Deliverable H-Prototype 3

GNG 1103
Group D-1.4

Names:

- Callum Bunston
- Youssef Hemdan
- Yassir Mechahouri
- Rasheeq Mohammad
- Yosr Ouali
- Jiaho Sun

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Introduction

The current document will present the team's third and last prototype, which will consist of the final product. The last 2 prototypes focused on CAD designs, dimensioning, proof of concepts and simulations. This 3rd prototype takes into account all previous tests, the final updated BOM, and final adjusted dimensions. The goal of the last prototype is to finalize all components of the THEC system, and to have the full system assembled. During the presentation, the team will demonstrate how the system and design is able to deliver a heated or cooled final air temperature of 23 degrees celsius.

Summary of results of previous prototypes

1) Prototype 1:
   -Cardboard box model of overall system
   -Finalized metrics of chamber box and inner/outer pipes
   -Discussion of mechanical parts required (fittings, joints, adhesives)

2) Prototype 2:
   -Final manufactured inlet
   -Inner pipe configurations and orientation
   -Calculations of air flow, heat transfer and time of air circulation inside pipes
   -Finalized electrical parts and representation of circuit diagram on tinkercad

Feedbacks and adjustments

- After talking with the PM, the team has realized that a prototype does not need to consist of the actual materials and is simply a representation. This helped to maintain the 100$ budget and made the manufacturing process a lot easier.
- Instead of the PVC, the inner and outer pipes were in vinyl.
- Instead of concrete, the chamber box will be a plastic insulated storage box
- Since we are not using the actual materials, it was suggested to lay out 2 sets of calculations one with the actual material, and the other with the prototype material. At the end, we compare the results and configure a scale. This can serve as a proof of our concept in the presentation.
- Regarding the arduino fan, it was explained that it must be according to the calculated cfm and the best option would be to order it from Amazon
- The pipe configurations and layout were approved by the TA

Final prototype and Analysis of Parts

1. **Air inlet**

Figure 1: Air inlet open

Figure 2: Air inlet closed

This is the final design created for our inlet. This final refined design not only functions the best but is also the highest quality build of the prototypes so far. We built off of our first two designs and developed our final design as a combination of both. In addition, with knowledge and experience gained from prior prototype work our final product was able to be made with very high quality.

The air inlet consists of 2 entry points which can be manually closed or opened. The inside view of the front face has a guiding tab on top and the bottom where the door can slide. When required to be open during warmer temperatures, the knob can be translated left or right with the knob. When it needs to be closed during cooler temperatures, the knob can be positioned in the center. The inclined top is a feature that will allow it to deflect the rain or prevent snow accumulations. Finally, on the bottom, there is a ¾" diameter drilled hole where the pipe connected to the chamber box will be fitted. After the manufacturing of the inlet, there were little gaps in the corner due to the inaccuracy of the welding, but they were closed with duct tapes around the sides. The only thing missing is a support system for the inlet to hold in place, which will be completed by tomorrow.

2. **Inner pipe**

Figure 3: Inner pipes inside chamber box

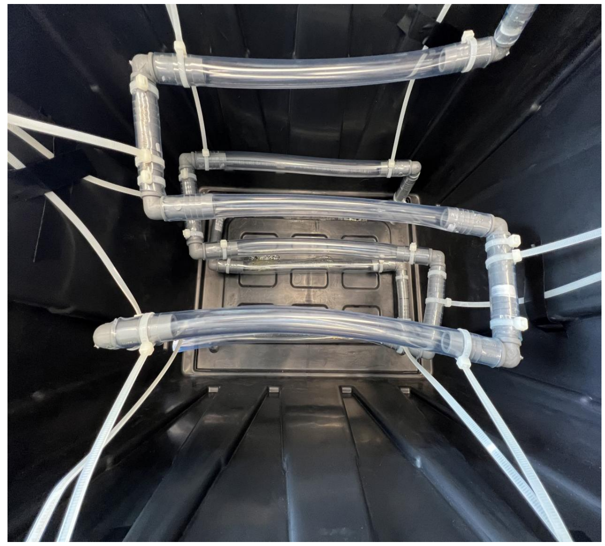


Figure 4: Inner pipe design

These are the photos of our overall chamber box and inner pipes design. Using a secure and sealed plastic box as our chamber box allowed us to simulate the needs of the final product while still staying within our cost boundaries.

As for the inner pipes, we slightly modified the pipe design from the previous prototypes (3 by 3 layered pipes instead of 2 by 6) to fit inside our box, increased the lengths of the pipes to 12 inches long, to accommodate the new box size and finally, we updated the material of the pipes, deciding to use ¾ inch vinyl piping as it again allowed us to simulate the final piping functions while staying within the budget. To hold these pipes in place we have used zip ties. Not only did these help to secure the piping and inner connector pieces together, but also allowed us to easily hold the pipes in their suspended vertical positions. Of course in the final product these zip ties would be traded out for more sophisticated supports, as well as being supported by the inner clay/water mixture, but for the sake of the prototype, they serve as good and cost effective substitutions.

