Energy Capture Using Heat Pipes in a Photovoltaic Thermal System

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Introduction

Photovoltaic (PV) solar power is expected to play a pivotal role in transitioning the world away from reliance on carbon-emitting fuels. In order to augment a sustainable future that relies on PV solar power, our team designed a PV-thermal system that attempts to capture waste heat and maximize solar cell performance.

The thermal system is an array of round heat pipes attached to the backside of the solar cell. The heat pipes used in this project are copper material with an outer diameter of 0.5mm and a length of 450mm. The internal evaporator-condenser structure allows the heat pipes to efficiently transfer heat. Additionally, the thermal system can allow a PV solar cell to operate at optimal temperature; studies have found that a single degree temperature increase of a solar panel decreases efficiency by 0.45%. Heat pipes are traditionally used for aerospace, medical, HVAC, or consumer electronics applications. The team investigated heat pipe properties by conducting experiments with a solar cell..

Objectives

The main objectives for this project were to:

1. Test the viability of a PV-T system based on heat pipes
2. Capture and transfer heat for a secondary use
3. Create a reproducible, affordable design to be implemented at an industrial scale

Methods

Multiple experiments were done in order to optimize several heat pipe parameters including heat pipe a) effective length and b) angle. Heat pipe effective length conveys information about the relative lengths of the pipe that are insulated, heated, and cooled. Effective length is expected to be inversely proportional to the total heat transferred by the pipe. Based off of manufacturer's data, there is expected to be an optimal angle of the heat pipe for maximum heat transfer as gravity can help or hinder internal transport of the working fluid in liquid form.

Experiments were also conducted to c) vary the speed of the air used as a cooling fluid. Changing the speed of the air was expected to be a tradeoff of increasing the heat transfer coefficient with higher flow rates and allowing enough time for the air to heat up with lower flow rates. Final experiments were conducted on a fully integrated setup and will be discussed in the final design section.

