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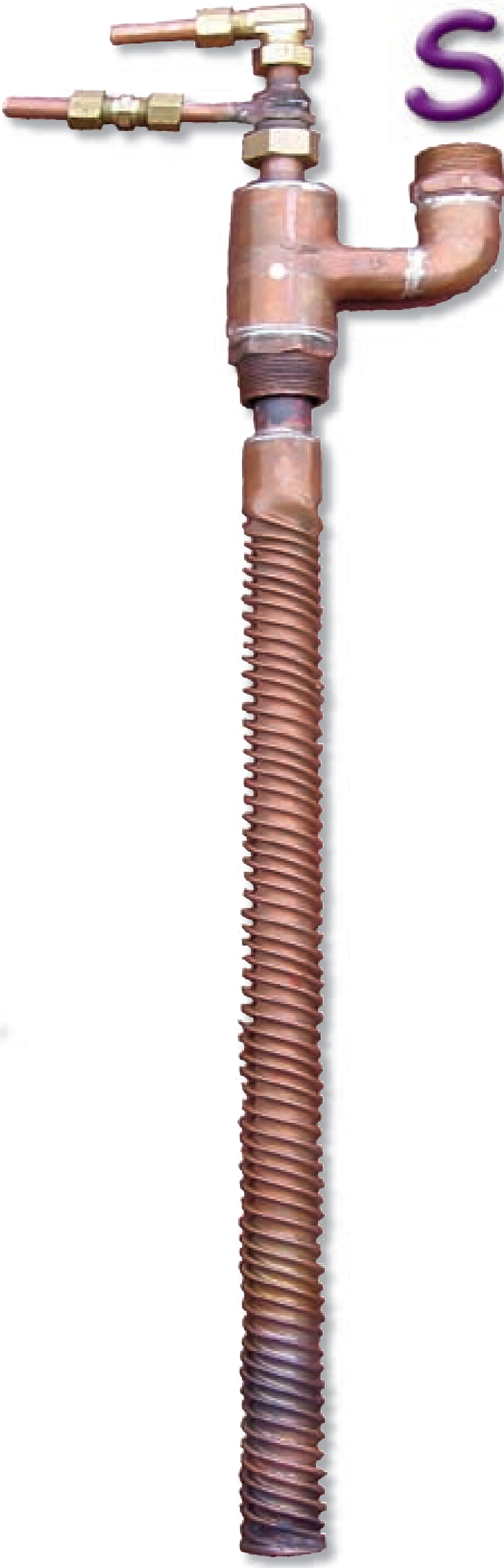
Solar Wand



Hot Water Assist for Cold Climates

Barry Butler

Do you want a freeze-protected solar domestic hot water system (SDHW), but the cost and complexity are slowing you down? This article will show you a simpler and cheaper way, using your existing water heater.

This system uses a double-walled heat exchanger that screws into your existing hot water tank. These systems are relatively new to the market, since the double-walled heat exchanger that fits into existing water tanks only became commercially available in January 2003. Instead of a pumped open loop in the hot water tank to provide solar-heated water, the Solar Wand system uses only the pumped antifreeze in a solar collector closed loop, and natural conduction and convection.

The solar-assist system costs less because it is less complex and has fewer parts. But the system may not deliver as much solar energy to the residence since it uses only the water storage capacity of the existing hot water tank. Previous articles in *Home Power* (*HP84* and *HP85*) have covered the fundamentals of solar water heating systems and other alternatives for cold climate SDHW systems.

The flat-plate solar collectors are usually connected in parallel, and installed on a roof or mounted on the ground, with their highest point above the top of the hot water tank. The assembly containing the heat pipe radiator, the pressure relief/vacuum recovery valve, and the overflow reservoir is mounted on the highest point in the system, usually just above the collectors.

The in-tank heat exchanger is inserted into the water tank, and the pump, valves, and temperature gauges are mounted on top of the hot water tank. The differential control box is mounted on the wall near the top of the hot water tank. Here's a closer look at the function of each of these components.

