Prototype One and Client Feedback

Client Feedback

After our first client presentation, our client gave us valuable feedback about our design concepts. To begin, the client noted a few areas where issues may arise; for example, using a water dam to sustainably power the electric components of the system. The client agreed with the reasons we didn't move forward with the idea: it would only apply to those living near an accessible water source and would be much more difficult to implement. Also, the client agreed with our decision to use concrete for the main box unit rather than a PVC box. The PVC box would not be able to withstand decades underground as well as concrete could, especially when considering the constant pressure and moisture of the soil. While the client was impressed with the innovative solutions we presented, after discussion, we ultimately agreed that they were too costly and too unattainable for the scope of the design. Such designs included lining the inside of the main box until with stainless steel to increase the rate of heat transfer and using environmentally sustainable cement alternatives, like pulverized fuel ash or ground granulated blast furnace slag. Finally, the client was in full support of our implementation of solar panels, choice of PVC piping, and decision to construct the main box unit out of concrete.

Prototype Development

OUR FIRST PROTOTYPE TEST PLAN:

Goal: to test the functionality and compatibility of the software and electronics systems.

1. Temperature sensor: test whether the temperature sensor registers different temperatures
2. Fan: testing whether the fan turns on, off, and functions appropriately
3. Temperature sensor and fan: testing whether the fan turns on when the temperature sensor reads a specified value

Critical Component Analysis

Monthly Energy Consumption

The electronic systems that consume power in this prototype include the temperature sensor, the fan, and the sump pump. The following diagram assumes that the sump pump will be run twice a month for a 10-minute interval to clear out the system. We also assume that on average the fan will be in use for two hours every day.

MONTHLY ENERGY CONSUMPTION:

Part:	Monthly (30 days) Energy Consumption:
Temperature Sensor, "TMP36GT9Z", Power: 0.000205 Watts.	0.0001476 kWh, negligible. (0.000205W x 720hr)/1000
Fan, "ARCTIC F8 PWM" Power: 1.08 Watts.	0.0648 kWh, (1.08W x 60hrs)/1000
Sump Pump, "Vipe mini micro submersible motor pump"	0.0003366kWh, (0.51 x 0.66)/1000

Power: 0.51 Watts.	

Total: 0.0652842kWh

The following diagram now considers our source of power – the solar panel. Energy production calculations assume that Ottawa receives about 3.9 hours/day of direct sunlight.

MONTHLY ENERGY PRODUCTION:

Part:	Monthly (30 days) Energy Production:
Solar Panel, "CANADUINO 5V", Power: 1 Watt	0.117kWh (1 x 117)/1000

Total: 0.117kWh

From this, we can see that our energy production exceeds our demand. Our final monthly energy consumption is – 0.0517158kWh.

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:

$p_{total} = p_{soil} + p_{water}$

$p_{total} = \rho_s \, g \, h \; + \rho_{sw} \, g \, h_w \quad + \; \rho_w \, g \, h_w$

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.

Durability of Vinyl

Vinyl tubing is a cheaper alternative to materials such as copper, carbon steel, ductile iron, and many other materials used for piping. Vinyl is an extremely common material when working with piping. The flexibility and durability of the material allows it to be utilized in difficult places and adapt to many harsh environments. Vinyl piping can withstand many external pressures that will be applied both under and above ground, this is beneficial due to its low pricing and ability to do many things other types of piping material cannot.

Vinyl Piping durability statistics:

- Tensile strength (psi) of ranges between 1,800 – 2,400
- Maximum working pressures (22°c) of 30 – 50 psi
- Maximum working pressures (51°c) of 15 – 23 psi
- Operating temperature range -23°c - 80°c

The natural lifespan of vinyl pipes fluctuates based off its use and the amount of pressure it experiences overtime. In fact, vinyl piping is meant to last under pressures from water both internally and externally, making it the perfect material to transport and keep out water at a wide range of pressures (psi). Vinyl, like all materials, has its weaknesses: exposure to the sun causes a vinyl pipe to deteriorate and its durability and lifespan can shorten due to damage to the outer layer. This just means that if a vinyl pipe is exposed to the sun, then it should be regularly monitored and replaced when damage occurs, which can be said for all materials under external stresses. Vinyl is known for its durability, flexibility, functionality, and strength, meaning it is an exceptionally reliable material to be using under the circumstances of this project and it will not disappoint, especially considering what you are getting for the price.

Longest Energy Reserve Requirements

Since our system's monthly energy consumption is 0.065, a 1kWh battery charged by solar panels will supply enough power to our system during periods when the solar panels are non-functional. When the battery is fully charged it will allow the system to run without the solar panels for 15 months, which will provide a generous amount of time for the solar panels to be replaced or fixed. Also, since our monthly solar power production is 0.117 kWh, there will be excess energy in the battery if energy production falls below 0.065kWh some months. Power generation is affected by both the weather and time of day, which were crucial considerations when choosing the battery size. In brief, a 1kWh battery will be functional as the system storage battery.

