

SOLAR WATER HEATING IN PRINCE EDWARD ISLAND



Summary:

Over the past year, I built a “\$1000” solar drain-back domestic water heater for my house here in Cornwall, Prince Edward Island, Canada. The system includes two 4' x 6' flat plate solar collectors and a 150 US gallon tank. Cold water is preheated in a heat exchanger in the solar water tank on its way to the existing indirect oil fired water heater. Preheating the water reduces or eliminates (in good sunny weather), the run time and oil consumption of the oil fired water heater. The following is a description of the system and its construction.

Why a Solar Water Heater?

A couple of years ago, motivated by the dual goals of saving money and doing my part to reduce green house gases, I decided to take some action to reduce our large annual household consumption of heating oil. Our 26 year old furnace was replaced with a new Biasi high efficiency - triple pass - cold start model with an outside temperature controller and indirect oil fired water heater.



Illustration 1: The new Biasi high efficiency furnace with a Superstor Ultra indirect 30 gallon water heater cut our heating oil consumption by about 25%

Next, I insulated our basement walls to R-28 and replaced our home's original windows with new Energy Star rated ones. We have a heated garage attached to our house, and although we usually keep the thermostat there turned down to less than 40 F degrees, I thought that a pop can solar heater would help to reduce the demand on the furnace (at least on sunny days), while reducing heat lost by conduction from the walls of living space adjacent to the garage. While researching solar air heaters on the web, I came across the Build it Solar website, www.builditsolar.com and was intrigued by Gary Reysa's \$1k solar water heaters. I liked the simplicity of the drain back system including the non-requirement for glycol or other chemicals, and the low cost and quick payback period of Gary's design appealed to my frugality. My focus shifted from solar air heating to solar water heating.

After mulling over a design in my mind which entailed locating a couple of collectors on the 1st floor roof of our house, I took the plunge and bought a pond kit with 10' x 10' EPDM pond liner on sale for \$60. Next, I bought a Grundfos UPS 15-55SFC stainless steel 3 speed pump with enough head to pump water to the collectors from the basement, a Steca 301 controller and copper coolie roof caps.

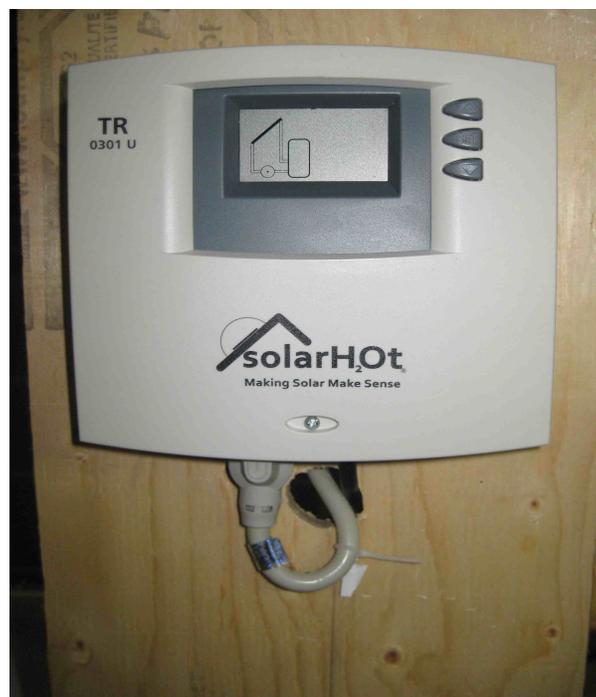


Illustration 2: Steca 0301 U Solar Controller turns on the pump on and off.

After further consideration, I decided against locating the collectors on the roof. Instead, hanging them from the side of the house would allow the use of a smaller pump which would consume 40 watts less power than the Grundfos (I can use the Grundfos to replace the 30 year old one on my oil fired furnace) and installation and maintenance of the collectors would be much easier closer to the ground. The downside would be slightly more tree shading of the collectors, and loss of some garden space.

