Wesley Garcia
Noah Kincheloe
Randall Holgate
Brittney Rogers
Jessie Russell

Red Feather B12 Capstone Final Presentation

Background

- Red Feather does work primarily on the Hopi Reservation and in Navajo Nation
- Many homes on the Navajo nation and Hopi Reservation don't have adequate sources of heat during the evening, many rely on coal or wood-fired stoves
- They have started implementing solar furnaces, but that doesn’t provide heat at night

Project Description

- The project is to create a thermal storage device that can store enough heat to warm a house at night.
- All the materials used must be locally sourced, easy and within the budget set by Red Feather
- The design for the thermal storage device needs to be straight forward and not too large
- It needs to be reliable and durable in the environment it is in

Design Requirements

Engineering Requirement	Derived from this Customer Need	Method of measurement	Unit of Measurement	Target ER	Proof
Device maintains consistent house air temperature (60deg F)	Device should maintain comfortable indoor temperature throughout night	Thermometer Temperature Sensor for temperature of air	Fahrenheit BTU/h	60F 10,000 BTU/h	To meet this, device must output 10,000 BTU/hr. This number is based on the output of modernized hybrid stoves used on the Navajo reservation as part of their air quality control program, and is intended to reflect the type of heat source the project intends to replace [1]
Device works in environments with outside temperatures ranging from 20 degrees to 60 degrees Fahrenheit.	Device should provide consistent heat source to keep houses warm at night, functioning within standard season range of Navajo Nation and Hopi Reservation temperatures.	Thermometer or Temperature sensor	Fahrenheit	20-60F	Heat loss calculations based on a house with concrete block structure, plywood floors and ceilings, and aluminum siding determined a heat loss roughly equal to the above 10,000 BTU/hr number. As such, the device must be able to maintain this heat output over the course of several cycles of operation on cold nights. Equation: $Heat\ Loss = \frac{A_{surf} * \Delta t}{R_{surf}}$
Device stores heat in an effective method.	Device should provide consistent heat source to keep houses warm at night AND device should store heat during the day and release it at night.	Heat equation, using mass, material qualities such as the specific heat of the medium fluid, and a measured change in temperature	Fahrenheit	175F	It was necessary to find a thermal fluid that could most efficiently store the required amount of heat. The following equation was used: Q=cmΔt to calculate the necessary volume of different storage fluids, which were tabulated for comparison.

Heat Transfer Fluid Comparison Table

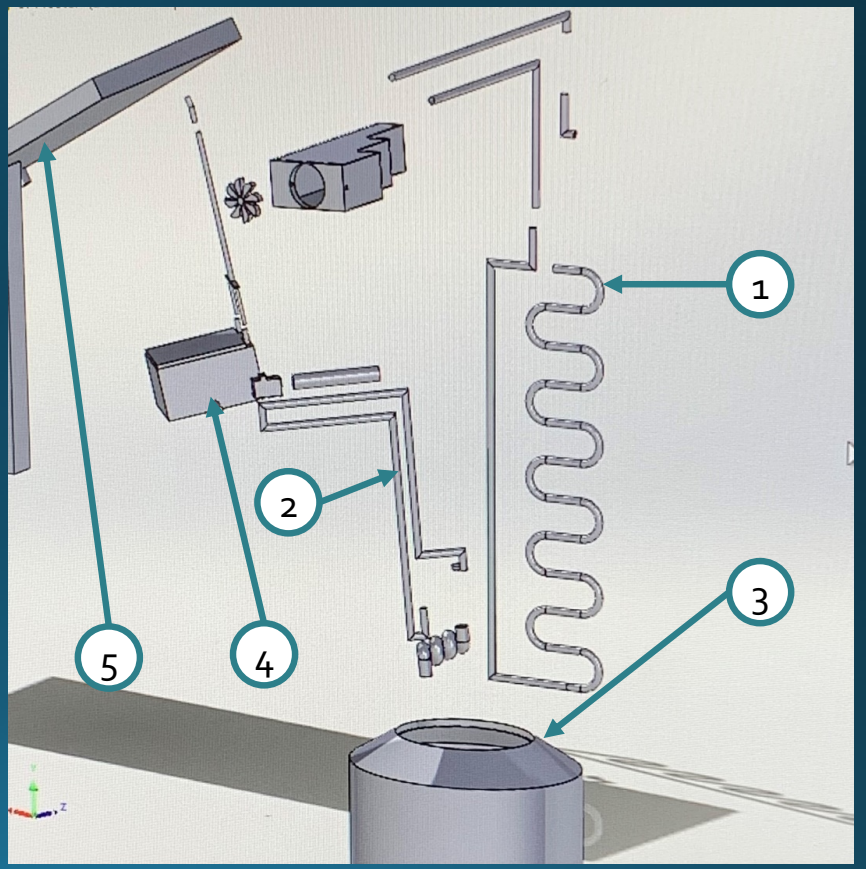
Name	Density	Specific Heat	delta T (F)	Q (BTU)	mass (lb)	volume (ft^3)	volume (gallon)
Fresh Water	62.4	1	115	140000	1217.391	19.50947603	145.9410256
Salt Water (Sea)	63.93	0.938	115	140000	1297.859	20.30124407	151.8638623
Ammonia (176°F)	38.55	1.29	115	140000	943.7142	24.48026432	183.1251068
20% Propylene Glycol Solution	62.7	0.968	115	140000	1257.636	20.05798477	150.0441562
20% Ethylene Glycol Solution	63.8	0.96	115	140000	1268.116	19.87642542	148.6859979

