Solar Heat UPGRADE

by Guy Marsden

Expanding & Improving an Owner-Installed System

The author with his expanded solar thermal system that provides heat for his office and workshop.

Can a solar thermal heating system keep you warm, even if you live in a location with harsh winters like here in Woolwich, Maine? You bet it can. In 2001, I installed a solar thermal system to heat my workshop and office (see *HP89*). After living with the system for almost six years, I've definitely learned several interesting lessons. If you want to improve the performance of your solar heating setup, or get started on the right foot before you install your system, here are some pointers.

Solar Collector Upgrades & Additions

My original solar heating system was designed by a local solar energy system designer and equipment supplier. Since I'm handy with both plumbing and electrical work, I decided to install it myself. The system parts list included two SunEarth 4- by 8-foot Empire series collectors, a Secespol B 130 heat exchanger, two El-Sid PV-powered circulator pumps, and a Rheem 80-gallon storage tank. For backup heat during extended cloudy periods, I installed a Bosch AquaStar instantaneous gas-fired water heater in series with the solar thermal system output. The system heats a well-insulated, 24- by 28-foot building with a radiant slab on the ground floor where my woodworking equipment is located. My electronics lab/office is on the open second floor and was originally heated by convection from the first floor slab, with hot air rising up the stairway and through the open door at the top.

A few months after I had finished installing the system, my system designer informed me that the collectors I purchased had a design flaw that would cause them to underperform. I was seeing a maximum collector temperature of about 180°F on bright sunny days. SunEarth offered to replace the collector absorber plates, and at the same time I decided to also add two more collectors to the system. These changes resulted in peak collector temperatures of 240°F on similar days—a dramatic improvement!

Getting the Pumps Under Control

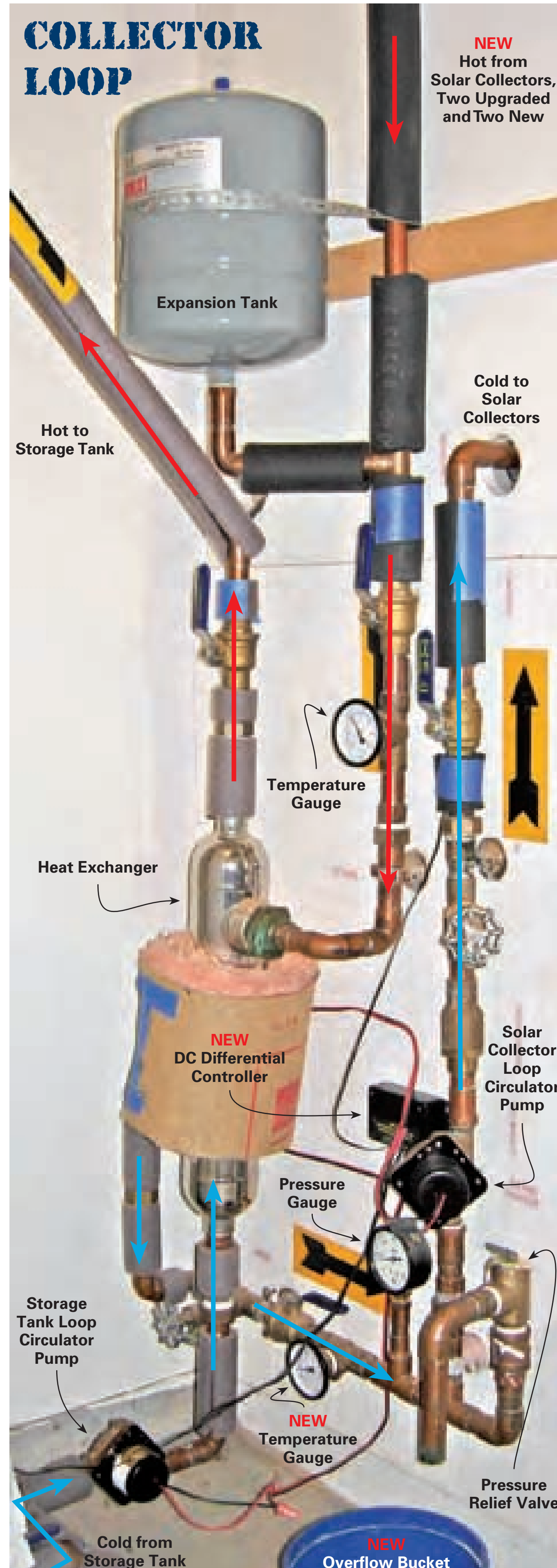
Both the collector loop and the loop from the heat exchanger to the solar storage tank used solar-direct pumps without controllers. Whenever the sun was shining, the solar-electric (photovoltaic; PV) modules powered the circulator pumps. Each of the two 10-watt pumps was powered by 20 watts of PV.

