Red Feather 20F02 Capstone Midterm Presentation

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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

Full System Schematic

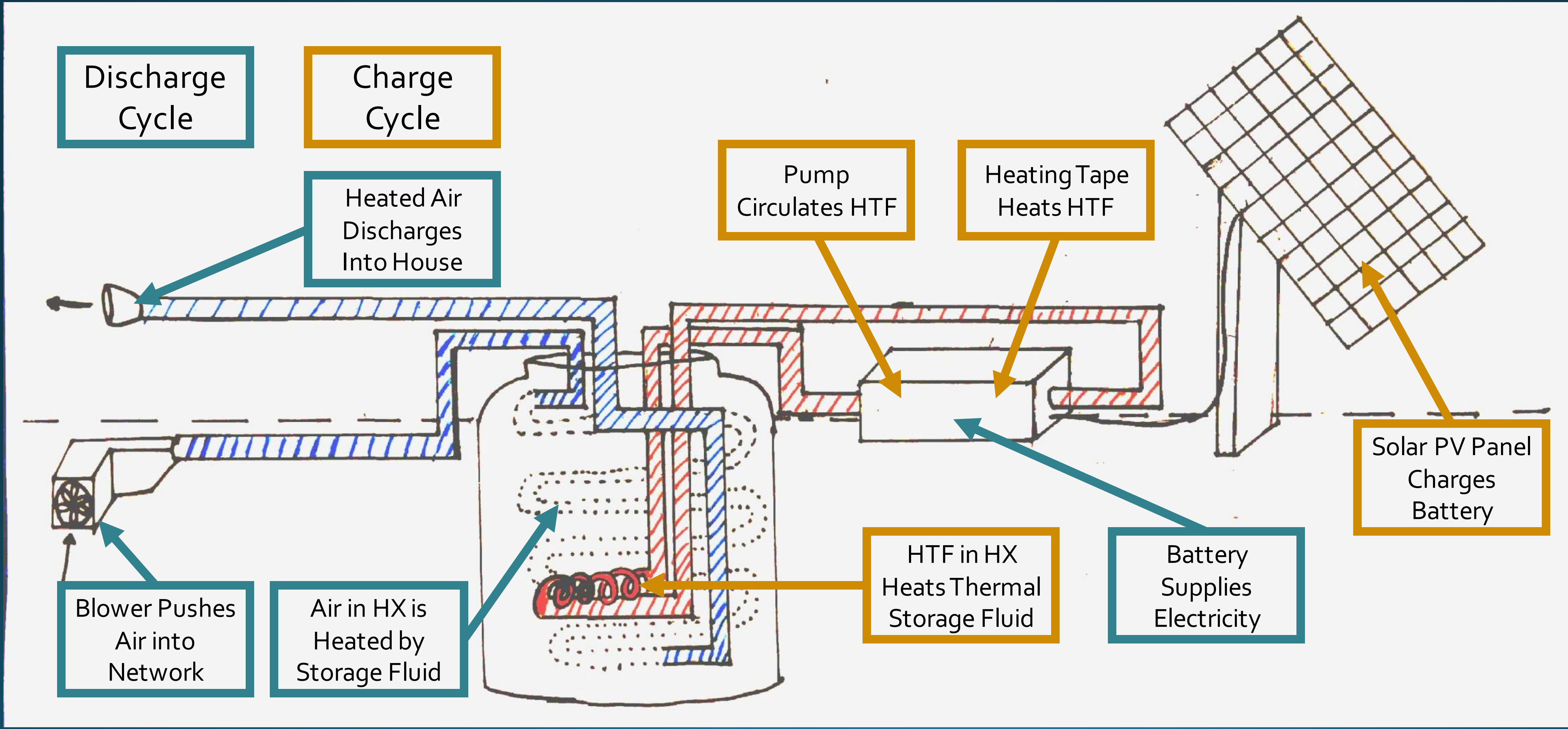

Figure 1: Full System Schematic

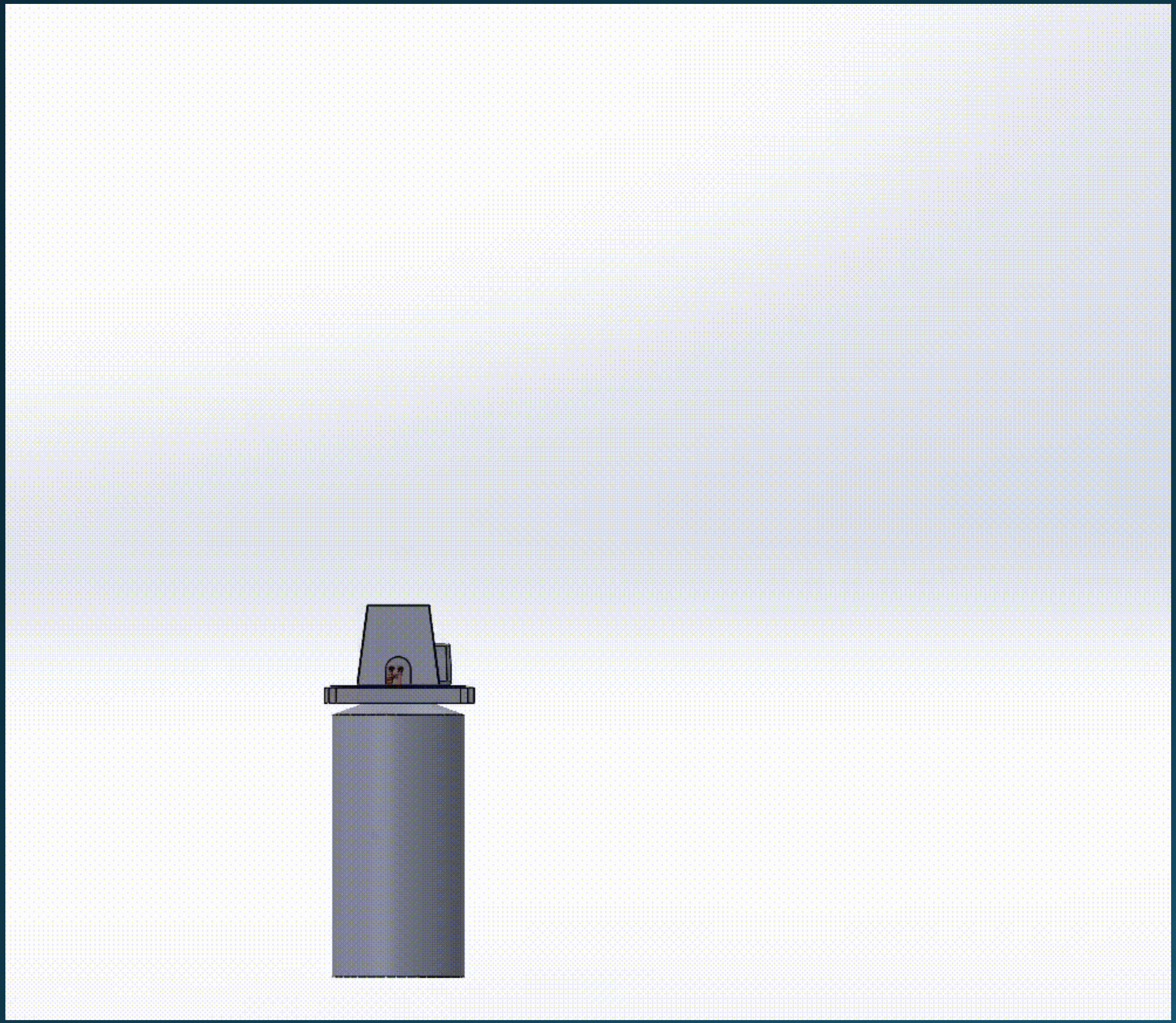

Figure 2: CAD Assembly GIF

CAD Draft

- The Design features 5 main subsystems.
  1. Air Pipe Network
  2. Fluid Heating Network
  3. Storage Tank
  4. Control System
  5. Power supply
- Tank acts as housing unit to most of the parts

Current State of System

Our current system is yet to be fully assembled but is current in several partially assembled pieces (Subassemblies).