Design Requirements continued…

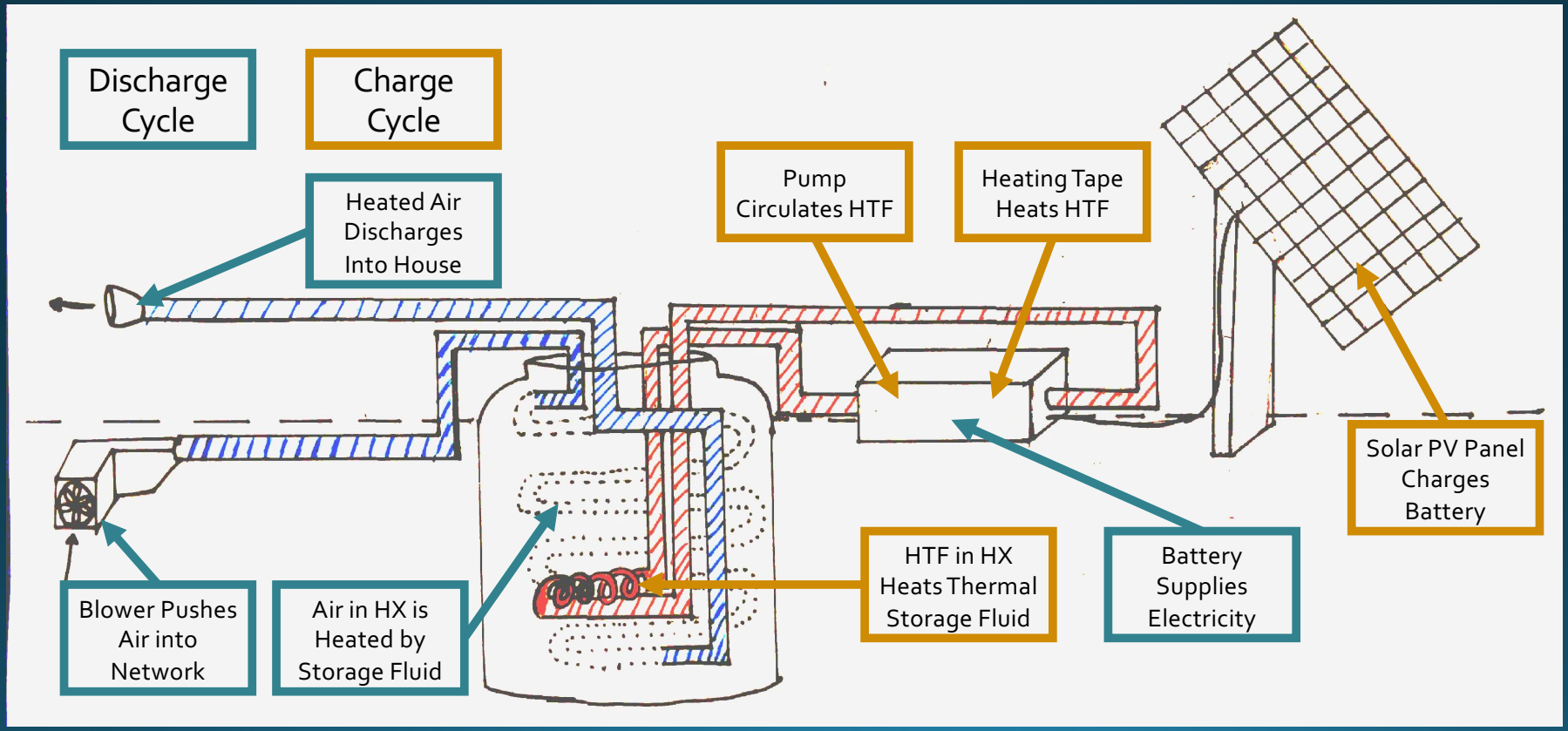
Device budget is within $1,500	Device should be within purchasing capabilities of Red Feather and the relevant clients.	Pricing	Dollars	$1,500	On Bill of Materials the total cost is $1251.51
Device has no more than 12 unique parts.	Design should be straightforward.	Counting	Unitless	<=12	On Bill of Materials there are 11 parts
Device able to install onto a variety of homes.	Device geometry should fit a variety of housing situations (no roof cave-ins)	Device dimensions and weight	Feet, Lbs.	4ft.x 8ft <500 lbs.	Reference Bill of Materials
Materials should have minimal delivery (transit) time	Materials should be readily available in the region	Transit time of materials	Miles	<150 miles	Distance from/to a Home Depot: 39.3 miles from Leupp 48 miles from Cameron 62.4 miles from Joseph City 62.4 miles from Bird 74.1 miles from Tuba City 103 miles from Hopi Reservation
Device should work without interruption or maintenance.	Design a reliable design.	Amount of time device works without stopping	Days	7 days	We will need to test the device by running it without interruption to see if it continues to work or fails. This is one of the testing procedures for next semester.
Device should be able to withstand all weather conditions.	Create a durable and robust design.	Amount of water on the electronics case that can be withstood over time.	Lbf, Volume of water	5 gallons of water	Test the waterproof case next semester