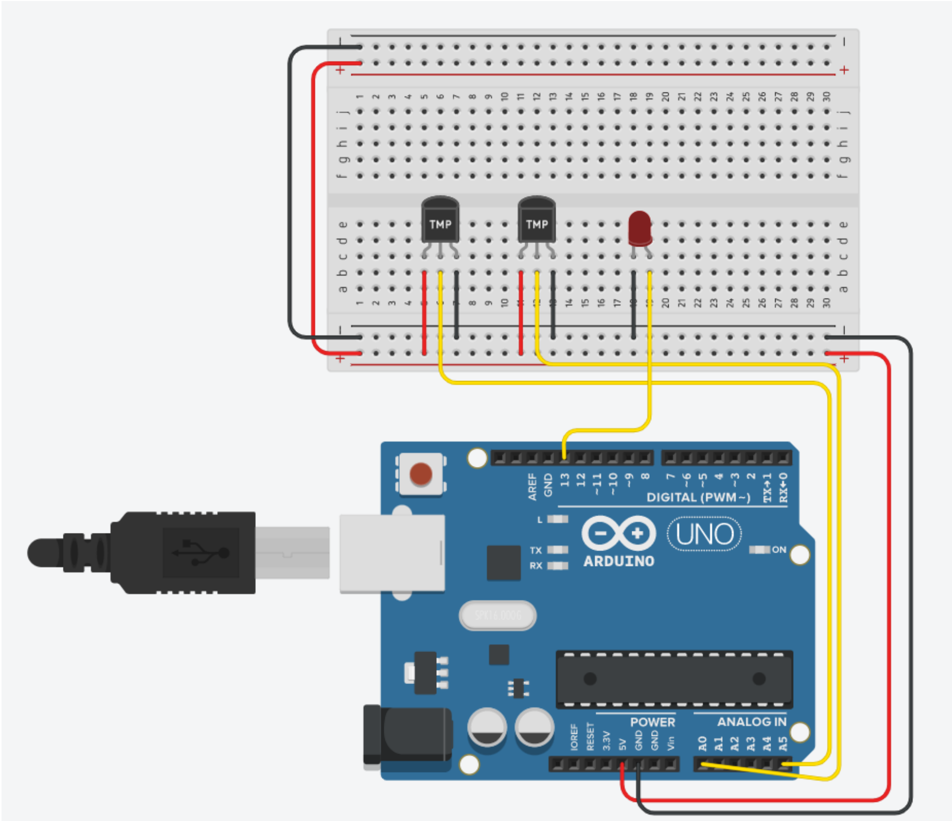
Electrical Materials and Circuits

Arduino UNO microcontrollers, temperature sensors and #24 AWG wires all have very long lifespans and should last more than 30 years if kept in proper condition. Given the fact that our system will not suffer from over voltages, overheating, and electrical discharge, which are the main causes of circuit failure, our system should last a specified lifetime of 40 years.

Prototype Results

```
// C++ code
//
int TH = 5;
int TS = 0;
int FAN= 13;

void setup()
{
 Serial.begin(9600);
}

void loop()

{
  // 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 > 20 && TSC > 20)
  {
    digitalWrite(FAN, LOW);
  }
  // if house > 20 and pipe air < 20 -> fan on:
  else if (THC > 20 && TSC < 20)
  {
    digitalWrite(FAN, HIGH);
  }
  // if house < 20 and pipe air > 20 -> fan on:
  else if (THC < 20 && TSC > 20)
  {
    digitalWrite(FAN, HIGH);
  }
  // if house < 20 and pipe air < 20 -> fan off:
  else if (THC < 20 && TSC < 20)
  {
    digitalWrite(FAN, LOW);
  }

}
```

Circuit for temperature sensors and fan:



Analysis and Results: The four scenarios that we mentioned in our prototype testing plan work in this circuit. Tinker CAD is sometimes inconsistent when the values are too far apart but when we keep the values within a 15 degree range all scenarios work as intended. When we create the physical version of our circuit, we will not use a bread board and instead solder all our wires together to minimize bulk and increase circuit effectiveness. The leftmost temperature sensor is the thermometer while the rightmost sensor is the actual temperature sensor. The fan has been replaced with an LED light that turns on or off depending on the temperatures being read by the sensors. We will add solar panels, the battery, and the sump pump when wiring the physical prototype. Finally, the circuit pictured above is our new updated circuit that we will be using in our final prototype. It is still subject to change, as we need to remove the bread board but the set up will stay the same.

