Development of a Polycarbonate Solar Water Heater

Sawyer Buck and Kelsey Welsch

Mentor: Dr. Kim Pierson | Physics and Astronomy, University of Wisconsin-Eau Claire

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INTRODUCTION

Solar technology is becoming a prevalent economical and environmentally friendly source of renewable energy. Successfully designing a low-cost and efficient panel would produce competition for the pricey commercial panels available now, thus creating a more economical market for solar water heater panels. By perfecting the design of this ongoing experiment, the goal was to reduce the reliance on nonrenewable energy and make renewable energies more economically viable to the average consumer.

Solar Water Heater Systems

Current commercial designs use copper fins to absorb and transfer heat energy to water within the panel. The heat energy travels along the fin to a pipe which contains water and then gets heated. The polycarbonate design utilizes a polycarbonate honeycomb panel. Sunlight hits this panel and transfers energy to the panel which then transfers energy to the water that is flowing through the panel. The theoretical efficiency of a copper fin panel was compared to the theoretical efficiency of a polycarbonate panel. Although polycarbonate has a lower thermal conductivity, the shorter distance that the heat has to transfer through the surface causes the polycarbonate design to be about three times more efficient.

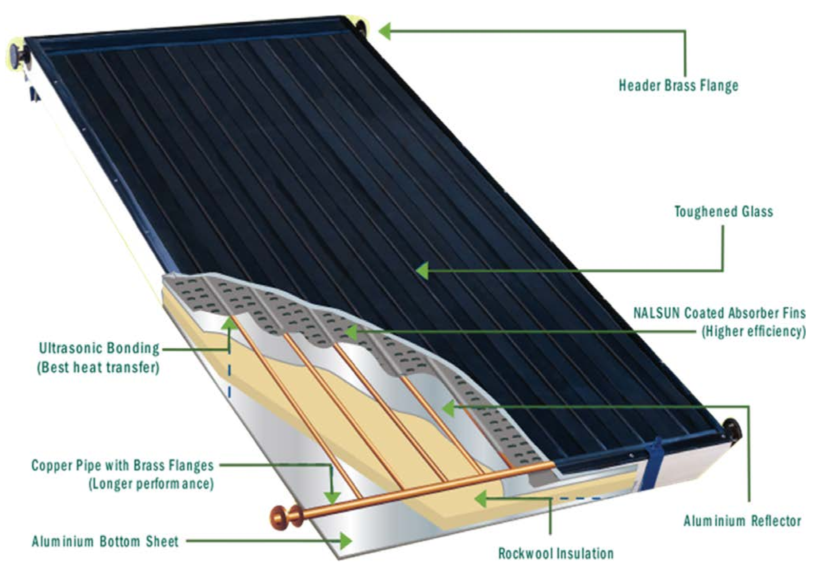


Figure 1: Cut-away diagram of a typical solar water heating panel

Adding a Heat Pump

Heat pump systems gather thermal energy (heat) from the air or by pumping cold water into the ground to absorb heat. Instead our system replaces the ground loop and cold water flows out of the heat pump and into the solar water heater. The water moves through the panel and absorbs the sun's energy and warms up. Our system was specifically designed to produce a large volume of warm water that is sent back into the heat pump and turned into a smaller volume of hot water. This hot water is then used directly or used with a radiant heating system to heat homes. The now-cold water is then sent back to the solar water heater to repeat the process.