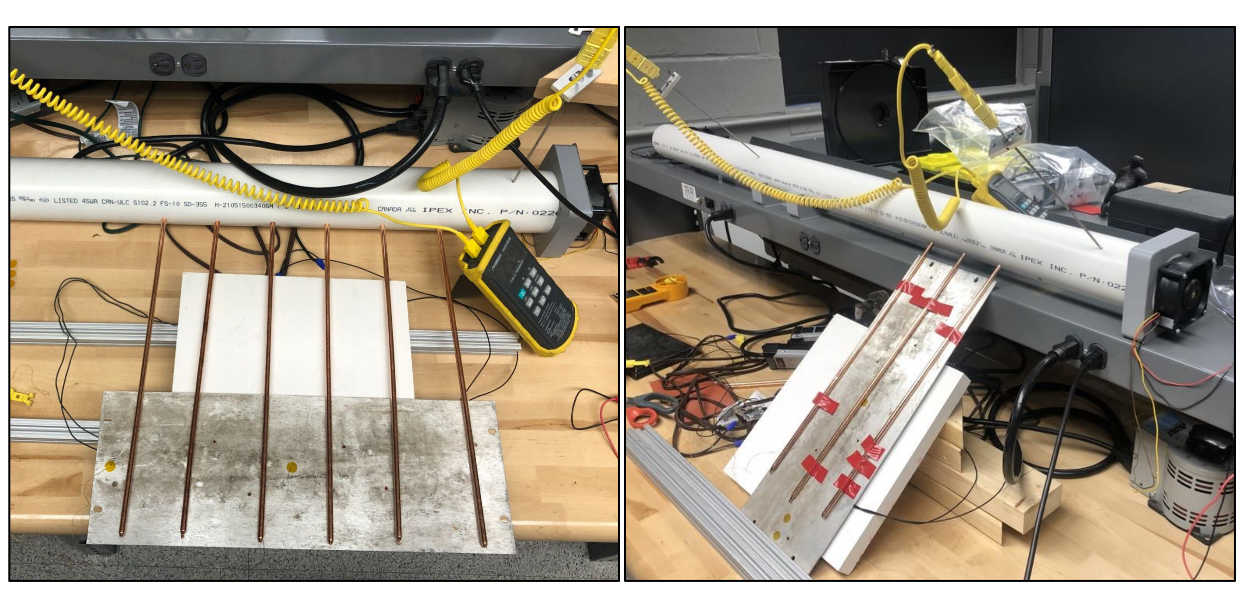

Fig. 1: Level (left) and angled (right) heat pipe experimental setups

Results

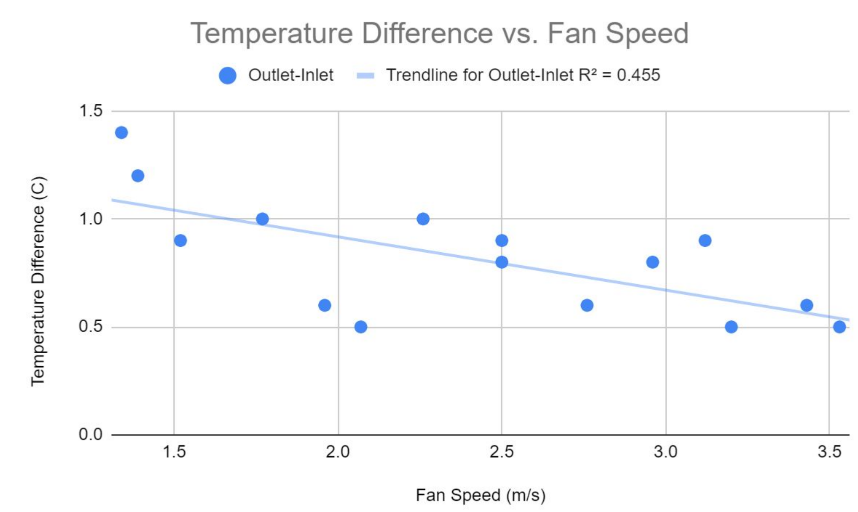

Fig.2:Higher air speeds roughly correlate with lower temperature differences

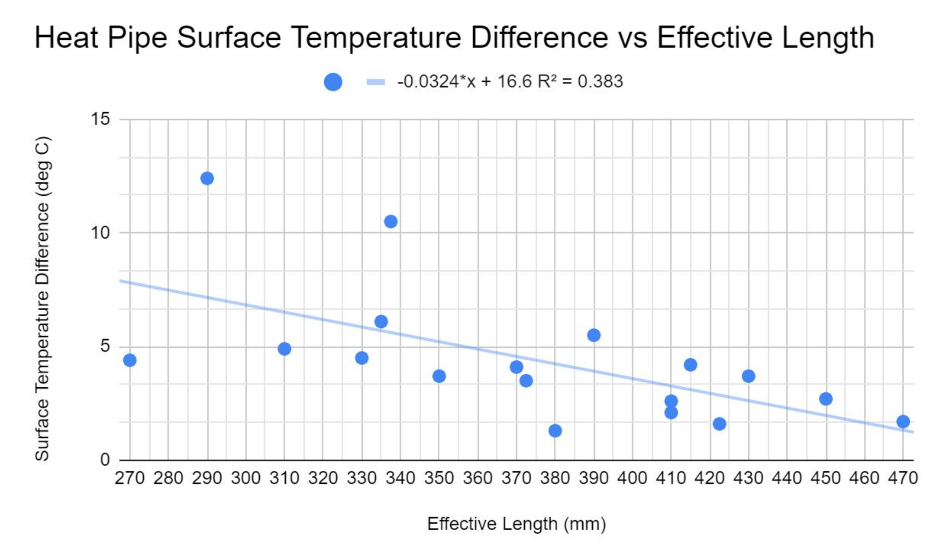

Fig.3:Higher effective length correlates with lower temperature differences

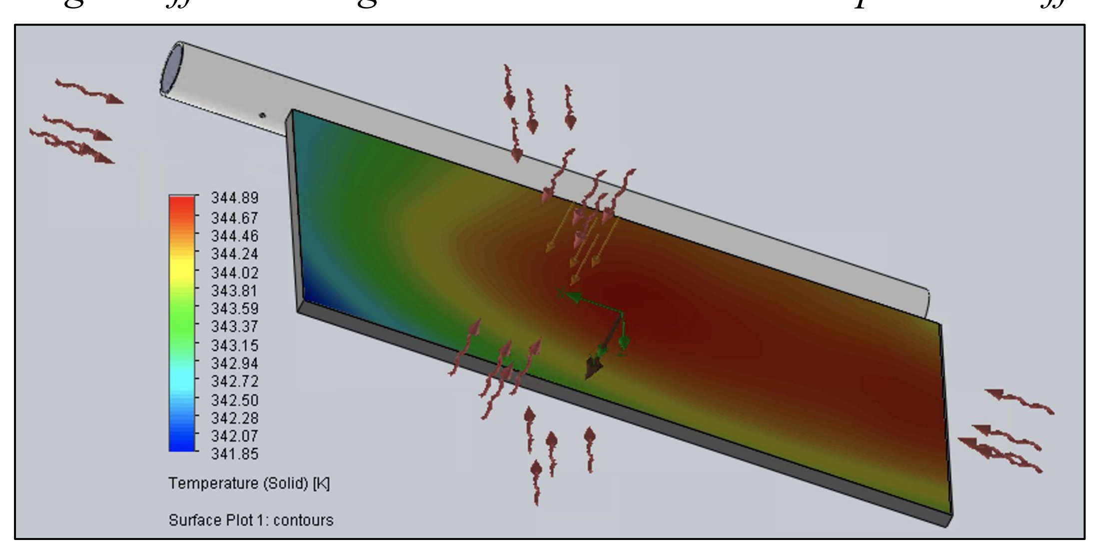

Fig. 4: Panel With Free Convection

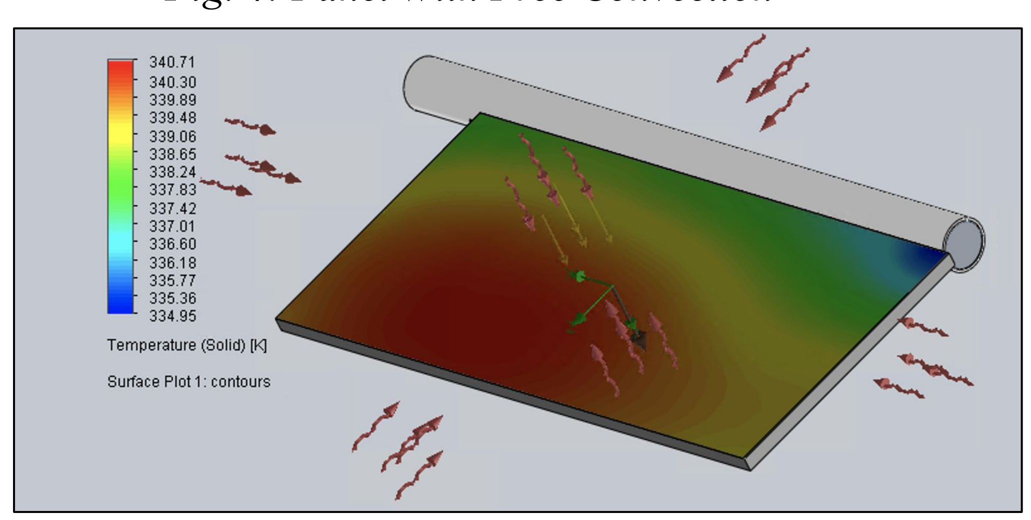

Fig. 5: Panel with Forced Convection in PVC

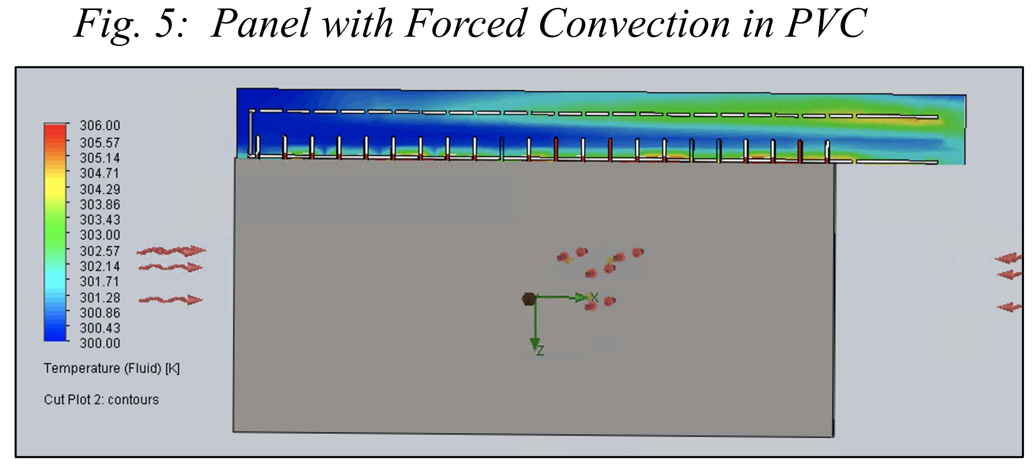

Fig. 6: Simulation Predicts Air Temp Increase of 2ºC

