Solar Thermal Dish Heating and Energy

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Abstract

This project studied solar thermal energy and designed an experiment using a heat gun to measure the thermal properties of a novel receiver design. Solar thermal energy generation and storage utilizes sunlight to transfer heat energy to a heat transfer storage system. A model system was used to analyze different receiver configurations for a copper tube containing water as a heat transfer fluid (HTF). The inlet and outlet temperatures of the water was measured. The effect of HTF flow rate was measured as well as receiver coil design. The thermal energy source was modeled using a heat gun. A heat exchanger was constructed using HVAC parts, copper tubing, aluminum foil, and a ceramic pot. The goal of the study was to determine feasibility of a heat exchanger to be used with an existing parabolic dish. The results of an initial test demonstrate the ability of the system to heat water a few degrees, better setup or additional modifications to the heat exchanger would be necessary. An analysis was also done to calculate and evaluate working fluid and mass flow rates.

Figure 1. Parabolic Dish Solar Thermal Concentrator. This is an example of a concentrator. It functions by focusing solar energy to a smaller area to generate heat that may be then used as heat or further converted into energy.

Introduction

CO_2 release is the most likely cause of climate modification. According to a 2020 report from the US energy department, renewables constitute 20% of overall energy production in the U.S. with solar making up 2.3% of the overall energy production. The Energy Information Administration also discusses how the limitations of solar energy are that solar radiation is not constant. One way around the sun not always shining is to store the solar energy by converting it into thermal energy and converting it into electricity as the need arises.

Heat is transferred through 3 processes, conduction, convection, and radiation. Heat transferred through conduction occurs when a substance with less energetic particles interacts with another substance with more energetic particles. Heat transferred through convection occurs between a solid surface and a fluid that is moving past it.

Methods

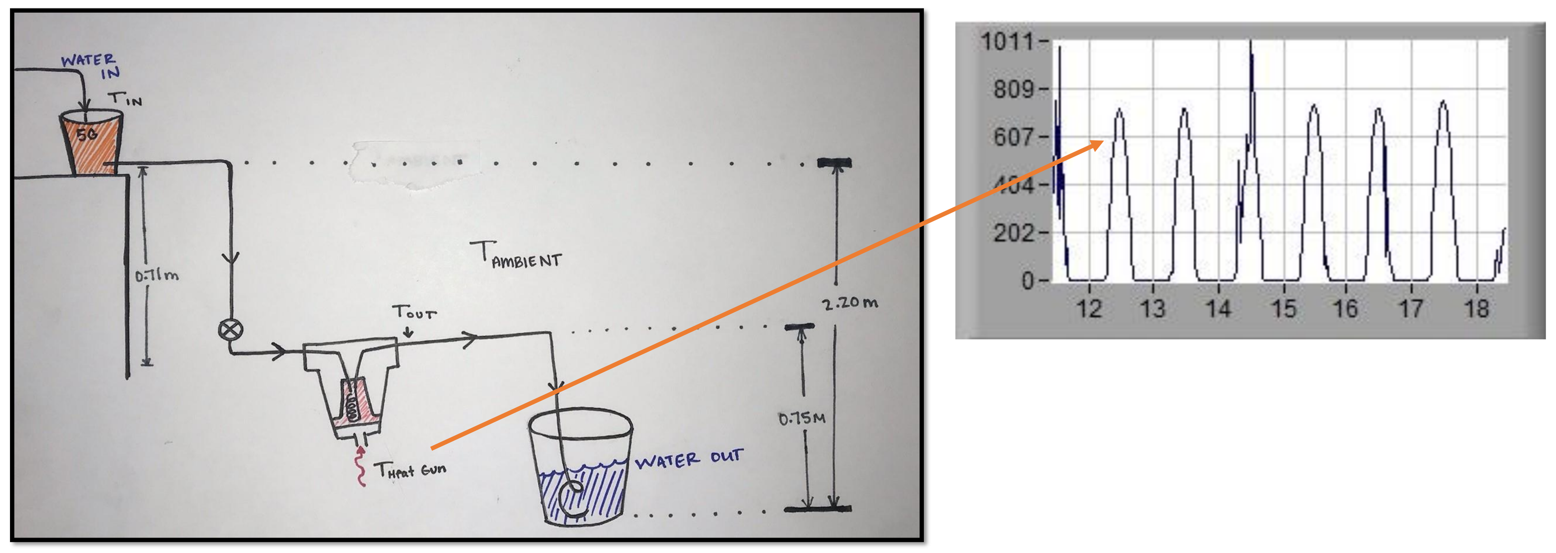

Figure 2. Schematic (Above). Table on the right are measurements of fluctuations in solar power during one week. For this experiment, peak solar hour energy estimated to be 600 W. Above is the schematic for this experiment design. Unfortunately the heat gun does not allow precise control of heat output, only temperature, so it was not possible to fully mimic the sun's energy. The comparison across the trials should follow the same principal, however.

Figure 3. Apparatus (Below). Photos of the actual experimental setup.

