Solar Heating

Three in One

David Sweetman

The Sweetmans' six, original, 4 by 8 ft., American Solar King collectors. An electrically operated awning is used to cover three of the panels to limit hot water production in the summer.

I am now retired, living in remote Nevada. The location is perfect for the use of renewable energy systems—plenty of land, clean air, sunshine, and wind. I described our renewable energy electrical system in *HP86*. I also wanted to use solar heating, not only for hot water, but also for spa heating and backup space heating.

We had heard varied reports on the workability of solar heating. But we were determined to try, since solar heating is clearly one of the most cost-effective applications of renewable energy to implement.

Three Applications

Prior to retiring and moving, we had to make some improvements on our home-to-be. One immediate improvement was to install a new roof, so the time seemed appropriate to install a solar heating system.

We live in the high desert, at about 38 degrees north latitude. We have plenty of sunshine. The high desert gets cold—it can reach -15°F (-26°C) at night in the winter—and heat is an important commodity. Our house had an existing electric forced-air furnace, which was subsequently replaced with a geothermal heat pump. Additionally, a therapy pool has been installed. So there are three uses for solar heat: first to heat domestic water, second to heat the pool, and third to heat the house. The concept was to use one system to accomplish all three purposes.

Our three new sources of heat are solar hot water panels, a geothermal heat pump, and a wood-burning furnace. The therapy pool is only heated by solar panels. Domestic hot water is normally heated by solar panels, but can use either the wood-burning furnace or electricity as backup. Space heating is normally done with the heat pump, but can use solar hot water (if available) or the wood-burning furnace as a backup. All electrical equipment, with the exception of the geothermal

The Sweetmans' newer 4 by 10 ft. SunEarth collectors.

compressor, is on the renewable energy electrical system. So even if the grid goes down, wind, sun, or batteries will power the applicable pumps and fans.

Evolution

The system was originally designed to provide normal usage of hot water, about 40 gallons (150 l) per day for two adults, at about 120°F (49°C). There was also capacity to heat a spa of about 500 gallons (1,900 l) and to provide some backup space heating for the house. The backup space heating used a liquid-to-air heat exchanger in the forced-air ducting. Additionally, the system interfaces with a wood-burning furnace to provide another backup source of heat, for those days when there is inadequate sunshine.

The system underwent quite an evolution over the last seven years. The primary change was to increase the system size to account for the use of a 3,800 gallon (14,000 l) therapy pool instead of the 500 gallon (1,900 l) spa. When the original electric furnace failed and was replaced with a geothermal heat pump, the system interface (using the same heat exchanger) to the forced-air ducting had to be modified.

We have buried 3,000 feet (914 m) of coiled hose, 10 feet (3 m) underground to circulate the heat pump transfer fluid. A trench 3 by 100 by 10 feet (0.9 x 30 x 3 m) was dug and filled. The system needs a 50 to 55°F (10–13°C) inlet temperature, which for us in the dead of winter occurs at about 9 to 10 feet (2.7–3 m) underground.