This seemed like an elegant solution. But after observing my system for the first year, I noticed that the storage tank temperature would drop considerably within an hour of sunset, and also in the early morning. As the sun went down, the collectors became cooler than the storage tank. I finally realized that the hot water stored in the tank was being radiated out through the collectors (via the heat exchanger) because there was still enough sun to run both of the PV-powered circulator pumps.

Most solar thermal systems use a controller to prevent the pump from running when the collector fluid is cooler than the stored hot water. In my system, the collector-to-heat-exchanger pump is direct-wired to the PV module without a controller, and is not a problem. But the second pump, which circulates hot water from the heat exchanger to the storage tank, needs to be controlled to prevent heat loss and maximize system performance.

While affordable, high-quality differential temperature controllers are readily available, the ones I found all run on 120 VAC. It didn't seem appropriate to run the DC PV-powered pumps with an AC-powered controller—what if the grid fails, as it does often here in rural Maine? This would leave my heating system crippled until utility power was restored.

As an inventor and an electrical engineer, I decided to build my own controller that would run on 12 VDC from a PV module. Sensors on the collector outlet pipe and one near the top of the storage tank are wired to the controller, which only activates the heat exchanger-to-storage-tank pump if the collector fluid is hotter than the stored water.



A DC-powered differential controller, designed and built by the author.

More Heat for the Second Floor

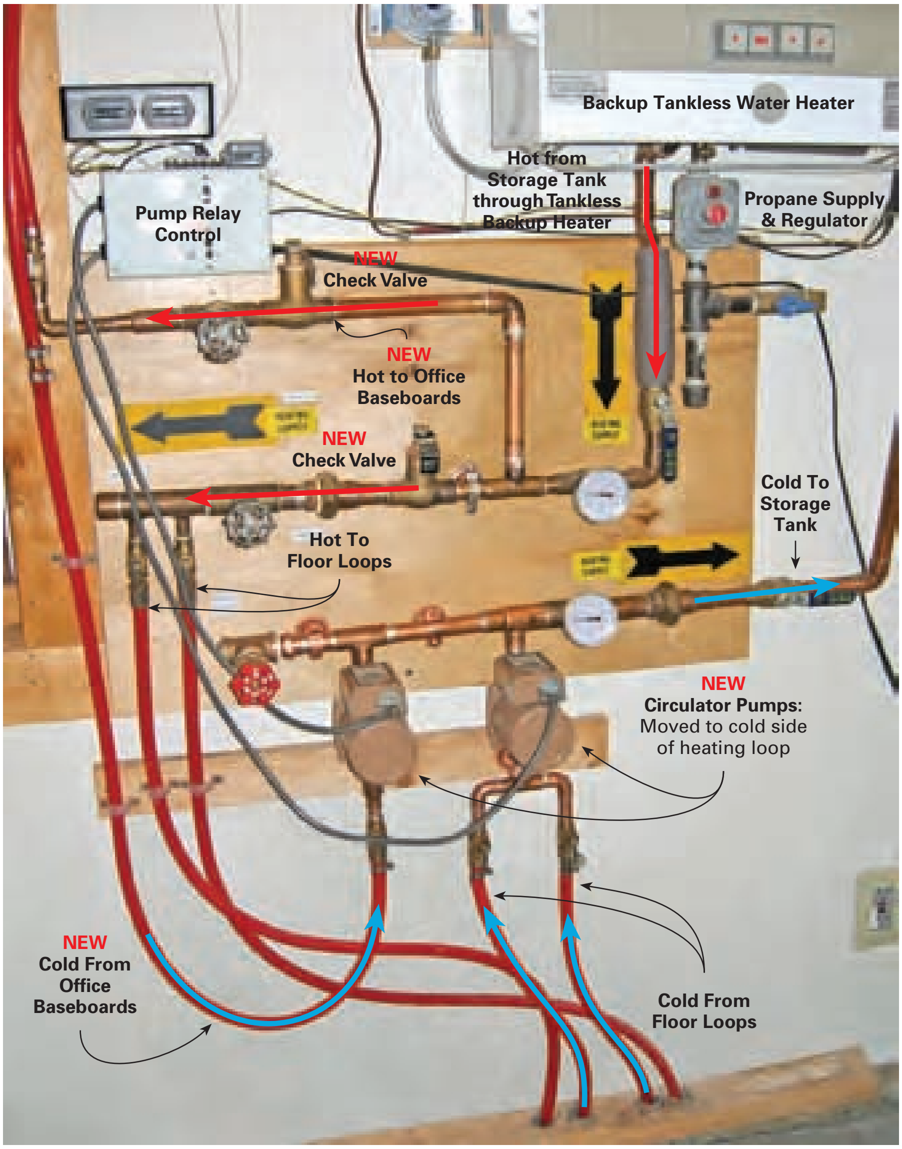
With my original system, the second floor office was a bit chilly in the mornings, since I had to wait for the heat to rise through the open stairwell. To remedy this, I added two 10-foot-long hydronic baseboard radiators upstairs.