Figure 3:
Air to Liquid Heat Exchanger

Figure 4:
Liquid to Liquid Heat Exchanger

Figure 5:
Bulk Components

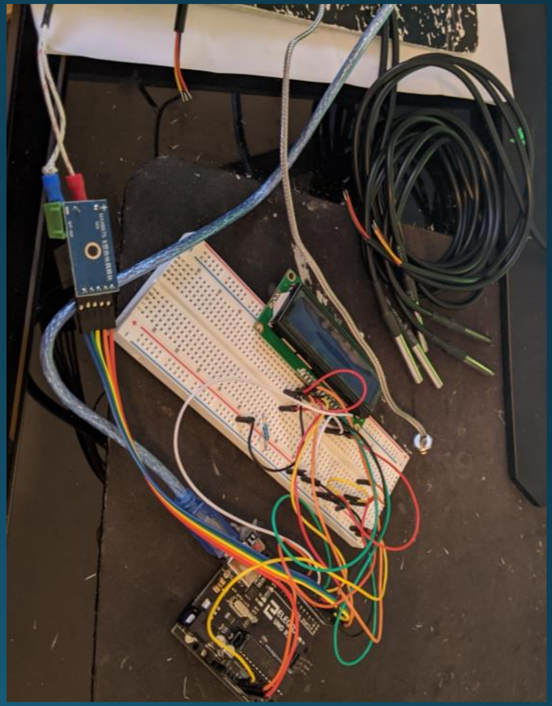

Figure 6:
Electrical Components

Current State of System

- Purchasing: Randall
- Arduino: Jessie & Randall
- CAD Updating: Noah
- Website: Noah
- Liquid to Air Heat exchanger assembly: Randall, Jessie, Wesley, Brittney
- Liquid to Liquid heat exchanger assembly: Randall, Jessie, Wesley, Brittney
- Total Assembly: Randall, Jessie, Wesley, Brittney
- Solar Panels and Integration: Brittney
- Analysis of systems: Wesley & Noah
- Scheduling: Jessie
- Bill of Materials: Brittney, Wesley, Noah

Bill of Materials and Budget

Key:			
(green)	Delivered	(yellow)	Not ordered, need to order
(blue)	Ordered, Not Delivered	(orange)	Not ordered, do not need to order