Collectors

For a solar-assisted hot water system using flat-plate collectors, use a selective surface absorber because it delivers more solar energy to the water tank. The collector's copper tubes bonded to the sheets can be arranged in parallel paths horizontally or vertically, or in a single fluid flow path, called serpentine. The serpentine configuration is best because the antifreeze fluid must pass serially through all tubing in the collector at a single flow velocity, eliminating the need to balance parallel flow paths.

For colder northern U.S. climates, which have more overcast skies, evacuated tube collectors are a good choice. These collectors have a space with a vacuum between the absorber plates and the outside air. While more expensive than flat-plate collectors, they lose less solar heat to the atmosphere, so they are more efficient. The design of evacuated tube collectors reduces the heat loss caused by convection (evacuated space), radiation (selective absorber), and conduction (long, thin glass paths).

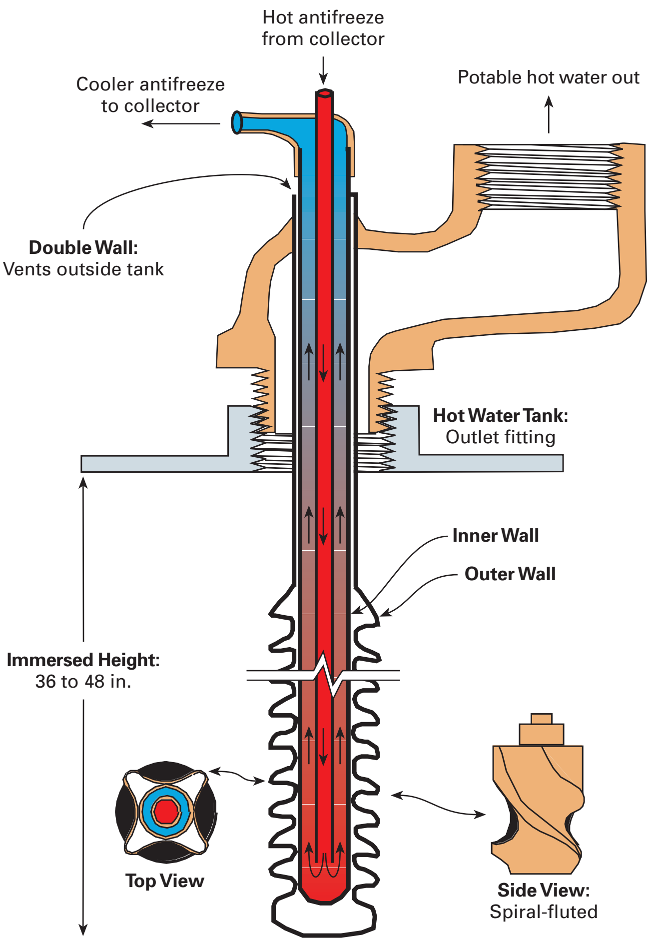
These collectors will easily bring the pressurized antifreeze closed loop to 212°F (100°C) in the middle of winter, improving heat transfer into the water tank. The 212°F closed-loop temperature is well below the boiling point of the 16 psi pressurized loop, which is 247°F (119°C).

DC Circulation Pumps

Closed-loop antifreeze systems do not need high flow rates, and do not have large head losses. Photovoltaic-powered pumps with a 10-watt photovoltaic (PV) module have worked well in some installations, demonstrating that low-head pumps are acceptable. Just like an automobile's radiator, the closed-loop antifreeze system is always maintained full. This means that the pump never has a differential fluid level pressure head to pump against, just the dynamic fluid friction in the fluid tubing, which is estimated to be less than 1 psi in most systems.

Solar installer Andrew Gerl of Blazing Solar of Mesa, Arizona, on the roof with solar thermal collectors, the PV module for the pump, and the TPFRS radiator/reservoir unit.

Solar Wand Cutaway View



The choice of pump will depend on cost and availability in your area, and the distance between the hot water tank and the solar collectors. For distances of 30 feet (9 m) or less, the lowest head, low-speed pumps are preferred. For distances higher than 30 feet, the higher-speed Laing models, with about a 28-watt PV module and linear current booster (LCB), are preferred. All of these pumps are extremely quiet, except the Hartell, which has more noise and vibration, but is not unacceptably loud.

