Project Deliverable G
Prototype II and Customer Feedback

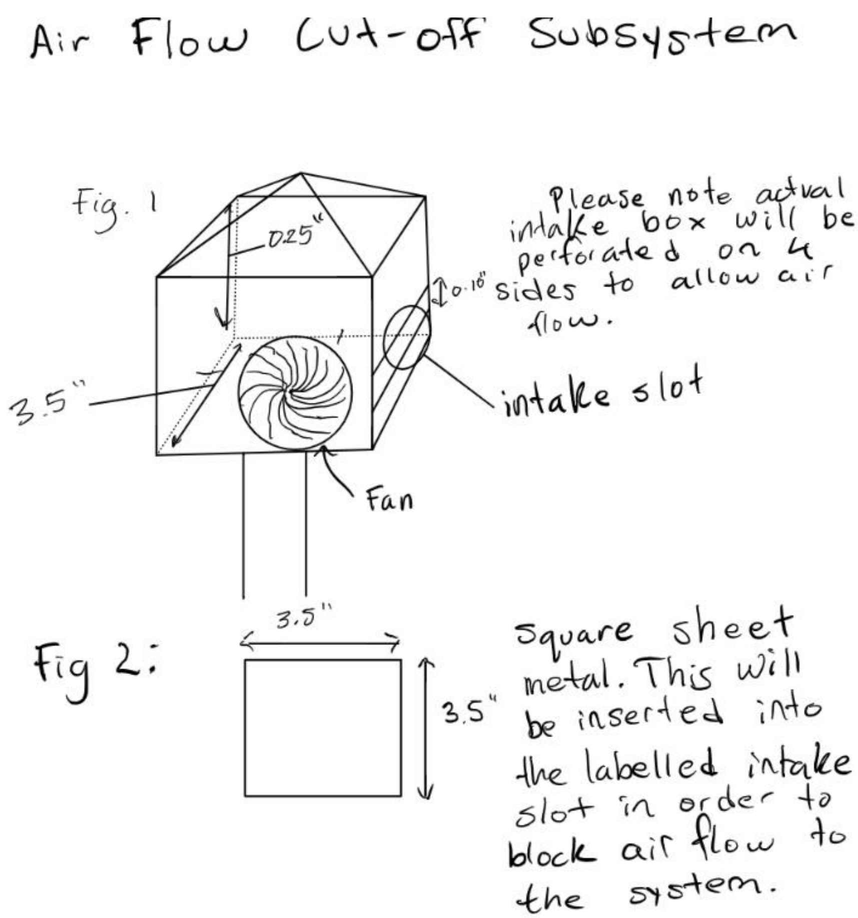
Client Meeting Feedback

Both the client and the professor questioned our decision to put a fan at the inlet pipe and not at the outlet pipe. We took this feedback into account and reevaluated our current design. In response, we decided to introduce a second fan at outline pipe, which will work in conjunction with the fan at the inlet pipe. This system will allow air to flow faster through our system and will reduce the amount of time that it will take to travel into the house.

