HEPA	High-efficiency particulate absorbing filter
HVAC	Heating, ventilation, and air conditioning
THEC	Thermal Heat Exchange Chamber
UPM	User and Product Manual

Table 2. Glossary

Term	Acronym	Definition
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A

1 Introduction

This User and Product Manual (UPM) provides the information necessary for the consumer to effectively use the Heat Control Chamber (THEC) and for prototype documentation. This document is developed for both the client and the consumer to safely and effectively use the THEC and to provide the adequate risks with using the device improperly. The document also provides instructions to setup and use the device, maintenance instructions, and to turn off the device. Also outlined in this manual are steps to troubleshoot and to properly configure the THEC. This document also consists of the design outline, Bill of Materials (BOM), and other design files for the prototype created. Any other relevant information about both the design and prototype are in the appendices that conclude this document.

2 Overview

The patented design of the client to replace current heating and cooling systems in houses is currently unable to provide sufficient heating in winter to heat homes to a comfortable range (Canada Patent No. 2626472, 2008). Our client needs a system that is environmentally friendly and uses renewable resources. It is a concrete box six feet underground with a series of pipes that use the ground temperature to heat or cool. Our system also includes the solar panels and hot water system on the roof that is piped to an underground hot water tank and provides heating to the system. Our geothermal system allows heating air in winter to around 20 degrees Celsius. Our system relies mainly on renewable energy sources, is compact, affordable, reliable, and efficient. Our system can efficiently extract energy from the earth into infrastructure/buildings to heat or cool, without using heat pumps, refrigerants, or fossil fuels. Compared to current HVAC systems require heat pumps and anti-freeze to preheat or cool homes. The current HVAC systems also require additional heating in winter. Therefore, current HVAC systems are more energy dependent and causes more environmental damage if there is a leak. Part of the system is implemented 6ft below the ground and uses a thermal storage chamber to transfer or dissipate heat. Our system has a solar water heater installed on the roof of the building, it relies on renewable solar energy to provide the electrical and thermal needs of our system. Our system captures thermal energy in water and stores it in a hot water tank we call the thermal battery. The thermal battery is to improve the reliability of our system in situations with a lack of sunlight, such as at night or on cloudy days. The water of our system is circulated by pumps running off solar panels. We have a thermostat for users to change the temperature and it also control the speed of the fan. The only thing the user need to interact is the thermostat, to control the temperature is produce by the system. The user doesn't need to interact with anything else.

