Red Feather Thermal Storage Device

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Abstract

Red Feather Development group would like a thermal storage device that can provide heat for the home at night. The goal is to develop a device that captures and stores heat from the sun's rays, stores that heat, and then releases the heat during a winter night. The materials should be within the price range set by the Red Feather group and their customers. This design uses a water-filled, insulated storage tank as a thermal storage device, in addition to two separate pipe networks used for charging and discharging it. During testing, an Arduino monitors the temperature of the outlet air and the storage fluid to evaluate system parameters. This system is powered by a solar panel during the day, and by a charged battery at night, to ensure continual operation. Each element of this system, can be divided into five main subsystems: the air pipe network, the fluid heating network, the storage tank, the temperature-monitoring system, and the power supply.

Requirements

1. Effectively heat the home to 60°F
2. Environmental Resistance: Device Operates in Outdoors Temp 20 to 60°F
3. Effective Thermal Storage Budget: Water in Tank Heated to 175°F
4. Straightforward Design: no more than 12 parts
5. Easy Installation: Dimensions 4ft x 8ft and <500lbs
6. Delivery Time: <150 miles away
7. Reliable Design: 7 days a week / 4 months
8. Dealing with Weather handles 5lbs of water damage

Theoretical Analysis

Heating Tape:
- Heating underpowered for providing necessary heat.
- Experimentation showed (Figure 3) output 216.2W
- 4,566W is necessary to heat the tank to 175°F In 8 hours

Heat Transfer Through Convection:
- Heat transfer rate through convection for the liquid to air heat exchanger was 239 BTU/hr.
- Refer to table 2 for calculations

Solar PV System:
- Total monthly load required is 15.9505 kWh on average
- AC energy production (Figure 2) greater than load
- Future designs should utilize panels with a greater wattage to have a larger factor of safety and more reliability.

Transient Heat in Tank:
- Idealized charge loop operating at 175°F would not be capable of providing adequate heat.
- Demonstrated inadequacy of heating tape, and that losses were negligible compared to necessary heat in.

Pipe Flow:
- Liquid-to-Liquid piping experiences 63.4 ft
- Liquid-to-Air piping experiences 20.4 ft
- Data can be seen in tables 1 and 2

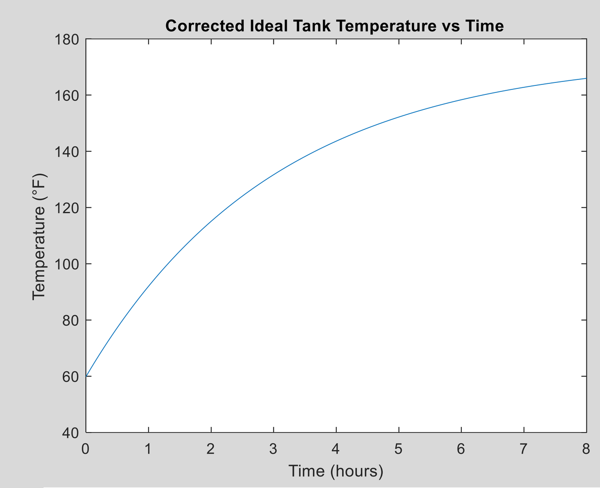


Figure 1: Ideal Temperature Values vs Time

RESULTS

Print Results

265 kWh/Year*

System output may range from 249 to 273 kWh per year near this location. Click HERE for more information.

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	4.71	18	2
February	5.50	19	2
March	6.52	24	2
April	7.58	27	3
May	7.72	27	3
June	8.08	26	3
July	6.99	23	2
August	6.73	22	2
September	6.67	22	2
October	6.00	21	2
November	5.05	18	2
December	4.38	17	2
Annual	6.33	264	$ 27

Figure 2: AC Energy Month Production

Table 1: Air Loss Calculations

Air Loss Equations:	Values	Units
Reynolds Number	919.8529	
Swamee-Jain	0.063578	
Major head loss	20.40386	ft
confusor	0.003421	
Minor Head loss	0.003421	ft

Table 2: Liquid Loss Calculations

Liquid Loss Equations:	Values	Units
Reynolds Number	19952.15	
Swamee-Jain	0.024944	
Major head loss	61.76753	ft
Elbow	0.263975	
Minor Head loss	1.583851	ft

Table 3: Heat transfer coefficient (h) Calculations in Liquid-to-Air Heat Exchanger

Surface Temperature(Ts)	175	F
Inlet Temperature(Ti)	40	F
Outlet Temperature(To)	150	F
Mean Temperature ™	95	F
Air Density(rho)	0.995	kg/m^3
Inlet Velocity(air)	5	m/s
Mass Flow Rate(air)	6.30E-04	kg/s
Specific Heat Capacity(air)	1.009	KJ/kgK
Delta Temperature Log Mean	65.23	K
Average Heat Transfer Coefficient(hbar)	1.12E-02	KW/m^2K
Heat transfer Value(Convection)	0.070	KW
	238.6719362	BTU/hr

Testing

- **Leak Test:**
  1. Test 1 - Found several leaks
  2. Resoldered all Leaks
  3. Test 2 - No Leaks Found
- **Air Velocity Test:**
  1. Test 1 – failed
  2. Cut down length of piping
  3. Test 2 – Air flow velocity of 1.1-1.2m/s
  4. fully assemble device
  5. Test 3 – Air flow velocity of 1.1 m/s
- **Liquid Loop Test:**
  1. Test 1 – Liquid flowed / seal insufficient
  2. Developed tighter seal method
  3. Test 2 – Liquid flowed / seal sufficient
- **Liquid-Heating Test:**
  1. Test 1 – Liquid reached 110 °F after 100 minuets
- **8-Hour Test:**
  1. Test 1 – Reservoir rose from 52 °F to 59 °F / Air rose from 56.4 °F to 58.5 °F
- **Solar Test:**
  1. Test 1 – battery did not charge / converter incompatible