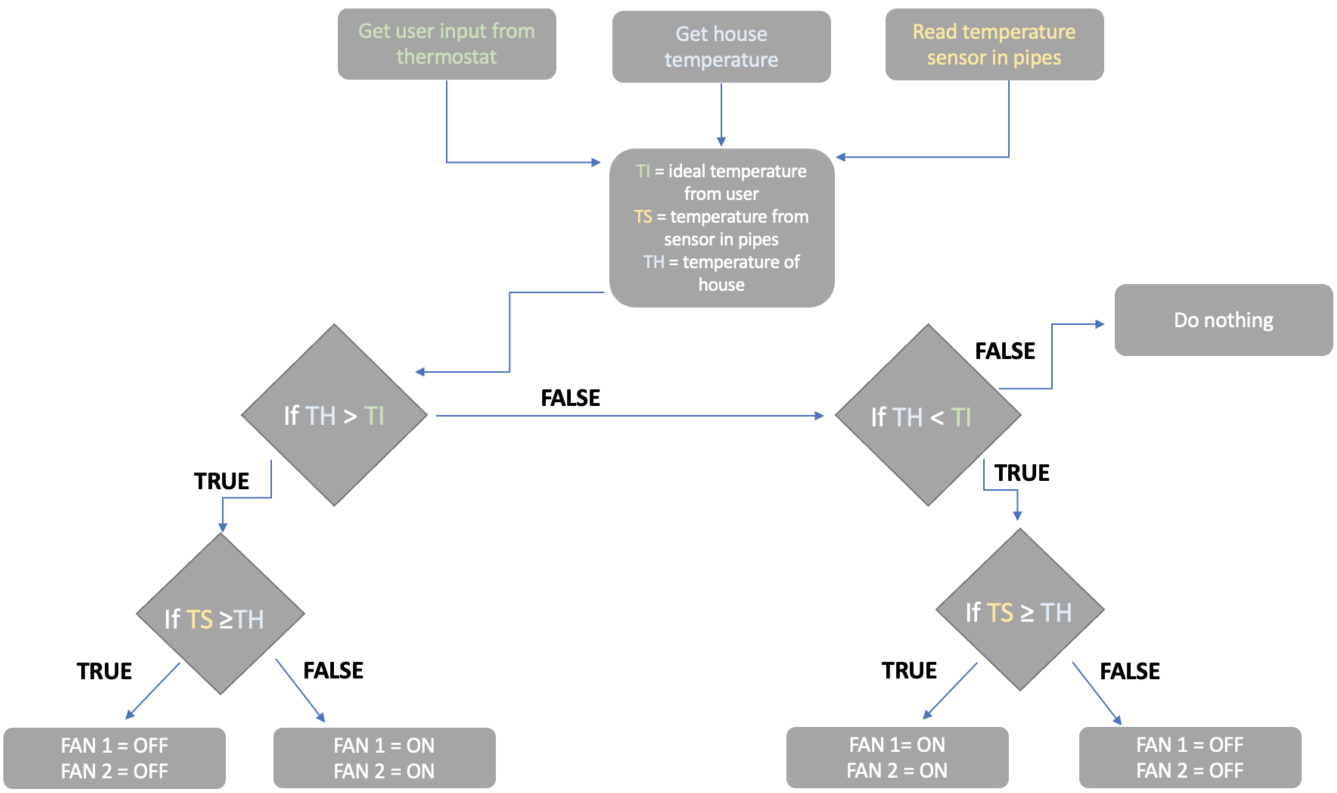
Prototype Update

Air Intake Unit

We analyzed the inlet system, which will house our first fan and control all external airflow into the system. Because the pipe diameter is quite small compared to the necessary sizes of the fan and air filter, we decided to house these items in a sheet metal enclosure that connects to the air intake pipe. To properly seal our system, we designed a manually-closing sliding door that can be easily controlled from the air intake unit. Finally, our air intake unit will be perforated to allow for greater airflow into the system.

