GNG 1103

Design Project User and Product Manual

The Heat Exchange Chamber

Submitted by:

Team Rocket - D1.4

Callum Bunston, 0300245953

Yosr Ouali, 300262652

Rasheeq Mohammad, 300264515

Yousef Hemdan, 300084544

Yassir Mechahouri, 300266705

Jiahao Sun, 300267367

April 20th, 2022

University of Ottawa

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List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
HVAC	Heating, Ventilation and Air Conditioning
LCD	Liquid Crystal Display
THEC	The Heat Exchange Chamber
UPM	User and Product Manual

Table 2. Glossary

Term	Definition
Geothermal Exchange	Energy that is exchanged with the earth through a liquid traveling in pipes that pass underground, or through a large body of water.
Potentiometer	A potentiometer is a manually adjustable variable resistor with 3 terminals.

1 Introduction

The purpose of this UPM is to provide information necessary for anyone to effectively use our heat exchange chamber as well as documentation on prototype development. The ultimate use of the THEC system is to regulate the temperature in commercial or residential spaces using geothermal exchange of energy with zero-emissions.

This document will begin with an overview of our system. Next a walkthrough of the system and supplementary system information will be provided. After, there is information on the use of the system, followed by troubleshooting and support resources. Next is product documentation, conclusions and future work. Finally is the bibliography and appendix, supplying links and resources used to create this manual.

This manual was created for users of the system as well as any future engineering students who want to learn from our project and make improvements based on it. It is important not to abuse any information provided in this document. Any information or concept is reserved for the group D 1.4. The ideas can be used but you can not copy or steal the concepts. For users, there are no considerations of confidentiality associated with this manual.

2 Overview

Figure 1: Overall system

Heating and cooling systems are essential to our lives and they should be included in every home. They allow users to enjoy ideal temperatures in their homes, throughout the entire year. Traditionally, the heating and cooling systems in residential buildings and houses relied on electricity or fossil fuels. These heating and cooling methods are expensive and not environmentally friendly.

With this in mind, the main goal of our project was to create an environmentally friendly heating and cooling system for residential buildings that reduces power consumption, has zero gas emissions and is cost efficient. We developed the heat exchange chamber which consists of a chamber box buried no less than 6 feet underground, that allows the air to enter from outside through an air inlet, and adjust its temperature to be equal to the ground temperature. The installed sump pump will prevent any condensation in the system while carrying the air to the house. In the final step, the heated or cooled air is then brought to the house through the furnace blower fan in the house.

Figure 1 represents the entire THEC system assembled together. It contains the air inlet, the chamber box, the inner pipes, the sump pump, the outer pipes, the fan blower and the electronics system. The custom inner pipe design consists of 3 layers of S-shaped piping, which allows the air received from the air intake to stay in the chamber box for an optimal duration and ensure maximum heat transfer. In addition, the sheet metal air inlet is designed with a beveled top that prevents the buildup of water and snow, which is a great benefit to users in terms of durability and maintenance, as well as a manually adjustable door (as per the client requests) to allow the user to control the amount of fresh air entering the system. Our thermostat and electronic system runs based on the following logic:

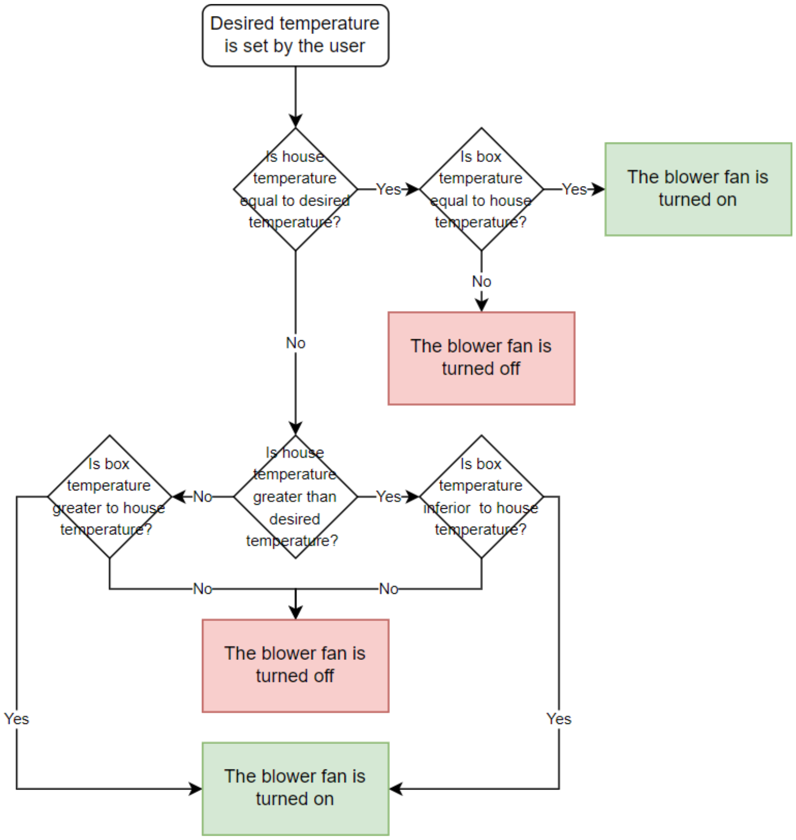


Figure 2: Functioning of the system

3 Getting started

Our system is an assembly of many elements. The air inlet is the entry point for the fresh air from outside. It is directly connected to the chamber box which receives the incoming air and performs the heat exchange for the system. The pipes inside the box form 3 layers of S-shaped piping supported by zip-ties. Leaving the box, the piping is divided into 2 branches and progresses towards the blower fan. At the division junction, the sump pump captures condensation and ensures no blockage in the system. Finally, the blower fan takes in the air into the building. The fan is controlled by a connected electronic system that reads the inner and outer temperatures and blows in fresh air to reach a target temperature. This target temperature can be set using a potentiometer, and its value will be displayed on an attached LCD screen. This air blown in balances out the temperature of the house, which concludes the cycle of the system.

3.1 Configuration Considerations

Our system consists of an air inlet, through which fresh air enters the system. The opening of the inlet is manually adjustable with a sliding door mechanism. The inlet is connected to the top of the chamber box (which is buried underground) through a single vinyl pipe. Throughout the box, there is a 3 by 3 layer of vinyl pipes. On the bottom left of the box, a single pipe leaves the chamber and connects to the sump pump. The pipe divides into 2 outer pipes, leading to the furnace blower in the house (represented by the furnace blower box/fan). The electronics parts are assembled in a separate enclosure besides the blower fan box. The system functions as follows: when the air inlet is left open, the fan blower starts running to suck in and distribute the air throughout the house. The electronics system can be used to adjust to the desired temperature by the user through a potentiometer.

3.2 User Access Considerations

Our design was created to be used in commercial/residential homes, meaning it is suitable for the use of any homeowner. Though the system is more accessible to HVAC installers and professionals. We recommend contacting these groups for set up and regular consultations.

3.3 Accessing/setting-up the System

Once the system is assembled, the air inlet grate must be opened to allow fresh air to enter the system. Next the thermostat should be turned on, starting the movement of the air through the system and controlling its flow. In the condition of winter or colder weather, the air inlet grate should be closed and the close loop system should be opened to allow for inside air to be circulated.

3.4 System Organization & Navigation

3.4.1: Air Inlet:

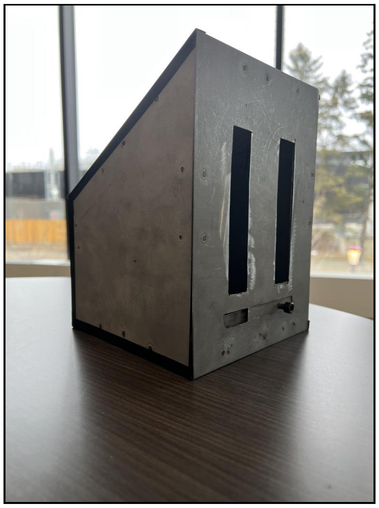


Figure 3: Air Inlet

The air inlet is the entry point in the system that receives the fresh air from outside. It is designed to have a manually adjustable door to control the amount of air entering the system. It has a slanted top to prevent any water and snow accumulation. A single vinyl pipe of 0.75 inches diameter should be connected to the air inlet in order to ensure the air transfer from the inlet to the chamber box.

3.4.2: Chamber Box:

Figure 4: Chamber Box

This is the chamber box, the container that receives the air from the air inlet and where the heat exchange for the system will be performed. The box contains two holes that allow access for air to enter and exit the subsystem. The first hole, drilled on the top of the box connects the inner pipes to the air inlet. The second hole is drilled in the side of the box, connecting the inner pipes to the outer pipe system.

3.4.3: Inner Pipes:

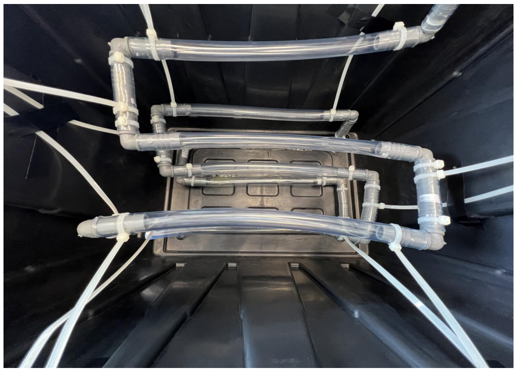
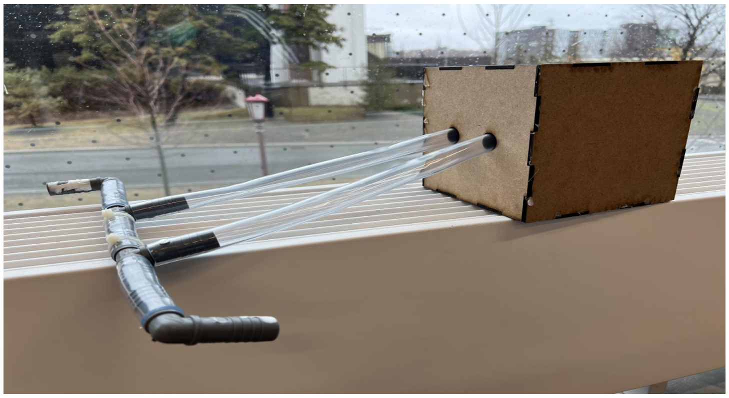


Figure 5: Inner Pipe system

Coming from the air inlet a series of pipes move the air through the chamber box. Through these layers of vinyl piping the heat exchange is done, with the time spent within them allowing the air to heat or cool. These 3 layers of S shaped piping have been designed to optimize the air flow and temperature change of the system. The use of zip ties ensures tight seals on the pipes as well as suspending the pipes in the box. This system is connected in the final pipe to the outer system.

3.4.4: Outer Pipes:



Figures 6: Outer Pipes

Figure 7: Sump Pump

As the air leaves the chamber box, it flows into our system of outer pipes.The main pipe splits into 2 and progresses towards the house. At this junction a sump pump is connected, which will capture the condensation in the pipes, and keep our system running nicely. This pump will be powered by the main electrical unit of the house.

3.4.5: Furnace Blower And Electronics:

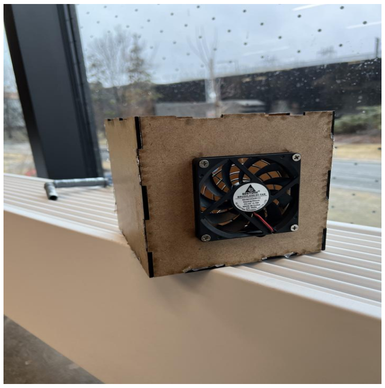


Figure 8: Fan Blower

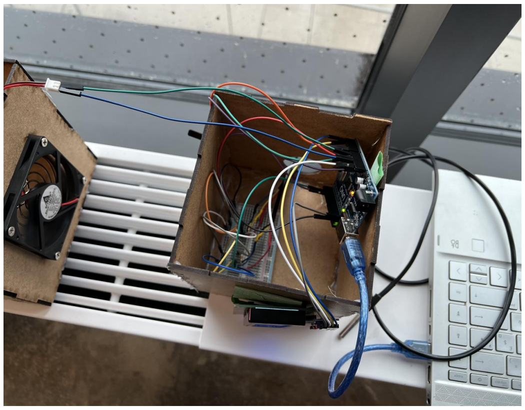


Figure 9: Electronic Connection

The air from the outer pipes will enter the house through the furnace blower. The blower is controlled by the electronics system (thermostat) in the house. It will be turned on or off depending on the temperature differences.

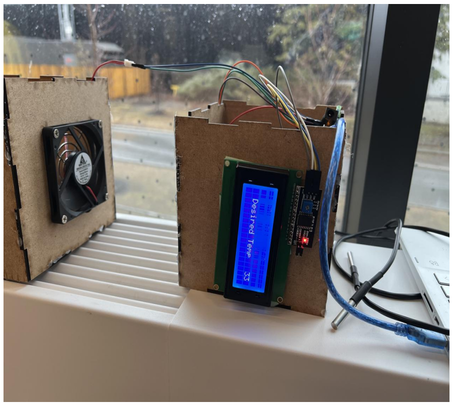


Figure 10: LCD Screen Display

The temperature inside the house will be controlled through a programmable thermostat, which is modeled by the electronics system. The system consists of 2 DS18B20 temperature sensors: one is used to read the actual temperature in the house and one is used to measure the temperature of the air coming to the house through the outer pipes (i.e. the heated/ cooled air from the chamber box). A potentiometer is provided for the user to set their desired house temperature (by turning the potentiometer knob) .That temperature will be displayed on the LCD screen. The Arduino microcontroller takes these 3 temperature readings as inputs and, through a simple temperature comparison logic, decides if the fan will be turned on or off.

3.5 Exiting the System

To properly turn off the system first the thermostat must be turned off. This will stop new air from being blown into the house, and will pause the movement of the air out of the system. Next the air inlet grate can be closed as well to ensure no new air will circulate through the system. Finally close the close air loop system if it is in effect. This will ensure that the system is no longer working.

4 Using the System

For the user experience, only the air inlet and thermostat are subsystems that require user interaction. The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of these systems of the THEC. See Section 3 for further details on the system.