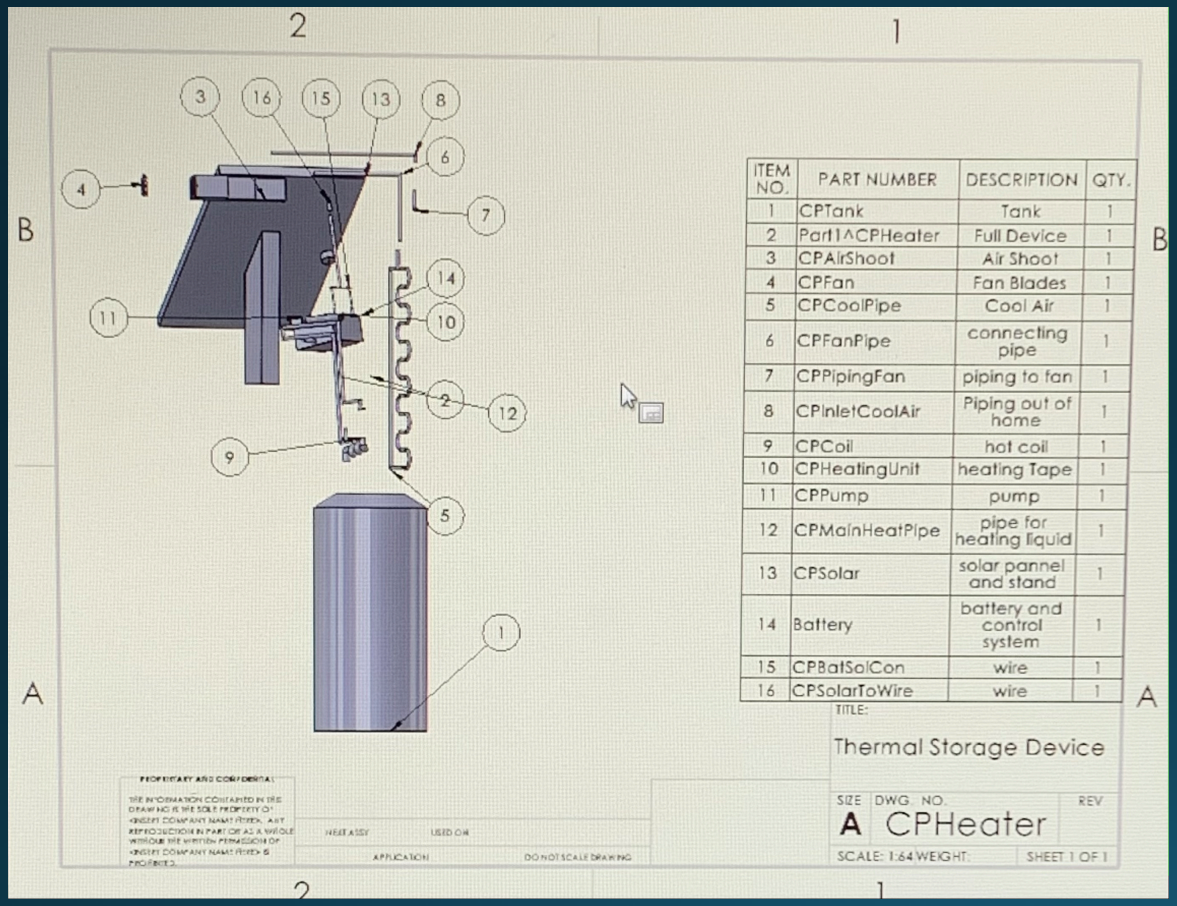
Design Description

- Current design features 5 main subsystems
  1. Air Pipe Network
  2. Fluid Heating Network
  3. Storage Tank
  4. Control System
  5. Power supply