Controller & Sensors

The controller is the brain of the system. It tells the pump when to turn on and off, which is determined by the collector and storage tank temperatures. All of its intelligence is focused on determining whether the collector outlet is sufficiently warmer than the bottom of the tank to warrant turning the circulating pump on. Sensors are located at the collector outlet, and at the bottom of the solar storage tank.

The Independent Energy GL-30 is an example of a good differential control. It has an adjustable temperature differential setting of 5 to 25°F (3–14°C). These controls have a high-limit cut-out that will shut the circulation pump off once the tank reaches a predetermined high temperature limit, adjustable from 110 to 230°F (43–110°C). The GL-30 uses industry standard 10 K-ohm sensors. These thermistor sensors read 10,000 ohms at 77°F (25°C).

Solar Pump Comparisons

Pump	Voltage	Watts	Rpm	Head (ft.) at 0.5 Gpm	Pressure (psi) at that Head
Hartell MD 101 U	120 VAC	140	1,720	20.0	8.66
Grundfos UP 15-42 F	120 VAC	85	2,590	18.5	8.01
Laing SM 909	120 VAC	69	3,450	14.0	6.06
Taco 006 BT4-1	120 VAC	60	3,250	10.5	4.55
Laing SM 303	120 VAC	35	3,450	6.0	2.60
Laing D-34/700B	12 VDC	24	3,450	10.5	4.55
Ivan Labs EL SID 2x2	12 VDC	10	1,720	2.5	1.08

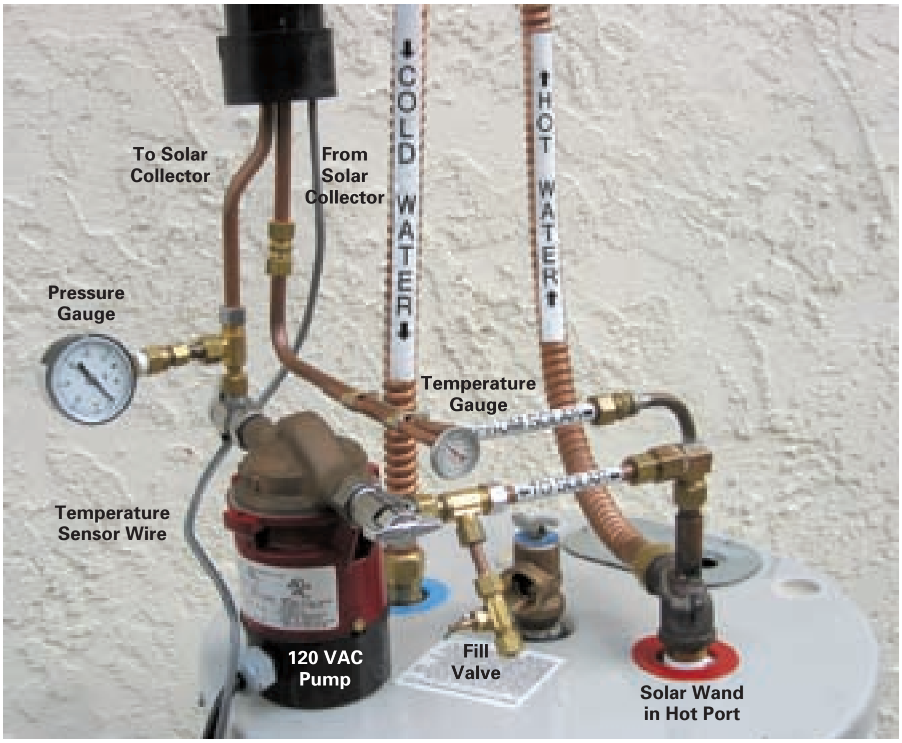
The PV-powered pumps circulate only when the sun is shining at more than 400 watts per square meter (you can just see your shadow). A snap switch cut-off or pump controller must be used to shut the pump off if the tank gets too hot. PV-powered pumps, panels, and controllers now cost only slightly more than 120-volt AC pumps and controllers.