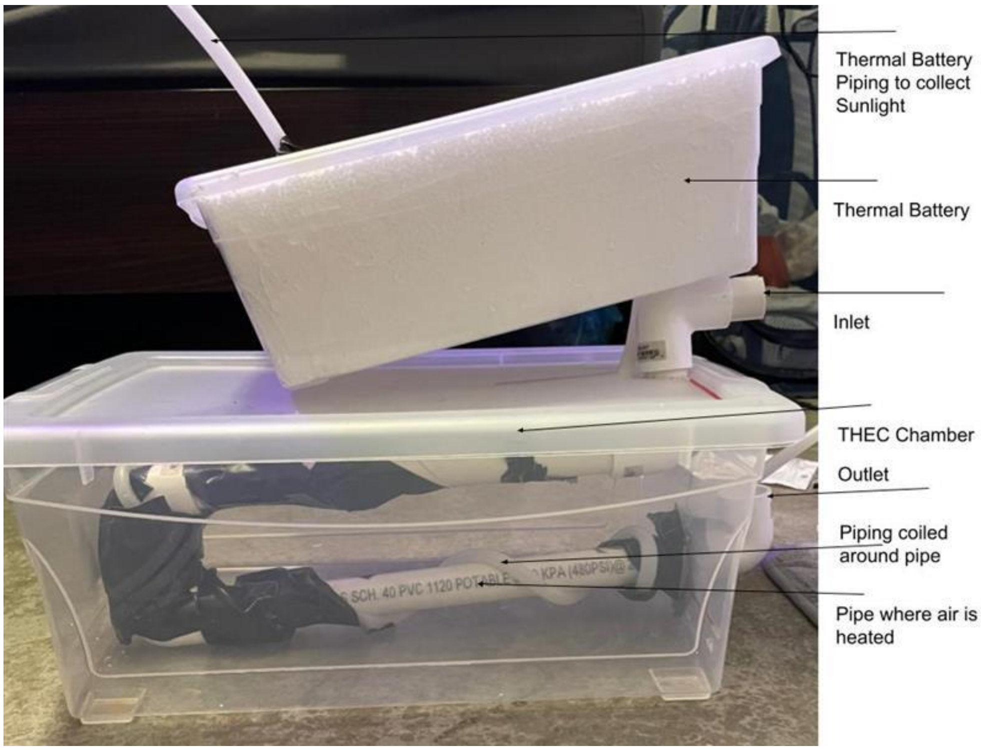


Figure 1: Labeled Prototype

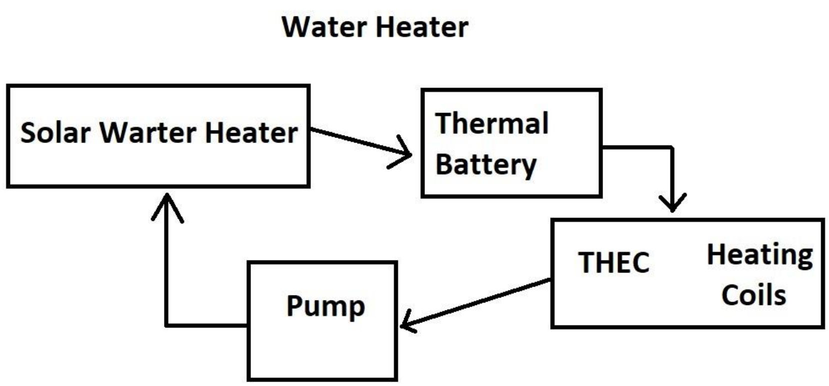


Figure 2: Solar Water Heater Block Diagram

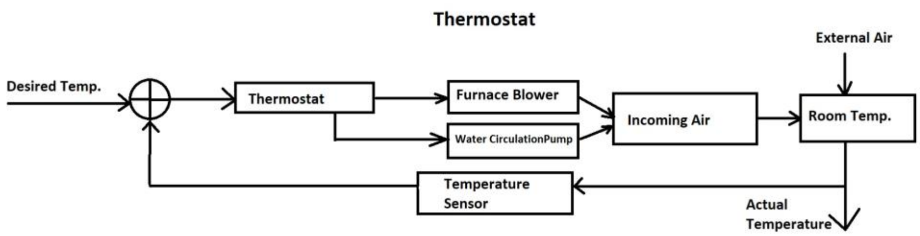


Figure 3: Thermostat Block Diagram

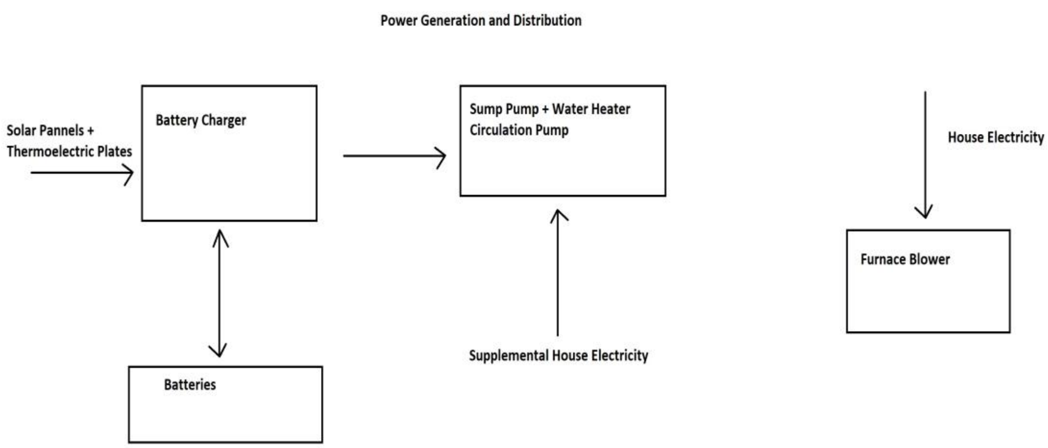


Figure 4: Electricity Block Diagram

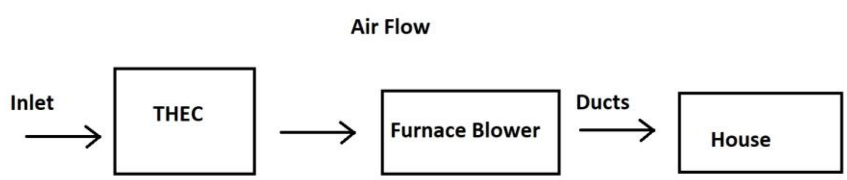


Figure 5: Air Flow Block Diagram

2.1 Cautions & Warnings

WARNING: Equipment used for heating, cooling and water heating can cause injury if safety precautions are not observed. Electrical shock and heat burn from the system could cause serious personal injury or death. Before performing any service or maintenance operations on the system, turn off main power switches of the unit.

Safety Precautions

1. Do NOT touch the solar water heater.
2. Do NOT operate the system with wet hands.
3. Replace the HEPA air filter every three month.
4. Contact our service department if you hear extraordinary air noisy or find any water leak.
5. Improper installation, adjustment, service, or maintenance may cause serious injury or property damage. For assistance or additional information, consult a qualified installer or service agency.

Prestart check

Is unit properly located, level, secure, and serviceable?

Have all cabinet openings and wiring been sealed?

Is the ductwork correctly sized, run, taped, and insulated?

Is the thermostat correctly wired, level, and in a good location?

3 Getting started

Welcome to your new THEC! These steps will help you setup your THEC and configure it to your needs.

3.1 Configuration Considerations

This system requires no external devices or tools to require it to function, aside from a thermostat component. The sufficient guidelines for this device to function is the placement of the THEC, the input to the THEC (inlet) and the output into the infrastructure this product is being used in.

3.2 User Access Considerations

The current size of the system is for the average homeowner. It provides ample heating and cooling for small homes with most of the components underground. This product is designed to be installed underground to provide adequate results in terms of heating and ventilation. The inlet is designed to be installed in a clear area to allow for adequate intake and to prevent any foreign bodies into the THEC. The electrical components are also designed to be underground beside the THEC, but connecting to the energy generating source above ground, preferably on a rooftop. This underground space may limit the users who do not have the available area that can be excavated to install the system. As well, limit users living in dense city environment. This system is not designed for multiple story structures, large facilities, and compact exterior space.

3.3 Accessing/setting-up the System

This system can be turned on by a flick of the switch. After all the components are installed and the THEC is configured for the specific building it is designed for, the electrical components may be turned on by a switch. The inlet must be in an “open” position to allow the THEC to intake air. The output must also be clear as backpressure may damage the system. The THEC will then begin to intake air, heat it up in the underground chamber, and output it into the building. Additionally, there are no detectable leaks or damage, and the exterior electrical components are not damaged or worn.

3.4 System Organization & Navigation

This system is designed to be as simple and least sophisticated as possible. The two major parts include the thermal battery and the heat chamber. These are connected with a set of pipes, filled with water, and wired to a pump and fan system. These systems work in sync to ensure the durability and functionality of the system.

3.5 Exiting the System

As this system is a permanent installation, it can be turned off via a switch on a control panel. This may be installed inside the building or close to the system in a protected area. The switch shuts off the power supply but does not disconnect the system from the HVAC.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the air inlet shutting system and the temperature controller.

4.1 Air inlet shutting mechanism

This system shuts the collapsible roof blocking the air from entering through the pipe system. This system also switches between the pipes entering the THEC. When closing the shutter roof, the system switches from taking the air from outside to exclusively taking the air from the house on a closed loop.

To operate the system, you need to push a button located on the back of the air inlet unit, and the ring is slid into the open or closed position, depending on weather it is desired that either of the two pipes (air inlet pipe, pipe coming from the house) will feed into the system.

This system's intended use is for when temperatures drop. It reheats the air already present in the house instead of heating the outside air, increasing the heating system's efficiency.