Full System Schematic

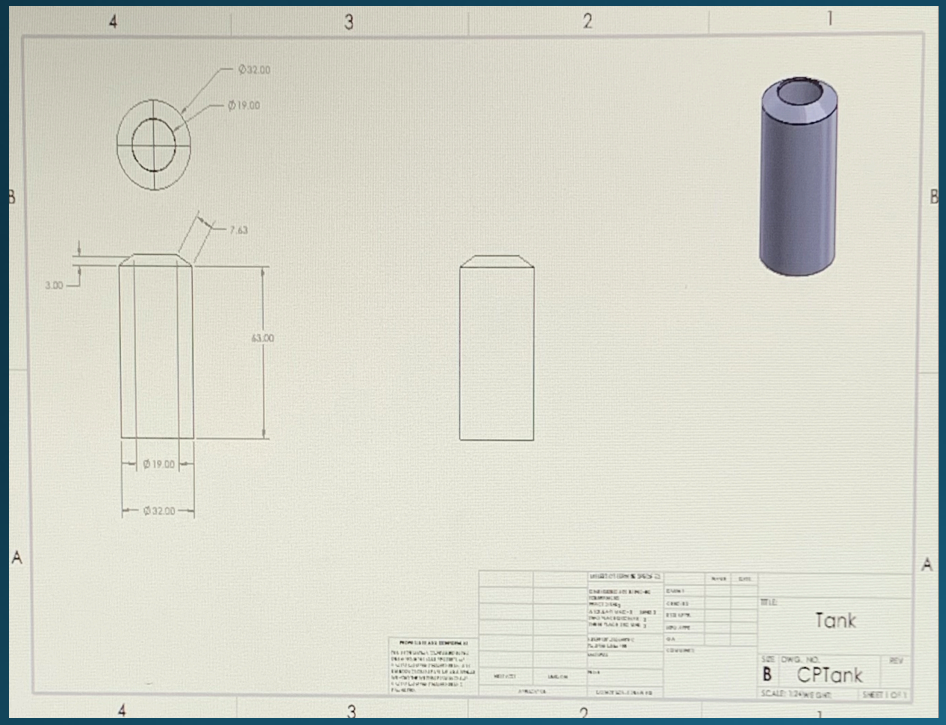




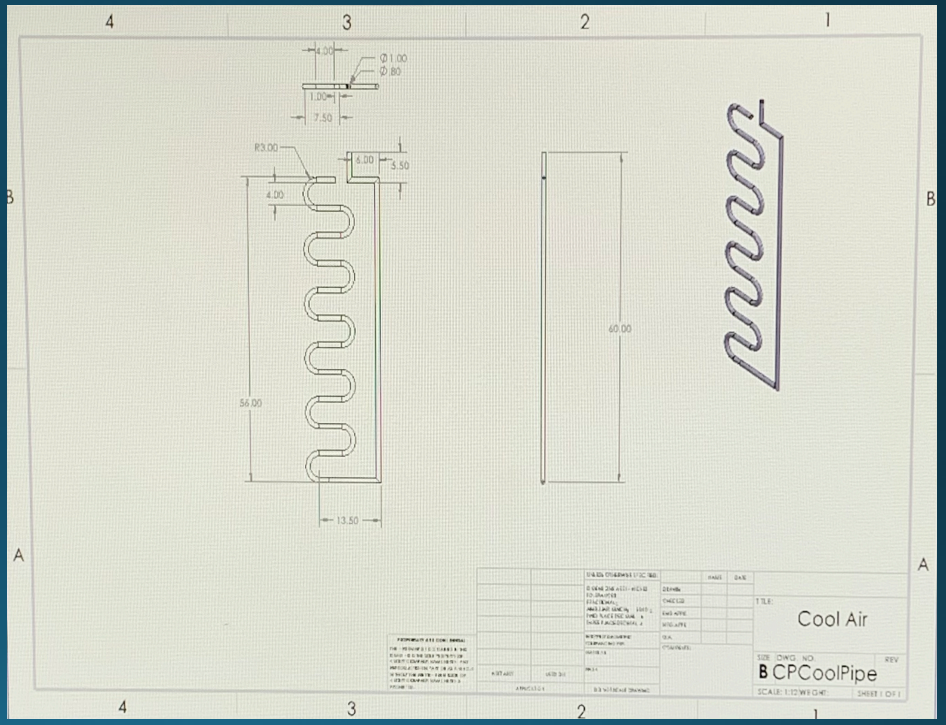
CAD Draft

- The Design has 16 parts in total.
- Tank acts as housing unit to most of the parts
- Each part is shown extended up from the tank