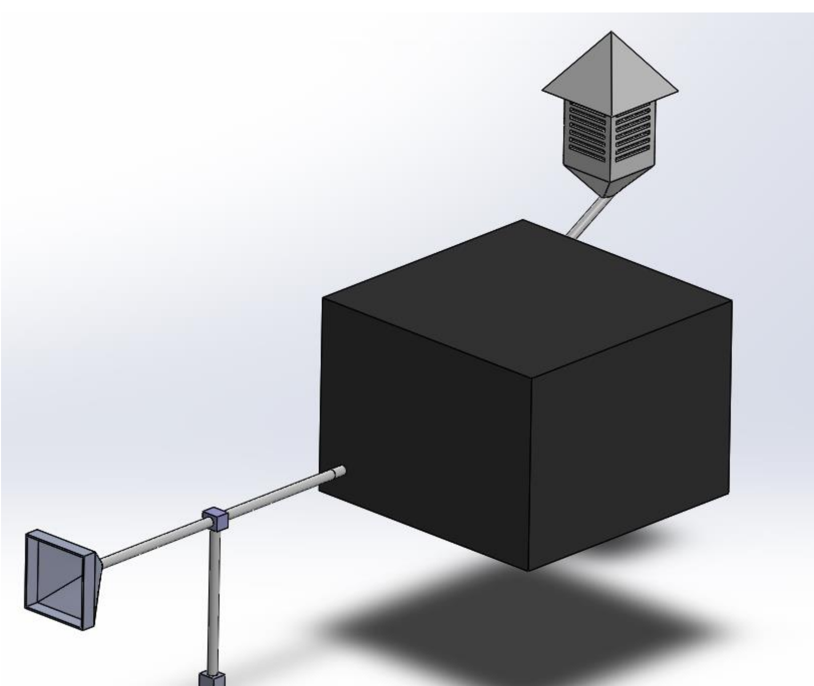


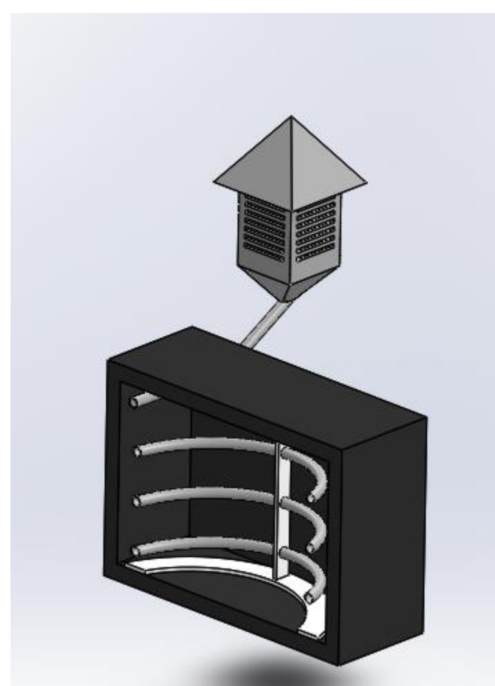
Updated Software Flowchart



Updated CAD Model

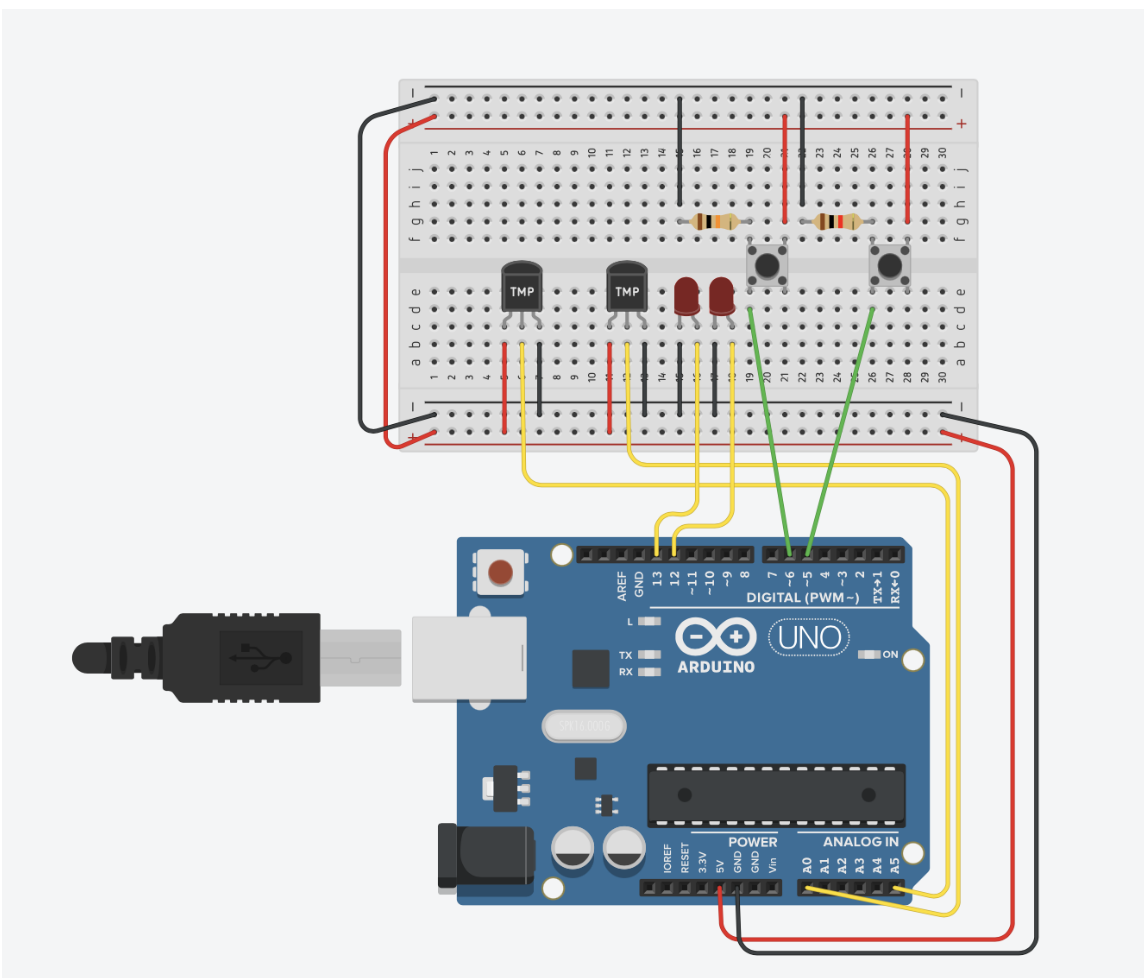
As demonstrated in the following CAD design, there is a second fan located at the air outtake pipe.