Heat Exchanger

A heat exchanger transfers the heat from the solar-heated closed loop to the domestic water. Factors that increase heat transfer are:

- Greater surface area
- High thermal conductivity
- Maximum temperature differential between the two fluids

A typical Solar Wand installation using a Laing AC pump.



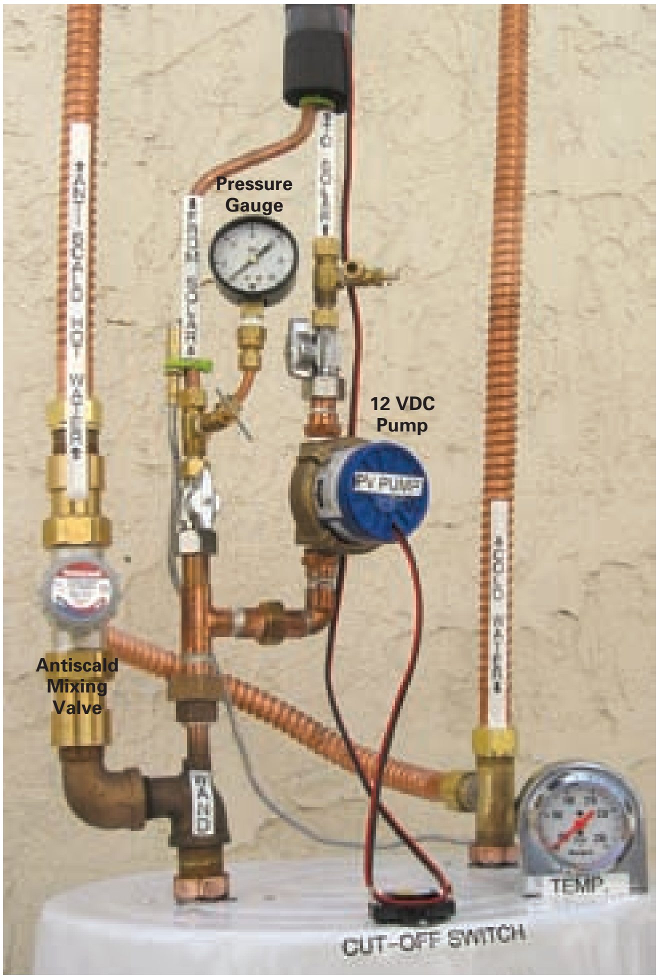
Heat exchangers may be categorized as single or double wall, which refers to the number of barriers between the two fluids exchanging heat. Single-wall heat exchangers are usually not permitted in potable (drinkable) water systems when a nonpotable heat transfer fluid is used. For example, systems that use glycol should not be used with a single-walled heat exchanger because of the potential for contamination of the potable water in the event of a leak.

Double-wall heat exchangers are required to ensure that the heat transfer fluid will not contaminate the potable water. The space between the two walls of the heat exchanger is usually vented to permit detection of a leak.

The Solar Wand heat exchanger used in this solar-assisted hot water system is unique, since it screws into the home's existing hot water tank. The wand is inserted into the tank via the standard hot water outlet, and uses a brass coupling, which is required to limit corrosion in the tank and piping. The wand is fitted with a new 3/4-inch male National Pipe Thread outlet for the hot water. The wand has a flow area equal to 1/2-inch pipe for a short distance in the outlet fitting. In most cases, the homeowner does not even notice the flow loss. (Residences subject to the Uniform Plumbing Code are required to have a total cross-sectional area of pipe equal to that of a 3/4-inch pipe serving a domestic water heater. Check with your local building inspector for requirements.)