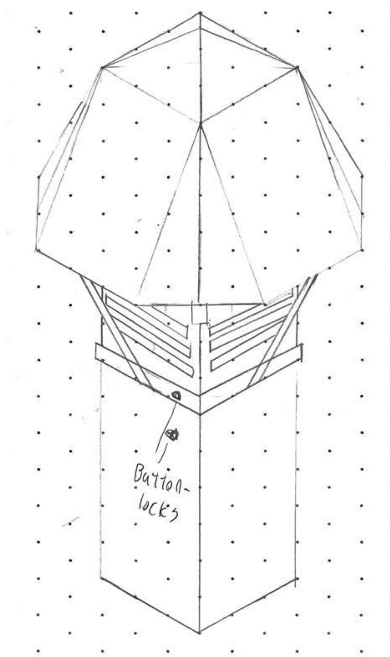


Figure 6 - Air inlet unit

4.1.1 Pipe switching system

A flap is located at the intersection of the pipe of the air inlet and the pipe coming from the house. It is connected to the same ring controlling the air inlet shutter mechanism via a string, and it blocks either of the air pipes while letting the other open depending on the state of the roof shutter. Figure 7

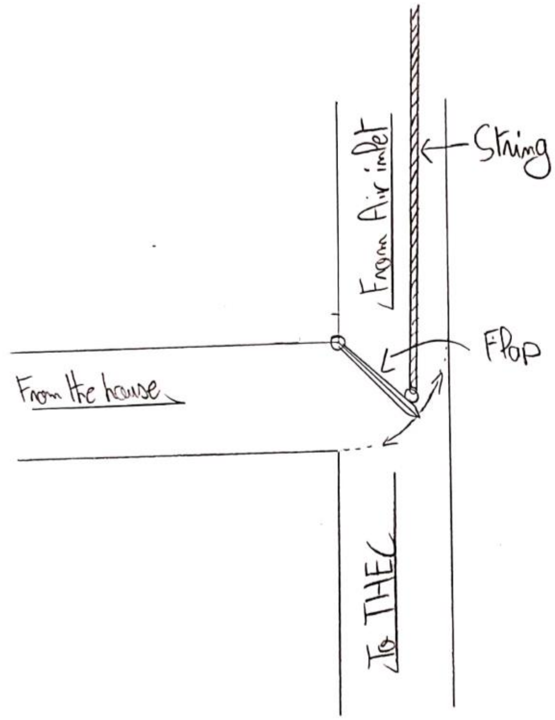


Figure 7 - Pipe switching system

4.2 Thermostat

The thermostat can be installed on any wall inside the house. It is used to set the desired indoor temperature. The system will make sure that the latter is reached by automatically controlling the frequency at which the heating/cooling system will engage.

The controller can also set the THEC mode, which is either cooling mode or heating mode.

5 Troubleshooting & Support

Most major errors with the heating system should be corrected by the system professional. These include leaks, damage pumps and electrical problems. There are a few procedures which you may take to attempt to fix minor issues with the system. If the system stops working or isn’t working properly, you can attempt any of the following options to fix the system, but if the system still doesn’t work properly, you contact our service department.

- Check for damage or debris on the solar panels, and solar water heater
- Restart the heating system by pressing the restart button
- Checking the furnace blower
- Restarting the thermostat

5.1 Special Considerations

- If you see or smell smoke, do not attempt to fix or troubleshoot the system yourself, immediately call the fire department and our service department.
- When troubleshooting or fixing the system yourself, do not attempt to fix any underground system on your own
- Keep small objects that can be dropped away from the air inlet when servicing
- Whenever you are attempting to fix an issue with the heating system, make sure the entire system is off
- Never dig the ground to attempt to fix the THEC yourself, reach out to our service department for support instead

5.2 Maintenance

It is advisable to perform at least one maintenance check up every ten months. In this check up, you should make sure the following system are running as intended:

- There is no damage to the air inlet shutter mechanism, and make sure the roof is collapsible.
- Make sure there is no debris caught on the air inlet.
- There is no visible water leakage on solar water heater as well on the water pipes leading underground.
- Make sure the solar panel is not obstructed by dust or debris.
- Check the air ventilation, make sure it is not obstructed by dust.

5.3 Support

You can always contact our service department whenever you are in need of support. Also, in any case of confusion, in need of emergency assistance, system support, or if you are unsure what to do in any given scenario, you can contact any of the following emails, and we will try to respond as soon as possible:

- aomar053@uottawa.ca
- bxue051@uottawa.ca
- isowa064@uottawa.ca
- hyous024@uottawa.ca
- mchen317@uottawa.ca
- azadi015@uottawa.ca

6 Product Documentation

The main part element this group wishes to test is the efficacy of the proposed heating system. The focus of this group is not on the power generation of the solar panels and thermoelectric plates, but rather on whether the required temperature output can be achieved. Thus, the only components involved in the project moving forward are a simplified pipe layout, THEC, thermal battery, solar water heater, fan, water pump, and a thermostat analog. To begin, the design includes a THEC filled with water with the fan attached at the larger lower exit hole using hot glue and electrical tape