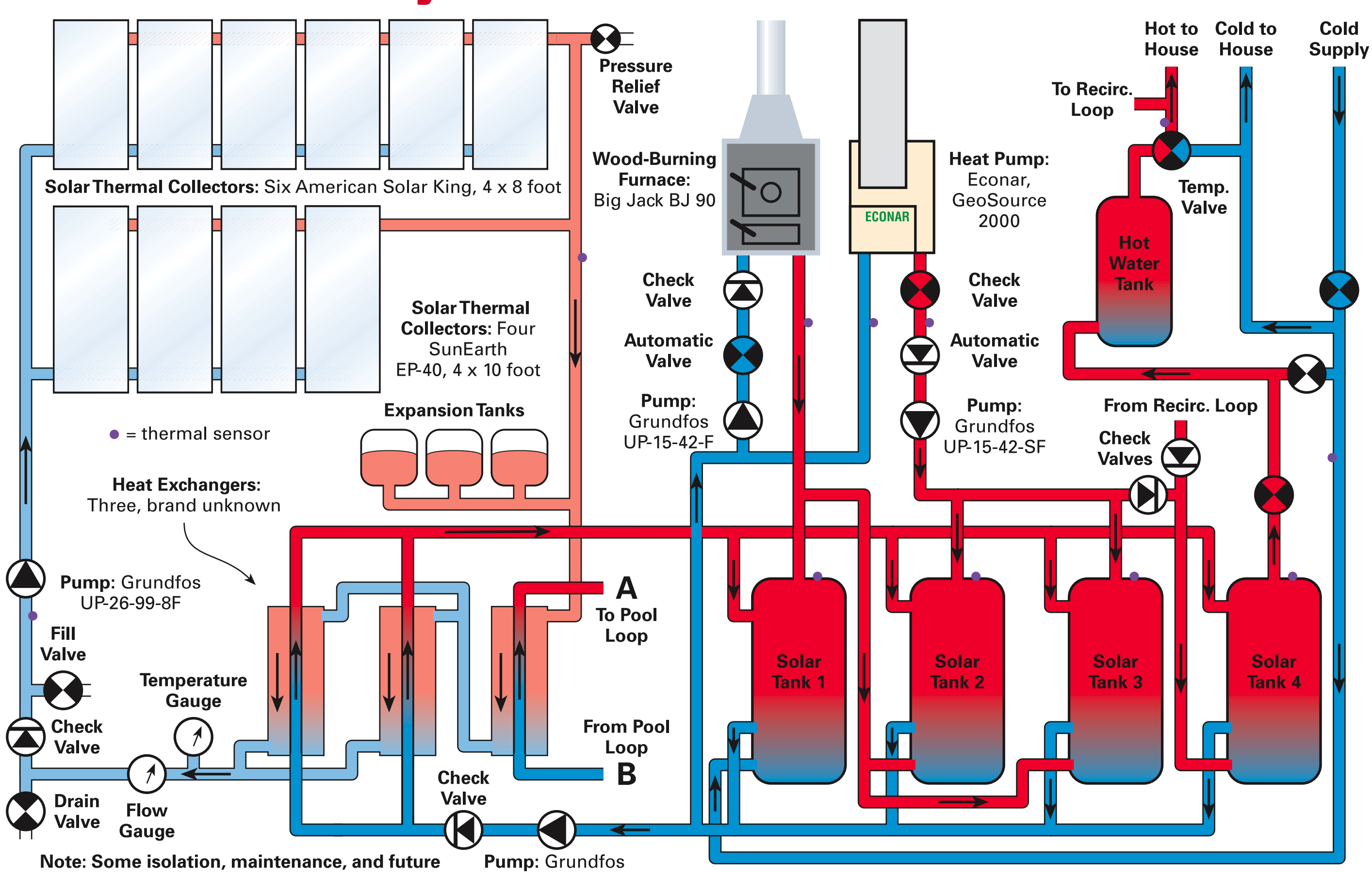
Ingenious Awning

The system was designed for winter loads, so excess heat is often produced during the summer. Climbing on the roof to cover the collectors is impractical for me, and the system did not incorporate a summer heat dissipation coil. Another plan was required. We have an electrically operated awning on our motorhome, and I thought the same principle could be used.

I had an awning made to cover three of the six 4 by 8 foot (1.2 x 2.4 m) panels. The awning is normally used as a window shade for a house or a patio cover, with a manually operated switch to open and close it, and an anemometer to automatically close it during high winds.

A dedicated GL-30 is used to automatically extend the awning whenever the temperature of the heat transfer fluid exceeds 180°F (82°C). This uses the NO (normally open) contacts in the GL-30. I could wire the NC (normally closed) contacts to automatically retract the awning when the temperature drops, but have chosen not to. We get enough wind that the anemometer control normally closes the awning during the night.

Solar Thermal System



The 3,800 gallon therapy pool is heated with solar energy.