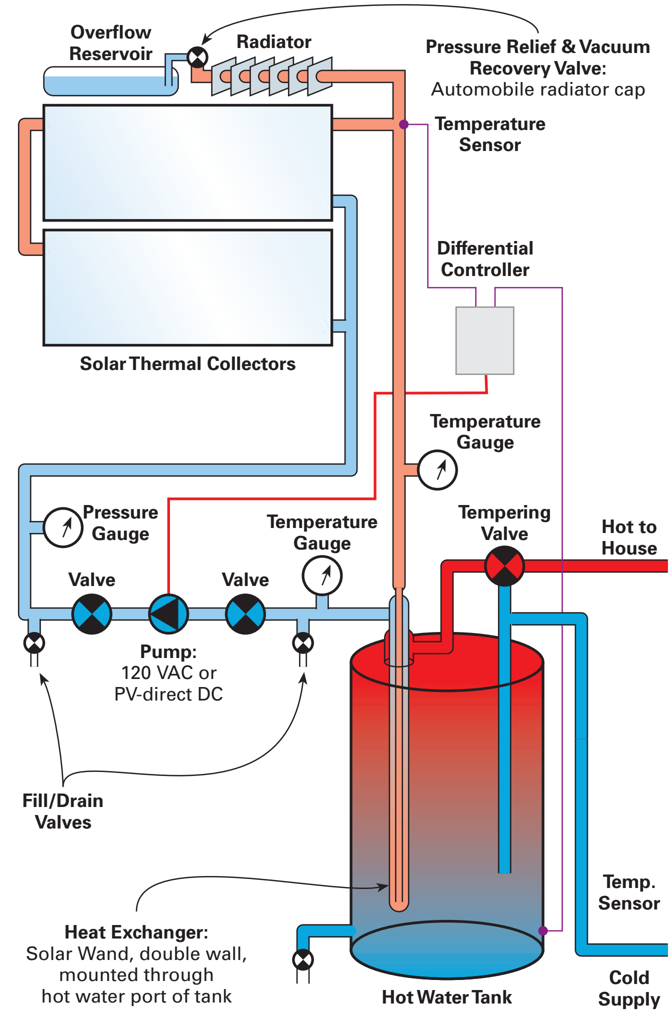
The wand is double walled, with the space between the two walls vented to the outside of the hot water tank. The standard length 48-inch (122 cm) wand has about 2 square feet (0.19 m^2) of heat exchanger surface area in the hot water tank. The solar wand's immersed heat exchanger transfers the closed loop's heat directly to the tank's water via conduction, and does not require a second pump. Convection maintains the normal tank stratification—hot on top and cold on the bottom.

The wand's small surface area—dictated by the size of the hole it must fit through to get into the tank—must be offset by higher temperature differentials. The temperature differential is based on a fluid flow in the solar closed loop of about 0.5 gallons (1.9 l) per minute. The wand transfers 3,600 BTUs per hour under these average conditions. Using hot water from the tank lowers the tank temperature. This increases the temperature difference, which increases the heat transfer. As tank temperature rises, heat transfer slows.



A typical Solar Wand installation using a PV-powered DC pump with cut-off switch, and an antiscald mixing valve.

A Solar Wand System



The solar wand is not the best heat exchanger. The heat exchange surface area inside the tank is only 2 square feet, limited by what will fit through the port into the tank. But this system has significant cost advantages over special hot water tanks, which have built-in heat exchangers. The wand can simplify the system, can be relocated from old to new tanks, and be very cost effective compared to external, double-wall heat exchangers.

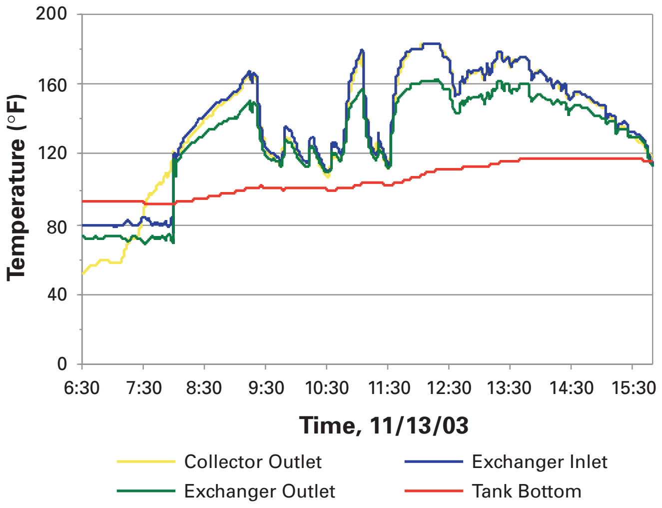
TPFRS

One device—the overtemperature, overpressure, fluid overflow, and recovery system (TPFRS)—replaces the conventional components of fluid expansion tank, pressure relief valve, air separator/air removal valve, and manually operated coin vents for trapped air removal. It also serves the additional function of a heat dissipater for the collector if the water tank gets too hot and the controller turns off the circulation pump.

