SDHW Installation Basics Part 2: Closed Loop Antifreeze

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Closed loop antifreeze is one of the most common solar domestic hot water (SDHW) systems for cold climates. This article concentrates on the assembly and installation of closed loop antifreeze SDHW systems, hereinafter referred to as closed loop systems. "Installation Basics for SDHW Systems" in *HP94* covered aspects of installation common to most solar water heating installations, such as collector location and mounting, pipe runs, soldering and insulation, and the control system.

Nancy Cochrell of AAA Solar puts the finishing touches on a SDHW system.

The operation of the closed loop system, the function of each of its components, and some guidelines for sizing were covered extensively in *HP85.* In brief, freeze protection is accomplished by circulating a nontoxic antifreeze fluid to remove heat from the solar collectors and transfer it to the domestic water via a heat exchanger. The antifreeze remains contained within a closed loop, so it never mixes with the domestic water.

The collector loop setup is nearly identical to conventional closed loop hydronic home heating systems, which circulate water heated in a boiler through baseboard radiators or a radiant floor. Most plumbing and heating contractors recognize the closed loop system as a common design and are familiar with all the components on the parts list in this article.

Laying out the components and plumbing parts in advance prevents headaches after the soldering begins.

Modular Assembly Rules!

The major components, other than solar collectors and storage tanks, are easier to deal with if you have the space to assemble the parts into a component module before installation. Many modules in earlier systems had cosmetic covers, but this has been shown to cause excessive heat buildup, which can cause premature failure of certain pumps. The components can be placed anywhere consistent with good access and straightforward pipe runs, but they are usually installed near the storage tank.

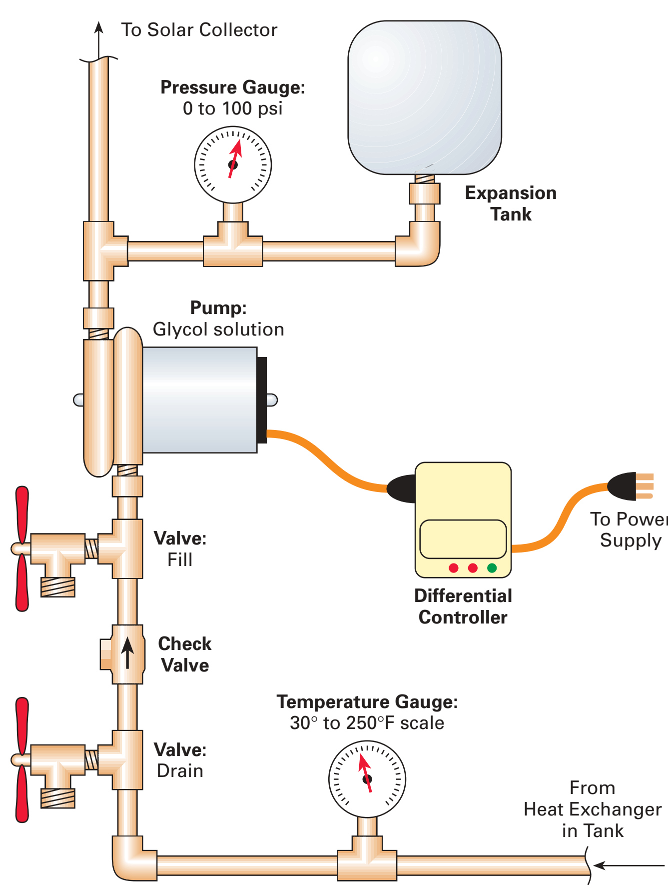
A 3/4 inch (19 mm) plywood board, approximately 2 or 3 feet (0.6 or 0.9 m) by 4 feet (1.2 m), is an excellent mounting surface for the component module. You can also use a square channel product called UniStrut for wall-hung equipment. If you have the space on a wall for a module of this size, the installation will be much cleaner, with less chance of piping errors. Placement of the components is based on convenience and access, and a few good rules as provided below and illustrated in the drawings.

When your module is completed, you will have either two or four connections to the rest of the system. For systems using an external heat exchanger, you will have four connections, including collector supply, collector return, heat exchanger supply, and heat exchanger return. For systems with a heat exchanger integrated within the storage tank, you will have only two module connections—one that goes to the collector and one to the tank heat exchanger.

