Solar Water Heating in Iowa

Roy W. Tonnessen,
Photos by Dick Arnold

Roy Tonnessen's self-installed solar hot water system supplies all his family's DHW needs many months of the year.

Using the sun to heat your domestic water is one of the most practical and least expensive applications of solar energy. We installed a solar domestic hot water (SDHW) system for our two-person family in the small town of Fairfield, Iowa toward the end of 1999. During the year 2000, we turned off our natural gas water heater for nine months, from mid-February to mid-November. We got all of our domestic hot water—for clothes washing, dish washing, bathing, showers, etc.—from three solar water heating collectors.

A properly designed and installed SDHW system will provide enough savings to pay for itself quickly. It consists mainly of tried and true traditional plumbing parts, and it can be expected to last for 20 to 30 years. The sooner you invest in an SDHW system, the sooner you will be able to enjoy basically free hot water. Solar water heating is right for the environment. Pollution is reduced. Solar water heating will make you and the nation more self-sufficient.

Capability & Cost

In the summer, a properly sized SDHW system can meet 100 percent of your water heating needs in most parts of the United States. During the winter, depending on where you are located, it may only supply a portion of your needs, and can then function as a preheater to your backup water heating system.

During some summer days, the water/glycol mixture coming from my solar collectors reaches 190°F (88°C), and the temperature in the hot water storage tank is regularly at 160°F (71°C). I often shade one or two collectors, since we can't make use of all the hot water. At 9:30 AM, one sunny morning last winter, the outside air temperature was -6°F (-21°C), and the temperature of the water/glycol mixture coming from the solar collectors was 85°F (29°C). At noon when the outside temperature was 0°F (-18°C), the incoming water was 110°F (43°C).

During the coldest days of winter, I see the temperature in the storage tank moving from 57°F (14°C) (the temperature of the city water) in the morning, to 80°F (27°C) at noon. The solar collectors clearly help to preheat my domestic water, and cut down on the time the natural gas water heater needs to run during the winter months.

What does it cost? The Department of Energy (DOE) estimates that a professionally installed SDHW system of this size will cost US$2,000 to US$3,000. The parts for my system cost about US$900. I obtained several Yazaki, 3 by 6 ft. (0.9 x 1.8 m) collectors from a large, dismantled system. Since I had some extra used collectors, I traded with my neighbor Fred. He got three collectors in exchange for designing and installing my system. I provided my labor assistance for both his and my system.

We bought most of the other parts from a local plumbing supply store. They ordered some of the items for us, but most were in stock. We bought a stock tank (normally for watering cattle) to use as the solar hot water storage tank, and built the heat exchangers into it. We bought the sheets of insulation for the tank from a local lumberyard. I bought my differential thermostat from Kera Technology in Canada, and a few items from AAA Solar.

Conservation

There is no cheaper, cleaner, or greener energy than energy that you don't use—energy that doesn't need to be produced. Before you consider installing an SDHW system, determine what you can do to conserve water and energy. I installed two insulating blankets around my natural gas water heater. I also cut to fit and installed a 2 inch (5 cm) thick sheet of insulating board on top of it. (Be careful not to obstruct air passage around the draft hood at the bottom of the flue.)

I turned the water temperature setting on the water heater down to 120°F (49°C). The only negative result of the lower thermostat setting was that the soap in the dishwasher didn't dissolve completely. We chose to keep the thermostat setting low and turn on the electric temperature booster that is built into our dishwasher. We thus use a little more electricity, but have had no more problems getting dishes clean and free of soap residue.

We insulated our hot water pipes and installed good quality, low-flow shower heads to cut down on the volume of hot water used. When my natural gas water heater gives up the ghost, I will probably install a natural gas, tankless, on-demand water heater. Some models are specifically designed to work with SDHW systems.