4.1 Air Inlet

The air inlet is the entry point in the system that receives the fresh air from outside. It is designed to have a manually adjustable door to control the amount of air entering the system. The level of openness of the sliding door allows control of the amount of air going into the system. Keep the door open in nice weather to allow fresh air to enter. Close during winter months of colder temperatures, in order to keep the system running well.

Figure 11a: Air Inlet door ope

Figure 11b: Air inlet door closed

4.2 Furnace Blower and Electronics

The blower fan inside the house is controlled by the electronics system (programmable thermostat). It will be turned on or off depending on the temperature differences. Based on the operation of the system, the only user interaction with the electronics system is through the potentiometer. It enables the user to input their desired indoor temperature to the microcontroller. Its operation is fairly simple; the user just turns the knob. The right side of the potentiometer corresponds to the minimum input possible value of 0 degrees Celsius, and the left side corresponds to the maximum possible value of 50 degrees. The user can turn the knob in both directions to control the temperature input.

5 Troubleshooting & Support

For any problem occurrences please read through the following section:

5.1 Error Messages or Behaviors

Any errors in this system will typically be due to disconnections in the electronics system. Here are the possible error scenarios and the associated behavior of the system:

If the fan is disconnected, it will not turn. No error messages will display. If one or both of the temperature sensors get disconnected, an error message will display on the serial monitor window in the code editor software (Arduino IDE) and the system will not run properly. If the potentiometer gets disconnected, the temperature display on the LCD screen will not update. If the LCD screen disconnects, it will be turned off and nothing will be displayed on it.

If an error appears, please contact technical support (see 4.5). If the system is not running normally, please check your connections and notify technical support as soon as possible if the problem persists (see 5.4).

5.2 Special Considerations

In any circumstances where problems occur in the system, it is most likely that a disconnection happened in your electronics system. In this case, please contact our support staff to receive immediate service for your issues.

5.3 Maintenance

The pipes in the system should be serviced once to twice a year (see 5.4 for contact). These checks will examine air inlet condition, temperature control, start up and down control, and pipe condition to ensure the system is running at top condition. Moreover, to prevent any heating in the fan or cables, the user should always disconnect the system when it is not needed.

5.4 Support

For system support or help needed, contact us using the following:

Email: uOttawainfo@uOttawa.ca
Phone number: 613-562-5741

Instructions for how to identify a technical issue:

- If no air is coming into the house, check the thermostat and notice if the system is turned ON.
- If the thermostat was ON and the issue is not resolved, try to restart the system by turning OFF the thermostat and ON again.
- In case the problem is not resolved, send an email or contact the technical support, they will either help you to resolve the problem or they will send you a technician as soon as possible.

Instructions :

1. Turn off the system (see 3.5)
2. Call support to resolve technical issues

6 Product Documentation

This prototype was built using laser cut wooden panels, steel sheet metal, vinyl tubing along with other materials detailed in the instructions following. During assembly, it was necessary to ensure that everything was sealed and that the air traveled smoothly through the system and out into the house. For the electrical side of the prototype, an Arduino was used for temperature readings and control, with an LCD used to display this information. The following section will document the full prototyping and product work.

6.1 Mechanical Subsystem:

6.1.1 BOM (Bill of Materials)

Table 3: Bill of Materials for Mechanical Subsystem

Item name	Description/Details	Quantity	Unit cost	Extended cost
Pipes	Clear vinyl tubing ¾ In diameter x 20 ft length	1	12.73$	12.73$
Chamber box	HDX 45L box 21.68” x 16.06” x 12.60”	1	10.97$	10.97$
Elbow joints	Poly insert elbow ½ In	17	1.18$	20.06$
Tee joints	Poly insert tee ½ In	3	1.02$	3.06$
Epoxy glue		1	$4.79	$4.79
Zip-ties		1	$7.99	$7.99
Sheet metal		1	$15	15$

6.1.2 Equipment list

Table 4: List of Equipments for Mechanical Subsystem

Item name	Description	Type	Prototype #	Source
Hand drill	To drill hole on chamber box	Equipement	3	Brunsfield
OnShape	For CAD model	Software	1,2,3	Software
Drill press	Drill holes into sheet metal	Equipement	2,3	Brunsfield
Treadle Shear	To cut sheet metal	Equipement	2,3	Brunsfield/ MTC
Box and Pan Brake	Bend sheet metal	Equipement	2,3	MTC
Spot Welding	Welding sheet metal	Equipement	2,3	MTC

6.1.3 Instructions

For the final prototype we separated the mechanical work into work for each subsystem. The air inlet was manufactured first. We used steel sheet metal to create our final inlet design. This material was suitable for the design, although really any insulated metal would have worked.