Electrical and Software Systems

To develop out latest prototype, we designed and tested an addition to our software and electronic systems: a user interface and we added an additional fan. Initially, our heating system would be programmed for one ideal house temperature; after seeking external feedback and considering user needs, we decided to add a user interface, which will give the user the ability to set their desired temperature. While this change is reflected in the updated software flow chart, we also added this element to our circuit and tested the results. The user interface will include two buttons: one to raise the temperature by 1°C and one to lower the temperature by 1°C. In addition, we have added a second LED to the circuit, which sufficiently represents the second fan by the same digital functions. The second fan, located at the air outtake pipe, will be controlled by the same parameters as the first fan; they will operate in unison.



Text

1 (Arduino Uno R3)

```
// C++ code
//
int TH = 5;
int TS = 0;
int FAN1= 13;
int FAN2 = 12;
const int buttonpin1=6; //button 1
const int buttonpin2=5; //button 2
int Temp = 20;
int buttonState1 = 0;
int buttonState2 = 0;

void setup()
{
 Serial.begin(9600);
 pinMode(buttonpin1, INPUT); //initializing button 1
 pinMode(buttonpin2, INPUT); //initializing button 2
}

void loop()

{
  //---------------------------------------------
  buttonState1 = digitalRead(buttonpin1);
  buttonState2 = digitalRead(buttonpin2);

  if (buttonState1 == HIGH)
  {
    delay(200);
    Temp = Temp + 1;
    Serial.println(Temp);
  }
```

```
else if (buttonState2 == HIGH)
{
  delay(200);
  Temp = Temp - 1;
  Serial.println(Temp);
}
else if (buttonState1 == LOW)
{
 Temp = Temp;
}
else if (buttonState2 == LOW)
{
 Temp = Temp;
}
//---------------------------------------------

// read thermostat in celcius
int rTH = analogRead(TH);
float vTH = rTH * 4.68;
vTH /= 1024;

float THC = (vTH - 0.5) * 100;
//Serial.println(THC);

// read pipe temp sensor in celcius
int rTS = analogRead(TS);
float vTS = rTS * 4.68;
vTS /= 1024;

float TSC = (vTS - 0.5) * 100;
```