Our Solar Water Heating System

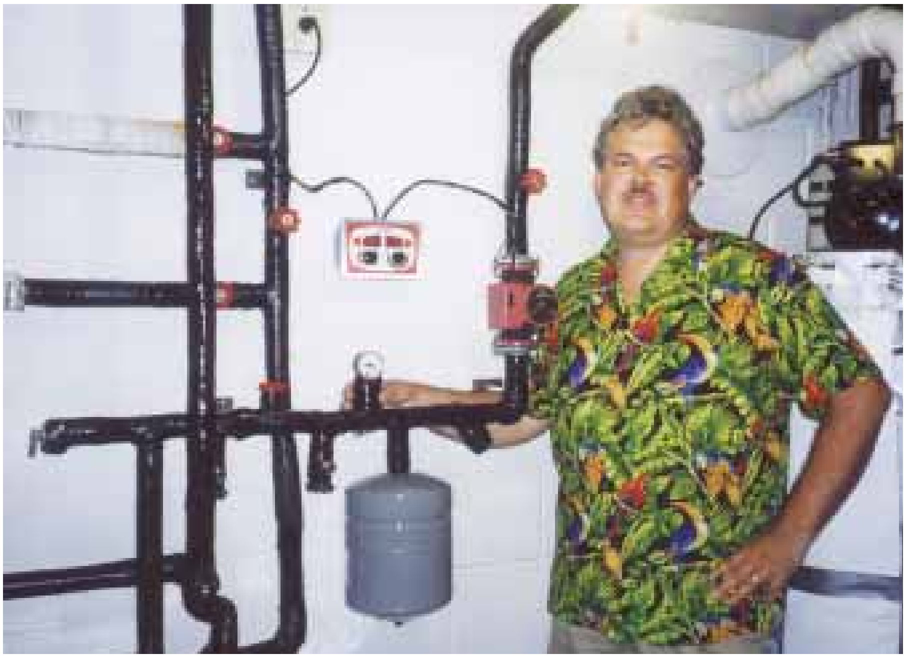
We have an active, closed loop, flat plate collector system. This system is appropriate for a climate with freezing temperatures. It can be switched to be either a one-tank or two-tank system.

It is called "closed loop" because it has an antifreeze, heat transfer fluid that moves through the solar collectors in a circle or loop. It is called an "active" system because a small, electric pump moves the fluid through that closed loop. "Flat plate" collectors are the most common type of solar hot water collectors. They consist of a flat, insulated, weatherproof box containing a dark absorber plate. The antifreeze liquid runs through passages in the absorber plate, where it absorbs the heat from the sun.

The five major component groups in our solar hot water system are:

- The solar collectors (panels). They capture the solar energy.
- The storage tank. Here a reservoir of water is heated by one of the heat exchangers, and the heat is stored there for immediate or later use. A conventional water heater can be used for additional water storage for most of the year, and as a backup during the winter.

At the works—Roy's maze of pipes is actually quite simple.



The single, AC powered, Grundfos circulating pump.

- The liquid-to-liquid heat exchangers. These transfer the sun's heat into your domestic hot water system. In my setup, one heat exchanger extracts the heat from the water/glycol mixture in the collection loop and transfers it to the water in the storage tank. The other heat exchanger warms the city water in the delivery system by transferring the heat from the water in the storage tank to the hot water we use.
- The plumbing system. It moves the heat, captured in a fluid mix of water and nontoxic glycol, from the collectors to a heat exchanger.
- The differential thermostat/controller. This regulates the operation of the circulation pump.

How Do the Panels Work?

When you open a car door on a warm summer day, you feel a blast of hot air, and the seats are too hot to sit in comfortably. The car is basically a box of metal with openings covered by glass. The sun's rays pass through the glass and heat up the inside of the car. The car acts as a solar collector.

The flat plate solar collector works similarly, but better. The sun's rays pass through the glass cover and hit the dark metal absorber plate below. The temperature on the metal surface may reach 250°F (121°C). The water/glycol mixture circulating through the absorber plate picks up heat. The insulated, glass-covered collector helps contain the heat. If you turn off the circulation pump in an SDHW system on a sunny day, the water/glycol mixture in a flat plate collector can easily reach boiling temperatures.

With most common collectors, many thin water pipes are sandwiched between two sheets of metal absorber plate, usually running vertically. In my system, a small, Grundfos UPS 15-42, circulating pump pushes the antifreeze mixture of distilled water and nontoxic propylene glycol very slowly through the pipes. As the fluid exits the top of the solar collectors, it has picked up quite a bit of heat from the metal sheets.