Results

	Ein	Q-dot*(W)	Heat Gun In(deg c)	Inlet Pipe (deg c)	Outlet Pipe (deg c)	Ambient (deg c)	Mass Flow Rate (g/s)
Trial 1	1437.606474	1500	704.4	25.4	29.3	25.0	1.9
Trial 2	1444.207836	1500	704.4	25.2	26.2	25.0	1.6
Trial 3	1443.143101	1500	704.4	24.9	26.7	25.0	1.4
Trial 4**	**'	1500	704.4	25	**'	25.0	1.6
Trial 5	1444.420784	1500	704.4	24.9	26.1	24.9	1.8
Trial 6	1446.763203	1500	704.4	24.8	25.0	24.9	1.6
Trial 7	1445.48552	1500	704.4	24.7	25.6	24.9	1.6

Figure 4. Results. This is the raw data from the trial. During trial 4 the apparatus came apart and had to be repaired, so we were unable to obtain outlet pipe temperature and thus could not calculate energy in. This was not used in later calculations. Trials 1, 4, and 5 were done with the longitudinal coil and trials 2 and 3 were done with the lateral coil. Trials 6 and 7 were done with the longitudinal coil using insulation.

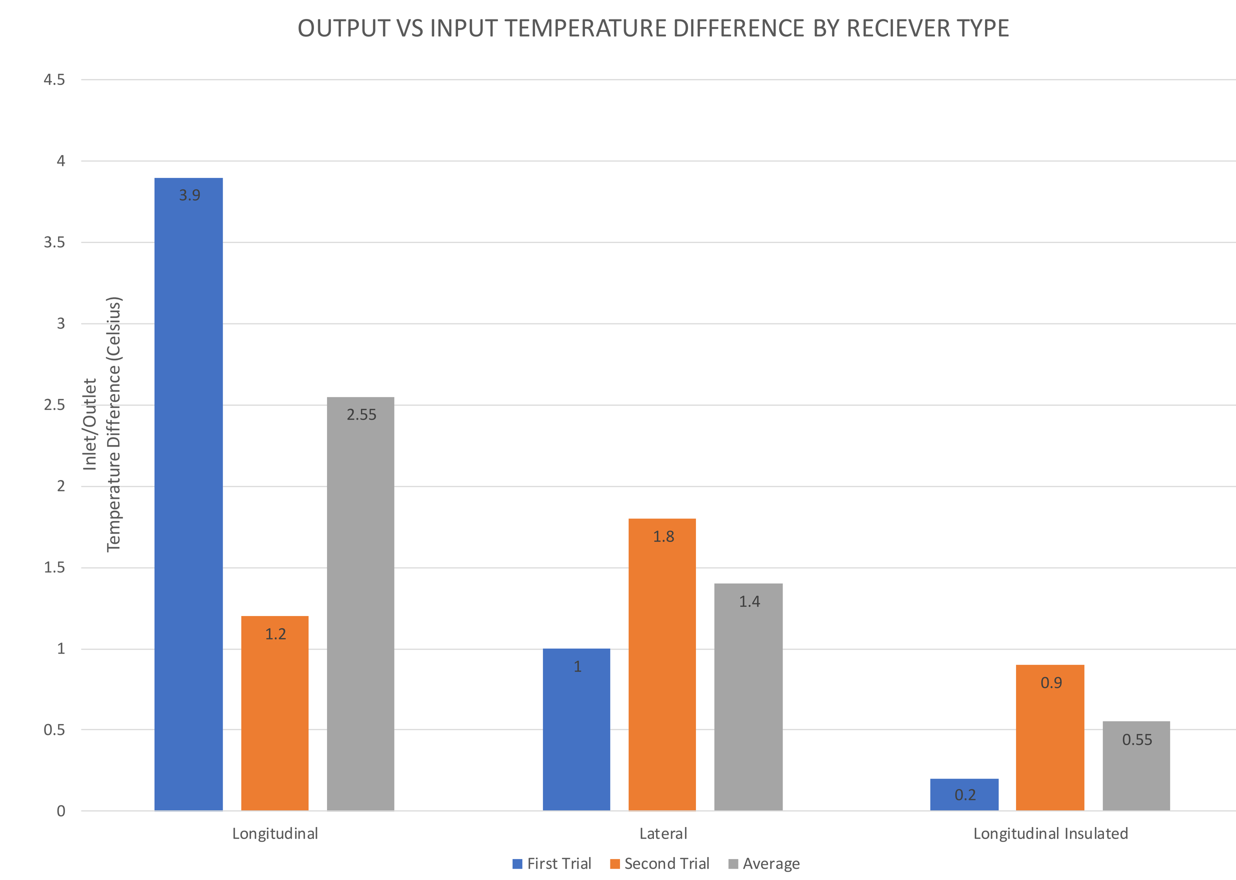

Figure 5. Temperature difference between receiver types. Although the data is not statistically significant, results do seem to favor the longitudinal coil design for better heat absorption. Insulation did not seem to help and may have even decreased heat absorption.

Summary

- The experimental setup was somewhat clunky and not precisely controllable.
- The experiment did not function as intended.
- Insulation had little effect and may have been detrimental – additionally, it burned during one of the trials, making it a potential safety hazard.

Conclusions

- The receiver types did not yield statistically significantly different results, but seem to favor longitudinal design.
- A final temperature from the reservoir was obtained and found to be 40.3 C, but not measured as part of experiment, raising questions about variables measuring copper pipe vs the fluid inside.
- Boiling possibly lowered final temperature at outlet, add inline flow meter, variable rate pump, and more stable way of holding heat gun.

Acknowledgements

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