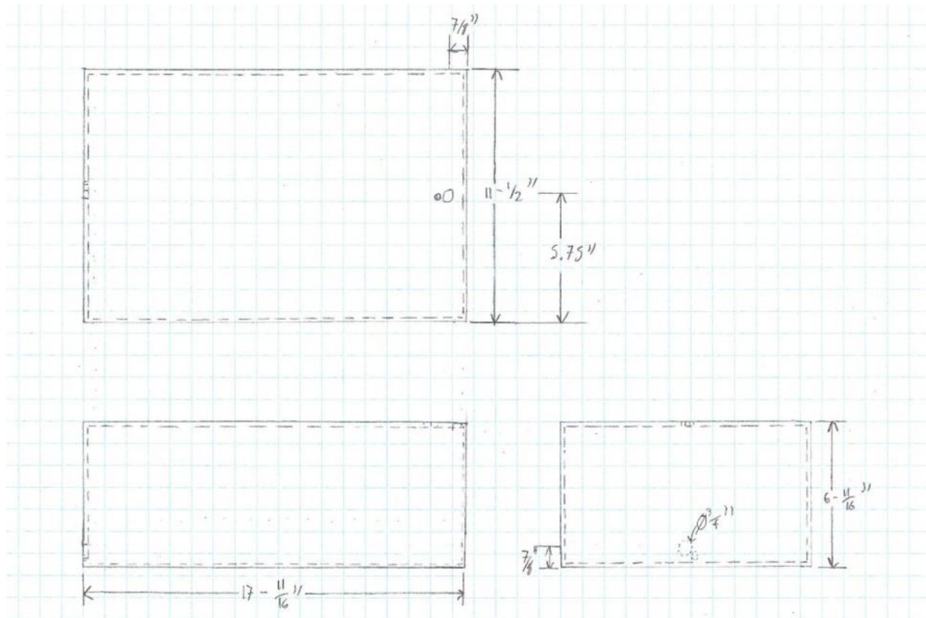


Figure 8: THEC Prototype Concept Sketch

The simplified pipe layout connects the larger holes and is the main airflow pipe of our system. The lower hole will be drilled to the diameter of the pipe and watertight seal using hot glue to ensure there are no leaks between the pipe and THEC. As the upper hole will be cut in a lid no adhesive of permanent fixation will be used to ensure THEC can be opened for modification and transportation.

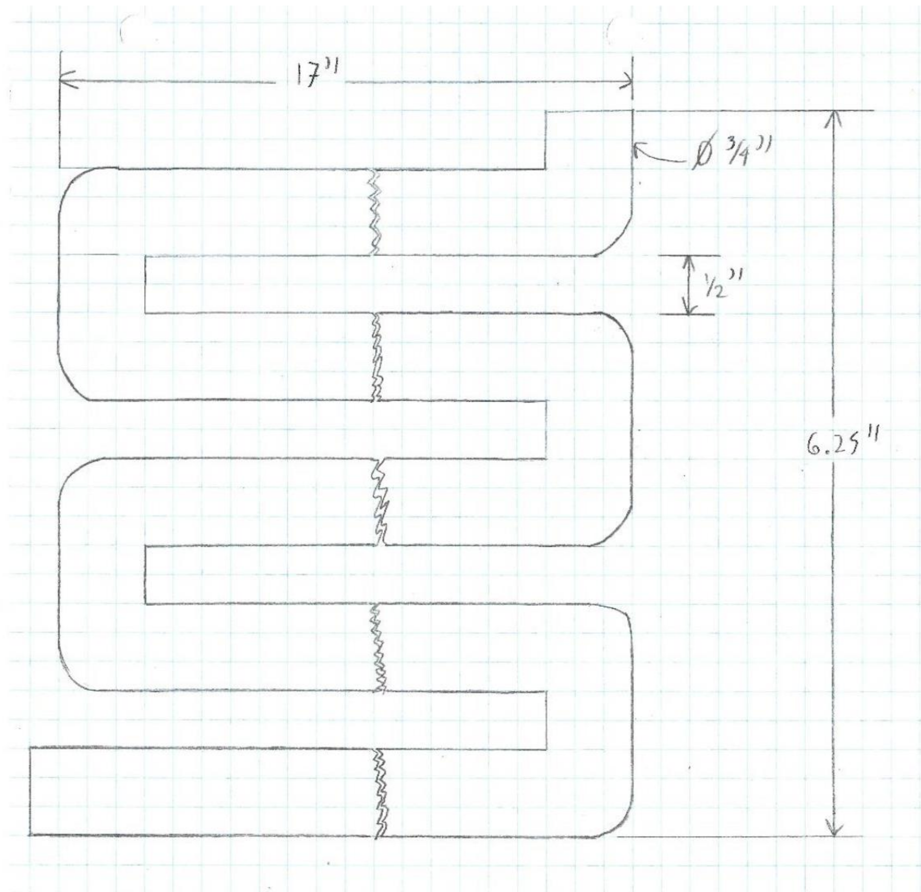


Figure 9: Prototype Pipe Layout Concept Sketch

The smaller holes in THEC are intended for the vinal tubing that coils around the larger airflow pipe . This vinyl tubing is connected on either end to the thermal battery and the circulation pump, the upper and lower small holes on THEC respectively, and is once again sealed using hot glue.

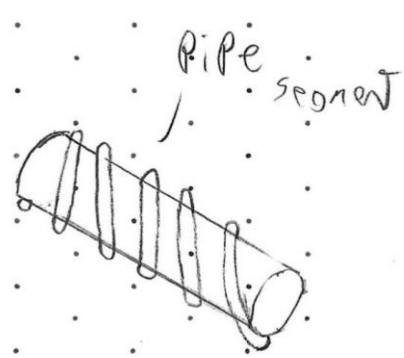


Figure 10: Heating Coil Drawing

The pump circulates water from the coil exit up to the solar water heater that is made from more vinal tubing held in place by 2 or more Styrofoam blocks. Creating an arrangement as seen in. As the blocks are there to rigidity, there is no need for adhesive or fasteners.

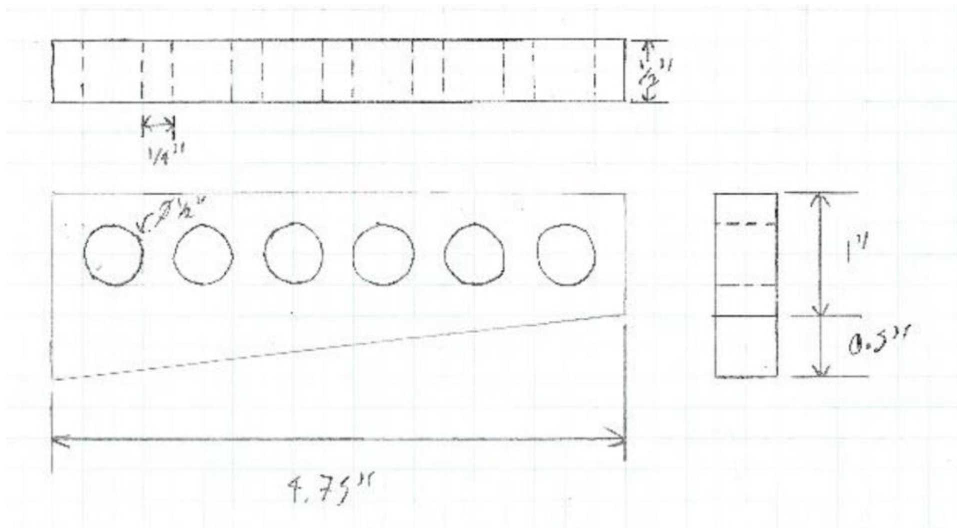


Figure 11: Solar Water Heater Blocks Concept

The outflow from the bottom of the solar water heater is transported by tubing to the thermal battery. The battery is a plastic box like THEC but with Styrofoam insulation glued to all edges of the box. There are two holes in the box where tubing can be inserted to connect the solar water heater and the THEC.