The liquid continues from the solar collectors outside my house to the liquid-to-liquid heat exchanger at the bottom of the water storage tank located in my basement. As the hot liquid passes through the heat exchanger, some of the heat circulating through it is transferred to the water surrounding it in the water storage tank.

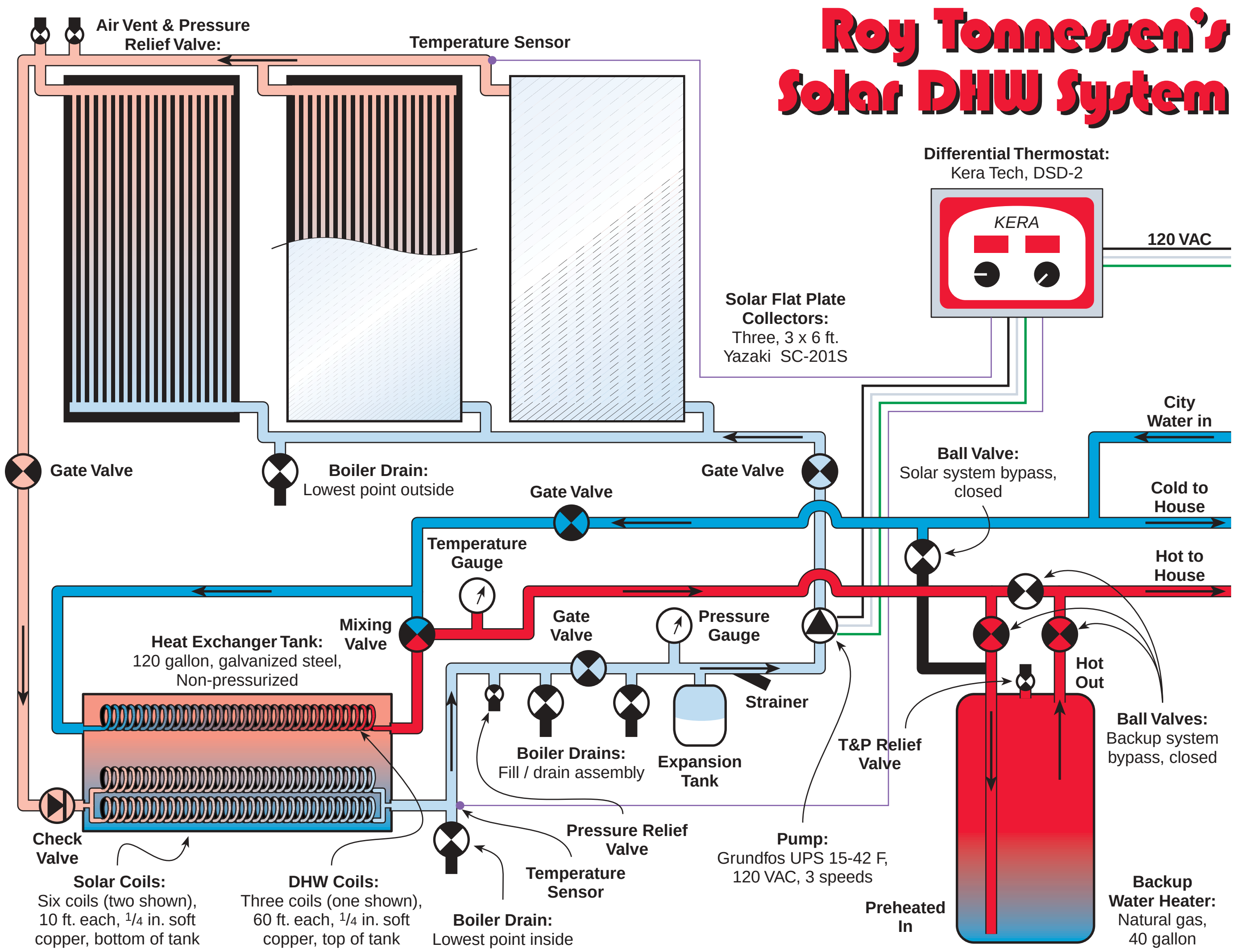
The fluid is cooler after it has passed through my homemade heat exchanger, and is then pumped back to the solar collectors. If the sun is still shining, the cycle starts all over again, continuing to heat the water in the storage tank. All of this happens in a closed loop where the water/glycol mix runs in a circle, and never mixes with the water in the storage tank. This part of the system is often called the collection or solar loop.

