Red Feather Thermal Energy for Homes

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Abstract

Currently, a major health and energy crisis affects the Navajo and Hopi Native American reservations in Northern Arizona and New Mexico. Many residents on theses reservations do not have access to electricity and natural gas which are the main resources used for heating homes during the winter months. The residents are often left using coal and wood stoves to keep warm during harsh winters. These stoves create airborne pollution that can cause high rates of asthma and other respiratory diseases in inadequately ventilated homes. In addition, these resources are now scarce due to the closing of the Kayenta coal mine and increased strain on local wood suppliers.

Objective

The team has been working with Red Feather Development Group to determine safe and affordable solutions for heating the reservation homes. During the first semester, the team evaluated the use of Phase Change Materials (PCMs) to absorb solar radiation during the day and re-circulate it during the night. From this analysis, the team ruled out PCMs mainly due to their high cost and low return. For the second semester, the team has switched focus towards the use of solar furnaces as a supplemental heating option to reduce the usage of coal/wood stoves. The team's main goal was to design a solar furnace that would produce a similar energy output to commercially available products for a lower price.

Methods

- First semester - Team conducted analytical modeling using eQUEST energy modeling software to consider different heating solutions in a 500 square foot home cinder block home.
  - Team tested insulation, phase change materials (PCM) and considered solar air heating.
- Second Semester - Team modeled and constructed Solar Furnaces to determine feasibility of use and perhaps local manufacturing by Red Feather
  - Team built multiple scaled prototypes in which temperatures were recorded to determine BTU/time outputs.

Figure 1: From left to right, ducted solar furnace, control solar furnace, aluminum can solar furnace, and steel shutter model solar furnace prototypes.

Testing Procedures

- Initial testing - output temperatures measured from different designs
- Further testing conducted after designs refined
  - Head loss was calculated to determine pressure drop inside the device, and the volumetric flow rate was derated.
  - Thermocouples mounted at furnace inlet, outlet, and interior space to measure temperatures
  - Arduino UNO converts thermocouple readings to useable data