The outflow from the bottom of the solar water heater is transported by tubing to the thermal battery. The battery is a plastic box like THEC but with Styrofoam insulation glued to all edges of the box. There are two holes in the box where tubing can be inserted to connect the solar water heater and the THEC.

To power this system and simulate using a thermostat the group intends to run both the pump and the fan in parallel off a wall adapter with a temperature switch.

Based on our prototype tests and analysis, we calculated the energy the system brings to the house per unit time and mass flow rate of our prototype, the result is 43.16 W(J/s) and 5.73*10^-4 kg/s.

This means there are 43.5 joules of energy the system brings to the house per second and 73*10^-4 kg of air pass through the system per second.

When we transform the results from the prototype to the actual building, the heat that the system produces can keep the building warm.

We also calculated the heat transferred by the process of radiation since the prototype test will be conducted under sunlight. The room temperature is around 20C degrees, after 4-6 hours of exposure of sunlight, we expect the temperature would increase to 40C degrees. In the end, we get the result of 3.096*10^-8 W,

$q = mc_p(T_{m,o} - T_{m,i})$ $T_s - T_m$

$q = mc_p(\Delta T_i - \Delta T_o)$ $\Delta T = T_s - T_m \begin{cases} \Delta T_i = T_{s,i} - T_{m,i} \\ \Delta T_o = T_{s,o} - T_{m,o} \end{cases}$

Newton law of cooling: $q = hA\Delta T_{lm}$

$\Delta T_{lm} = \frac{\Delta T_o - \Delta T_i}{\ln \frac{\Delta T_o}{\Delta T_i}}$ A → Surface Area

ΔT_i → the inlet mean temperature

ΔT_o → the outlet mean temperature

Length of the pipes = 12x6 inch

= 1.83m

diameter = 0.0095 m

the average heat transfer coefficient is $100 W/m^2\text{-}k$

via analysis/estimation and research: the inlet mean temperature is -5°C

the outlet mean temperature is 13 °C

ΔT_s → the surface temperature of the pipe is 15 °C

$\Delta T_i = \Delta T_{s,i} - T_{m,i} = 15 - (-5) = 20°C$

$\Delta T_o = T_{s,o} - T_{m,o} = 15 - 13 = 2°C$

$\Delta T_i - \Delta T_o = 20 - 2 = 18$

Figure 12: Prototype 1 Calculations

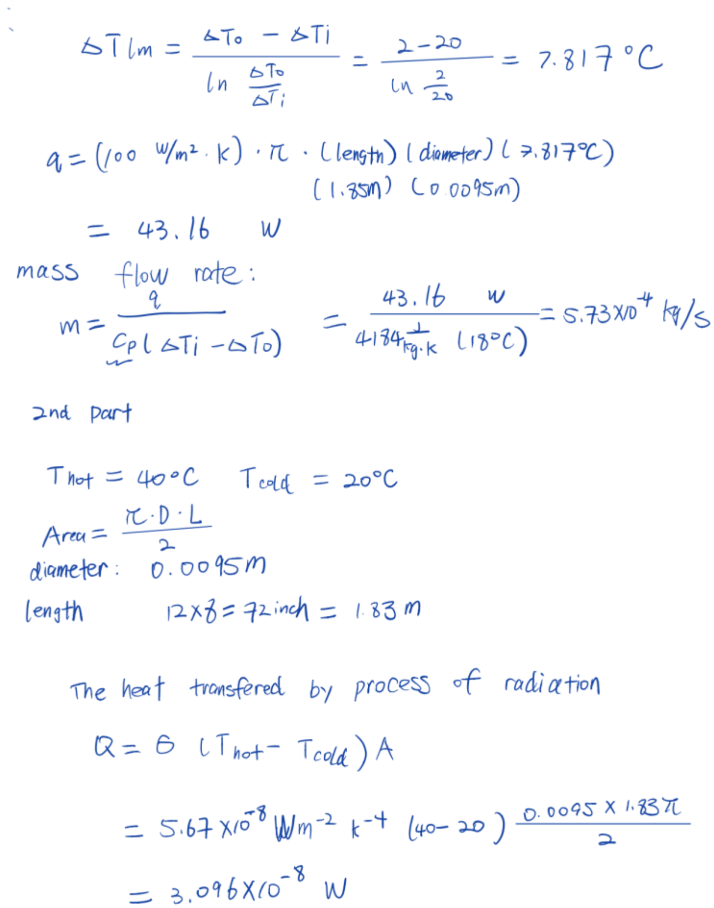


Figure 13: Prototype 1 Calculations Continued

Our final prototype is made from 25 ft of partially clear vinal tubing, and an electric water pump, with 8 out of the 25 ft serving as the main solar water heating coil.