The TPFRS must be placed at the highest point in the closed loop, and uses a small section of finned, baseboard heater, radiator pipe to connect the solar collector closed loop to the automotive-type radiator cap. This cap limits the system pressure to its rated value, usually 16 psi above the static head in the system. Each day, as the closed-loop fluid heats up, any trapped air and excess fluid is forced past the

A TPFRS unit showing the radiator on the left, automobile radiator cap in the middle, and the overflow reservoir on the right.

System Water Temperatures



cap and into the bottom of a fluid reservoir, which captures the fluid and releases the air.

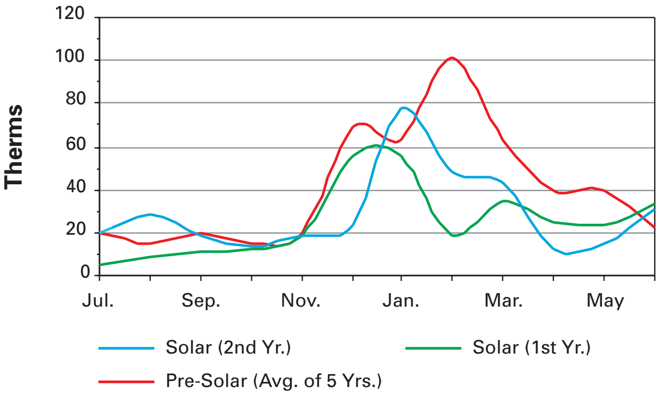
When the closed-loop system cools down, only fluid is drawn back into the system, via the radiator cap's vacuum recovery valve. This is the same way a car's radiator stays full of fluid and helps eliminate corrosion-causing air in the system. These parts are inexpensive and proven to have a long life.

The heat dissipation function is a simple steam heat pipe. When no one is home to use hot water, the tank temperature may max out, especially in summer. When this happens, the controller shuts off the closed-loop fluid circulation pump. The collector starts to boil in minutes. The steam from the collectors tries to reach the radiator cap. Steam at 16 psi reaches 247°F (119°C). The hot steam reaches the radiator, and the radiator fins conduct the heat from the pipe to the outside air, condensing the steam in the pipe.

This steam heat pipe safely dissipates the solar heat from the collector to the outside air. It keeps the collector at a maximum temperature of 247°F (119°C), just below the temperature of 250 to 325°F (121–163°C) where glycol in the collector fluid breaks down and forms corrosive acids.

The collector closed loop circulates an antifreeze solution—usually a 50:50 mixture of propylene glycol and water. The solar collector overtemperature protection slows the breakdown of the glycol water mixture. Follow the manufacturer's instructions for replacement. As long as oxidation has not darkened the fluid significantly, it is usually OK.

Natural Gas Usage Comparison for a Southern California Home



Gauges & Meters

The pressure gauge tells you if the closed loop is within an acceptable range of pressure. This ranges from 5 to 30 psi, depending on the fluid temperature and height of the collectors above the gauge. The difference in pressure between pump on and off is about 1.5 psi, so you can see whether the pump is operating and circulating. If there is no circulation because of low antifreeze level, the pressure gauge will not change when the pump switches on and off.

Two temperature gauges are used to read the fluid loop temperature at the input and output of the wand heat exchanger. A temperature difference of 15 to 20°F (8 to 11°C) indicates effective operation. Choose gauges that will measure temperatures in excess of 247°F (119°C), since on hot summer days, these temperatures could be reached.

The Goldline GL-30 controller has a liquid crystal display option, which shows the collector outlet temperature and the tank bottom temperatures, measured by the thermistor sensors. This is an excellent option.