Multiple Loops

This is a multi-loop system, with the primary loop circulating a heat transfer fluid (antifreeze) through the solar panels and liquid-to-liquid heat exchangers. Secondary loops circulate water through the heat exchangers to and from the storage tanks or pool. Additional loops and pumps circulate hot water through the heat pump heat exchanger and the wood-burning furnace heat exchanger.

The primary loop is filled with an antifreeze solution. We originally used standard RV propylene glycol solution (nontoxic), but the fluid appears to degrade after a few months of summer use. We changed to DowFrost HD, as recommended by SunEarth, the solar panel manufacturer.

The system was originally constructed with 3/4 inch copper pipe, although the fittings for the original six, 4 by 8 foot (1.2 x 2.4 m) solar collectors were 1 inch. The idea was to save money on piping, yet this can create problems with system expansion. In addition, a slightly larger pump may be needed to overcome the friction loss (head loss) associated with smaller diameter pipe. If large diameter pipe is used initially, it will be easier to expand later by replacing the pump with a larger one. When we added four SunEarth EP-40 (4 x 10) panels to the system, as much of the 3/4 inch piping as possible was replaced with 1 inch.

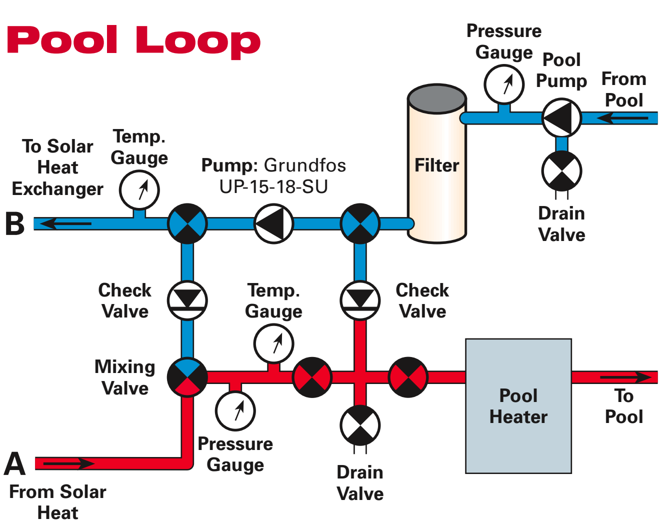
All primary loop piping has special high temperature insulation called Rubatex. Regular insulation used for domestic hot water lines will melt when exposed to the high temperatures that can occur in a solar heating system. I used the same insulation on the hot water lines in the storage tank system for the same reason.

There are two major secondary loops. The first heat exchanger heats the therapy pool, and the second parallel pair of heat exchangers heats the storage tanks used for hot water and space heating.

The heating of the storage tanks was straightforward. Essentially, the major job was with the plumbing—installation of pipes, valves, gauges, pumps, fittings, and insulation. The only major changes from the original design were to add an additional storage tank, install a tempering valve (the water gets really hot, and you do not want to get scalded when turning on the hot water), install a recirculation pump for the hot water (the upstairs shower is quite a distance from the hot water tank and water in the desert is more precious than heat), and install solenoid isolation valves in various loops (to prevent thermosyphoning).

The therapy pool heating system had to be designed from scratch, since the pool manufacturer was only familiar with electric or gas heating. Since the filter pump would not necessarily run at the correct hours, duration, or correct flow rate, an additional solar heating pump and Goldline

Pool Loop



Detail of the pool loop.

The water heater and four solar storage tanks.

Sizing & Design Considerations

Sizing and design is relatively easy for small solar thermal systems, but larger complex systems are difficult to engineer with precision. Energy from sun, earth, and wood all contribute in varying degrees depending on the season, time of day, living patterns, and end-use efficiencies. This system evolved over a period of time and has integrated multiple energy uses and multiple energy sources. The system is in the process of being upgraded again to correct some known and suspected inefficiencies that are probable causes of the lower than expected system output.