Tests: To make sure this piping system works we will examine 2 tests. The first test is to measure the security of the piping. With this test we will send water through the tubing to ensure the tight connection between the pipes and make sure there are no cracks/impurities within it. The second and most important test is to test the transfer of heat transferred inside the box. We will place the chamber box and inner piping system outside in the cold and the air inlet part inside in warm conditions. The warm air will feed through the pipe and go into the piping system outside in the cold. We will use a thermometer to measure the inner temperature and the final temperature to test for system temperature change. When there is temperature change we can say that this test proves that the piping system works for our prototype, and should work for other scaled models.

3. **Chamber box**

Figure 5: Inner pipe entry

Figure 6: Inner pipe exit

Using a secure and sealed plastic box as our chamber box allowed us to simulate the needs of the final product while still staying within our cost boundaries. The box dimensions have been slightly increased from previous prototypes in order to make the process of assembling the prototype easier, though its function remains the same.

These photos showcase our chamber box which displays the layout for the outer pipes and how the air inlet will be connected through the upper pipe. The use of a plastic chamber box is as efficient as other boxes, being able to do the required job of cooling or heating the incoming air.

4. Outer Pipes

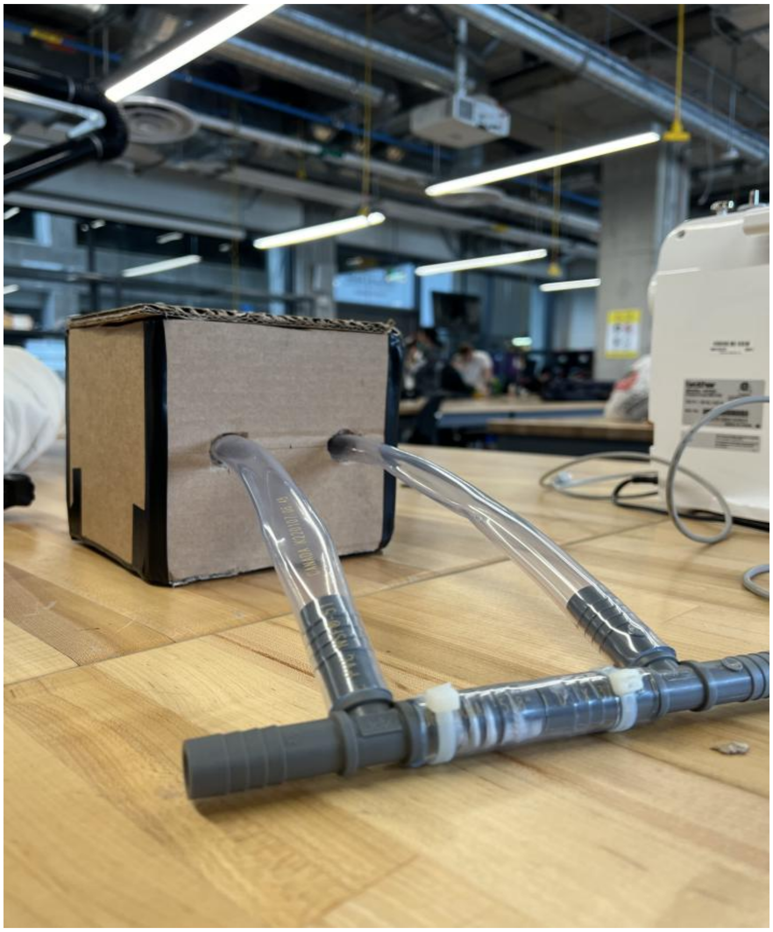


Figure 7 : Outer pipes connected to the entry of house

The layout of the outer pipes that will lead to the house consists of 2 pipes. In the representation shown above, one side of the connectors will connect to the sump pump which will collect the condensation/excess and the other is connected to the exit point of the inner pipes. The cardboard enclosed box represents the house furnace. Inside this will be a fan fitted at the back side to blow and suck the final receiving air. That is also where the temperature sensors (both inside and outside of the box) will be positioned. Finally, nearby the box all the electrical components will be contained in their own enclosure with an attached display screen of the temperature.

5. Electrical system and software

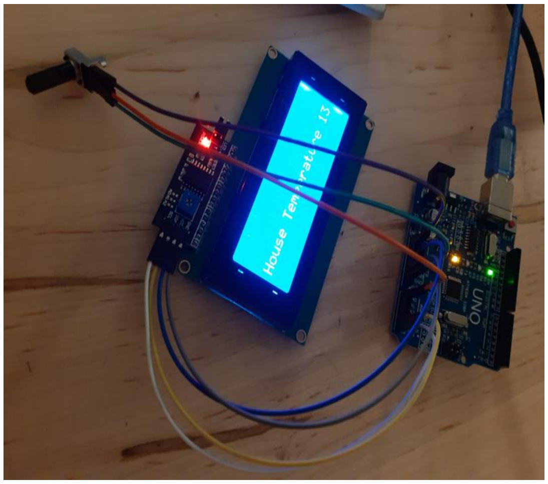


Figure 8: LCD display reading “House temperature 13”