Hot Water Storage & Antiscald Valve

Hot water tanks heated electrically or with gas are stratified, meaning that hotter water is at the top and colder water is at the bottom. As hot water is drawn from the tank, cold water is directed to the bottom of the tank via a plastic dip tube on the cold water inlet. The solar in-tank heat exchanger does not upset normal tank stratification.

Typical wand systems will heat the hot water tanks to 160°F (71°C) or above on summer days. An antiscald valve is mandatory for this type of system. The antiscald valve is put in place to limit the temperature of the hot water delivered to the house to 120°F (49°C). It accomplishes this task by blending hot water from the tank that exceeds 120°F with cold water from the cold water supply.

If the hot water in the tank is heated to 160°F (71°C) and the incoming water supply is 50°F (10°C), for each gallon of 120°F (49°C) water delivered, only 0.64 gallons (2.5 l) of water would come from the solar-heated hot water tank. The balance is cold water, blended in to prevent scalding. This means a 40-gallon (150 l) tank heated to 160°F by solar energy will provide as much hot water as a 60-gallon (230 l) tank holding 120°F water.

Typical Solar Wand System Costs

Item	Approximate Cost (US$)
2 ACR Fireball 2001 flat-plate collectors, with mounts	$1,050
Internal heat exchanger, double wall	250
Honeywell AM mixing valve	250
Goldline GL-30 controller with 2 sensors & digital display	200
Coolant system, incl. temperature, pressure & overflow protection & recovery system	175
Copper pipe, pipe insulation & wire to collectors, 3/8 in.	150
Laing SM 909 AC circulating pump	150
Valves, temp. gauges & pressure gauges	100
ABS pipe & elbows	75
Shipping	63
Fluid Tec filling pump, with tubing	25
Peak Sierra propylene glycol	12
Total	$2,500

Solar Wand

The Solar Wand heat exchanger provides a low-complexity, low-cost solar hot water system, and may produce up to half of the hot water for a family of four people. Over its installed lifetime, each system can displace up to 55 tons of carbon dioxide if you are using a gas water heater and 36 tons of carbon dioxide for an electric hot water heater.

Access

Barry Butler, Butler Sun Solutions, PO Box 1666, Solana Beach, CA 92075 • Phone/Fax: 858-259-8895 • butlersunsolutions@adelphia.net • www.butlersunsolutions.com • Solar Wand in-tank heat exchangers & parts for solar-assisted hot water systems

SolarRoofs.com, Al Rich, 5840 Gibbons Dr. Ste. G, Carmichael, CA 95608 • 888-801-9060 or 916-481-7200 • Fax: 916-481-7203 • richsolar@aol.com • www.solarroofs.com • Solar collector manufacturer

Thermomax USA/Canada, Patrick Spearing, 3181 Kingsley St., Victoria, BC, Canada V8P 41J5 • 250-721-4360 • Fax: 250-721-4329 • patrick@solarthermal.com • www.solarthermal.com • Evacuated tube collectors

Goldline Controls Inc., 61 Whitecap Dr., North Kingstown, RI 02852 • 800-294-4225 or 401-583-1100 • Fax: 800-343-0827 or 401-583-1200 • technical_service@goldlinecontrols.com • www.goldlinecontrols.com • Differential controller

Ivan Labs Inc., 305 Circle West, Jupiter, FL 33458 • 561-747-5354 • Fax: 561-746-9760 • ivandelsol@juno.com • 12 VDC circulating pumps & Delta-T controls

Laing Thermotec Inc., Mike Solso, 2295 Main St., San Diego, CA 92154 • 619-575-7466 • Fax: 619-575-2739 • customerservice@lainginc.com • www.lainginc.com • 12 VDC & 120 VAC circulating pumps

Honeywell Water Controls, 65 Access Rd., Warwick, RI 02886 • 800-247-2919 or 401-738-4290 • Fax: 800-777-2726 or 401-738-4156 • www.honeywellwatercontrols.com • Antiscald valves for DHW systems

Solar Converters Inc., Dan Pringle, C1-199 Victoria Road S., Guelph, ON, Canada N1E 6T9 • 519-824-5272 • Fax: 519-823-0325 • info@solarconverters.com • www.solarconverters.com • Linear current amplifiers & Delta-T controls for PV-powered pumps

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