Installing them was fairly simple. I ran 1/2-inch PEX radiant floor tubing from the main heating system manifold to the new radiators and back. (Copper tubing would have been fine as well—but the PEX is so easy to work with!) To minimize heat loss in the new plumbing runs, I insulated the exposed tubing with high-density foam pipe insulation. Since the radiators are on the second floor, I had to move my automatic air vent up to the new highest point in the hydronic system, which was right at the end of one of the radiators.

When I first ran the separate circulator pump for the radiator loop, I found (by feeling the pipe) that the water going to the radiators was not hot. Some models of circulator pumps have built-in check valves, but mine didn't. I discovered that the pump was pulling cold water in a reverse flow from the floor loop, instead of directly from the storage tank, so I installed a couple of check valves to keep the water flowing in the right direction in each loop.

Installing a larger expansion tank eliminated overpressure problems.

HEATING LOOP

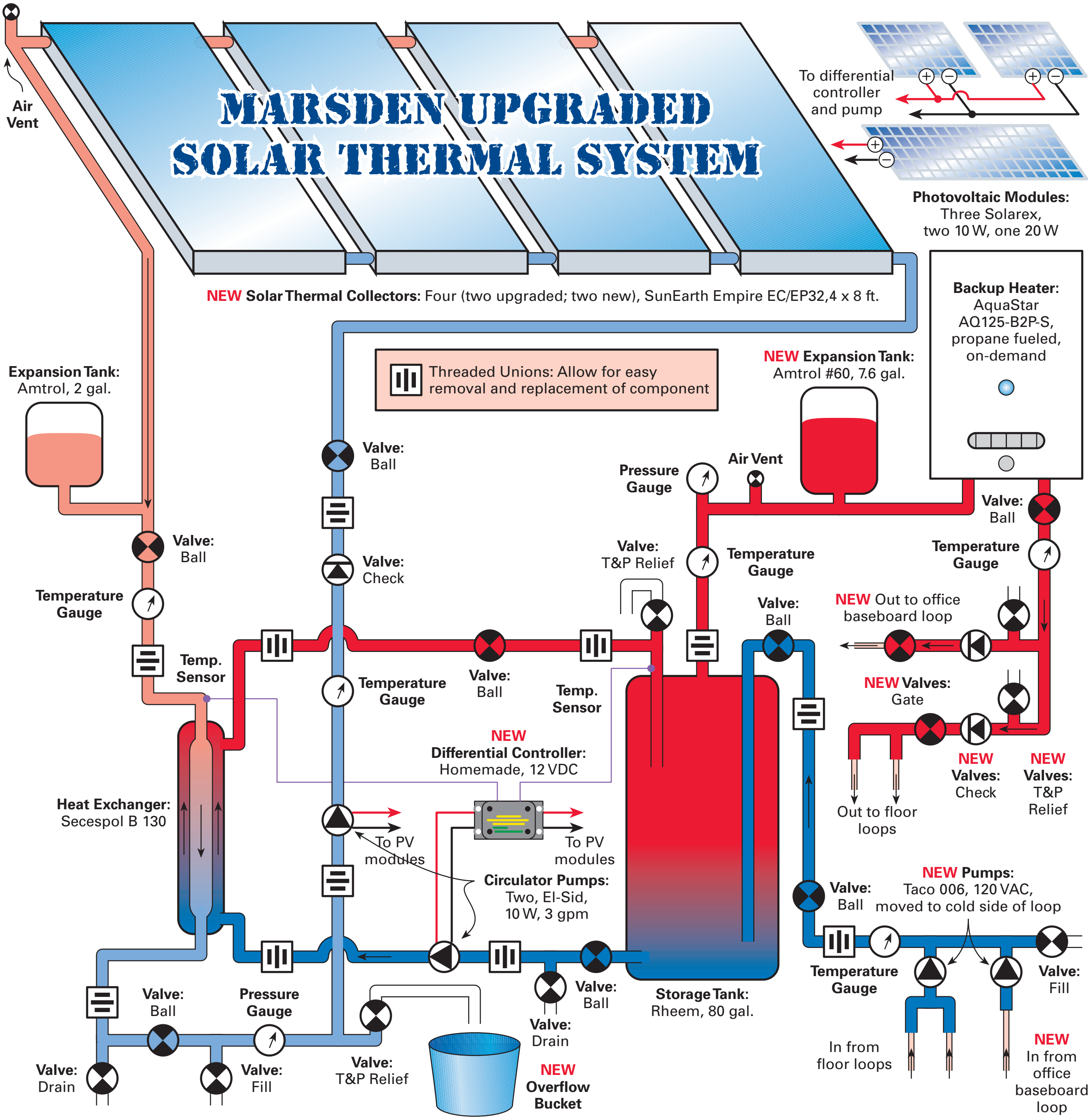