An armchair estimate of the system design would attribute one or two, 4 by 8 foot (1.2 x 2.4 m) collectors to domestic hot water (for an energy conservative two-person household in Nevada). Collector area for the pool is generally about about half to three-quarters of the pool surface depending on the pool temperature and whether the pool cover is used when not in use. The rest of the system contributes to home heating.

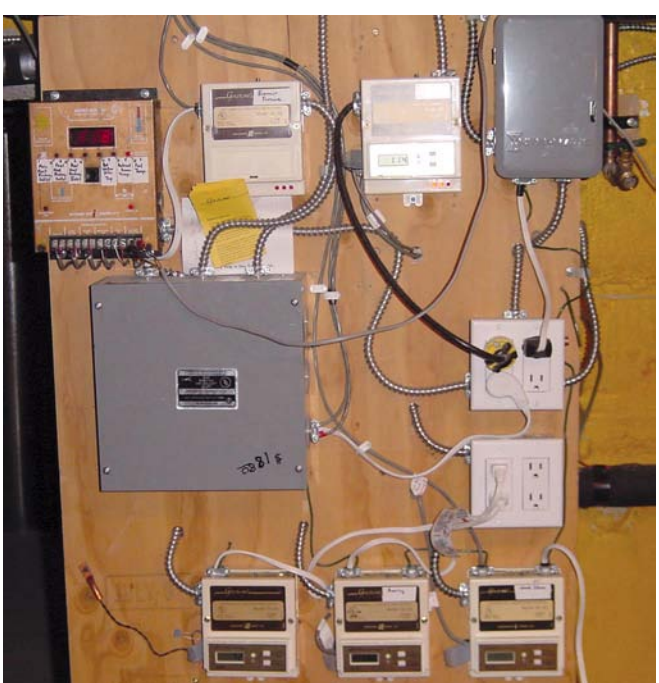
Ken Olson—Solar On-Line (SōL)

pool temperature controller were added. Since the water can get hotter than the plastic piping rating (standard for the pool), a tempering valve was added so that the pipe temperature limit (140°F; 60°C) would not be exceeded. This system works extremely well, keeping the therapy pool at a constant 98°F (37°C), which also helps heat the house during the winter.

Controls

Since the solar heat storage tank room can get quite warm during the summer, a fan was installed to vent air from the basement room. The fan is controlled by another GL-30. (These differential temperature controllers are very useful for a wide variety of tasks, not just turning solar pumps on and off.) A field adjustable dial in the control allows you to adjust the fan turn-on temperature. The other input is connected to a thermistor (10 K-ohm sensor) that measures ambient room temperature.

The central mounting board for various GL-30s and the old GL-100 used for monitoring, along with a box containing relays for geothermal control.



The storage tanks are specifically designed for use with a solar heating system. The normal cold-water inlet is at the bottom of the tank and the hot-water outlet is at the top of the tank. One third up from the bottom is the heat exchanger inlet, and two thirds up from the bottom is the exchanger return. The tank has the option of electrically heating the water, which I have not connected. A 10 Kohm sensor that can be used for either controlling or monitoring temperature is also installed.

The original system used a GL C-100 differential temperature controller (no longer manufactured). This controller has the advantage of being able to display up to six different temperature locations. Although this controller's pump-switching function was replaced with the GL-30, I still use the monitoring capability (five of the six inputs still work). Goldline also now makes a separate unit to display up to six locations. The GL-30 has the option of including a digital display, which can be valuable.

Monitoring temperatures at various locations in the system is vital if you want to optimize performance. I made a simple temperature probe with a standard 10 K-ohm sensor attached to some alligator clips to clip on an input to the GL C-100. This allows me to check various points in the system.

The Econar GeoSouce heat pump adds to the system with heat from 3,000 feet of buried tubing.

Although the physical interface of the hot water heat exchanger in the forced-air ducting was just a matter of some sheet metal fabrication work with appropriate plumbing, the control system was not so simple. As with a normal heat pump, the geothermal heat pump turns on when the thermostat calls for heat. The heat pump extracts heat from a fluid circulated underground. Since the underground temperature is much higher and more stable than the outdoor air temperature, much less energy is required to extract the same amount of heat compared to using an air source heat pump.