Final Design

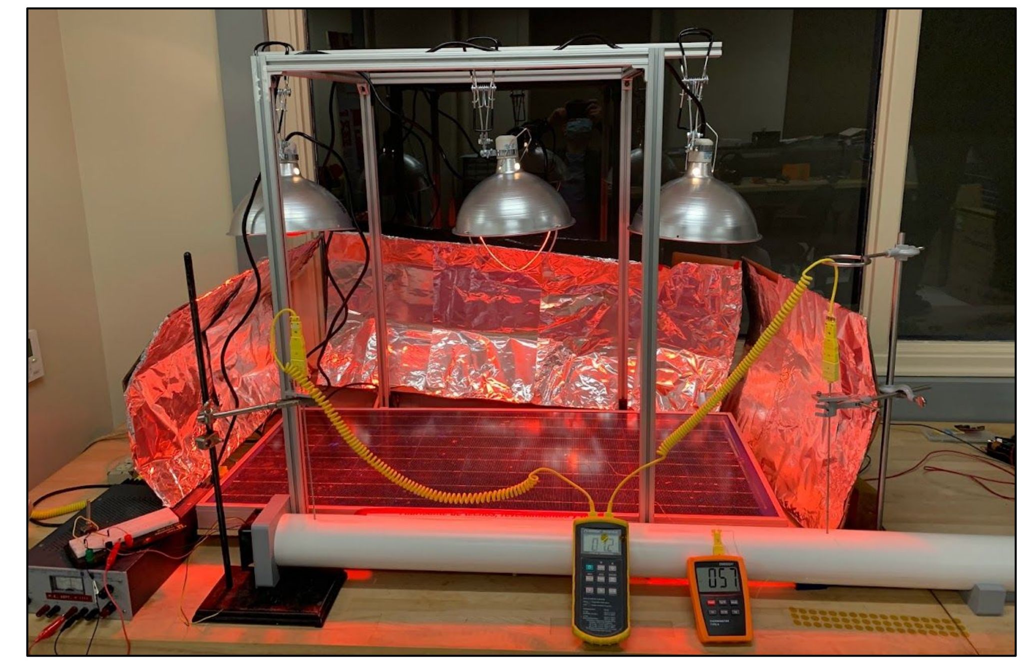

Figure 7: Final integrated system design

Key features of the final design include:

- Six heat pipes attached to the back of the panel
- Three 250W heat lamps suspended over the panel
- Aluminum foil panels to create a more even temperature distribution on the panel
- PVC pipe cooling manifold
- A multi-speed fan
- Thermocouples and an anemometer to measure temperatures across the system and fan speed respectively

Discussion & Future Work

A restrictor was placed at the end of the PVC pipe to increase air temperature by reducing the mass flow rate; a temperature increase of over double previous experiments was achieved. Moving forward, the team will investigate different levels of flow restriction. In initial designs, insulation was used to seal the back of panel to create a pocket of hot air around the heat pipe evaporator ends, but it was found to increase the temperature of the panel and was removed. Adding more heat pipes may allow for the readdition of the panel insulation backing if they can transfer sufficient heat to reduce overheating. This may increase the temperature of the harvested air.

Acknowledgements

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