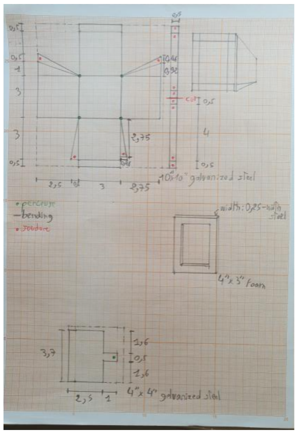


Figure 12: Air inlet sketched design

With our design created we sketched out the rough shapes of the box onto 7 sheets (6 sides and the sliding door), and cut the plates out. With these cut out, we used small folded metal tabs and tack welded them to the sheets to connect them all as a box. With all sheets connected this way, we finally connected a knob on to the sliding door.

Following this we have our chamber box. We debated between using a plastic vs a concrete box, though in the end we decided on using a plastic box. Considering the properties needed for our prototypes, both options essentially functioned the same. In addition, a concrete box would have added extra prototype development time and would have been more of a nuisance when working with. Deciding on plastic, we purchased a plastic box from Canadian Tire that fit the specifications needed for our design being (21.68” x 16.06” x 12.60”).

From this we created our inner and outer pipe design. We considered using pvc, pex and vinyl piping, though decided on using vinyl due to cost and ease of use. All of these pipes had similar functionality though and could be easily compared using calculations and testing. With the layout in mind for the piping, we cut and organized the vinyl in the proper “s” shaped formation (3 columns x 3 rows), using plastic pipe connectors to hold the shape. After this zip ties were added to tightly secure the pipes. They were also fastened to the side of the box to hold our piping system in place.

The outer pipe system used the same materials as the inner piping, as well as the same plastic connectors. The outer pipes come out of the box and meet in an intersection, merging into 2 separate tubes that both head back to the house, with a third heading to the sump pump. The sump pump (although not functional in our prototype) was created using laser cut wooden pieces assembled using glue. An actual sump pump was not cost efficient for our prototype, nor was it necessary to be functional for testing of our system, so the sub-system in our design was more to represent space. The main 2 tubes heading towards the house connect into another laser cut box representing the house, which housed the fan and electrical system.

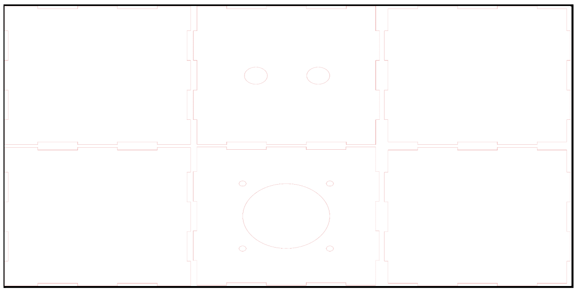


Figure 13: Laser Cut Box Design

6.2 Electrical Subsystem:

6.2.1 BOM (Bill of Materials)

Table 5: Bill of Materials for Electrical Subsystem

Item name	Description/Details	Quantity	Unit cost	Extended cost
Arduino (Uno)	Uno	1	9.00$	9.00$
Jumper wires	male-male	12	0.10$	1.2$
Jumper wires	male-female	7	0.10$	0.70$
Resistor	4.7 kohm	2	0.01$	0.02$
Potentiometer		1	0.95$	0.95$
LCD screen	4 pin, 20x4	1	14.48$	14.48$
Temperature sensor	DS18B20	2	3.80$	7.60$
Fan		1	8.99$	8.99$

6.2.2 Equipment list

Table 6: List of Equipments for Electrical Subsystem

Item name	Description	Type	Prototype #	Source
OnShape	For CAD model	Software	1,2,3	Software
Breadboard	To test circuit	Temporary material	3	Makerlab

6.2.3 Instructions

As mentioned in section 3, our prototyping electronics system is used to model the function of a programmable thermostat. Our system consists of 2 DS18B20 temperature sensors, a potentiometer, an Arduino Uno microcontroller, a breadboard, resistors, LCD IC2 screen, a 5V fan, and jumper wires (male-male and male-female).

First, we connected the Arduino Uno Microcontroller to a power source (a laptop) through a USB cable. Using jumper male-male wire, we connected the breadboard to the Arduino Microcontroller through the power pins 5V and GND. Then, we connected the fan to the arduino through the 3V and GNG pins to power it.

Next, we plugged one temperature sensor (reading the house temperature) to the breadboard with its resistor, and connected it to the Arduino Uno microcontroller Digital pin number 2. We plugged in the second temperature sensor (reading the temperature of the air from the outer pipes) with its resistor to the Digital pin number 3 on the arduino.

Then, we used a potentiometer to get the user desired temperature. The potentiometer is directly connected to the Arduino Microcontroller through the power pins (GND and 5V) and Analog Pin 1. This input temperature will display on the LCD IC2 screen. We connected the IC2 unit of the LCD screen to the arduino power pins and to analog pins 4 and 5.