Collectors:

In the end, I decided on two 4' x 6' collectors, each with 7 copper tubes running horizontally and the headers oriented vertically. This allowed for efficient use of 6' copper tubes (I cut 6" from each one to use as the header pieces) and 12' sections of polycarbonate glazing (which were cut into three equal sections). It was a lot of work to cut all the copper tubes and sand them, but the actual soldering process went quickly and worked well (though not perfectly as I later found out).



Illustration 3: Copper grids soldered and awaiting placement on the collector panels

The Collector inside frames are constructed with 2 x 4s which were covered on the front with 7/16" oriented strand board and on the back with 3/16" plywood. I used 3.5" fiberglass batts rated at R-12 for insulation. The use of polyisocyanurate insulation board would have obviated the need for a 2X4 frame and the back sheet of plywood, thereby saving some weight, but I couldn't find polyisocyanurate locally and I had lots of fiberglass batts left over from a previous project. The outside frame is made of 5/4" X 6" pressure treated lumber top and bottom and 3/4" plywood on the sides. The copper grids are sloped about 2-3 inches to ensure good drain back .



Illustration 4: Three inch strips of aluminum under the copper grid. The strips were painted to avoid galvanic corrosion.



Illustration 5: This shows the layout of the tubes on the left collector. The top is on the right side of the photo.

I bought two 50' rolls of 9" wide painted aluminum flashing to make the absorber fins using Gary's press and sledge hammer method. The press worked fine. I also fabricated a fin vice tool modeled after his. This worked reasonably well, although I should have used stronger metal teeth in it. Since the aluminum was on the thin side, I laid a 3 inch strip under the copper pipe grid to improve heat transfer.

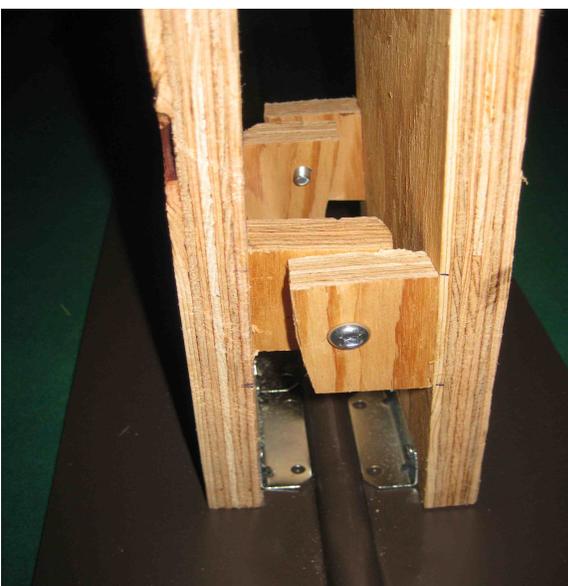


Illustration 7: Fin clamping tool in action.

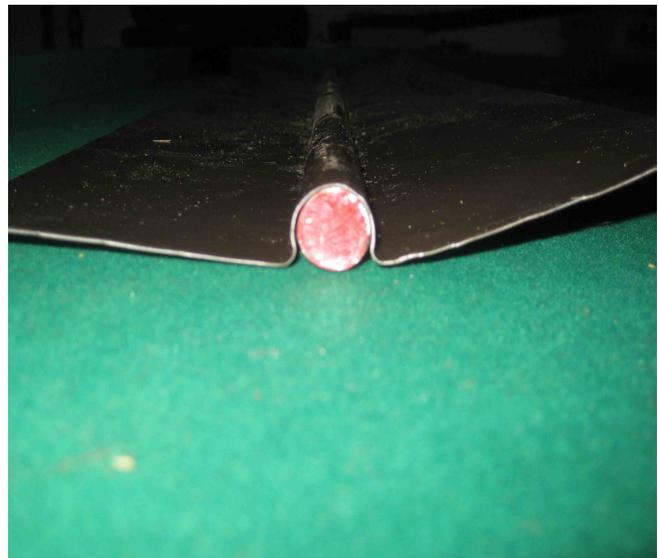


Illustration 6: A newly minted fin showing good contact.