Link to software prototype:

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

Concept Feedback

At our most recent project meeting, our project manager gave us several suggestions for improvement. Firstly, our design drawings were too generalized and hard to edit since they were hand drawn; as such, we are developing CAD models of our system to allow for more detailed and efficient editing. We have managed to finish a part of this objective (the circuit) as seen above. Secondly, it was recommended that we verify the durability of some of our design's materials, which we have researched and detailed in the "Critical Component Analysis" section. Thirdly, we were encouraged to perform some calculations to determine the reliability of our energy source. As detailed in the calculations in the "Critical Component Analysis" section, relying purely on solar power will not only be environmentally sustainable but also provide our system with more than enough energy.

Prototyping Test Plan for Prototype Two

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 box's ability to withstand pressure, (simulating conditions underground)	To simulate the pressure, we will place weights on top of the box. The amount of weight we place on top of the box will correspond to the actual pressure of the soil once the system is buried	If the box survives for 30 minutes and does not collapse under the pressure of the weights, this should be a decent indicator that our design is solid and does not need to be altered. Should we notice any cracks or deformations, we may need to add some internal support inside the system so that it does not collapse.	We plan to have a physical version of our prototype ready by the 12th of march. The actual test should take less then 30 minutes to perform.

2	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. 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.	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 will know we have a breach	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.	The internal pipe system can be tested before the actual box is built. We plan to test it by the 11th of march. The test should take no more than 20 minutes.
3	Verify that the Pipes have a continuous decline. To prevent water stagnation, which can occur if water condensates inside our pipes, we must allow the water to flow downwards towards the sump pump which will expel it from the system.	The pipes must be installed at a small degree decline inside and outside the box to ensure that they will not allow water to stagnate. We will drop a small marble into the air intake pipe to verify the decline.	There are only two possible outcomes in this test: A) The marble comes out from the air outlet B) The marble disappears (remains inside the pipes) Should the marble exit the system, we do not need to make any changes as this demonstrates that there is sufficient decline for objects/substances to flow downwards towards the sump pump. If the marble gets stuck inside the pipe	We will test pipe decline once the main system has been assembled. The actual test should take less than 2 minutes to do. We will be able to test this on the day we finish the pipes.

			system, then we will need to create a steeper decline for our pipes, otherwise we risk water stagnation which can cause unwanted odors.	

Other Objectives:

We want to get feedback on our prototype testing plans from our project managers so we can refine our ideas into better test plans, enabling us to make improvements for our next prototype. Furthermore, we will utilize outside opinions to review our ideas and help identify issues that we may have overlooked.

Citations

Ottawa Solar Power Information: Solar Energy Systems: Solar Panels: Ontario Canada. Ottawa Solar Power Information |Solar Energy Systems |Solar Panels |Ontario Canada. (n.d.). Retrieved March 4, 2022, from http://ottawasolarpower.com/osp2010/solarbasics2.htm#:~:text=The%20average%20amount%20of%20useful,hours%20out%20of%20each%20day.

Curbell Plastics . Vinyl Hose . (n.d.). Retrieved March 6, 2022, from https://www.curbellplastics.com/Research-Solutions/Specialty-Products/Tubing-and-Hose/Vinyl-Hose

The longevity of PVC piping - making it last. PVC Fittings Online. (2020, January 9). Retrieved March 6, 2022, from https://www.pvcfittingsonline.com/resource-center/how-long-pvc-lasts/

https://www.engineeringtoolbox.com/underground-pipe-pressure-soil-transport-d_2145.html

Water Data Brasher Falls. USGS current conditions for USGS 444904074455201 local number, St-40, near Brasher Falls NY. (n.d.). Retrieved March 4, 2022, from https://waterdata.usgs.gov/nwis/uv/?site_no=444904074455201&PARAmeter_cd=72019%2C72020%2C62611

Annual Water Statistics for Brasher Falls. USGS Surface Water Data for USA: USGS surface-water annual statistics. (n.d.). Retrieved March 6, 2022, from https://waterdata.usgs.gov/nwis/annual?referred_module=sw&search_site_no=01639000&format=sites_selection_links

Soil Horizons and landscapes. Soil Landscapes. (n.d.). Retrieved March 6, 2022, from http://www.soilinfo.psu.edu/index.cgi?soil_land&us_soil_survey&map&pa&Centre&soil_info&soil_genesis&lab_soil_char&clay

Underground pipes - earth pressure. Engineering ToolBox. (n.d.). Retrieved March 6, 2022, from https://www.engineeringtoolbox.com/underground-pipe-pressure-soil-transport-d_2145.html

How strong is PVC pipe? How Strong are PVC Pipe Comments? (2020, May 21). Retrieved March 6, 2022, from https://www.pvcfittingsonline.com/resource-center/strength-of-pvc-pipe-with-strength-chart/