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7 Solar Water Heating System Designs

By Michael Hackleman

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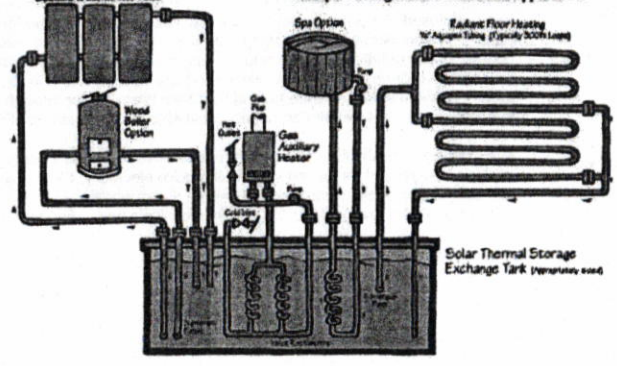
(Rob Harlan is a general and solar contractor with 25 years of experience with solar water heating systems in Mendocino County, California. Rob primarily designs and installs photovoltaic systems today.)

Mh: Rob, will you give a brief history of the last 30 years of solar-water heating system design and implementation?

Rob: Solar-water heating systems got a real boost in the 1970s when tax credits were offered by state and federal programs to help folks make the investment. These systems were intended primarily for domestic hot water, i.e., showers, dishwashing, cooking, and clotheswashing. They were also popular for heating the water in pools and hot tubs. This movement slowed to a snail's pace when the tax credits ran out.

Fig. 1: Solar water-heating systems will handle multiple heating sources and various applications



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Mh: As I recall, a lot of manufacturers also disappeared when the tax credits went away. Of course, some of these systems were poorly designed, used cheap components, or lacked adequate protection against freezing, overheating, or corrosion. I know that you've upgraded solar water heating systems over the years, or older systems from homes and businesses in favor of newer designs. What's your experience of the design and hardware from 30 years ago?

Rob: Some designs were indeed flawed—poorly implemented, overly complex, or incorporating untested ideas. Still, even good designs require some maintenance. The lack of knowledgeable service personnel and parts crippled some systems. The solar collectors from these systems are actually pretty rugged and often find their way back into new installations sold "as is" or used. Today's manufacturers of solar water heating systems and components have benefited from the lessons learned long ago. Things are back to a steady pace, with a variety of manufactured system types. Most offer good reliability, are warranted, and generally follow time-tested designs.

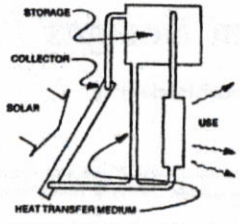

Fig. 2: Block diagram of a solar water-heating system

Mh: There are a few parts that are basic to most solar water heating systems (Fig. 2): collector(s), storage tank, heat transfer medium, and interconnecting plumbing. The collector intercepts the sun's rays and converts it into heat which is transferred to the storage tank using a fluid such as water or antifreeze. An expansion tank is used in closed systems to accommodate the slight changes in volume that result when water or antifreeze is heated and expands. If glycol (a non-toxic antifreeze liquid) is used, a heat exchanger is needed to transfer the heat from the collector to the water that will exit the faucet. A T&P (temperature and pressure) relief valve is a common safety device found at the top of water heaters. If the water gets hotter than it should or the system builds up too much pressure, this valve will open, releasing water until the temperature or pressure drops to safer levels. The simplest control system disables the backup heating system (gas or electricity) during daylight hours, giving the sun a chance to heat all of the water in the storage tank.

Rob: And—on active systems, a controller turns a pump on and off as solar heat is available. Let's define a few terms used to describe these systems—active vs passive, open vs closed. An active system is one that uses pumps to move the heat about. A passive system is one that contains no pumps, relying instead on natural convection, conduction, or radiation to move heat. An open system means the water circulating through the collector is the same water you'll use in a shower (Fig. 3). A closed system circulates the separate heated fluid from the collector through a small loop that includes a heat exchanger, usually located in the storage tank (Fig. 4).

Mh: I understand why some people choose passive over active designs. Pumps, controls, relays, and motorized valves all require electricity. Electricity is a very specialized and sophisticated form of energy. Folks who live in the country beyond the grid know what a luxury electricity is. We know it's a luxury because it's expensive to

Rob: A wonderfully detailed overview of solar hot water systems, complete with schematics and technical information, is found in the Solar Water and Pool Heating Design and Installation Manual from the Florida Solar Energy Center at (407) 783-6300. Triple A Solar in Albuquerque, NM (800-245-0311) sells used solar-thermal collectors at good rates. Check out local sources of used panels to avoid shipping costs. Six Rivers Solar (816 Broadway, Eureka, CA 95501) at (707) 443-5652 sells a high-quality, rectangular thermal storage tank that integrates the inputs and outputs of collectors, auxiliary heating sources, DHW, radiant floors, and hot tubs (Fig. 1).