I used silicone under the fins to ensure a good thermal contact between the copper tubes and fins. I think that the silicone will also help to keep the fins in place should the staples tend to work loose over time.

After all the fins were stapled down, the collectors were spray painted with flat barbecue paint. I cut 2' X 12' sheets of Suntuf polycarbonate glazing into 3 sections and affixed them with the use of wiggle strips on the top and bottom and silicone and metal roof screws on the sides. 1" square wooden strips screwed on the top and bottom ensure consistent pressure along the length of the wiggle strips.



Illustration 8: The right collector after application of barbecue paint. The outside frame goes on next.

I drilled a hole through the back of the left collector near its top to feed the wires for the temperature sensors for the controller and data logger. These two sensors were sandwiched between sheets of aluminum and siliconed to keep them in place and improve the thermal contact. The exterior of the collectors was coated with a green transparent stain to match the look of our pressure treated wood patio. Latex caulking was applied to the joints where the plywood and frame meet to prevent water penetration into the collectors.

Tank:

The tank is constructed of 3/4" plywood with a 2 X 4 horizontal frame members and it sits on 4" of pink polystyrene insulation board. The inside dimensions are 32 7/8" X 29 3/4" X 39" high. In addition to the top and bottom frame sections, I added a third frame section around the middle to provide added support to hold in the 1200 lbs. of tank water. Before installing the EPDM liner, the inside was sanded and silicone was applied to the corners for smoothing. It was awkward to install the liner and I didn't do a very neat job with the corner folds, but it got done.



Illustration 9: Tank, showing sloppy corner tucks.



Illustration 10: 2 X 4 tank bracing

I couldn't locate plastic decking planks to place over the edges of the EPDM on the rim, so I used 1" X 6" pressure treated lumber. Time will tell how long this will last in the tank's humid environment. I used 3.5 " fiberglass batts for insulation on the sides and covered these with 1/8" hardboard that comes pre-painted white. I used some pine for trim.



Illustration 11: R-12 fiberglass batt insulation.



Illustration 12: Hardboard being applied

The top lids are constructed of 2 X 3 frames dadoed so that the white hardboard fits into grooves for a neater job. I glued 2" pink polystyrene insulation board to the underside of the white hardboard top. The lids are fastened with 4" bolts and wing nuts for easy removal. I siliconed a 7/16" round foam backer strip on the rim to provide a seal between the rim and cover and laid a sheet of poly over the seal (covering the entire top of the tank).



Illustration 13: The tank is starting to take shape. It resembles an oversized washing machine.

Heat Exchanger:

Initially I planned to buy a 500' roll of 1/2" pex for the heat exchanger, however, Gary correctly pointed out that the pressure loss would be considerable using this much 1/2" pex, so I bought a 500' roll of 3/4" pex and used 350' of it for the heat exchanger (and some of it for the feed and return lines). (If you must use 1/2" pex you could run several loops in parallel to reduce the velocity through each, thereby reducing pressure drop). A jig was used to coil the heat exchanger. Coils were tied together after inserting 1/2" pex spacers. I ended up with three layers of coils. This took maybe 6-8 hours and got progressively more difficult since I was working from the outside in (bad idea). In retrospect, maybe I should have started on the inside row and worked out. I hope that the time spent on spacing out the coils of the exchanger will increase the exchanger surface contact area with the water and improve exchanger efficiency.



Illustration 14: Heat exchanger coiling madness.



Illustration 15: Coiling order being restored.

The outlet end of the exchanger travels via a 5' length of 1/2" copper tube to a 30 gallon indirect oil fired water heater. I installed three gate valves in the water supply so the solar water heater can be bypassed if servicing etc. is needed.



Illustration 16: Heat exchanger in tank. Inlet pipe is foreground.



Illustration 17: Connection between solar tank and existing oil fired water heater.