	Part number	Part description	Manufacturer	URL	Dimensions	Weight	Quantity	Unit Cost	Total Cost for Part
ordered	1	Heating Fluid Pump	Ferroday	https://www.amazon.com/Ferroday-Magnetic-Temperature-Stainless-Thread/dp/B073P19L8P/ref=pd_sbs_328_1/135-2595842-7354842?_encoding=UTF8&pd_rd_i=B073P19L8P&pd_rd_r=ba90b309-a961-43fb-bdb2-05d75ae8fab7&pd_rd_w=bcJPj&pd_rd_wg=U2bs7&pf_rd_p=52ff3488-8ecd-4341-9663-52e4fb00f500&pf_rd_r=YC463V2QZJBD08AYDTSX&psc=1&refRID=YC463V2QZJBD08AYDTSX	10.2 x 7.6 x 6 inches	4.59 lbs.	1	$79.99	$79.99
	2	Liquid to Liquid Heat Exchanger	AB	https://www.amazon.com/dp/B07R5BQP2L/ref=sspa_dk_detail_1?pd_rd_i=B07R5BQP2L&pd_rd_w=yBKnN&pf_rd_p=45e679f6-d55f-4626-99ea-f1ec7720af94&pd_rd_wg=CYJ6R&pf_rd_r=5ACG1DKCCK9MZH7J4CYE&pd_rd_r=c51dabc0-afe2-44b9-aae5-91bd7c88573c&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExNlAwMDBITjFXTVZGJmVuY3J5cHRlZElkPUEwMjQ3MzYzM1NNN0OwTlkxUUxRUiZlbmNyeXB0ZWRBZElkPUEwODE4NDY1MkJZSzRJUEZDQVM3OCZ3aWRnZXROYW1lPXNwX2RldGFpbCZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU&th=1	3"x8" 10 plates	3.29 lbs	1	$89.99	
ordered	3	Heating Band	heating Element Plus	https://www.heatingelementsplus.com/heat-tape-heating-cord/high-temp-fiberglass-heat-tape-br-up-to-1400-degrees/high-temperature-standard-insulated-heating-tapes/high-temp-standard-insulated-heating-tape-1-x-96-1250-watt.html	1" x 96"		1	$119.90	$119.90
Ordered	4	Copper Piping	Cambridge-Lee	https://www.lowes.com/pd/Cambridge-Lee-1-in-x-10-ft-Copper-L-Pipe/1000044589?cm_mmc=shp-_-c-_-prd-_-plb-_-google-_-lia-_-142-_-potablepipefittings-_-1000044589-_-0&placeholder=null&gclid=CjwKCAiAtK79BRAIEiwA4OskBieNJBtxiW6WxQu2XLfV5hxMUhq_50uOJ_XNZdD2C9cjECTRtcSVxxoCW54QAvD_BwE&gclsrc=aw.ds	10' and 1" dia		1	$34.77	$34.77
Ordered	5	Storage Tank	Norwesco	https://www.plastic-mart.com/product/472/210-gallon-vertical-plastic-storage-tank-47401?gclid=Cj0KCQjw59n8BRD2ARIsAAmgPmIpnAwtD2eT9_JZJRKWsWW9mAILJBj_wzSvRuY9e47--Bg0pCJw29gaAhNpEALw_wcB	32" dia. x 67"H and 210 gallons	65 lbs.	1	$578.33	$578.33
ordered	6	Fan	Ridgid	https://www.homedepot.com/p/RIDGID-600-CFM-Portable-Blower-Fan-Air-Mover-with-Daisy-Chain-AM2265/301703580#overlay	13 x 12.3 x 10.6 in	12.25 lbs	1	$79.97	$79.97
ordered	7	Battery	Crown	https://unboundsolar.com/9960167/crown/batteries/crown-cr305-6v-flooded-battery	12.19 × 7.19 × 14.13 in	92 lbs.	1	$235.00	$235.00
ordered	8	Electricity Solar Panel	Grape Solar	https://www.homedepot.com/p/Grape-Solar-50-Watt-Polycrystalline-Solar-Panel-for-RV-s-Boats-and-12-Volt-Systems-GS-STAR-50W/206869234	26.18" x 24.4"	10.58 lbs	2	$51.41	$102.82