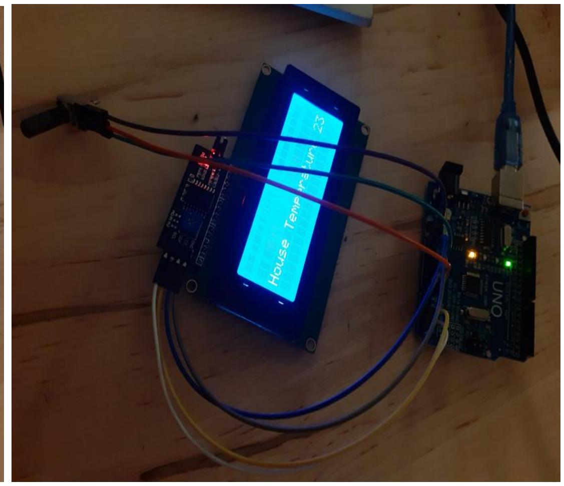


Figure 9: LCD display reading “House temperature 23”

Getting_user_input_and_display_on_LCD §

```
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);

int Value = 0;

void setup()
{
    Serial.begin(9600);
    pinMode(A0, INPUT);
    lcd.init();
    lcd.backlight();
    lcd.setCursor(20, 0);
    lcd.print("House Temperature");
}

void loop()
{
  Value = analogRead(A0);
  Value = map(Value, 0, 1023, 0, 50);
  delay(5000);
  lcd.setCursor(38, 0);
  lcd.print(Value);
  delay(5000);
}
```

Figure 10: Coding for user input and display on LCD

For the electrical system, the user input is displayed on the LCD screen. The potentiometer allows you to adjust the desired temperature.

6. Calculations

These calculations were done in order to mathematically decide the formation of our pipes and the specification of the fan in the house.

Heat transfer = 8.4 J
Time of air circulation inside chamber box = 55 seconds
Speed of air at the exit of inner pipes = 45.5 m/s

• Outside: 30°C • Box: 10°C • Target: 23°C

* For now we take an arbitrary volume of air that goes into the system each second: $V = 1\ L$

• $\rho_{air} = 1{,}2\ g/L \Rightarrow m_{air} = 1{,}2\ g = 1{,}2\times10^{-3}\ Kg$

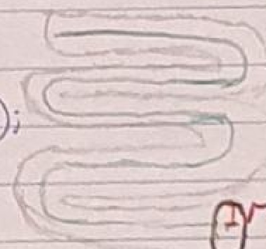
• $C_{air} = 1{,}00\ kJ/Kg \Rightarrow Q = m_{air} . C_{air} . \Delta T$

$$= 1{,}2\times10^{-3}\times1{,}00\times10^{3}\times(30-23)$$
$$= 8{,}4\ J$$

↳ To cool 1 L of air from 30°C to 23°C, the heat transfer needs to be of 8,4 J

• $T_p = 10°C$ • $T_F = 23°C$

$L = 2{,}286\ m$



• heat transfer coeff of air (based on lab5): $h_{air} = 100\ W.m^{-2}$

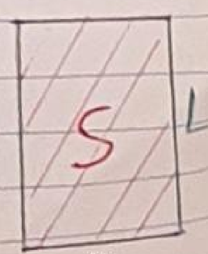
$r = 8{,}9535\times10^{-3}\ m$

$p = 2\pi r$

• $\Phi = h_{air} . S . (T_f - T_p)$

$$= 100\times2\pi\times8{,}9535\times10^{-3}\times2{,}286\times(23-10)$$
$$= 167{,}183\ W = 167{,}183\ J.s^{-1}$$

$S = 2\pi . r . L$



• Time spent by 1L of air in the system:

$$t = \frac{Q}{\Phi} = \frac{8{,}4}{167{,}183} = 50{,}244\times10^{-3}\ s$$

• Target speed of air: $V_{air} = \frac{L}{t} = \frac{2{,}286\times10^{3}}{50{,}244} = 45{,}5\ m.s^{-1}$

7. Updated final BOM

Item name	Description/Details	Quantity	Unit cost	Extended cost
Mechanical				
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	2	1.02$	2.04$
Epoxy glue	All purpose glue	1	2.00$	2.00$
Nylon zip ties	6” length pack of 20	1	1.25$	1.25$
Duct tape		1	1.25$	1.25$
Sheet metal	9” x 6.5”	7	15.00$	15.00$
Electrical				
Arduino (Uno)	Uno	1	9.00$	9.00$
Jumper wires	male-male	14	0.10$	1.40$
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	80 x 10 mm size DC 5V 2200 rpm	1	8.99$	8.99$
			Total cost before taxes	108.44$
			Taxes (13% HST)	14.10$
			Total cost	**122.54$**

7.1- Cost analysis
Budget constraint: 100.00$
Total final product cost: 122.54$
The final product will be 22.54$ over the budget.

7.2- List of Equipment

Item name	Description	Type	Prototype #	Source
Breadboard	To test circuit	Temporary material	3	
Hand drill	To drill hole on chamber box	Equipement	3	Brunsfield
OnShape	For CAD model	Software	1,2,3	
Cardboard	For air inlet and chamber box representation	Temporary material	1	
Cardboard Paper	For pipe representation	Temporary material	1	