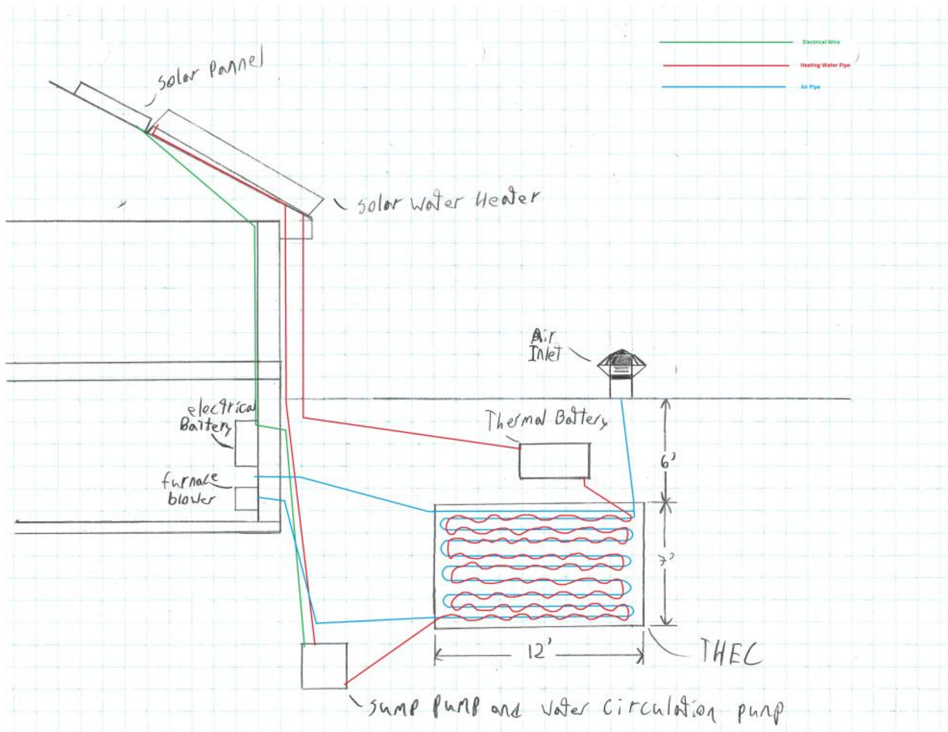


Figure 14: Full System Concept Wire Sketch

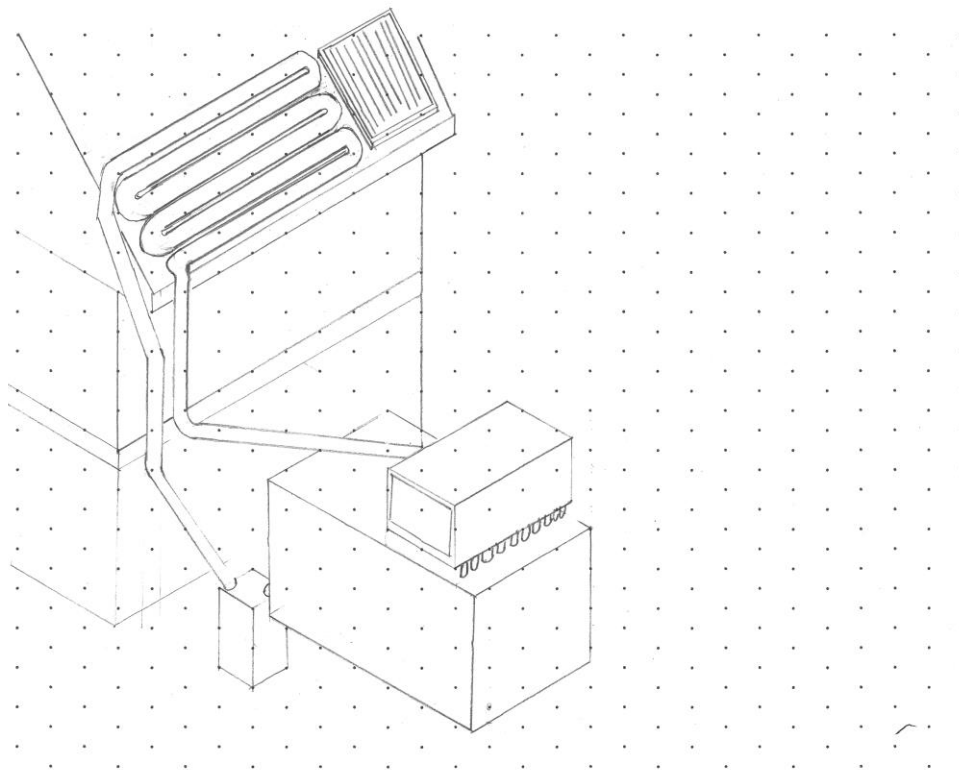


Figure 15: Heating System Isometric

6.1 Heating

6.1.1 BOM (Bill of Materials)

Item #	Item and link to purchase	Unit price	Quantity	Total Price	Purpose
1	Small Plastic container	$ 3.99	1	$ 3.99	For thermal battery
2	Fish tank pump	$ 12.00	1	$ 12.00	For circulating the water
3	Styrofoam sheet	$ 8.99	1	$ 8.99	Insulation for the thermal battery
4	large plastic container	$ 9.99	1	$ 9.99	THEC box
5	vinyl tubing	$ 11.90	1	$ 11.90	Heating tubes
6	Hot Glue	$ 1.25	1	$ 1.25	To seal and attach most components

6.1.2 Equipment list

Hand drill, 3/8 drill bit, hot glue gun, razer blade

6.1.3 Instructions

Take the plastic box for the thermal battery and drill the 3/8 hole in the lid and bottom of the container. Then using the razor blade cut the Styrofoam into panels to cover the inside of box. Leave a hole in the Styrofoam to insert the vinal tubing later. Again, using the razor blade cut the vinyl tubing in half. Insert approximately one inch of one half into the hole of the lid and seal from the inside with hot glue. Insert the other half into the bottom hole by about one inch and seal from the inside using more hot glue. Check seals by filling the container with water and observing for leaks. Seal any leaks as necessary. Glue the Styrofoam panels into place and connect the input of the pump to the bottom tube and the output to the top tube. The system can then be filled with water and powered.

Figure 16: Complete Heating system

6.2 THEC

6.2.1 BOM (Bill of Materials)

Table 3: BOM for THEC

large plastic container	$ 9.99	1	$ 9.99	THEC box
¾-inch PVC Piping	$ 13.40	1	$ 13.40	Air pipe
90 deg elbow	$ 1.18	5	$ 5.90	To connect the air pipe into pipe layout

6.2.2 Equipment list

Hack saw, 1" hole saw, hand drill, 3/8" drill, hot glue gun

6.2.3 Instructions

First using the hole saw cut a hole in the lid center along the short end and far to one end of the long side. Then drill into the one of the small sides of the box centered horizontally and low down such that the air pipe runs flush with the bottom of the box. Next drill the 3/8" hole near the hole saw to make things easier to coil the heating tubes. Finally, using the hack saw cut the pipe such that they cleanly fit inside of the box. The pipe going through the bottom hole should have about an inch of overhang through the hole. Using the elbow joints layer as many pipes as possible. In the case of the materials used in the prototype only 2 layers were obtained. The top layer will use an elbow joint and a small section of pipe through the lid. Cap the excess pipe with additional elbow joints. Seal, the inside of the box with hot glue. The additional holes will have the output of the thermal battery that coils around the air pipe and should be sealed as well when assembled into the final prototype.