In this case, I wanted the fan to turn on (forced air), but the heat pump to stay off when hot water circulates in the ducting heat exchanger. With help from Econar (the geothermal heat pump manufacturer), control circuitry was designed and built to operate only the solar heating side when the solar heat storage tank temperature is above 135°F (57°C), and turn on the heat pump when the solar heat storage tank temperature is below 135°F.

Wood Furnace

Originally we had a wood-burning stove with a simple, copper tube heat exchanger on top. Not only were the stove and heat exchanger not very efficient, the stove drew combustion air from the house, which is even worse. The stove was replaced with a wood-burning, forced-air furnace that is also plumbed for a heat exchanger to heat the water in the storage tanks.

A separate area in the basement was walled off for this unit, with direct ducting to the outside for combustion air. When the furnace is operating, a GL-30 will turn on a pump to circulate storage tank water through the heat exchanger. An external manifold on the furnace is directly ducted into the forced-air system (supply and return), with an associated fan to circulate hot air (with no combustion byproducts) in the forced-air ducting.

The fan is controlled using a standard fan temperature controller. A separate fan and controller vents the room air to a cooler part of the house, in case the temperature in the room exceeds a preset value.

Financial Analysis

The cost of all the components and installation in the various systems is probably in excess of US$40,000. The cost of the wood-burning furnace was about US$2,500 (including special tools to install the water heating exchanger), plus installation. The cost of the geothermal furnace was about US$9,000, plus installation.

The wood-burning furnace with fan controls and ducting.

Thermal System Costs

Item	Cost (US$)
4 Mor-Flo/American solar tanks, 120 gal.	$3,928
4 SunEarth EP-40 4 x 10 ft. collectors	3,652
5 Goldline GL-30 controllers with displays	1,600
6 American Solar King 4 x 8 foot collectors	1,500
6 Grundfos pumps, various sizes	900
5 Heat exchangers	625
3 Solenoid valves	525
Misc. electrical, insulation, & ducting	500
GE hot water tank, 50 gal. electric	400
Goldline GL-235 pool temp. controller	400
2 Ranco fan electronic temp. controllers	400
Misc. pipe, valves, & fittings	300
2 Flow gauges	200
4 Temperature gauges	80
Intermatic timer	75
2 Tempering valves	58
2 Duct fans, 120 VAC	50
Total	$15,393

Will the system have a reasonable payback? At the current cost of electricity, the entire system is marginal. Obviously, this is a much more complicated system than is needed to just heat water, but I still think the effort was worthwhile.

The systems to heat water for home use and the therapy pool are definitely cost effective. The space heating system is probably marginal, especially since the therapy pool adds significant heat to the house during the winter.

The geothermal heat pump is much more efficient than other forms of nonrenewable energy heating. The geothermal system uses a standard forced-air circulation system to heat the house. Since the geothermal heat pump gets most of its heat (or cooling) from the relatively constant earth temperature, as opposed to the ambient air temperature, much less heat (cooling) is required from conventional energy sources, such as fossil fuels, wood, etc. Since the heat pump is installed indoors, not only does the system last longer, but it is also not exposed to the temperature (and humidity) variations that make it work harder.

We use about 40 gallons (150 l) of hot water per day, which would take about 9 KWH per day to heat electrically. The therapy pool would take about 21 KWH per day. At US$0.08 per KWH, that is a savings of about US$876 per year. That is a long payback, except that the cost includes the geothermal and wood-burning backup systems, and the savings do not incorporate the home heating savings (which are very difficult to estimate). There is no question that just the water heating (both home and pool) is cost effective. The rest of the items are useful, but will not fully pay for themselves until the cost of nonrenewable energy becomes higher—which will happen!

Practical Solutions

The average homeowner does not want to be concerned with design, component selection, or installation, and wants minimal operation and maintenance requirements. Manufacturers should put together standard systems, with good written documentation that people can buy off-the-shelf and install using standard plumbers and electricians, or by themselves.