Differential Thermostat

The controller or brain of our system is a Kera Tech DSD-2 differential thermostat (DT). The DT is used to turn the circulation pump on and off at the appropriate temperatures.

A differential thermostat is not like the household thermostats you may be familiar with. It measures the *difference* in temperature between two points, based on readings from two heat sensors. The two points are the temperature at the outlet of one of our solar collectors,

A Kera differential thermostat controls operation.



and the temperature at the top of the solar hot water storage tank. If I set the DT at 19°F (11°C), it will search to see if the temperature in the solar collector is higher than the temperature in the storage tank. When the water/glycol mixture in the collector gets to be 19°F warmer than the water in the storage tank, the DT will start the circulation pump.

The DT will continue to register the difference in temperatures. The pump will be turned off when the temperature in the solar collector is down to 6°F (3°C) warmer than in the storage tank. Our DT allows us to select any temperature differential from 3°F to 22°F (2–12°C) to start the pump. We can choose to let the circulation pump be turned off when the temperature difference is at any point between 2°F (1°C) and 12°F (7°C).

Our unit has two digital displays, which alternate to show four different readings. At a glance, I can see the temperature of the water/glycol mixture in the collectors, the water temperature in the storage tank, and the two temperature differentials I have selected. On my DT, a light comes on when the circulation pump is running. The pump is so quiet that I usually cannot hear it.

Tank & Heat Exchanger Details

An expansion tank automatically absorbs the changes in liquid volume and pressure. An air vent is installed at the highest point of the loop at the collector outlet. A check valve in the solar loop prevents reverse thermo-syphoning of the antifreeze mixture at night when the collectors become cooler than the storage tank. This swing check valve does not have much restriction to flow, and opens easily. It must be mounted in a vertical position so it is normally closed by gravity.

A nonpressurized solar hot water storage tank houses the two heat exchangers. We used a galvanized steel cattle watering tank. It is 5 by 2 by 2 feet (1.5 x 0.6 x 0.6 m), and holds roughly 120 gallons (455 l) of water. For most of the year, when I turn off the gas water heater,

Tonnessen SDHW Costs

Item	*Cost (US$)*
3 Yazaki SC-201S panels, incl. plumbing, insulation, etc. (used)	$259
Kera DSD-2 differential thermostat with sensors	152
Grundfos UPS 15-42 F circulation pump, 3 speed, 1/25 hp	110
Heat exchangers, homemade	100
Stock tank, 5 x 2 x 2 feet, approximately 120 gallons	66
Extrol #15 expansion tank	50
Watts mixing valve, 3/4 inch, brass	48
Propylene glycol, 3 gallons (nontoxic)	47
2 Adjustable pressure relief valves	39
Air vent, float type	11
Pressure gauge	10
Check valve	10
Total	$902

we use the solar hot water storage tank for storing the water heated by the solar collectors before it enters my super-insulated, conventional, 40 gallon (150 l), natural gas water heater. I then have a storage capacity of 160 gallons (605 l). We have enough hot water stored to go without sunshine for two days. Our system is plumbed so that I can bypass the gas water heater tank if needed.

My fabulous neighbor Fred is a master plumber. He designed and installed my system and one for himself, including the two liquid-to-liquid heat exchangers in each system. It is important to have appropriately sized heat exchangers. Otherwise you may get disappointing results.

Since the water/glycol mixture coming from the solar collectors will be warmer than the water in the supply line from the city, the heat exchanger in the solar loop is placed at the bottom of the hot water storage tank. This heat exchanger consists of six coils, each 10 feet (3 m) long, made from 1/4 inch (6 mm) soft copper refrigeration tubing that the solar heated water/glycol mixture has to pass through.