Results

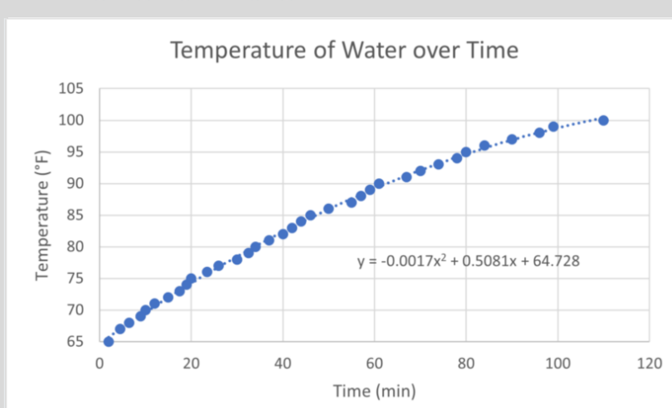
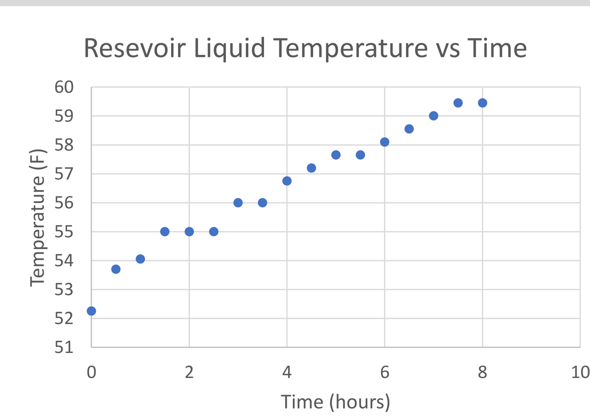


Figure 3 (above): Liquid Heating Test Results, comparing the temperature of water in the reservoir over time as the heating tape heats up 51 inches of piping connecting the pump to the liquid-to-liquid heat exchanger.

Figure 4 (on the right): 8-hour test results: change in temperature of the liquid in the reservoir, which was equivalent to the water in the tank and got the liquid up to 59.45°F.



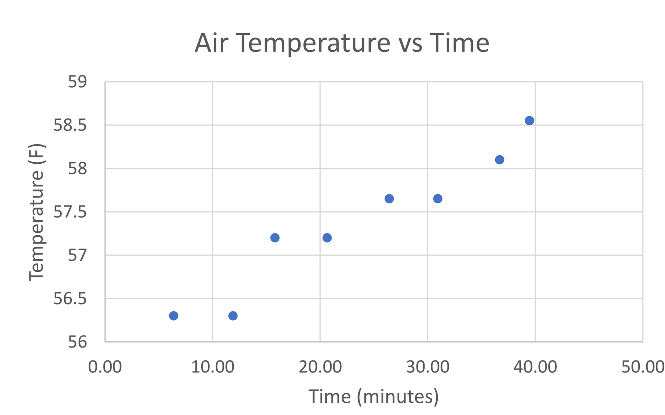
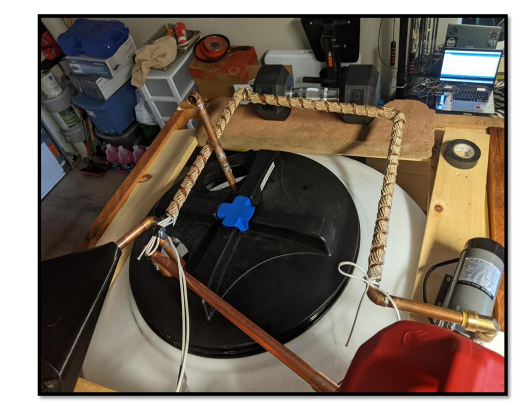


Figure 5 (on the left): 8-hour test results: After performing the 8-hour heating cycle a 40-minute air discharge cycle was monitored with the max temperature being like the liquid.

Design Process

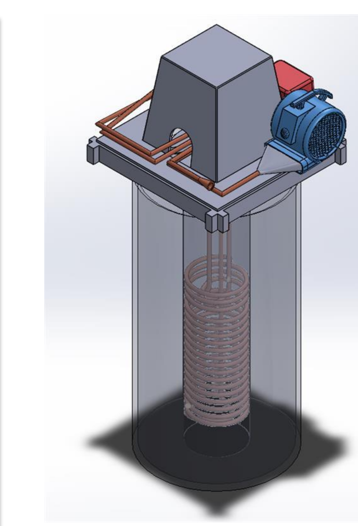
HX's in Duct

Platform with Components



Tank Design

CAD



Conclusions and Recommendations

- With designed heat exchangers, heat transferred successfully between liquid heating loop, water in the tank, and air in the air heating loop
- Greater power/heat output heating element (4,566W) necessary to heat the water in the tank to 175°F
- Three parallel 50W solar panels can power the given blower and pump. A battery and inverter compatible with the solar panels is necessary for future solar implementation
- More fitting components, such as HVAC-specific blower or suction, would improve effectiveness [Look at second to last paragraph of final report for future recommendations to fill this out]
- Improved insulation on the tank, reservoir, and exposed piping would greatly improve design to not lose heat.

References

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Acknowledgements

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