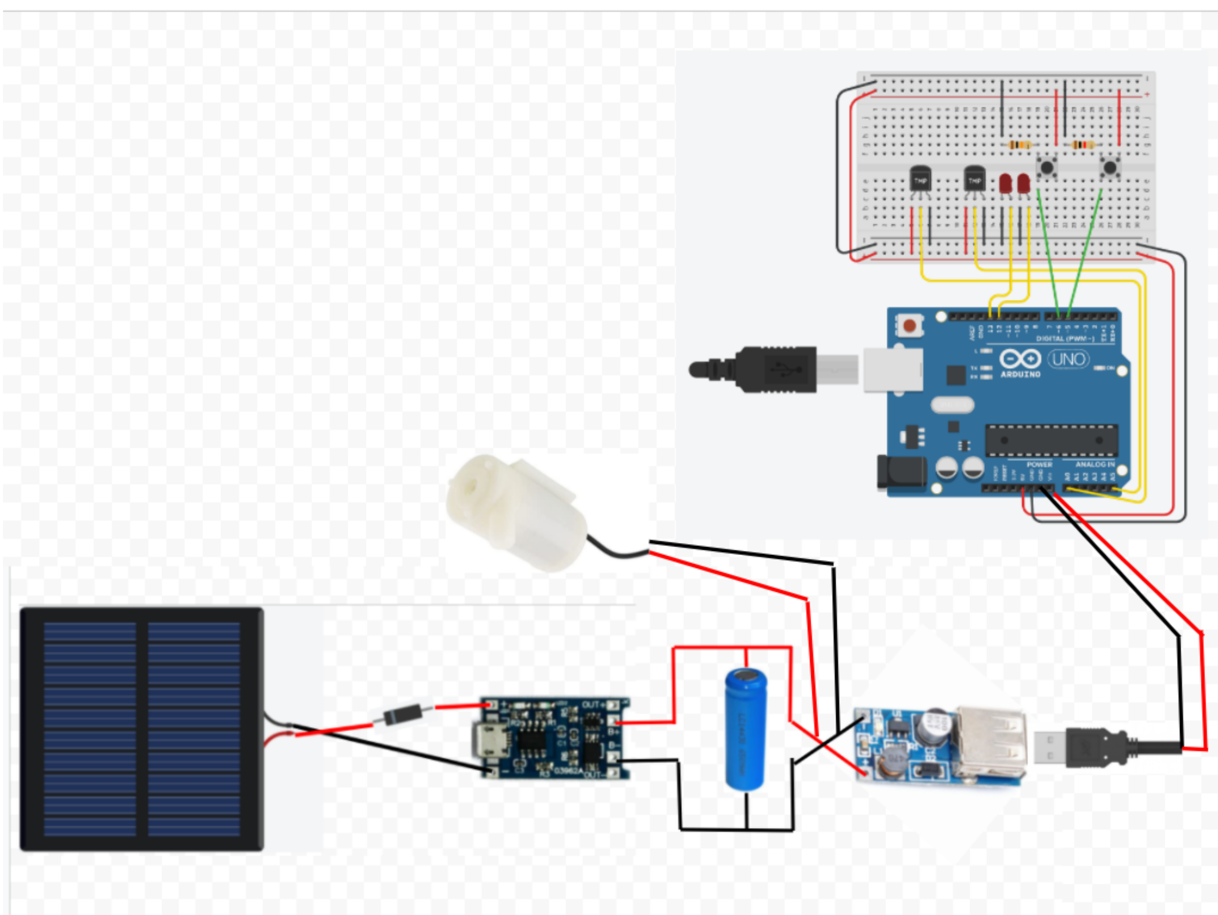
```
 // Serial.println(TSC);
  // 4 cases
  // if house > 20 and pipe air > 20 -> fan off:
  if (THC > Temp && TSC > Temp)
  {
    digitalWrite(FAN1, LOW);
    digitalWrite(FAN2, LOW);
  }
  // if house > 20 and pipe air < 20 -> fan on:
  else if (THC > Temp && TSC < Temp)
  {
    digitalWrite(FAN1, HIGH);
    digitalWrite(FAN2, HIGH);
  }
  // if house < 20 and pipe air > 20 -> fan on:
  else if (THC < Temp && TSC > Temp)
  {
    digitalWrite(FAN1, HIGH);
    digitalWrite(FAN2, HIGH);
  }
  // if house < 20 and pipe air < 20 -> fan off:
  else if (THC < Temp && TSC < Temp)
  {
    digitalWrite(FAN1, LOW);
    digitalWrite(FAN2, LOW);
  }

}
```