Finally, we wrote our code in the arduino IDE using the C/C++ programming languages. We verified it and uploaded it to the arduino Microcontroller.

The following figure shows the tentative circuit design built on tinkercad. Some of the components in our design are replaced by other feasible and more practical components in the real life model that have the same functionality.

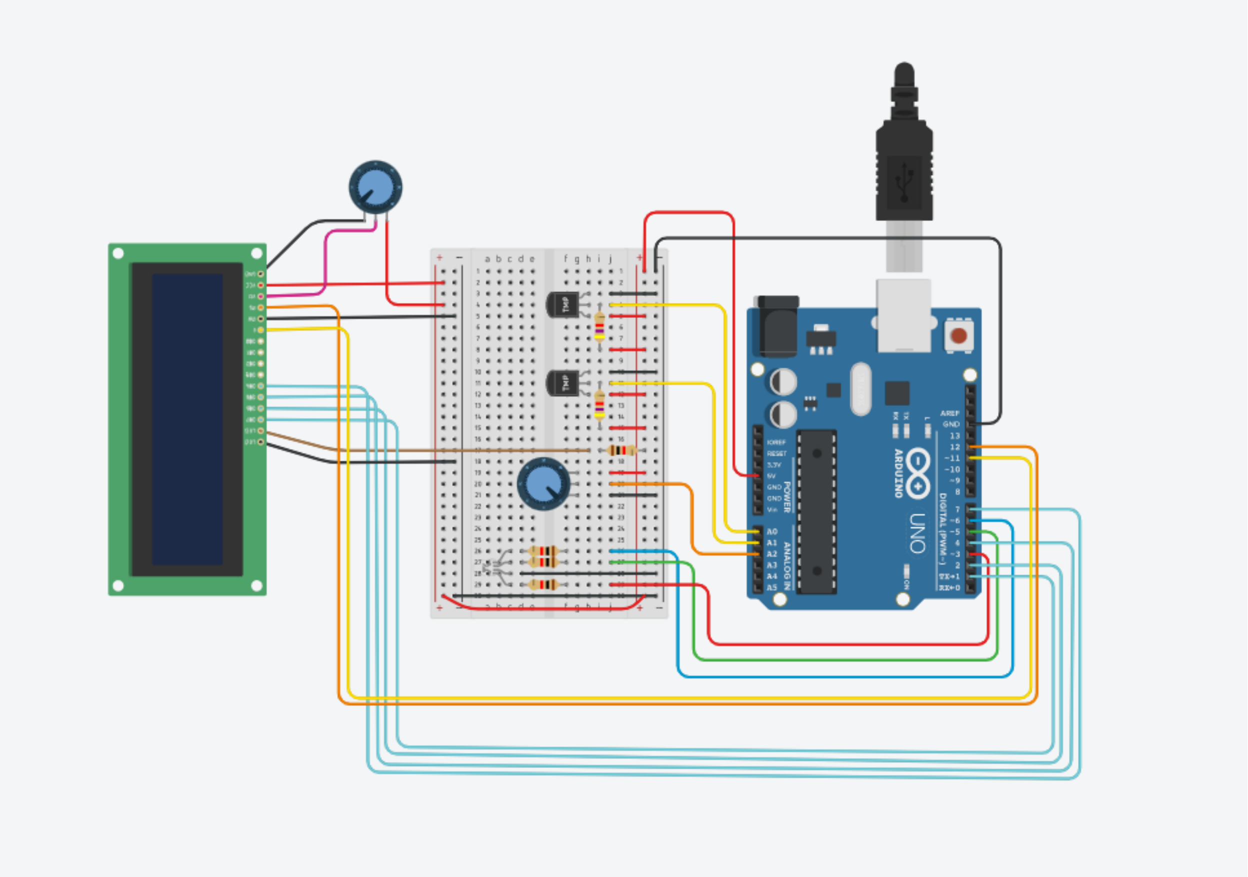


Figure 14: Electronics configuration

6.3 Testing & Validation

To test the functionality of our THEC system, mainly the inner pipes and the electrical systems, we have conducted an experiment with a few assumptions and then plotted our data into a graph to illustrate the trend and outcome. Here is a summary of the testing performed:

Goal of experiment: The driving question for this test was: Is the designed system capable of cooling the house? The ultimate goal was to verify the efficiency of the system in summer times when indoor spaces are required to be cooled.

Experiment: The inlet which received the incoming air and the chamber box which contains the inner pipes were placed outside at a constant cold. This environnement was modeled underground. The pipe that exits the chamber box to the outer pipes was placed inside a warmer environment of 22C which is where the air is blown and distributed in the space. So one sensor served to measure the temperature from the outer pipe entering the house, and the other sensor was used to measure other parameters to define testing conditions: the temp inside the box=7.5C, inside the building = 22C, and the outside environnement=4.5C.