6.3 Fan

6.3.1 BOM (Bill of Materials)

Item #	Item and link to purchase	Unit price	Quantity	Total Price	Purpose
1	Computer fan	$ 13.00	1	$ 13.00	To act as a small furnace blower

2	Fish tank pump	$ 12.00	1	$ 12.00	For circulating the water

6.3.2 Equipment list

Soldering iron, wire cutters, wire strippers, electrical tape, and solder

6.3.3 Instructions

Cut the wires connected to the pump in the heating system and any connections attached to the fan. Strip these wires and solder the leads together and insulate using electrical tape. The fan will then be glued to the bottom outlet of the air pipes.

6.4 Testing & Validation

Prototype II

In the testing of this prototype there was an unavailability in measurement equipment. No team member in Ottawa had access to a thermometer and no thermometer could be delivered or found before the testing of the prototype was to be completed. As a result, there was no ability to quantitatively measure the rate heat was absorbed by the water for this prototype. Instead we performed different tests to ensure that all components were functional in the final prototype.

Instead, we tested whether the prototype if functioning appropriately enough in its ability to move water to move forward to the next prototype. Firstly, we determined that the pump was capable cycling the water in a closed loop as we desired.

Figure 17: Prototype 2 Closed Loop 1

Figure 18: Prototype 2 Closed Loop 2

Air gaps in the pipe were seen to repeatedly circulate the pipe through the pump over and over, indicating that the water in the pipe was circulating.

We then modified the prototype by disconnecting it from a closed loop and coiling it around 5 ft of what is going to be the air pipe. This is approximately the same length of pipe that will be coiled in the final prototype. Using a stopwatch, we timed to the nearest second the time for 1 L of water to circulate in the system. This was determined by the time it takes the pump to intake 1 L of water from a reservoir. Five trials were done with times 55, 50, 50, 60, 48 seconds for an average 52.6 seconds to pump 1 L of water.

What as also realised but not tested in detail was the maximum height the pump could push the water. The pump fell short of pumping water from the floor to the maximum height by a few inches (estimate) but could easily pump from the ledge to the maximum height. This height from ledge to maximum is near the total height as presented in the CAD model of the final prototype thus indicating there should be no concerns to the pump and solar water heater performing as required.

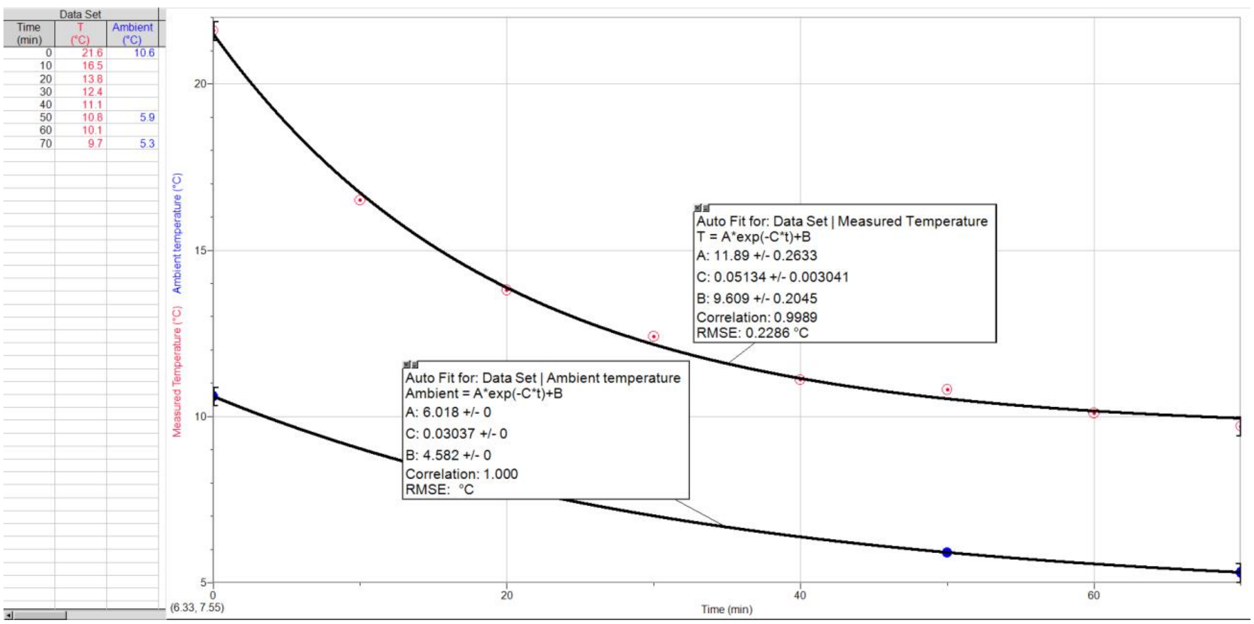
Figure 19: Prototype 2.1 Small Height

Prototype 2 is a complete physical model of the heating system comprised of the unmodified pump and the tubing that creates the solar water heater panel and thermal battery. The purpose of the prototype is to analyze and confirm the heat gained from solar energy and heat lost from static water in the thermal battery, related to weather and length of tubing. The prototype will encounter one test measuring the rate of heating using a thermometer to periodically measure the temperature of the water in the system. The prototype is placed indoors in an area with large availability to sunlight and the pump will be able to run continuously over a full day. The test will ideally be run several times with different levels of sunlight. Each test will conclude after the sun sets each day, or if the temperature of the water in the pipe nears 60 degrees Celsius the maximum temperature rating for the pump. Also, in this time we wish to complete the final prototype which will contain all critical components outlined above. The final prototype function as a model to simulate extended use of the design and see whether the design is successful.