Serial Monitor

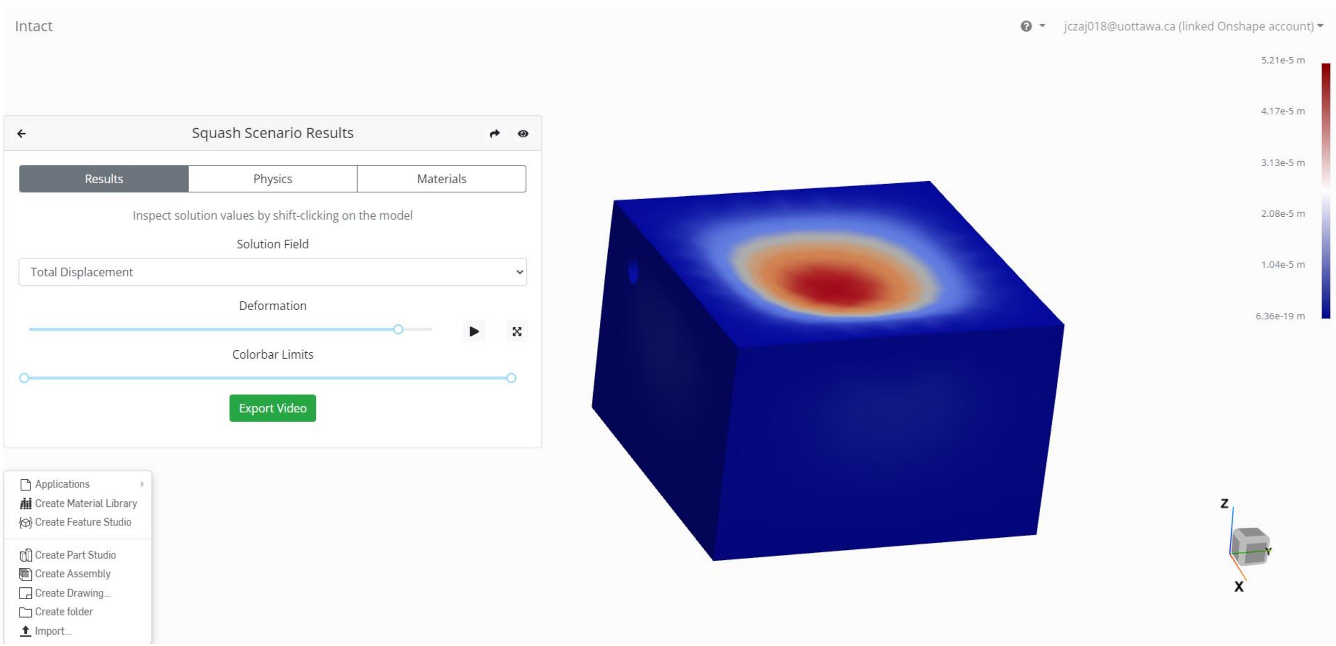
TinkerCAD link: https://www.tinkercad.com/things/6OsBoxANtNM-pelicans-sensor-system-prototype/editel?sharecode=FB1tF8qp8PzT59iVd35XegRPdWosmGu4uZ00PG4b9Qw

Full Electrical circuit:



Virtual simulation of Pressure

Finally, we also managed to simulate the conditions under which the box would be in. In the previous deliverable, we calculated that the box would have to withstand around 8.66 psi (~60 000 Newtons per square). This means that the top of our box would have to withstand around 12 000 newtons of force (Area in m^2 of the top face is around 0.2). As evidenced by the simulation result below, we should put a pillar in the center of the box as to prop up the lid better against the pressure. This will ensure increased longevity of our system. As we did not manage to build the box for this prototype, we decided to simulate it in a virtual environment. The red area and the orange are are the areas where the lid will be most susceptible to cracking or breaking, therefore these places should be reinforced with a single large pillar whose radius will be equal to the radius of the red circle in this simulation.



