

Solar Thermal Panel Closed Loop System Design: Construction and Application

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INTRODUCTION

“Solar collectors” or “solar hot water heaters” are designed generally for use in the process of generating hot water for domestic use. Another, less common use for solar thermal panels is radiant heating of spaces by conveying heated liquid from the collector through walls and floors via a circulating pump. Specifically, my system is an active indirect circulation system utilizing a flat plate collector design. The design is active because a pump is used to push the liquid and it is indirect because a heat exchanger is used to indirectly heat up a tank of water as the moving liquid (water or a propylene glycol mixture) flows through tubing in the tank. Flat plate collectors are insulated to some degree and have an absorber board beneath one, two or even three plastic (polymer) glazing covers to increase absorption of heat while decreasing emission of electromagnetic radiation. Glass is often used too for this covering purpose. The absorber board I made is a combination of copper tubing, copper fittings and aluminum fins all sitting above an exterior plywood sheet. Details of the entire design will be discussed in the methods section.

Construction and Installation

Copper Grid- To build the copper grid, I used six 10 ft. tall L rated copper tubes which have a medium thickness walled section suited for water supply and pressure applications (plumbing). Type L copper tubing has blue lettering on its walls and is in between type K which is the thickest and type M which is the thinnest of their kinds. I needed seven riser tubes each of 90 inch height. Since I only had six copper tubes of at least 90 inches, the seventh riser tube was a fused piece of two copper tubes which equaled the proper length. The other six riser tubes were cut to the appropriate length. Scrap copper from the original copper supply was used in making connector pieces of six and one-half fit length to join the risers. These connector pieces fit into Tee fittings along both ends. Both manifolds combined used 12 Tees and two elbows with the connecting pipe in between to complete the copper grid and make a solid frame. The two elbows were

placed at opposite corners of the copper array.



Figure 1: The copper grid built by Tyle L copper tubes.

Building the copper array in this fashion forms a water channel where at one lower corner water flows in and at the opposite top corner water exits. By having the risers structured in this manner, water should flow up at equal rates and have a chance to be heated substantially. Before soldering the frame together, the fittings and the copper tubes were cleaned with sand paper. Then, solder flux was applied inside the Tees and outside of the copper tubes before doing the sweating. Heat the joint past the solder's melting point with a blow torch and then apply the solder.



Figure 2: The Tee fittings

Wooden frame, Complete Absorber board and Glazing:

The dimensions of the copper grid are to allow for it to be centered on a 4 ft. by 8 ft. exterior piece of plywood. 90 degree turn fittings with an extra copper segment must be soldered to the grid's open Tees on the manifolds for the outlet and inlet. That is done for the tubing connections. The copper segments must be long enough to penetrate all the way to the backside and have room for a connection to Pex tubing. There should be a few inches of gap all the way around the edges of the plywood with the copper grid above. When the copper grid is center with the new inlet and outlets mark where to drill and then choose a bit just slightly larger than the half inch copper tubing. Holes were drilled for the inlet and outlet copper tubing so that the water or any other liquid mixture can enter and exit the collector. I made the wooden frame from 2x4's with an inside track of 1x1's to which the exterior plywood rests above. To add rigidity to the frame I nailed a 2x6 to the header and also to help shield the inside from rain once the glazing was added. Insulation (polystyrene) was cut out to fit the inside track. Through the back, this minimizes heat dissipation. Adding strength to the frame was done by putting metal strap in the shape of an X across the backside. Any small air gaps were filled with silicone caulk.

Thin aluminum flashing was cut to the appropriate length; I chose to cut pieces six and a half inch wide, 18 inches long to be situated. I pounded a 5/8 inch steel rod over the aluminum flashing placed over top of a jig that had a groove in it that allowed for the fin to take its shape. The aluminum fins fit tightly over the copper riser tubes to aid in heat transfer. Small 3 inch wide strips were put under as well to maintain an enclosed conducting wall around the copper tube and to retain continuity. Enough were cut to make a cover for each riser tube which in my design used 6 with a slight overlap stretching from one manifold to the other. Once all of the fins have been cut out and pounded into the necessary amount put silicone caulk on the inside of the groove of the fin to minimize the air gap when the fin is stapled to the plywood over the copper tubing. Also, run a small bead of silicone caulk on both sides of the three inch strip to make a more effective heat transfer design because silicone is better at conducting heat than air. Keep pressure on the fins when securing them to the copper tubes with staples. Be sure to use stainless steel staples. Rustoleum high heat black paint was used to coat the inside of the solar collector to help absorb solar radiation. Multiple coats were done.