When I turn on the upstairs thermostat now, the radiators get 140°F water right away and the room temperature rises by about 6°F per hour—even when temperatures outside dip below 10°F.

Of course, the system has its limits. Despite the tight, well-insulated building envelope, the design of my heating system just can't keep up when it's well below 0°F outside. We had a record –20°F this winter, and even with the propane backup heater running day and night, the system could not maintain the 65°F setting on the thermostat. Once the outside temperature got above 10°F, the system operation returned to normal.

Reorienting the Pump

Occasionally in the mornings, I'd find the building more than 5°F below the 65°F thermostat setting, indicating a performance problem with the system. Listening to the circulator pumps, I would hear a gurgling sound that made me suspect that there was air trapped in the pump. This is called cavitation, and it can prevent the pump from working



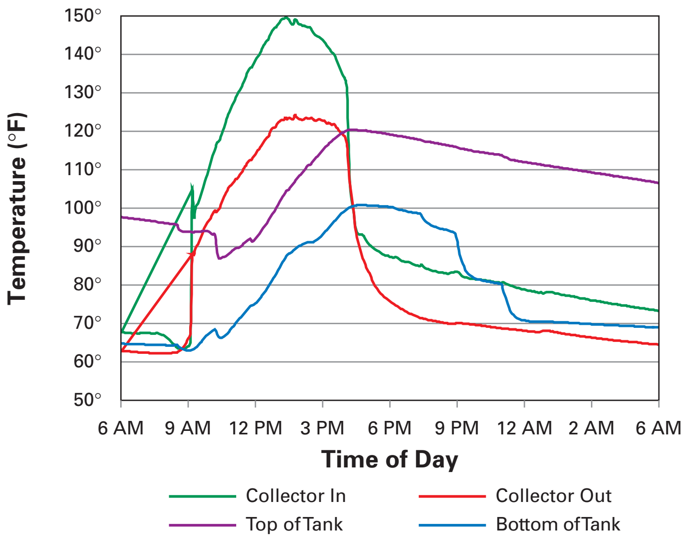
or even cause irreparable damage in some cases. Through ignorance, I had oriented the pumps horizontally (the fluid entered and exited from the sides), which increases the incidence of cavitation with some pumps.