Bill of Materials and Budget

Ordered	9	Arduino	ELEGOO	https://www.amazon.com/ELEGOO-Board-ATmega328P-ATMEGA16U2-Compliant/dp/B01EWOE0UU/ref=sr_1_3?crid=FU07R7F1O3EX&dchild=1&keywords=arduino+elegoo+uno+r3&qid=1605133159&sprefix=arduino+elegoo%2Caps%2C202&sr=	3.15 x 2.36 x 0.39 in	2.24 oz.	1	$12.98	$12.98
Ordered	10	Thermocouples	Aideepen	https://www.amazon.com/Aideepen-DS18B20-Waterproof-Temperature-Stainless/dp/B01LY53CED/ref=sr_1_9?dchild=1&keywords=thermocouple+arduino&qid=1605133670&sr=8-9	3.7 x 3.1 x 0.3 in	0.81 oz.	5	$2.60	$13.00
	11	Electronics Case		https://www.amazon.com/SOCKiTBOX-Weatherproof-Connection-Electrical-Transformers/dp/B00274SLK8/ref=asc_df_B00274SLK8/?tag=hyprod-20&linkCode=df0&hvadid=198064502357&hvpos=&hvnetw=g&hvrand=17172852412394839608&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9030289&hvtargid=pla-351181085901&th=1			1	$22.99	$22.99
Ordered	12	Piping Clamp		https://www.homedepot.com/p/FabTek-Logic-Fin-Clamp-Baseboard-Element-for-1-in-Copper-Baseboard-Piping-2-ft-Section-FCL-1-0CX2FT/301076355			1	$80.28	$80.28
	13	Propylene Glycol	Dynalene	https://www.dynalene.com/product/propylene-glycol-dynalene-pg-xt/		10 lbs	1 (gal)	$38.00	
	14	Copper Piping	Home depot	https://www.homedepot.com/p/Cerro-1-2-in-x-10-ft-Copper-Type-M-Hard-Temper-Straight-Pipe-1-2-M-	10' and 1/2" dia		3	$11.27	$33.81
	15	Round metal pipe duct	Home depot	https://www.homedepot.com/p/Master-Flow-10-in-x-5-ft-Round-Metal-Duct-Pipe-CP10X60/100204114	12" x 5'		1	$16.80	$16.80
	16	Gas can	Home depot	https://www.homedepot.com/p/Garage-Boss-Press-N-Pour-5-Gal-Gas-Can-GB351/307464272?	5 gallons; 14" x 7"		1	$23.97	$23.97
	17	Copper coil piping	AZ central supply		1/2" x 50' Copper coil		2	$62.00	$124.00
	18	90 degree bronze fittings	Home depot	https://www.homedepot.com/p/Everbilt-1-2-in-Forged-Bronze-Lead-Free-Pressure-90-Degree-Cup-x-FIP-Elbow-Fitting-C7073LFHD12/204620762?NCNI-5	1/2" 90 degree bronze elbow		2	$7.93	$15.86
	19	Solder	Home depot	pot.com/p/Oatey-Safe-Flo-8-oz-Lead-Free-Silver-Solder-W	8oz. lead free solder		1	$20.95	$20.95
	20	90 degree fittings	Home depot	https://www.homedepot.com/p/Everbilt-1-2-in-Copper-Pressure-90-Degree-Cup-x-Cup-Elbow-Fitting-C607HD12/204620176	1/2"		5	$0.74	3.70
	21	cover	Home depot	https://www.homedepot.com/p/Hanover-20-in-White-Resin-Beadboard-Square-Planter-HD1114-	20"		1	$39.98	$39.98
	22	wood	Home depot				3	$1.69	$5.09
	23	couplings	Home depot	https://www.homedepot.com/p/Everbilt-3-8-in-x-1-2-in-Copper-Pressure-Fitting-x-Cup-Reducer-C600HD21238/204620287	3/8" x 1/2"		4	$1.76	$7.04
	24	cpvc pipes	Home depot	https://www.homedepot.com/p/Charlotte-Pipe-3-4-in-x-2-ft-CPVC-Water-Supply-Pipe-CTS-12007-0200/203019298	3/4" x 2'		6	$2.16	$12.96
							Total Cost for Design		$1,664.19

Implementation Plan

- Final prototype manufacturing begins with subassembly preparation
  - Heat exchangers should be coiled to fit the duct
  - Heat exchangers are completed by soldering on appropriate pipe extensions and fittings
  - Next, it is necessary to build the tank cap housing, which will be made from 2x4 wood pieces, plywood, and a planting box.
  - Once the cap is completed, the reservoir, pump, and pipe fixtures can be mounted or removed as needed for testing
  - Holes are drilled in the lid of the water storage tank, and fluid storage reservoir
  - Heating tape should be wrapped around a length of straight pipe that is attached to the pump

Figure 7: Coiling the Heat Exchangers

Implementation Plan

- Prior to full assembly, the team will test each heat exchanger
  - Circulation and electronics tests for each
  - Electronics testing determines basic functionality of systems
  - Circulation testing runs air or water through the heat exchangers, checking for leaks and pump or blower deficiencies
- Once this is complete, the team can move to assembly
  - The two coiled heat exchangers should first be nested together in the duct. The liquid-to-liquid heat exchanger is on the bottom to facilitate convection
  - The Liquid to air heat exchanger on top and is supported /suspended by four horizontal pipes
  - Once the duct package is assembled, it should be carefully lowered into the tank with the four inlet/outlet pipes arranged at the top

Figure 8: Ensuring that heat exchangers fit in the duct

Implementation Plan

- Assembly (continued)
  - The team will cut the manway lid according to the heat exchanger in/out arrangement
  - After this the lid is replaced, and the cap set on top
  - The reservoir and piping for the liquid-to-liquid heat exchanger will then be filled with a 5% propylene glycol solution. Once full, run the pump, adding additional fluid if needed. Watch to make sure it operates nominally
  - External pipes should then be joined to the heater and pump setup, as well as the duct system and fan blower responsible for delivering the system's heat
  - Once these are installed, the team will carefully connect solar panels, battery, and any other remaining electrical components