Figure 3: The solar collector

The next step was to install the glazing which is the cover for the solar thermal panel. I had to cut corrugated polycarbonate glazing down to two 2' by 8' sheets to fit over top of the panel's perimeter. This cover over the absorber board creates an airlock and reduces convective losses of heat. Without the polycarbonate glazing we would just radiate heat back into the surroundings because of the difference in temperature of the board to the environment. We drilled holes big enough for two intermediate supports (EMT electrical conduit) to fit 1/3rd and 2/3rds the way up the panel so when the glazing is in place there will be no concavity from the added weight. Since the cover has a waffle pattern, buy Styrofoam that will fit the edges of the cover exactly, thus making the cover flush; down the long sided walls the poly carbonate can be nailed to the frame on its flat side. Combining the two polycarbonate sheets into one cover for the whole collector, we applied epoxy glue down one seam and overlapped the other sheet meeting the dimensions required; we used lead weights to help secure the overlapped seam while the bonds were setting. Also, use nails for both the top and bottom of the collector; I hammered nails in the valleys going across the cover's waffle pattern. Use silicone caulk around the edges to minimize heat losses.



Figure 4: The solar collector after being applied silicon caulk

Collector Location, Pump, Tubing(heat-exchanger), and Storage Tank- With not to many options for a reasonable location for the solar collector closed loop system to be left alone without disturbing someone else's research or getting in the way of general movement from Building and Grounds personnel, the best solution was for it to be mounted to the green house. This green house is under control by professors in the biology department was to be my experimental lab room for the time being. What limited the exact spot was the need for electrical outlets, decent sun exposure and running water for pressurizing the system. Eventually, laying the board in between two windows on the green house while the panel was propped on two cement blocks was the simplest approach. On the inside of the greenhouse both windows were opened and plastic tubing was hooked to both inlet and outlet with compression fittings.

Conveying specifically heated fluids is a top priority for our pumping needs and nothing short will compromise. In our configuration a Grundfos three speed circulation pump is ideal for conveying heated fluids in a closed loop system. Talking properties, the Grundfos pump is not a submersible pump and must sit outside of the water. With this in mind, I constructed a mount for the pump. Using a square piece of scrap plywood, I centered the pump so that

there were two inch gaps on the edges. I fastened it down using metal strap and screws. On the side for wiring, I had installed a switch over an electrical box which housed the wires from a power extension cord cut to an appropriate length for reaching the wall. Common, ground and power from the extension cord were tied in with the switches wires. The electrical box was placed to the left of the pump on the board. Determining the pump's location in the closed loop system required a lot of careful consideration. I weighed numerous configurations before deciding on a final plan. I knew that the system had to be pressurized by being full of water with negligible air present. The air inside all tubing, whether copper or Pex, would have to be forced out by gradual water filling. To achieve this concept, I figured that placing valves in front of and directly behind the pump was easiest for the pressurizing process and for being absolutely certain water had made its way completely around the circuit. Doing it in this manner enables the experimenter to hook a hose up on the left valve and circulate water all the way around the closed path and then close it off once water exits the other valve's nozzle. Utilizing this method, one can be sure the water has had time to fully circulate and that air pockets are reduced. All of the fittings that were purchased and that needed to be installed from the pump's flanges all the way to the way to the copper outlet or inlet of the collector consisted of: 4 compression Pex to copper fittings, 2 – $\frac{3}{4}$ to $\frac{1}{2}$ inch copper adapters, 2 – copper T's, 2 – $\frac{1}{2}$ inch adapter valve fittings, 2 quarter turn valves and enough copper pipe for the connecting segments. As far as implementing the Pex tubing into the closed loop system, a 100ft. roll was purchased from Lowes. A 10 ft. piece was chopped off to be used on the inlet side of the collector from the pump. The remaining 90 ft. was connected from the outlet side and ran to the storage tank where it acted like a heat exchanger to the reservoir of water and then ran to the opposite side of the pump. Pex has an advantage for not deforming with increasing temperatures compared to other kinds of plastic tubing; it is suited for all hot water usage. The storage tank itself was a Rubbermaid bin, nothing elaborately designed. It was solely used to see how well hot water could be generated once the pump was cut on and to collect initial data. Of course the preliminary data collected was done manually and I used thermal couple probes to get my temperature data.

Conclusion and Future Work

In the future more emphasis must be put on designing a heat insulated storage tank and patching up other heat loss areas such as on the inlet and outlet sides where there are small openings to the inside of the absorber board. Another avenue of exploration will be making the data acquisition fully

automated. This will be done by programming an Arduino board to store my measurements to an SD card which can be later retrieved and analyzed. Once these steps are taken I can begin to really understand my system's solar efficiency and rates at which radiant heat can be generated based on solar radiation harnessed.

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REFERENCES

1. Reysa, Garay. "Copper Tube/Aluminium Fin Collector" Construction of Copper/Aluminum Collector. N.p, 24 July 2009.
2. "Solar Water Heaters." Energy.gov. N.p, 7 May 2012.