Some of the heat contained in the 50/50 glycol/water mixture is transferred to the water in the storage tank. The warmer water rises toward the top of the storage tank where the second heat exchanger is placed. If we consume a lot of hot water, this will lower the temperature in the storage tank, but it is amazing how fast it jumps back up again on a sunny day.

The heat exchanger in the delivery system is very similar. It consists of three coils, each 60 feet (18 m) long, 1/4 inch (6 mm) soft copper tubing, that the cold city water coming into the natural gas water heater has to pass through. This heat exchanger sits in the upper part of the water in the storage tank that has been heated by the heat exchanger in the solar loop. This setup has worked extremely well so far.

The amount of copper tubing we used in the heat exchanger is a major reason for this system working so well. You need to have enough surface area for the cold water to travel through, so it can pick up a lot of heat from the water in the storage tank. The heat coming from the solar collectors is transferred more easily, so its heat exchanger has less copper tubing. Since I have a two-tank system, 40 gallons (150 l) of hot water sits in the natural gas water heater, ready for use at any time. My family can take two showers and also use another faucet at the same time without any problems.

The plumbing code dictates that you have to use a double-walled heat exchanger, so two pipes will have to fail at the same time before there is any chance of contamination of your drinking water. My setup with two single wall heat exchangers submerged in a tank filled with nonpotable water should fulfill this requirement, since there is still double protection. Nevertheless, you do not want to use traditional automotive antifreeze (ethylene glycol) in your solar hot water system, since it is very toxic.

The hot water delivery system consists of:

- A homemade liquid-to-liquid heat exchanger installed toward the top of the water storage tank.
- A pressurized 40 gallon (150 l) high-efficiency natural gas water heater.
- A 3/4 inch mixing valve.
- Various valves, copper pipes, fittings, and pipe insulation.

The mixing valve is used to add cold water to the flow of water from the storage tank when the water exceeds a selected, preset temperature, to avoid scalding. Mine is adjustable. The heat-sensing element of a mixing valve must be removed before soldering, and reinstalled afterwards or it may be destroyed.

Natural Gas Backup

I have a direct-vent, high-efficiency, natural gas water heater. The ironic part of having this so-called high-efficiency unit is that an electric fan is needed to force

The heavily insulated, backup, natural gas water heater.

air into the burn chamber when it is running. The good thing is that this allows me to put the fan motor on a timer, which shuts down the heater. I have chosen to set it so that our natural gas water heater, during the months that we use it, is turned off between 9:30 PM and 7:30 AM, which fits our lifestyle and daily routine.

This alone will prevent the water heater from running unnecessarily about 40 percent of the day, and there is no downside that I know of. You just need to allow the water heater to start 30 minutes before you need hot water in the morning. The cost of the timer will be paid for in savings in just a few months.

For part of the year, we turn off our natural gas water heater completely. When I open a hot water faucet, the cold water from the city moves through a liquid-to-liquid heat exchanger immersed toward the top of the solar hot water storage tank. After it has been heated there, it passes through the natural gas water heater tank and continues on to the faucet. So every time we use warm water, it circulates through the traditional water heater tank, unless I have switched it to bypass the tank. In effect, I have two hot water storage tanks. The water can get so hot in the summer that after it has passed through the heat exchanger, the mixing valve mixes in some cold water.

During the coldest winter months, everything functions much the same, except that the backup natural gas water heater is on. When I open the hot water faucet, the water is preheated by the heat exchanger in the solar hot water storage tank, and continues into the natural gas water heater, where the temperature is boosted as necessary to meet the thermostat setting.

If the water is colder than the water heater thermostat setting, the natural gas heater will be activated and heat the water. If the water, preheated through the heat exchanger in the solar hot water storage tank, is warmer than the water heater thermostat setting, no backup heating is necessary, and it will flow through to the faucet, just as it does during the summertime. The collection loop collects and transfers the heat from the sun, and the delivery system receives the heat and delivers it to the house in the form of hot water.