Test 1 was to measure the efficiency of the solar water heater. The test was done on the heating subsystem exclusively before its integration into the final prototype, measuring the temperature of the water as a function of time compared to the ambient temperature.
This test was conducted during cloudy weather and was only stopped prematurely because of rain. Results do not look too promising for the temperature is constantly decreasing. However, there are some adjustments to be made to help the prototype to retain heat better.

Time (min)	Ambient	Temperature (°C)
0	10.6	21.6
10		16.5
20		13.8
30		12.4
40		11.1
50	5.9	10.8
60		10.1
70	5.3	9.7

Figure 20 - Temperature measured and ambient temperature as a function of time



Graph 1: Temperature measured and ambient temperature as a function of time

The second test was conducted on the final prototype and was a fully functional simulation of typical operation. The test measured air output from the THEC with our integrated heating system. The initial water was around room temperature and was not measured as part of the test. The purpose of the test was to determine whether our design could work in practice.

This test was conducted in doors from 18:00 – 20:20 (6 pm – 8:20 pm) with the prototype located next to a wide opened window. The air fan position was changed slightly, and duct tape was used to make it sturdier and stop water leaking. But the general plan is still the same.

Time (min)	Output Air Temperature (°C)	Ambient Temperature (°C)
0	23.4	-3
10	20.1	
20	20	
30	18.6	
40	18.1	
50	17.9	
60	17.6	
70	17.6	
80	17.5	
90	17.5	
100	17.4	
110	17.3	
120	17.3	
130	17.3	
140	17.3	
150	17.3	-1

Figure 21 - Temperature measured and ambient temperature as a function of time

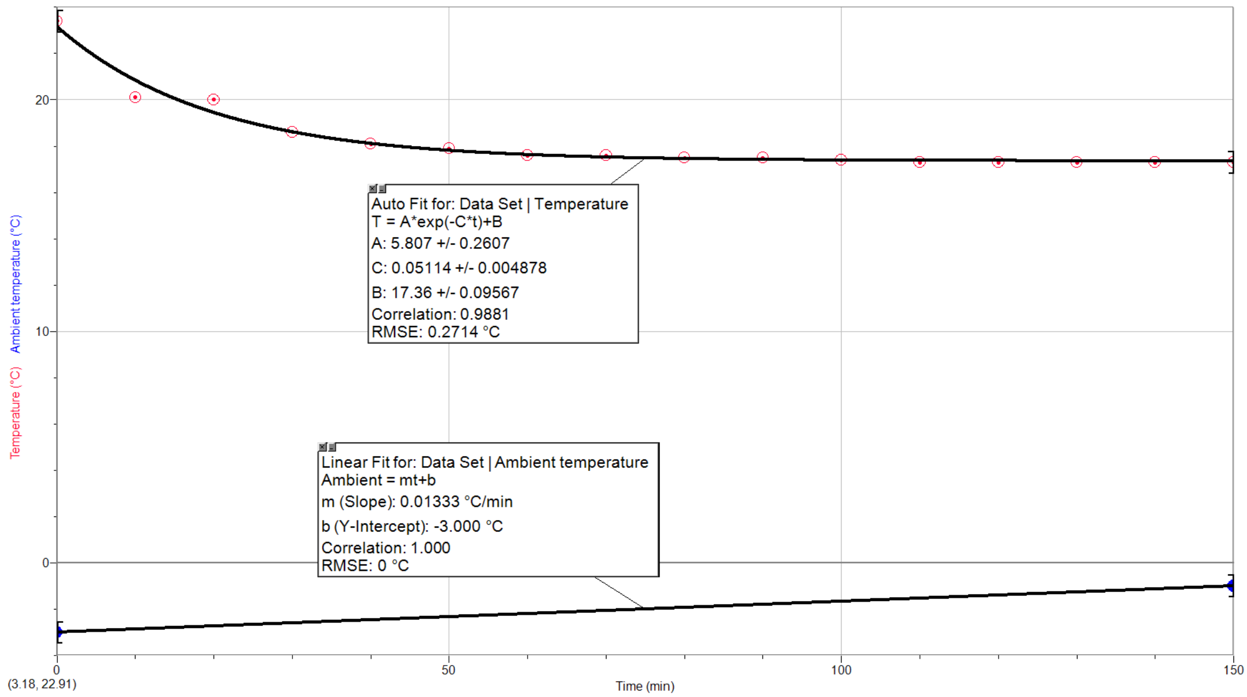


Figure 22 - Temperature measured and ambient temperature as function of time

The temperature dropped relatively drastically in the first 30min. However, after 30min into the test, it reached equilibrium with value measured of 17.3 – 18.1 °C. Remarks: The temperature dropped until an equilibrium point was reached, and we believe the better results were due to a tighter seal on the insulation and having previously exposed coils now enclosed in THEC.

7 Conclusions and Recommendations for Future Work

The team ran different tests on different prototypes to unsure the system efficiency, we first conducted a test based on the heating rate, then another test to make sure the pipes are able to cycle water in closed loops, and finally we measured the output air temperature.

As recommendations, we could do a few more long-term tests to ensure the system does not have issues when running for several days, then choosing better material for the prototype.

If we had more time to work on the system, we would find a better solution other than glue to seal the components but that would require a wider budget.

8 Bibliography

Enendu, C. (2008, April 7). *Canada Patent No. 2626472*.

APPENDICES

9 APPENDIX I: Design Files

Those documents outline our prototype and the critical components using detailed descriptions. Feedback for our prototypes, and design were obtained during the third client meeting. A brief section for the client feedback is included in this document. Those documents also includes sections for the potential user feedback and the third prototype plan. The potential user feedback section explains how our project plans were expanded by civil engineer, civil engineering student, contractor and what they thought about our project and prototype plan.

Table 4. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Prototype I and Client Feedback	Prototype I and Client Feedback.	Mar 7, 2022
Prototype II and Client Feedback	Prototype II and Client Feedback	Mar 14, 2022
Prototype III and Client Feedback	Prototype III and Client Feedback	Mar 28, 2022
Early Design Concept	Early Design Concept	Feb 21, 2022

10 APPENDIX II: Other Appendices

There are no files to be put here.