Plumbing, Pump and Controls:

Heat transfer water leaves the tank through a u -tube system modeled after Gary's design. A Swiftech MCP355 pump (designed to pump water to cool computer chips) which I purchased from www.ncix.com in Vancouver (and which operates at only 18 watts of DC power) circulates the water along 26 feet of 3/4 "pex to the collectors. A Sharkbite T is used to connect the feed line to the collectors. The return line is also 3/4" pex to ensure a generous route for air to effect the drain back process.



Illustration 18: Swiftech MCP355 pump uses only 18 watts and is quiet.

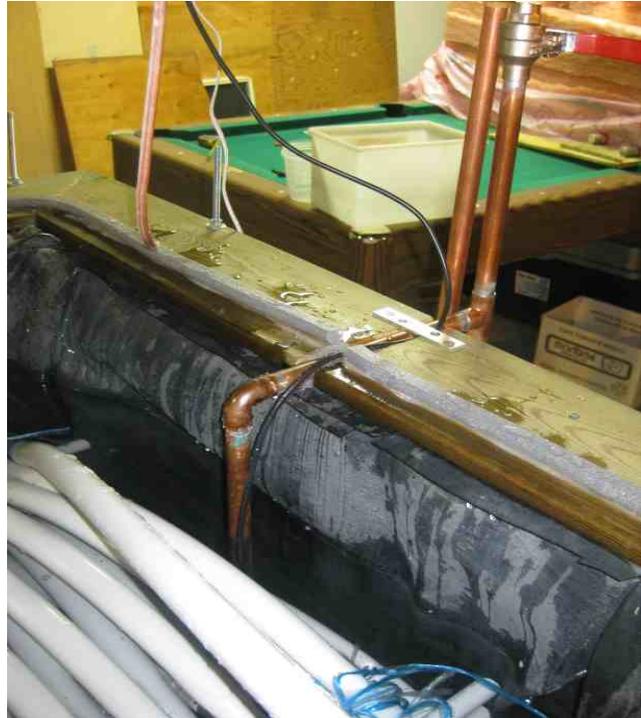


Illustration 19: Back of u-tube assembly. the black wire entering tank beside the u-tube is the tank temperature sensor.

I bought a Steca 0301 controller on eBay from seller "heatfromthesun". The tank temperature sensor wire runs into the tank where the U-Tube enters. I bought a 12 volt 2 amp (switching) adapter to power the DC pump, however, after reading Gary's experience with two Steca controller failures. I heeded his advice and bought a linear adapter from MCM electronics. (Apparently there is some concerns that a switching adapter can allow a voltage surge on start-up which can wreak havoc with the relay on the Steca solar controller, causing the pump to run continuously.) The flow rate through the collectors is 1.96 US gallons per minute or 0.04 US gallons per minute per square foot of collector area which is within Gary's recommended range. The head as measured from the top of the water in the tank to the top tube on the collector is 99 inches. This is well within the capability of the MCP355 pump.

Hanging the Panels:

The panels ended up weighing about 125 lbs. each...more than my back wanted to carry up the basement stairs. Thankfully, Barry and Brodie, carpenters who were working at our house, cheerfully agreed to carry them up for me. After locating the wall studs, I used 3 sets of heavy duty hooks, eyes and links to hang each collector. Two 2 X 4 pressure treated braces were used to elevate each collector to 47 degrees (i.e. slightly more vertical than horizontal). The latitude here in Cornwall, Prince Edward Island is 46.2 degrees so 47 degrees of tilt should be fine. I might have made the tilt 5 -10 degrees more vertical to help snow run off and so the collectors wouldn't protrude out so far from the house, but I had to make sure that the bottom of the collectors was high enough to allow good drain back through return lines which run through the rim joist of the house and I didn't want the tops of the collectors so high that they would block windows.



Illustration 20: The left collector is in position. One more to go.



Illustration 21: Collectors in position and ready for sun.

Start-up and Performance:

After more or less completing the project, on a sunny August Saturday at about noon I turned the controller on and the pump started up. After a minute and a half or so the water returned to the tank (the first bit was quite hot as the collectors were showing 238 F degrees in their stagnated state).