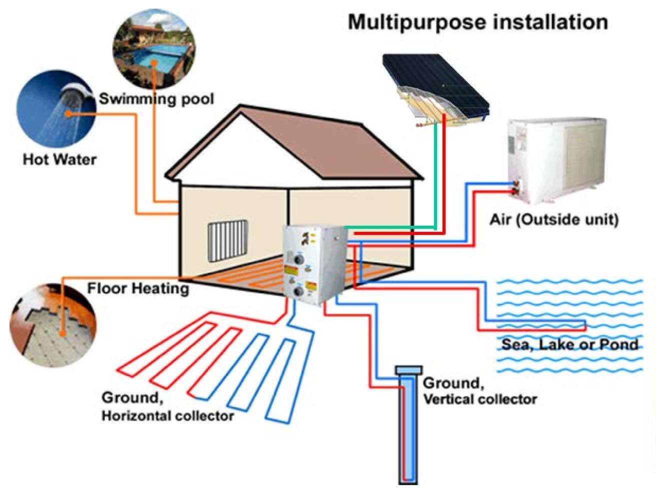


Figure 2: Sources of energy for heat pump system

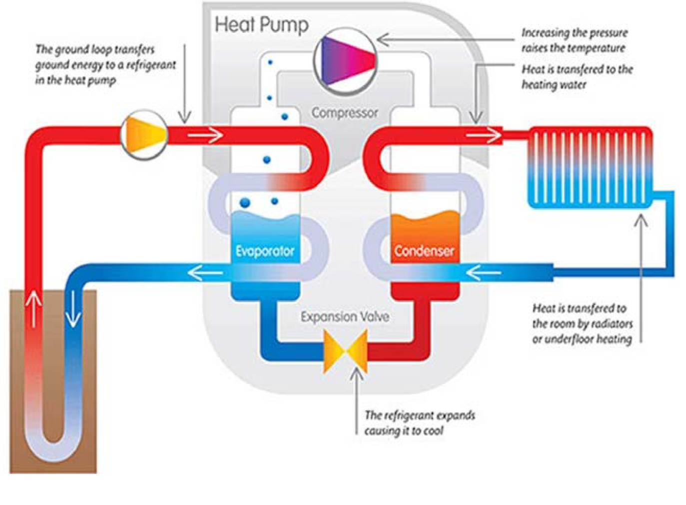


Figure 3: Ground source heat pump

EXPERIMENTAL SETUP

Figure 4: Picture of water heater panel set up with solar simulator

CALCULATIONS

Desired Flow Rate of Panel

A flow rate of 4 gal/min is desired to make the panel an effective replacement for a ground loop. To achieve this, a temperature change of about 16°F is needed. Using a 4' by 8' (3 meters^2) panel and an irradiance of 1,000 Watts/m^2 , the following calculations were done:

$$Q_{Sun} = mc\Delta T \gg \frac{\Delta Q}{\Delta t} = \frac{\Delta V \rho c \Delta T}{\Delta t} \gg \frac{\Delta V}{\Delta t} = \frac{I_R A}{c\rho\Delta T} \gg$$

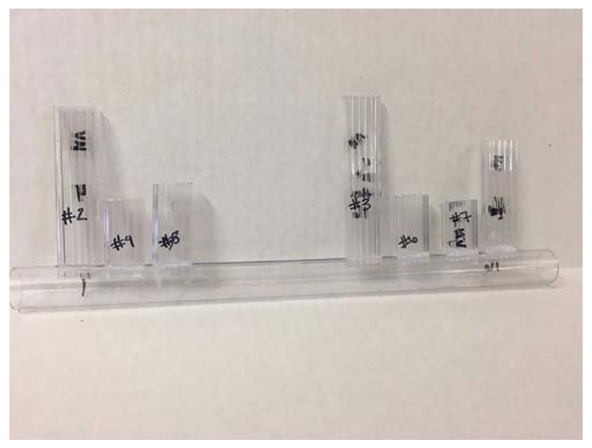
$$\gg \frac{\Delta V}{\Delta t} = \frac{\left(1{,}000\,\frac{Watts}{m^2}\right)(3\,meters^2)}{\left(4{,}186\,\frac{J}{kg^\circ C}\right)\left(1{,}000\,\frac{kg}{m^3}\right)(9^\circ C)} \gg \frac{\Delta V}{\Delta t} = 8.0 \text{ x } 10^{-5}\,\frac{m^3}{s} = 1.3\,\frac{gal}{min}$$

To achieve 1.3 gal/min, no energy could be lost within the panel and the conditions must match those in the calculation. Previous research has shown that the panels created for this experiment are about 70-75 percent efficient. Thus, to obtain a flow rate of 4 gal/min, four panels would be needed for the average home.

VITAL CHARACTERISTICS OF THE DESIGN

Glue or solvent bond

Previous work on this project ran into complications with the glue line. Inadequate sealing caused leaks within the panel, chiefly in the connection between the header pipe and panel. Multiple glues and solvents were chosen to test their durability due to their claims to bond polycarbonate efficiently. Samples of various glue/solvent combinations and number of layers were created to be mechanically tested, frozen and heat tested. Each sample was tested and checked for deformations, flexibility and cracking.



Sample	Description	Mechanical	Heating	Cooling
1	One layer of 16 glue	Failed	Failed	Failed
2	One layer of 4 Glue	Failed	Failed	Failed
3	Two layers of 4 glue, one layer of 16	Failed	Fair	Failed
4	Two layers of 4	Failed	Failed	Failed
5	Three layers of 4	Fair	Fair	Failed
6	Three layers of 4	Failed	Fair	Failed
7	Four layers of 4, Two layers of 16	Good	Good	Failed
Methylene Chloride	Four Layers	Good	Failed	Good

Figure 5: Header pipe bonding to panel experiments and results

Flat black paint vs solar collector coating

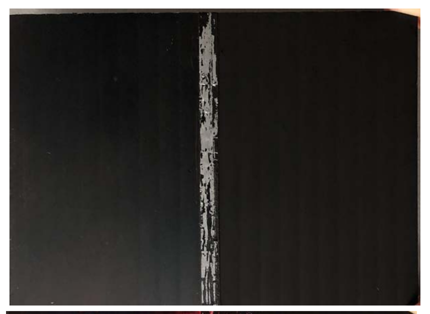


Figure 6: Test paint panel. Left side is flat black paint and right side is Thurmalox Solar Collector Coating paint. Thurmalox is designed to absorb more sunlight energy than ordinary flat black paint. It is specifically intended to be used with solar water heater collectors.