System Sizing, Location, Collector Orientation, & Tilt Angle

We have enough hot water storage capacity to get us through two days without sunshine. That works very well in our climate. The average hot water consumption in the US is 20 gallons (76 l) per person per day.

We placed our solar collectors on the top of railroad ties dug partially into the ground. The collectors are leaning up against the south-facing wall of the house, high enough off the ground to avoid rain splash and snow. The collectors are anchored to the wall and to the railroad ties. We kept outdoor pipe lengths to a minimum to avoid energy losses.

Natural Gas Savings

Year 2001 with SDHW, compared to 1999 (last year before solar)

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*
Reduction	27%	40%	88%	86%	100%	100%	100%	100%	100%	85%	83%	54%

Year 2001 with SDHW, compared to 6 year average before SDHW system

Reduction	72%	80%	92%	91%	100%	100%	100%	100%	100%	85%	91%	64%

Solar water heating panels may collect about twice as much energy during an hour in July compared to January. So we have plenty of sunshine available in the summer, but we need to catch every possible ray in the winter.

Solar collectors produce the most energy when their collection surfaces are perpendicular to the sun. Tilting collectors to match a particular site's latitude will produce the greatest amount of energy on an annual basis. But the sun's path is lower in the sky during the winter months, and there's less solar energy to collect. Setting the collectors at a steeper tilt angle gives us a leg up during the winter because the panels are more perpendicular to the sun's path.

The three Yazaki panels are anchored to railroad ties.

Tips from the Pros

Home Power magazine is rooted in the spirit of do-it-yourself ingenuity and systems that work. In recognition of the fact that there are many right ways to design a successful system, we have asked industry professionals to offer their comments, critiques, tips, and techniques for the benefit of readers inclined to homebrew their own solar hot water system. In some cases, opinions may differ from the installation presented here.

Heat Exchanger Design

The heat exchanger used in this system performs well under conditions of low demand. Generally a single pass of the domestic hot water (DHW) through a heat exchanger can result in poor performance if the DHW demand is high, such as when a shower and a washing machine are running at the same time.

The great length and narrow diameter of copper pipe used in this system is absolutely necessary to overcome the inherent inefficiency of this single pass heat exchanger. Although the three, 1/4 inch coils provide plenty of surface area required for an effective heat exchanger, most 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 to be sure of requirements.

Most closed loop systems use a much smaller but more efficient counter-flow heat exchanger configuration. Two pumps are used to circulate the two fluids simultaneously in opposite directions through the heat exchanger. This allows for the DHW to pass through the heat exchanger many times and the stored water is always available for times of high demand. The added cost of the additional pump, commercial heat exchanger, and electricity pays off in better performance over the life of the system. The exception is applications with a very low DHW demand.

Air Vent

Automatic air vents can be problematic in solar closed loop systems. They often fail under high temperature and pressures associated with solar water heating systems. Manual coin vents are generally adequate for household-sized, closed loop SDHW systems.

Pressure Relief Valves

Closed loop SDHW systems generally use pressure relief (PR) valves rated at about 50 to 75 psi. Temperature/pressure relief (T&P) valves, normally found on a hot water tanks, are not used in solar closed loops. They are generally rated to open at 210°F (99°C) or 125 psi. Temperatures of solar closed loops may regularly exceed the 210°F rating.

Pipe Insulation

Buried insulated pipe should be encased in 4 inch PVC pipe or suitable protection to keep the insulation from compressing and losing its insulation value.

Chuck & Smitty, AAA Solar,
Albuquerque, New Mexico

Temperature Stratification

Maintaining a high degree of temperature stratification within the solar storage tank can improve system efficiency significantly. The hottest water near the top of the tank is the optimum source for hot water delivery. The coolest water at the bottom of the tank is the optimum source for supplying the collectors. These heat exchangers are optimally located to take advantage of this principle, but would be even more effective in a taller tank with a higher degree of temperature stratification. The tank sensor is best located at the bottom of the tank in order to sense the coldest water in the tank. This will allow the system to operate longer each day to collect as much useful heat as possible.