Figure 15: Chamber Box Testing

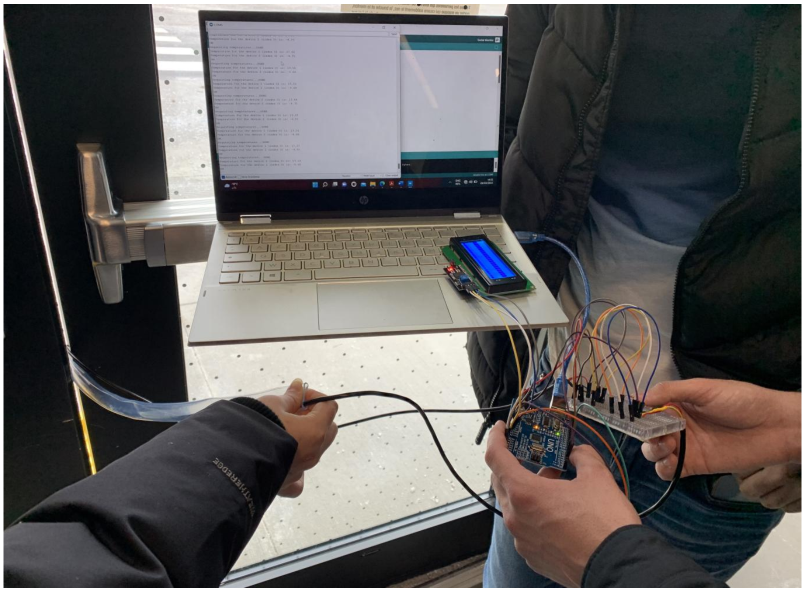


Figure 16: Electronics Testing

Result: From values gathered from testing we have been able to identify that the piping system is functional in cooling down a space. Using average results from both of our tests we found that the air was able to cool down by around 5 degrees in 6 minutes.

Downward slope starting at 22 C with a average delta of 5 degrees with a R^2 value of 0.963
This is an indication that the trend is consistent and is cooling down at a constant rate during the entire duration, which is realistic as ideally the temperature should drop gradually.

The experiment was done twice at a different time and a very similar trend was observed with a R^2 value of 0.96 inferring that our method was accurate and reliable.