So I replumbed the whole manifold, reorienting the pumps so the flow is vertical. This allows trapped air to escape to the highest point of the hydronic system, so the automatic air vent can eliminate it. In the replumbing process, I also moved the pumps from the feed side of the heating loops to the return side. I did this on the recommendation of a very helpful applications engineer at Taco. He said that the pumps would last longer if they were installed on the cooler side of the loop.

Dealing with Excess Heat & Pressure

During the early spring through the late fall months, the system produces more heat than I need. I've had various suggestions for solutions to this issue from a number of solar hot water system dealers who read my previous *Home Power* article. Suggestions included installing a thermostatic three-way valve that dumps heat to an outside radiator during the warm months, and covering the collectors with canvas boat

Winter Solar Thermal Collector Performance



covers. I have yet to implement these suggestions—I simply drain and flush the collector loop in the spring and refill it in the fall.

High temperatures in my storage tank used to drive the pressure to more than 100 psi, which once caused the pressure-temperature relief valve at the top of the tank to blow and dump hot water all over the place. My simple, stopgap solution was to place a gallon bucket under the outflow!

After struggling with this issue for more than a year, I read a brief article by *Home Power* solar thermal editor Chuck Marken about expansion tanks, which give solar water heating systems "elbow room" by regulating system pressure so the relief valve does not need to open to release excess pressure as the water gets hotter. When it dawned on me that the expansion tank might be undersized for my system, I asked Chuck, who pointed me to the expansion tank sizing calculator at the Amtrol Web site (www.amtrol.com).

The calculator confirmed that my expansion tank—a #15 with a 2-gallon capacity—was undersized. Based on my system specs, Amtrol recommends a #60 tank with 7.6-gallon capacity. At a cost of about $90, I replaced my tank, and the solar storage tank's pressure has remained relatively constant ever since.

Frozen Pipes

Last winter, record low temperatures of -20°F caused my collector plumbing to freeze somewhere in the 15-foot-long, insulated (but outdoor) plumbing to the bottom of the collectors. It turned out that when I had filled the collectors in the fall, I had miscalculated the 50 percent ratio of propylene glycol needed, and had only used a 40 percent glycol mixture. I had to drive through a heavy snowstorm to the local plumbing supply warehouse to get an expensive 5-gallon container of antifreeze.

By mid-afternoon, the ambient temperatures were up to 10°F, and I was able to use my fill pump to unblock the frozen plumbing by forcing fluid into it until the heated collector fluid cleared the pipes. I then drained some fluid and pumped in a healthy dose of antifreeze. I used a chart provided by the antifreeze manufacturer to figure out what ratio would protect pipes to -20°F in the future.

Warm in the Winter

After these small tweaks and some fine tuning, I am very pleased with the performance of my solar-augmented heating system. I keep the building at 65°F downstairs and 72°F upstairs through the Maine winters, and have had relatively few problems for a home-built design. We certainly do get a lot of clear sunny days in the colder months—parts of Maine have almost as much annual solar insolation as New Orleans—and the solar collectors definitely contribute to a significant savings on propane.

With the supplemental solar heating, my propane bills—at $1.49 per gallon—averaged $140 per month for the five months of winter weather during 2004–2005. The following winter, due to warmer weather and the additional heat from a newly installed wood heater, bills averaged $100 per month. That's not bad in this climate for a building of more than 1,300 square feet!

Access

Guy Marsden, 61 Delano Rd., Woolwich, ME 04579 • 207-443-8942 • Fax: 866-427-8832 • guy@arttec.net

System Components:

Art Tec • www.arttec.net • Differential temperature controller

Ivan Labs, 350 Circle W., Jupiter, FL 33458 • 561-747-5354 • El-Sid circulator pumps

Rheem • www.rheem.com • Solar storage tank

Secespol • 905-602-4505 • www.secespol.com • Heat exchanger

SunEarth • www.sunearthinc.com • Collectors

Taco Inc. • 401-942-8000 • www.taco-hvac.com • Circulator pump