Critical Parts and Their Dimensions

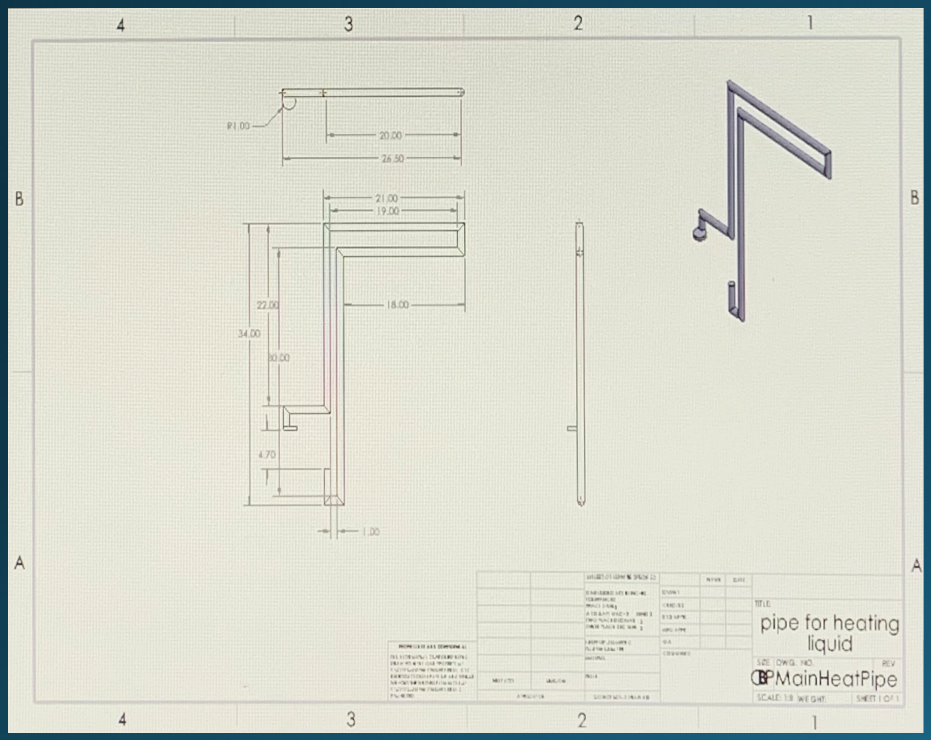


Tank

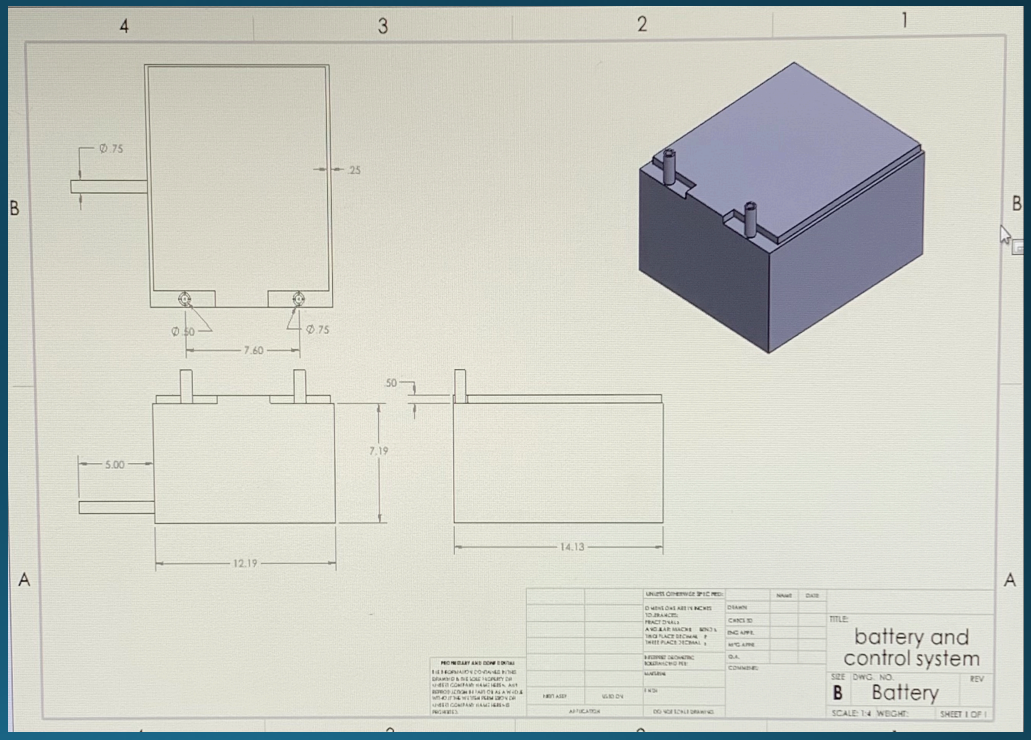


Air circulator

Critical Parts and Their Dimensions Cont.



Heating Fluid circulator



Battery and Control System

Design Validation

- Potential Critical Failures
  - 10 Most likely critical failures involve **high temperatures damaging to** piping and metals in heat exchangers and thermocouples and **corrosion from chemical changes and bacteria.**
  - Other critical failures involve corrosion pitting, crevice corrosion, fretting corrosion, stress corrosion, erosion corrosion, thermal shock, high and low cycle fatigue, caused by **high velocity of the fluid**, **poor insulation against cold temperatures**, and **broken belts and parts within the heating pump.**

Design Validation

- Risk Trade-offs
  - No Risk mitigation works as a detriment to any others
  - Mitigating risk from temperatures requires higher quality, more expensive metals
  - Mitigating risk from chemical and bacterial damage requires addition of phosphate or algae, as more expensive additions to the fluid and piping
  - Mitigating risk from high velocity fluids involves increasing the diameter of the pipe, which only makes finding parts more difficult
  - Mitigating risk from freezing involves creating more insulation for the storage tank

Design Validation

- **Testing Procedures: (performed at Engineering Building)**
  - **Testing Procedure #1: Consistent air temperature: 10,000 BTU/h over 14-hour night**

  We will run the device for 14 hours at night and use thermocouples to measure temperature and then calculate the amount of BTU/h the device output.
  - **Testing Procedure #2: Operating in outdoor temperature range: 20-60 degrees Fahrenheit:**

  Set up the device to run nonstop throughout a 14-hour night outside in temperature ranging from 20 to 60 degrees Fahrenheit.
  - **Testing Procedure #3: Thermal Storage Tank: To see if device stores heat in an effective method**

  Measure the temperature of the water of the storage tank to see if it maintains 175 degrees Fahrenheit over 14 hours.