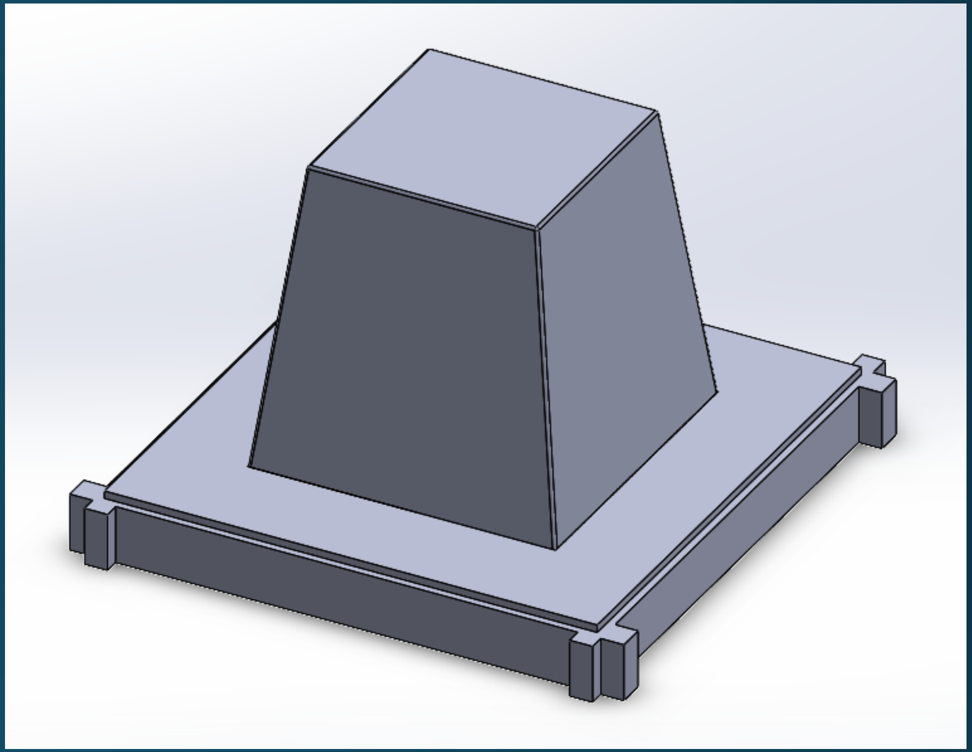

Figure 9: Current Tank Cap Design

Implementation Plan

- …Once the heating loop has been filled and is running properly, the Arduino system should reflect this
  - Since the loop should remained filled with fluid, the pump can be turned off and on as needed
  - The device should operate automatically once time is set, based on sensor inputs
  - During the day, it will begin the "charge" (heating) loop. At night, the discharge loop should release heat through the duct into the desired area
    - This should probably be based on both temperature and time
  - After initiating the loop, and starting the device, it should cycle through processes as designed.

Implementation Plan

- Who oversees what in the future:
- Tech Analyses:
  - Piping/HVAC/Circulation – Wesley
  - Heating Loop #1: Heat input to tank, pump, liquid to liquid – Noah
  - Heating Loop #2: Heat exchanger and heat coil, liquid to air – Randall
  - Solar Panels: How to connect, series/parallel – Brittney
  - Heating tape/Heating up water pump – Jessie

- **After Tech Analyses:**
  - Finish CAD/Update Website – Noah
  - Testing/Analyzing Tests – Team
  - Final Report/Presentation – Team
  - Poster - Team

Testing Plan (Components)

The First major testing will be done on the 2 main subsystems

Subsystem 1: Liquid to Air Heat Exchanger

- Basic test of electrical components to see if they are functioning properly.
- Testing will be done for how well the air circulates through the piping system. This includes testing waterflow throughout the heat exchanger to see if there are any leaks

Subsystem 2: Liquid to Liquid Heat Exchanger

- Preform basic test on electrical components to see if they are functioning properly.
- Testing will be done to see how well the Propylene Glycol circulates through the piping.