The system appeared to be working as planned and the water temperature in the tank rose from 60 F degrees to 95 F degrees in a few days. Three days after start up, however, I noticed a problem. The right collector was much hotter to the touch than the left collector. Further investigation showed that there was no flow through the right collector. I tried adjusting the plumbing setup at the collectors on the feed and return lines, but this didn't help...then I noticed on start-up one morning a spoonful of water leaking from a T half way up on the right collector. This was followed by a hissing sound. Air was being sucked in at the site of the leak from the vacuum created by the force of the water in the left collector draining back to the tank. I guess that there was less resistance for the water to go all the way through the left collector than to go half way up the right collector after start-up.

I reluctantly unscrewed the fasteners holding the polycarbonate glazing on the right side and bottom of the right collector and after carefully sanding and generously fluxing the site of the leak, I carefully applied the blow torch and lavish amounts of solder. Luckily I didn't set the collector on fire and the repair worked. System heating performance improved thereafter and I have had no other problems in the first month of operation.



Illustration 22: The leak site after soldering. It held!



Illustration 23: The tank and controls. Note the feed and return lines to the tank.

Following Kevin's example (see Kevin's Far North \$1K system on Gary's site) I purchased a picaxe data logger system from www.hvwtech.com in Calgary, and once I have set it up and recorded some data, I will endeavour to provide an update on system performance.

I've kept some manual temperature recordings. The tank will gain up to 15 F degrees on a good day and the highest temperature reached by the tank so far is about 120 degrees. We could benefit from a higher average tank temperature. We have tree shading of the collectors prior to 10 a.m. and after 2 p.m., so on sunny days I have about 4 hours of operation. Solar noon is at about 1:10 p.m. these days, and given the orientation of my collectors (approx 9 degrees east of South), the sun is perpendicular to the panels at maybe 12:40 p.m. or so. After the arborist does some tree pruning, the pump should run till 3:30 p.m. on sunny days most of the year.

The collectors reach 180 F degrees around solar noon hour on a sunny day and this generates rapid heat gain. My rough calculations (I'm not an engineer) show that the system harvests 1200 watts of power when the system is running, about the same power output as an electric kettle.



Illustration 24: Yogurt and Cali leisurely watching the collectors harvesting sun.

Conclusions:

- So far the system is working well, however better water heating performance should be achieved once some tree shading is rectified. The considerable energy being collected at solar noon on a sunny day is readily apparent by touching the feed and return lines and feeling the difference in temperature.
- The system cost approx. \$1800 CDN including sales taxes or about \$1700 US at the current exchange rate. It didn't come in under the \$1000 mark since the cost of materials is generally higher in Canada than in the US and I used expensive Sharkbite fittings as I don't have a pex tool. (Sharkbite fittings have the advantage of being easy to take apart if you need to adjust or service the plumbing). I think a payback of about ten years is possible. The data logger setup cost an additional \$150.
- Perfection is not necessary, as long as your design parameters are reasonable, the system should work OK. For instance, my collectors face 9 degrees east of South, but according to Gary's "RadOnCOL" program, the loss in solar radiation as compared with collectors facing due South is only 0.2%. Similarly, slight variations in collector tilt shouldn't significantly affect performance. One thing you do have to get right in climates where freezing occurs is a downward slope in the feed and return lines all the way from the collectors to the inside of your home.
- It's a good idea to pressure test your system. Leaks which occur where there is negative pressure in the system may not be apparent as air may be sucked in rather than water leaking out. If you think you have an air leak and don't have a vacuum tester, after the system is operating, place the end of the return line under water and see if there are any air bubbles.
- The project took more hours than I had planned, however, there is a satisfaction in building something that works well. Many thanks for the help of Gary, Kevin and others who have taken the time to post articles on their solar water heaters. Having built one system, I could build another in perhaps a third less time, however, I'm thinking of a pop can heater for the garage as my next solar project.

Disclaimer:

My solar water heater is experimental. I make no claim as to the safety of the design and it has not been tested or certified by any accredited authority, therefore, anyone who copies any part of this design does so at their own risk.

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