Design Validation

- **Testing Procedures**
  - **Testing Procedure #4: The Device is within $1,500 budget**

  We will check the Bill of Materials to see if the total cost is within budget.
  - **Testing Procedure #5: Device Simplicity: Device has no more than 12 unique parts**

  We will check the Bill of Materials to see if there are more than 12 unique parts.
  - **Testing Procedure #6: Device can install onto a variety of homes:**

  Check dimensions with measuring tape to see if they are within 4ft x 8ft and under 500 lbs.

Design Validation

- Testing Procedures
  - **Testing Procedure #7: Materials should have minimal delivery time**

  We will check mile radius on locations to see they are within 150 miles of a Home Depot, where most supplies are available.
  - **Testing Procedure #8: Device should work without interruption or maintenance:**

  Run device without interruption for 7 days straight to check for any interruptions
  - **Testing Procedure #9: Device should be able to withstand all weather conditions:**

  We will submerge the electronic components case within a bucket of water of 5 gallons to see if the water is sealed out, or if any water gets through

Next Semester Schedule

Task	Plan Start Date	Plan End Date
Finalizing and Purchasing Parts (including Testing Procedure parts)	1/11/2021	1/25/2021
Meet with Clients	1/15/2021	1/29/2021
Website Development Check-up	1/27/2021	2/3/2021
Concept Check-up	2/3/2021	2/5/2021
Building Prototype	2/5/2021	2/12/2021
Parts Analysis	2/17/2021	2/26/2021
Testing Procedures	3/5/2021	3/13/2021
Testing Procedures Results/Analysis	3/17/2021	3/27/2021
Meet with Clients	3/31/2021	4/2/2021
Preliminary Report	3/31/2021	4/11/2021
Final Report	4/14/2021	4/25/2021
Website Final Check-up	4/21/2021	4/25/2021

Bill of Materials and Budget

Bill of Materials							
Part number	Part description	Manufacturer	Dimensions	Weight	Quantity	Unit Cost	Total Cost for Part
1	Heating Fluid Pump	Ferroday	10.2 x 7.6 x 6 inches	4.59 lbs.	1	$79.99	$79.99
2	Liquid to Liquid Heat Exchanger	Duda Energy	7.5" x 2.9" x 2" 2.58 ft2	N/A	1	$57.55	$57.55
3	Liquid to Air Heat Exchanger	Outdoor Furnace Supply	24" x 24"	N/A	1	$225.00	$225.00
4	Heating Band	Omega	8 ft length, 1 in width	N/A	1	$93.49	$93.49
5	Copper Piping	Cambridge-Lee	10' and 1" dia	N/A	1	$34.77	$34.77
6	Storage Tank	Norwesco	32" dia. x 67"H and 210 gallons	65 lbs.	1	$276.00	$276.00
7	Fan	Ridgid	13 x 12.3 x 10.6 in	12.25 lbs	1	$79.97	$79.97
8	Battery	Crown	12.19 x 7.19 x 14.13 in	92 lbs.	1	$235.00	$235.00
9	Electricity Solar Panel	Canadian Solar	3.44 ft x 6.92 ft	N/A	2	$71.88	$143.76
10	Arduino	ELEGOO	3.15 x 2.36 x 0.39 in	2.24 oz.	1	$12.98	$12.98
11	Thermocouples	Aideepen	3.7 x 3.1 x 0.3 in	0.81 oz.	5	$2.60	$13.00

References

[1] M. K˙ng, "NAVAJO NATION EPA AIR QUALITY CONTROL PROGRAM INDOOR AIR QUALITY." [On ˙ne]. Ava˙ ab e: https://www.env.nm.gov/wp-content/uploads/sites/2/2016/11/Navajo-Nation-EPA-Indoor-Air-Quality.pdf. [Accessed: 15-Nov-2020].