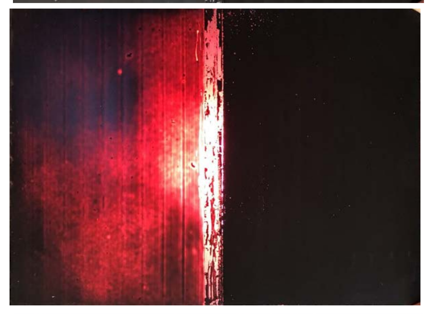


Figure 7: Test paint panel with bright halogen inspection lamp shinning through from behind the panel. Clearly, Thurmalox more completely covers the plastic panel and therefore should absorb more sunlight than the ordinary flat black paint on the left.

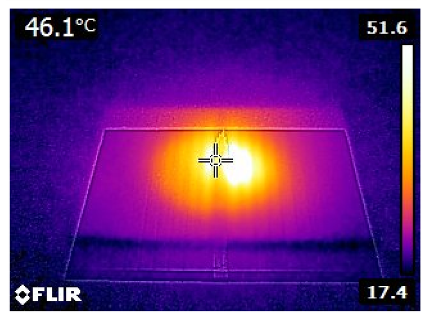


Figure 8: Infrared camera picture of test paint panel after irradiation with high intensity halogen inspection lamp. Right side is brighter which indicates the Thrumalox paint absorbed more light energy and became warmer than the left side flat black paint.

PAINT HEATING EFFICIENCY RESULTS

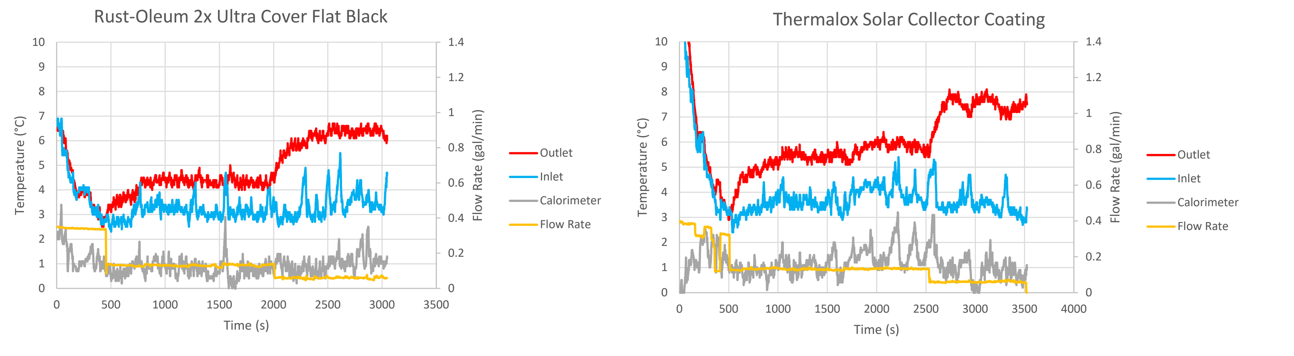


Figure 9: Temperature and flow rate versus time results for two types of paint.

A special light that mimics the solar spectrum was used to irradiate a small test panel (Figure 4) while changing the flow rate of water pumped through the polycarbonate absorber panel. The change in temperature between the water entering the bottom of the panel versus the water flowing out the top was monitored. The larger the temperature difference the more efficient the paint is at absorbing the simulated sunlight energy. Notice that the jump in the outlet water temperature on the right sides of the graphs occur because the flow rate was lowered. This was done to increase the temperature difference and help determine which paint is more efficient.

SUMMARY OF RESULTS AND FUTURE TESTS

The research done thus far has proven an efficient and economical polycarbonate solar water heat pump is feasible. Of the bonding agents tested, none could withstand all three of the tests conducted on them, thus continued research on the glue joint must be done. Preliminary research on the advantages of solar collecting coating over flat black paint are inconclusive and more research is needed to come to a conclusion whether the solar collecting paint in fact has a positive effect or not. Tests on the insulation on the back of the panel will be conducted next to determine which material provides the highest energy gain.

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