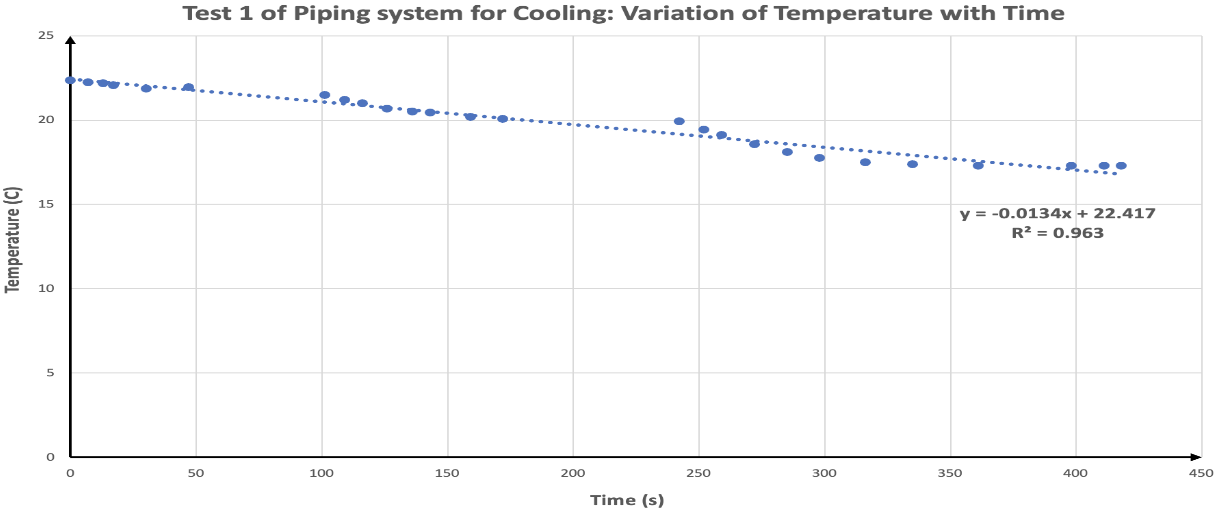


Figure 17 : Graphed results of test 1

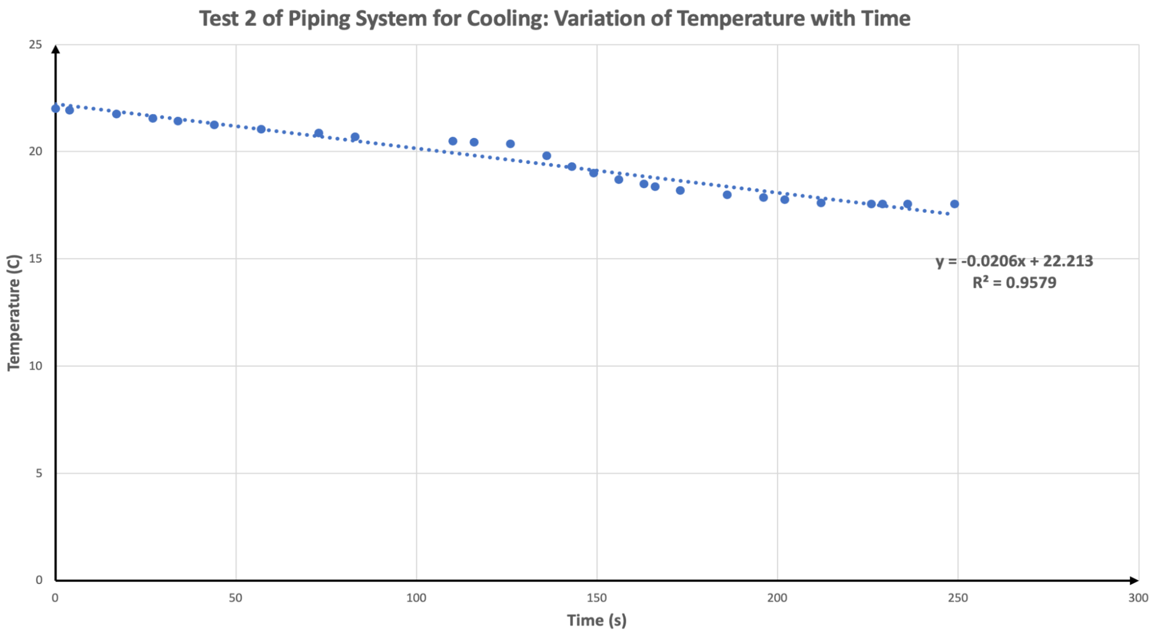


Figure 18: Graphique results of test 2

Assumptions: Due to minimal facilities at our disposal, Some assumptions are to be noted:

1. Chamber box was not physically buried underground at 5ft below the surface where the temp is constant between 10-16C. We have simply installed it outside at a cooler temp then the inside space and assumed its constant.
2. In reality, the chamber box would be in concrete and the piping in PVC. In the prototype, it was a plastic chamber box with vinyl piping. The type of materials is a major dependency regarding the efficiency of the system. Concrete is a much better heat insulator than plastic and can better hold the heat transfer to the house.
3. In order to receive the outside pipe inside the space, the door had to be held slightly open. In reality a house would not have these openings as the outer pipes would be sealed in place through drilled holes at the entry point of the house. The inner space wasn't fully air leakage.

Conclusion: This test served as a proof of our prototype design concept.

Considering these assumptions, our designed system was still able to cool down the space at a reasonable rate demonstrating its functionality and great efficiency.

7 Conclusions and Recommendations for Future Work

After completing the work done through the design and prototyping stages we have taken away a few learned lessons. The first is time management. Spending our time better and allocating more time for project work would have not only allowed us to have more time to work on the project but also to not to have to worry about rushing our work. Group communication and working as a group was another big area of learning and improvement for us. We learned to make sure to communicate with the group about availability for work, our thoughts and ideas on the project as well as problems we had with the work, all of which helped to ensure that our project moved along efficiently. Finally, we all learned a lot more about the design process and how to become more efficient and thoughtful for our futures working through the process.

If we had more time to work on the project, we would have spent more time in the designing stage, considering every and all possibilities for our design. More time allocated here may have not only reduced some of the time prototyping but also may have led to a more fleshed out and better design. In addition, we had thought about soldering wires and electronics together during prototype work, but we did not end up doing so due to time constraints. With more time to work on the project, soldering would be done, ensuring everything stays in place. This would also allow for the electronics to be manipulated easier while working with the system.

8 Bibliography

No external sources were referenced in this document.

APPENDICES

APPENDIX I: Design Files

Table 7. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Onshape File	https://cad.onshape.com/documents/35f5e268d3023cb9ef00c858/w/630a837424932a85c3882008/e/b7e1a6d1ae2a1e6344673d48?renderMode=0&uiState=6260bdf6edca450039765b3f	04/20/22
Code	In makerepo	04/20/22
Circuit on Tinkercad	https://www.tinkercad.com/things/dCAMS6XfEG1-design-project-electronics-1-/editel?sharecode=LQHZhtJKcAv1JH9U_iJ9w5JvGIdIGWLXuw2CBGSTRt8	4/20/22

MakerRepo Link:

https://makerepo.com/CallumB/1097.gng-1103-the-heat-exchange-chamber-d14

APPENDIX II: Other Appendices

Final presentation:
https://docs.google.com/presentation/d/1-ZpAr6a3tXn7vb0vIOnDQUZDbQbtErUV19OnKwDqrzQ/edit?usp=sharing