Numerical Analysis

Pressure and Moisture of Earth

- The pressure exerted by the soil is given by the following equation:
- $p_{soil} = \rho_s\, g\, h + \rho_{sw}\, g\, h_w$

- *Where: ρ_s = density of soil above the groundwater (1600 kg/m^3), g = gravity (9.81 m/s^2), h = depth from surface to object (m), h_w = depth from groundwater level to object (m), ρ_{sw} = density of soil below groundwater level (increased due to groundwater - 1760 kg/m^3)*
- We must also consider the pressure caused by ground water at its highest level in the year and add it to the pressure exerted by the soil. The pressure exerted by groundwater is given by the following equation:
- $p_{water} = \rho_w g h_w$; where ρ_{sw} = *density water (1000 kg/m^3)*
- We could not find data on groundwater levels in Ottawa; however, we did find extensive data on groundwater levels in Brasher Falls which is only 100 kilometers south of Ottawa. The highest-level groundwater reaches are in March when it begins at a depth of 1.89 meters. The box will be at a depth of 3 meters.
- Calculations:
- $p_{total} = p_{soil} + p_{water}$
- $p_{total} = \rho_s g h + \rho_{sw} g h_w + \rho_w g h_w$
- Data: ρ_s =1600, g=9.81, h=1.89, hw=1.11, ρ_w =1000, ρ_{sw} = 1760
- p_{total} = 1600*9.81*1.89 + 1760*9.81*1.11 + 1000*9.81*1.11
- p_{total} = 59.72 kPa = 59.72 kN/m^2 = 8.66 psi
- This is not a perfect calculation of the pressure exerted upon our system; however, it should provide us with a good frame of reference and will allow us to correct our current design in our second and third prototypes.
- Using the value we calculated above, we can safely assume that the air intake and outtake pipes will not collapse as the pressure exerted upon them is far below their maximal external pressure value: 375 psi for schedule 40 PVC piping and 1050 psi for schedule 80 PVC piping. As we will be using schedule 40 PVC piping, the external pressure conditions will be very comfortable for our pipes. This means that their regular lifespan should not be affected; they should last a solid 40 years.
- Finally, this amount of external pressure will not be a problem for the type of concrete we will use as it will have a maximal pressure of 2500 psi which is far greater than our predicted external pressure. Our system will be very comfortable in its real condition.

Expected Heat Transfer

The inside of our box will be 16in x 16in, and our vinyl pipes will be spiraling around the center of the box with 2in of space on either side. So, each loop of piping will have a 12in diameter. Our current design involves 3 loops, so we calculated the required piping as follows:

$$\begin{aligned} L &= 3C \\ &= 3\pi d \\ &= 3\pi(12in) \\ &= 3\pi(1\text{ft}) \\ &= 9.42\text{ft} \end{aligned}$$

Using this length of piping, the heat exchange rate can be calculated using the formula: $A = \frac{Q}{U\Delta T} \rightarrow Q = AU\Delta T$. To begin, the surface area of the pipe must be calculated. Our pipes have a diameter of 0.5in, which is equivalent to 0.0416667ft.