Ken Olson, SoL Energy & *HP* solar thermal editor

Fairfield, Iowa, is located at 41 degrees northern latitude. To optimize our system for the winter months, we installed our collectors at a 56 degree angle. This has turned out to work very well. In our climate, this steep angle also helps keep the collectors free of snow. We used a simple angle indicator, available at the local hardware store, to install the collectors at the desired angle. More details on collector siting, angle, etc. can be found in Ken Olson's articles that are referenced in the Access section.

Collector Shading

We used a Solar Pathfinder (reviewed in *HP16* and demonstrated in a video clip on *HP's* Solar1 CD) to locate the collectors so that we would avoid shading between 9 AM and 3 PM. It is an ingenious contraption. For each month of the year, it shows you how many hours the sun will shine on any location where you are considering placing solar collectors. It shows you any obstructions from buildings, trees, hilltops, etc. that might appear in the path of the sun for that specific location.

You can create a simple chart for each location and quietly sit down afterwards and calculate what percentage of the possible 100 percent you will be able to catch at each specific location. For example, if you move your collectors a few feet, you may be able to clear the shadow from a building nearby and thereby increase the output of your collectors.

Efficient Use Patterns

When you install an SDHW system, you may find that you have a different attitude, and feel more connected with nature. You will look out the window in the morning and see that it looks like a bright day, and then use your clothes washer or dishwasher. You may hold off doing your laundry for a few days if it is overcast, and then try to squeeze in several loads when you have a bright, sunny day.

You need to work with nature to get the most out of your solar water heating system. You also have to bring your family or house mates into the process before installing a solar water heating system, since you will benefit if everyone is willing to change their routines now and then.

If possible, use your dishwasher and clothes washer between 10 AM and 3 PM on days when the sun shines brightly. The hot water you use will then be easily and quickly replenished by the sun, without any need for help from your gas or electric water heater. You will then have a nice reservoir of hot water to last you through the sunless evening and night, and keep you comfortable if the sun should hide behind a cloud for a day or two.

Solar Hot Water System Maintenance

Weekly

❏ Check that system pressure is 15 to 30 psi.

❏ Check that pump is operating when it is sunny.

❏ Remove snow if necessary.

Monthly

❏ Check for a distinct temperature differential between the supply and return pipes in the collector loop (15–20°F; 8–11°C is typical). A noticeable difference in temperature with bright sun is a good indication that everything is fine, the pumps are working, and the heat exchange is good. Solar pros do this with one hand on each pipe if the system isn't too hot. Caution! Test the pipe with a wet finger like you do an iron before using your hands. If it's too hot or you want really accurate data, use a thermometer.

❏ Check for leaks in the system and home—pressure relief valves, temperature pressure relief valve on the storage tank, faucets, bath, and shower.

❏ Confirm that there is no shading of the collectors between 9 AM and 3 PM.

❏ Check that the collectors are clean so that the sun can easily reach the dark absorber plate; clean the glass if necessary.

Annually

❏ Lubricate the circulating pump according to the manufacturer's recommendations (unless they are sealed bearings).

❏ Check insulation on pipes and tank.

❏ Look for signs of leaks at roof penetrations.

❏ Review energy bills to confirm savings.

Every Two Years

❏ Check the domestic water side of the heat exchanger for scaling. De-scale if necessary. (This can be done with a mild solution of muriatic acid and water or even vinegar if the scaling is not pronounced. A symptom of heat exchanger scaling is bright sun and pump(s) working, but little or no temperature differential between the supply and return pipes in the collector loop.

❏ Check the pH (acidity or alkalinity) of the propylene glycol heat transfer fluid. A pH of below 7 is a good indication that the mixture needs to be changed.

Plumbing Details

We used mainly 3/4 inch, type L sweat-soldered copper pipes and some flexible, type M copper pipe, because it is easy to bend. We used a 95/5 tin-antimony solder in the solar loop, and brazing solder for the heat exchangers. These have higher temperature ratings than 50/50 tin-lead solder. The 50/50 solder contains lead, and should not be used on domestic water lines. We used Rectorseal #5, yellow, soft-set, pipe thread sealant. Standard joint compounds for threaded fittings will not prevent leaks in pipes filled with a water/glycol mixture.