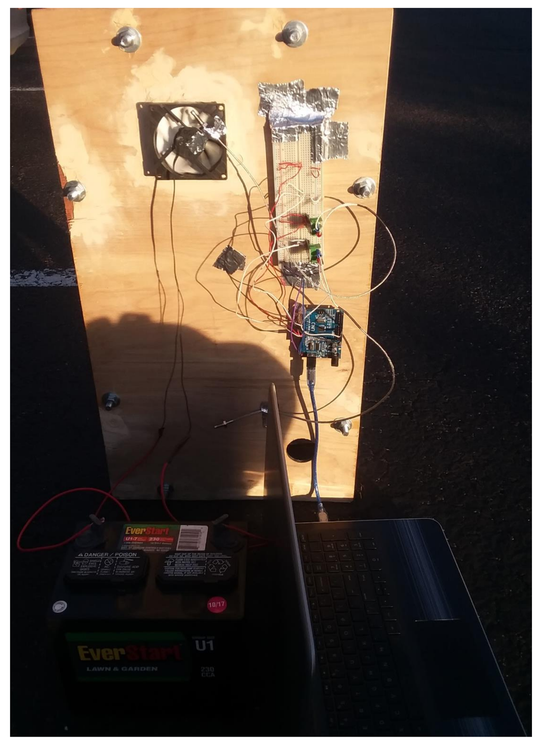

Figure 2: Prototype testing

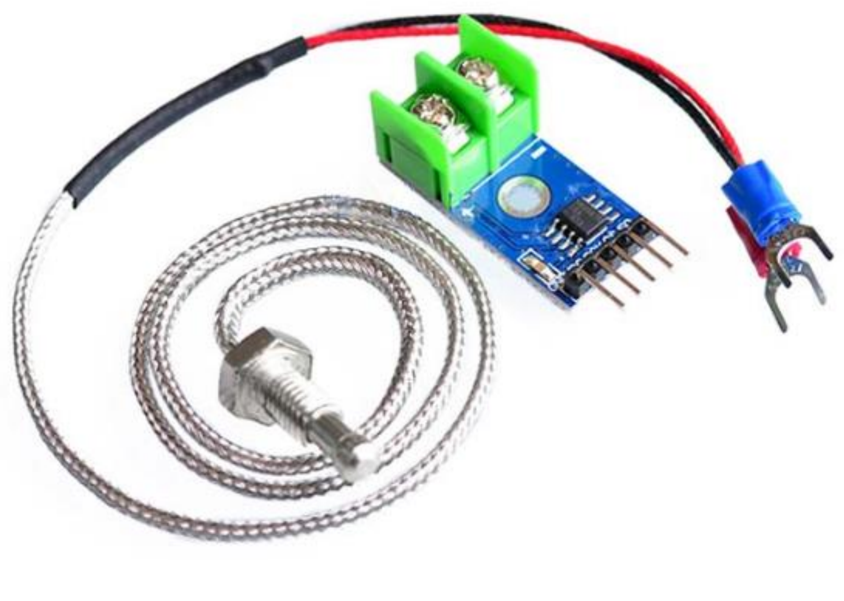

Figure 3: K-type Thermocouple

Results

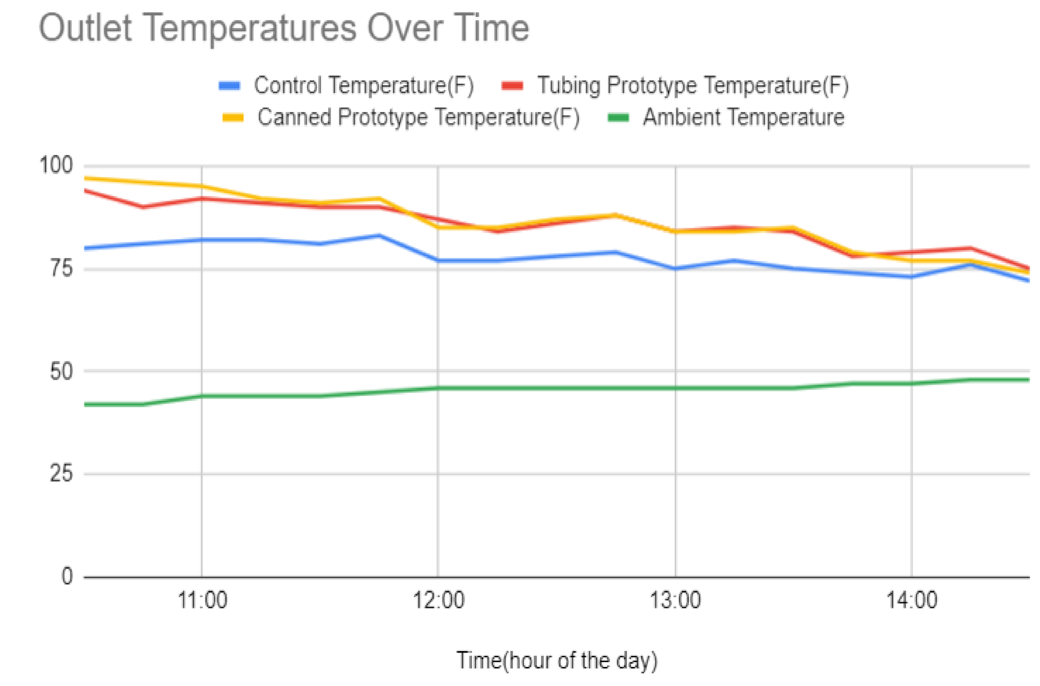

Figure 4: Preliminary Measured Output Temperatures

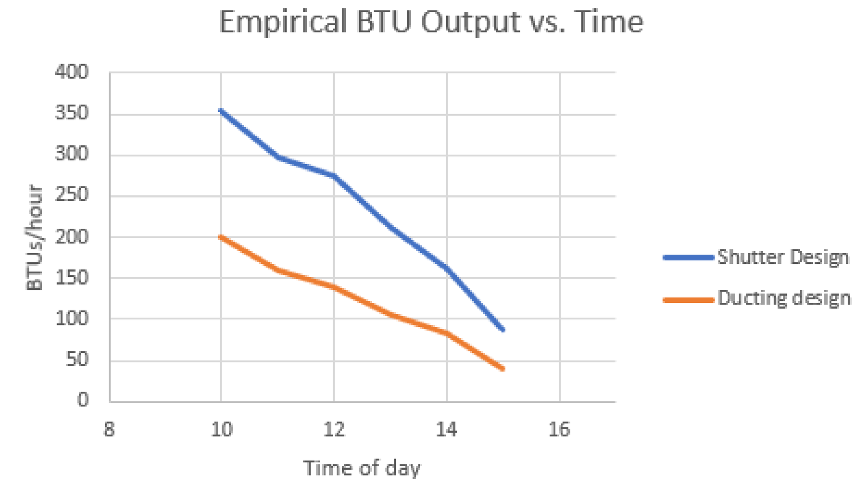

Figure 5: Shutter vs Ducting

Table 1: BTU Outputs of 2 Solar Furnace Designs

	Steel Shutters		Aluminum Ducting	
1/16 Scale Model	1296.761	BTU/day	687.933	BTU/day
Full Size	20748.18	BTU/day	11006.93	BTU/day

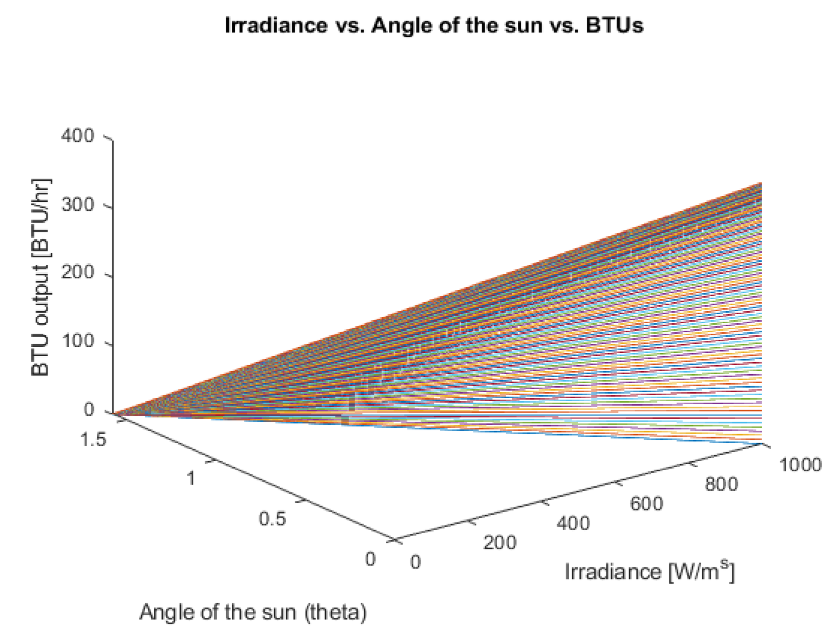

Figure 6: Irradiance vs Angle vs BTUs

Conclusion

- Based on testing results, the team concluded that the most effective design was the steel fin or shutter design. This model produced the highest thermal output as a result of both theoretical analysis and testing.
- This design is comparable to the Solar Sheat 1500 GS, with thermal outputs roughly equal to that of our design.
- Based on the pricing of the 4x8 models and the cost of electricity, the Solar Sheat 1500 GS would have a 23 year pay back period. Our design, which is quite a bit cheaper would have a 12 year pay back period.

References

[1] Red Feather Development Group, www.redfeather.org.

[2] Bergman, T., Lavine, A. and Incropera, F. (2017). Fundamentals of heat and mass transfer. 8th ed. WileyPLUS.

[3] "SolarSheat 1500GS PV - DC —solar heating", Your Solar Home, 2019. [Online]. Available: http://www.yoursolarhome.com/solarsheat-products/solarsheat-1500gs-pv-fan. [Accessed: 22- Oct- 2019].

Acknowledgements

Dr. David Trevas, David Willy, Carson Pete, Mark Hall, Joe Seidenberg, and The Red Feather Development Group