Tech Specs

System Overview

System type: Two-loop heat exchanger, antifreeze, direct pump
Location: Dyer, Nevada
Climate: Moderate to harsh, with hard freezes throughout the winter
Solar resource (annual average): 6 peak sun hours per day
Production: 3,125,000 BTUs per month average, (panel capacity ~ 50,000 BTU/day)
Number of people in household: 2
Percentage of hot water produced annually: 95

Equipment

Collectors: Four SunEarth Empire series, 4 x 10 foot; six, 4 x 8 foot from American Solar King
Collector installation: Roof mount, 210 degrees aligned with roof (corrected for magnetic declination) tilt at 50 degrees from horizontal (raised from roof)
Circulation pump: Grundfos UP-26-99-BF for primary loop of DowFrost, Grundfos UP-15-42-SF for secondary loop of water, Grundfos UP-15-42 (SU, SF, F) for other
Pump controller: Goldline GL-30
Heat transfer fluid: DowFrost HD from Dow Chemical

Storage

Tanks: Four Mor-Flo/American solar tanks, 120 gallons, plus GE 40 gallon electric water heater
Heat exchanger: Three, unknown capacity and manufacturer

System Performance Metering

Temperature: Three Letro SL2D (50-220F) plus 10 K-ohm thermistors to GL-30s and C-100
Pressure: Three Ashcroft, oil-filled, 0–100 psi
Flow: Two Letro LDF357B, 1–10 gpm in primary loop in series with parallel water storage heat exchangers; one Letro LDF359T in secondary loop

I have wondered for a long time why more people do not use solar heating. At first, I thought the reasons were economic, but especially for domestic water heating, there is every economic reason to use a system. I personally believe that virtually everyone should be using solar collectors to preheat domestic hot water.

So economics is not the major reason, especially with all the excess wealth in the country today—just look at what is spent on entertainment. Perhaps there is just a lack of consumer knowledge, which calls for more understandable and standardized system documentation. Documentation for design, installation, operation, and maintenance varies from mediocre to poor. Standardization of documentation and equipment would reduce costs and accelerate usage.

This article summarizes some of the issues in designing, installing, operating, and maintaining a complicated solar heating system. The hardware available is excellent, so that once the components are assembled, the system works well within expected performance parameters. Solar heating of hot water, either for domestic use or pools, is a practical solution to save money and energy.

Access

David Sweetman, PO Box 189, Dyer, NV 89010 • d-dsweetman@att.net

Ken Olson, SoL Energy, PO Box 217, Carbondale, CO 81623 • Phone/Fax: 720-489-3798 • sol@solenergy.org • www.solenergy.org

GFC Sales, Gary Fedor, HC 72, Box 03515, Dyer, NV 89010 • 775-572-3231 • Fax: 775-572-3343 • g.fedor@att.net • Solar thermal system installer

SunEarth, Inc., Rick Reed, 4315 Santa Ana St., Ontario, CA 91761 • 909-605-5610 • Fax: 909-605-5613 • rreed@sunearthinc.com • www.sunearthinc.com • Solar hot water panels

Econar Energy Systems Corp., Larry Wurtak, 19230 Evans St., Elk River, MN 55330 • 800-4ECONAR or 612-241-3110 • Fax: 763-441-0909 • lwurtak@econar.com • www.econar.com • Geothermal heat pump

The Dow Chemical Company • 800-447-4369 • Fax: 989-832-1465 • www.dow.com/heattrans/index.htm • DowFrost heat transfer fluid

CI Solar Supplies Co., John Clothier, PO Box 2805, Chino, CA 91710 • 909-628-6440 • Fax: 909-628-6440 • jclothi@attglobal.net • www.cisolar.com • Solar thermal components distributor

Alpha American Co., PO Box 20, Palisade, MN 56469 • 800-358-0060 • Fax: 800-440-1994 • sales@yukon-eagle.com • www.yukon-eagle.com • Wood furnace