Required materials for testing:

1. Anemometer
2. Blower
3. Water (acting as liquid substitute for propylene glycol)
4. Arduino and LCD Thermostat
5. Thermocouples

Deliverables:

1. Air Velocity
2. Evidence of water leaking/not leaking

Testing Plan (Full Assembly)

Final phase of testing:

1. First a basic testing proving that all the electrical components are functioning correctly will be taken
2. From there a test will be taken to see how hot the water inside the tank will get given its starting temperature and time given for it to heat up
3. With this understood the liquid to air heating loop will be testing similarly comparing the inlet and outlet air to see how much change in temperature is occurring given the starting temperature of the air and liquid
4. Test how long the device runs uninterrupted
5. Finally, make sure the electronic components are protected from water

Required materials For testing:

1. Propylene Glycol
2. Arduino and LCD Thermostat
3. Thermocouples
4. Anemometer

Deliverables:

1. Air Velocity
2. Air/Liquid Temperatures
3. Time for temperature changes
4. BTUs (Calculated from Temperature change and material properties)
4. Uninterrupted run time of device

Engineering Requirements (1-4)

Engineering Requirement	Derived from this Customer Need.	Method of measurement	Unit of Measurement	Target ER	Testing Procedure
Device maintains consistent house air temperature (60deg F)	Device should maintain comfortable indoor temperature throughout night.	Thermometer or Temperature Sensor for temperature of air	Fahrenheit BTU/h	60F 10,000 BTU/h	Over a 14-hour period, the device outputs 10,000 BTU/h
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	Run device for several day/night cycles with projected lows around 20 F; if device maintains minimum heat output over 20 or sub 20 F nights, it passes the test
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	Measure the temperature of the water of the storage tank. Over 14 hours, how much does the temperature decrease?
Device budget is within $2,000.	Device should be within purchasing capabilities of Red Feather and the relevant clients.	Pricing	Dollars	$2,000	Bill of materials

Engineering Requirements (5-9)

Engineering Requirement	Derived from this Customer Need.	Method of measurement	Unit of Measurement	Target ER	Testing Procedure
Device has no more than 12 unique parts.	Design should be straightforward.	Counting	Unitless	<=12	Bill of materials
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 weig ht	Feet, Lbs.	4ft.x 8ft <500 lbs.	Measuring tape 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	Odometer
Device should work without interruption or maintenance.	Design a reliable design.	Amount of time device works without stopping.	Days	7 days	Device functions without stopping for at least one week.
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	Submerge the electronic components case within a bucket of water to see if the water is sealed out.

Future Work Schedule

Completed:

Gantt Chart

Select a period to highlight at right. A legend describing the charting follows.

ACTIVITY	Start Date	End Date	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Finalizing and Purchasing Parts	1/11/2021	1/25/2021	1	2	1	2	100%
Self-Learning	1/15/2021	1/22/2021	1	2	1	2	100%
Meet with Clients	1/18/2021	1/29/2021	2	2	2	2	100%
Website Check-up	1/18/2021	1/25/2021	2	2	2	2	100%
Building Session #1: measurements, make H.X.#1	2/5/2021	2/7/2021	4	1	3	2	100%
Arduino Workshop	2/12/2021	2/28/2021	5	3	5		85%
Building Session #2: Modify tank lid, make H.X. #2	2/19/2021	2/21/2021	6	1	6		50%
Update CAD	2/19/2021	3/21/2021	6	5	3		60%
Implementation Memo	2/22/2021	2/26/2021	7	2	3		75%
Midpoint Presentation	2/24/2021	2/28/2021	8	2	4		100%

To be completed:

ACTIVITY	Start Date	End Date	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Tech Analysis	3/1/2021	3/12/2021	9	3			60%
Testing Procesdures #1	3/1/2021	3/5/2021	9	1			
Building session #3: Put H.X.'s into tank and put everything together	3/5/2021	3/7/2021	9	1			0%
Hardware Review #2: Prepping everything working together	3/12/2021	3/15/2021	10	1			
Procedures Analysis	3/22/2021	4/4/2021	13	3			0%
Testing Procedures #2	3/26/2021	3/28/2021	14	1			1%
Final Presentation	4/5/2021	4/9/2021	16	2			80%
Final Report	4/12/2021	4/18/2021	17	2			0%
Poster	4/19/2021	4/21/2021	18	1			0%