$$SA = 2\pi rh = \pi dh$$

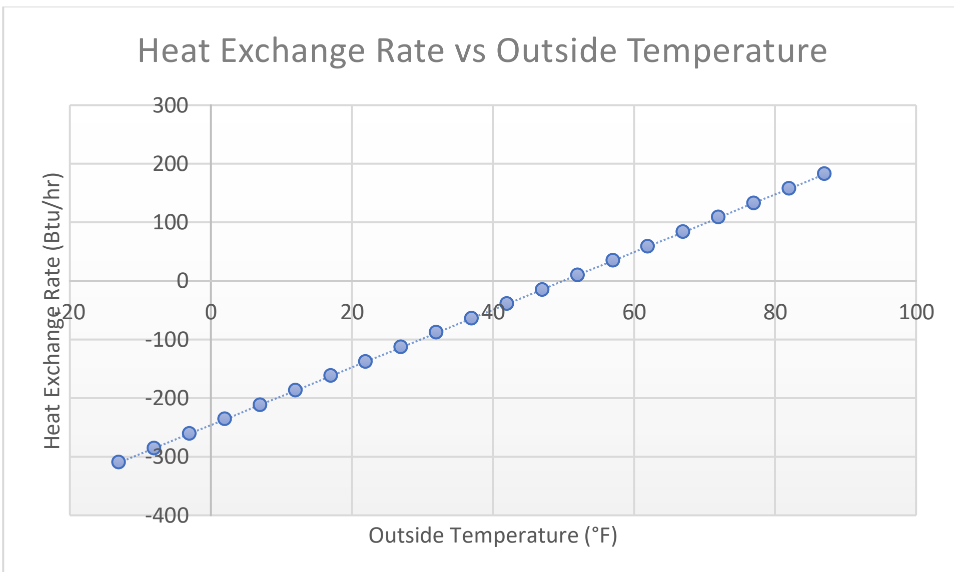
$$SA = \pi(0.0416667ft)(9.42ft)$$

$$SA = 1.23\ ft^2$$

Now, using the previous formula with a temperature difference of 35°F and a heat transfer coefficient of 4 Btu/hr:

$$Q = AU\Delta T = (1.23ft^2)\left(4\frac{Btu}{hr}\right)(35°\text{F}) = 172.2\ \frac{Btu}{hr}$$

Therefore, the expected heat exchange rate of our system at a 35°F temperature difference is 172.2 Btu/hr. Of course, this value will change depending on the external temperature throughout the seasons. The following graph depicts the relationship between the outside temperature and the heat exchange rate of the system, taking the ground temperature to be constant.



Updated Prototyping Test Plan for Prototype 3

Thus far, we have tested the software and electronic systems and have analyzed the functionality of our main box unit and pipe heat exchange rate.

Test ID	*Test Objective (Why)*	*Description of Prototype used and of Basic Test Method (What)*	*Description of Results to be Recorded and how these results will be used (How)*	*Estimated Test duration and planned start date*

				(When)
1	Testing the functionality of the sump pump system	A pipe that leads towards the sump pump will be fed water. The pipe must be at a 3-degree decline. The sump pump will be placed above a small box of dirt which will have a small hole dug directly underneath.	We will write down how well the pump works or if it works at all.	20 minutes
2	Testing the functionality of our user interface	As there is not software that allows us to test our OLED display, we will have to physically test our code with a physical OLED component. We will need to write the code that displays the house temperature on the display. It will also have to react to the buttons being pressed, i.e. it will need to visually show that the temperature has been increased and decreased.	We will continue to write and rewrite our code until we achieve what we wanted to achieve. Once we achieve this, we will post screenshots of our code into the deliverable document.	30 minutes – 1 hour (March 14th)
3	Verifying that all the joints in the system have been properly sealed. We do not want any air to be entering or exiting our system apart from the designated inlet and outlet. We will create mock versions of the actual seals. This way we do not need to risk improper sealing in the actual box, which would be a waste of resources.	We will pour soapy water over each of the joints that we sealed individually. We will test each joint one at a time, so we will need to blow air through the mockup multiple times. If we see that any soap bubbles exit the system, or if any water pours out, we	Observe the inside of the pipes, if bubbles exit the system or if water begins dribbling out, we will know there is a breach. If we find there is a breach somewhere, we will re-seal that joint, let the sealant rest, and then try again. Once we have tested all the joints and no bubbles or water exit the pipes, we will be able to stop this test.	20 minutes

	For example, we will take a small 1.5-inch slab of concrete or wood, drill a hole for the pipe and then seal it. This will allow us to assess the risk of a breach in the system without having to commit to implementing it in our box.	will know we have a breach		
7	Testing the functionality of our solar panels and battery	We will expose our solar panels to sunlight and connect them to the Lithium-Ion battery.	We will know if the solar panel is working if it charges up the batteries. We will test the battery by plugging them into a simple device that is powered by batteries.	Up to a day (March 15th)
9	Test filter	We will set up our filter in front or on top of a vacuum to facilitate air flow, and deposit debris or varying sizes (sand, dirt, stones) on the filter.	If the debris were to bypass the filter and enter the pipe, then we know that the filter would be ineffective	10 minutes