We placed gate valves on both sides of major components to allow us to service them without draining the whole system. They should not be installed in a way that can isolate the solar collectors from pressure relief valves and the expansion tank. Otherwise, the collectors could burst during stagnation conditions, such as if the circulation pump fails on a sunny day while the ball valves are closed. We installed the circulation pump after the heat exchanger, where the water is cooler, to put less stress on it.

We grounded the collectors to prevent damage from lightning. To make a continuous electrically conductive connection to ground, a copper wire jumper connects the collector frame to the copper pipe of the solar collector loop. Another ground wire is connected from the copper pipe to a suitable ground, such as ground rod. It is important to jumper around any dielectric unions, typically found on hot water heaters, or any other interruptions in the electrical continuity between collectors and ground.

The copper pipes in the solar loop and hot water delivery are very well insulated outside and inside the house. To shield the insulation from UV rays and provide some protection from birds and rodents who might otherwise love to use it as nesting material, I chose to wrap all my insulation with black tile tape (for joining and waterproofing tubing).

We used Rubatex elastomeric pipe insulation with 1 inch (25 mm) and in some places 1/2 inch (13 mm) wall thickness. In retrospect, I wish I had used insulation with 1 inch wall thickness wherever possible. We did not install the pipe insulation until we had pressure tested the system. Smitty at AAA Solar recommends painting the Rubatex insulation with a product called Ruf Snow. It is a white rubberized paint used to coat and seal mobile home roofs.

We installed the sensor wires for the differential thermostat running outside the insulation, to protect them from the high pipe temperatures. The wires are covered and protected under the black tape that I wrapped around the insulation. The sensors are installed in wells, special plumbing fittings that are made to accommodate these sensors. They allow you to remove or replace the sensors without losing system pressure or fluids. They also protect the sensor from corrosion by avoiding direct contact with the liquids.

Change Your World

Solar energy is wonderful because it is democratically distributed to the rich and the poor alike throughout the world. It is basically ours for the taking. One major challenge is how to efficiently collect, use, and store this energy. I have shared with you how we successfully installed our solar water heating system for a cold climate.

If you are inspired to run out and start purchasing plumbing parts to build a solar water heating system, please take some time and learn more about the different types of SDHW systems, heat exchangers, etc. that are available. The system I have described has worked extremely well for my family, with our pattern and level of hot water consumption, in our climate, with our level of sunshine. But it may be that another system or setup will fit your situation better. You owe it to yourself to do some research to find the system that will work best for you.

Margaret Mead's well-known statement has been an inspiration to me: "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed it is the only thing that ever has."

Access

Roy W. Tonnessen, PO Box 1443, Fairfield, IA 52556

Installation Guidelines for Solar DHW Systems, U.S. Department of Housing and Urban Development, May 1980, HUD-PDR-407(2), by Franklin Research Center, Philadelphia, Pennsylvania • Good, clear, drawings, explanations, definitions, checklists, & suggestions Available via government depository libraries

How to Install a Solar Water Heater; Closed Loop Antifreeze System, by James E. Cook, Save On Solar, 1988. ISBN 0-9619932-0-0 • Very clear and straightforward • Available used

Build Your Own Solar Water Heater, by Stu Campbell with Doug Taff, Garden Way Publishing, ISBN 0-88266-129-9 • Covers why and how different types of collectors work • Available used

HP84, page 44, and *HP85,* page 40, articles by Ken Olson. • Outstanding information, nice illustrations

HP25, page 37, and *HP27,* page 64, articles by Tom Lane. • Savings, payback, and sizing for SDHW systems

AAA Solar Supply, Inc., 2021 Zearing NW, Albuquerque, NM 87104 • 800-245-0311 or 505-243-4900 • Fax: 505-243-0885 • info@aaasolar.com www.aaasolar.com • Educational & informative Web site; SDHW components

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

Kera Technology, Andy Lukas, 1320 Midway Blvd., Unit 21, Mississauga, ON L5T 2K4, Canada • 905-566-0823 Fax: 905-566-9036 • keratech@interlog.com www.interlog.com/~keratech/thermsd2.htm • DSD-2 differential thermostat