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month or $551 annually. Propane at $1.41 per gallon costs about $26 a month or $307 per year. Natural gas and fuel oil are less, as is electricity in other parts of the country. Of course, when a solar water heating system is installed and has returned the investment, the energy from it thereafter is free.

Mh: Will you give me an idea of how long it will take to pay off the cost of several of these systems based on these rates?

Rob: I have that information, too. First, let me say that these figures do not include the cost of maintenance, the rise in the cost of utility electricity, the lost interest on the investment, and no tax on the savings. In my experience, these balance each other out.

A new integral collector/storage system using the ProgressiveTube™ design will cost about $2,500 parts and labor to install. After 7.3 years, the system cost will equal the cost of electricity to heat the same water during that time. With propane, it's about 13 years. If the owner installs the system, the cost is about $1,600. The payback is 4.8 years for the avoided cost of using electricity and 8.7 years if using propane.
A new drain-back system costs $3,500 parts and labor. This is equal to 8.5 years of electricity and 15.2 years for propane for domestic hot water. A system that will heat a hot tub will cost about $4,800. When heated electrically, the payback computes to 7.5 years.

Mh: In my experience, folks who install their own solar water heating systems usually begin by putting one collector in a loop to the existing water heater. If you shower in the morning, what's the conventional method for preventing the water heater from using electricity or propane to reheat this water before the sun gets a chance at the task?

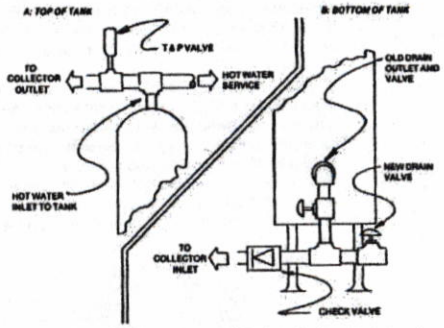

Fig. 13: Plumbing for an open system using thermosiphon

Rob: In an electric heater, it's easy. A 24-hour timer can be set to lock out the backup heating during daylight hours. The owner can manually override the timer with the flip of a switch during bad weather or unusually high demand. For a propane or natural gas heater, turn the gas valve to the pilot position.

Mh: There is a proper way to plumb the solar collector to the standard water heater, too. Today's water heaters position the cold-water inlet and hot-water outlet at the top of the tank. Cold incoming water to the tank actually drops through a tube inside the water heater which ends just above the bottom of the tank. For thermosiphon flow, this is not a good arrangement; you want the cold water return to the collector to exit directly from the bottom of the tank (Fig. 12). Fortunately, water heaters have a drain valve. There is a way to re-arrange this plumbing (Fig. 13) so that the collector will use this orifice for its thermosiphon loop while you retain the ability to drain the tank.

If someone wanted to assemble their own solar water heating system, what's a good source of information and parts, beyond the library and internet?

make. And very expensive to make a lot of it. It's a shock for folks who have lived most of their life with utility power to move beyond the grid. A passive solar heating design for making domestic hot water or warming a home requires little or no electricity to operate. Fewer parts, less to go wrong, less to take bites out of your pocketbook. With passive, it's all in the design. Considered experimental in the 1970s, passive solar heating has proven itself worldwide in a wide range of climates. Speaking of climates, why would someone choose a closed system over an open one?

Rob: Freezing protection. If the water in the collector freezes, it will burst a tube or header. It's messy, it dumps your hot water, and it must be repaired. You don't have to live in a place with hard freezes. Water in a collector open to a clear sky can actually freeze when the ambient air temperature is as high as 40 degrees F. This condition is called night sky radiation.

Mh: Incidently, there are two reasons why water that freezes will burst its plastic, metal, glass, or stone container. Actually, they are simply properties of water. One, water is virtually incompressible. Two, water expands slightly as it changes from a liquid to a solid. Water immobile inside a small tube or pipe and exposed to a freeze, then, will begin to expand as it becomes ice. Unable to compress itself, it makes a bigger volume by breaking whatever contains it.

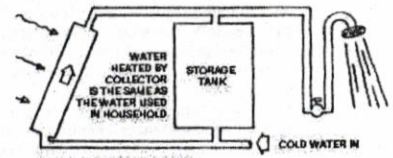

Fig. 3: An open system

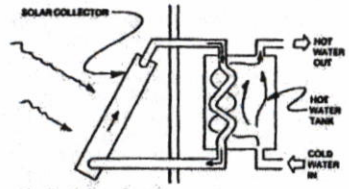

Fig. 4: A closed system

Rob: True. It's actually the different strategies used to combat the potential of freezing that define the major types of systems and their relative complexity. I've categorized existing systems into seven types: integral collector/storage, thermosiphon, three-season, drain-back, drain-down, re-circulation, and active closed-loop.

Mh: Will you describe them all, first generally and then assess their merits and liabilities from your own experience?

Rob: I would be glad to. I must say first that my experience with solar hot water is limited to my service area (coastal northern California) which is a fairly benign climate with occasional light freezes. I ask your readers to keep this in mind as I speak of various systems.