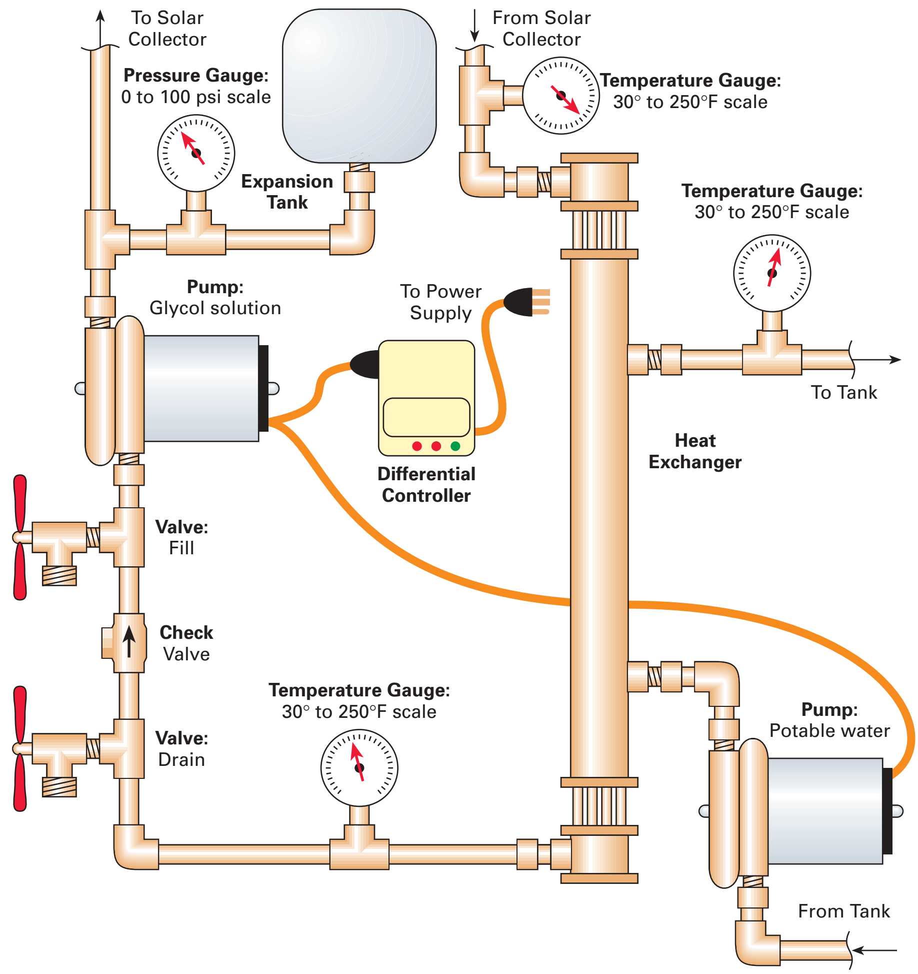
Rule #1

The pumps should be placed so that they are pumping the coldest fluid in the system. The coldest collector loop fluid is found after it has been circulated through the heat exchanger where it has lost most of its heat. The coldest DHW is at the bottom of the storage tank.

SDHW Module for Use with In-Tank Heat Exchanger



SDHW Module with External Heat Exchanger



valve assembly are usually placed downstream from the heat exchanger, near the collector fluid pump. Therefore, they are on the cold side of the loop as well.

Rule #5

If you place the expansion tank with the pipe fitting down (tank upside down), the tank will continue to function if the internal bladder fails. An expansion tank placed with the fitting horizontal will still hold air with a bladder failure, and may continue to function. A tank placed with the fitting up, upon failure, will introduce all the air in the tank to the collector loop piping. This is a common cause of failure in older systems.

Rule #6

A coin vent may be located anywhere that an air pocket is likely to form within the piping. Air pockets are most likely to form where the fluid is at its hottest, or where the piping makes a downward turn. A coin vent is usually placed at the collector outlet where the piping turns downward. Another may be located at a similar location in the collector loop at the closed loop module assembly.

Rule #2

Pumps should always be mounted so that the impeller shaft is horizontal. Mounting a pump with the shaft vertical will put too much pressure on the shaft bearings and cause premature failure. If possible, the pump(s) should pump upwards; this prevents trapped air from collecting in the pump chamber, which is possible with some pump models.

Rule #3

The check valve should be placed between the two boiler drain valves that are used for purging and filling the system. These boiler drains are also used for any future maintenance of the collector loop fluid.

Rule #4

The expansion tank, pressure gauge, and the boiler drain and check

Don Keefe mounts the expansion tank upside down—on purpose.

A pressure test fitting made from a Schrader valve and a female hose fitting.

Putting It All Together

The parts should be laid out dry before putting them together. You will need to cut pipe to the sizes needed, and fit the pipe into the various fittings and adapters. All of the piping, fittings, adapters, and components should be soldered before attaching them to the module backing. Gaskets should be removed from valves and other components, and set aside before soldering. Reassemble them once the fittings have cooled down.

The assembly can be pressure tested with a small air compressor if you are unsure of any joints in the system. You can make a small attachment for the pressure test with a hose connector and Schrader valve (tire valve) as shown. This can be screwed onto one of the boiler drain valves in the open position. Cap the inlets and outlets, and the pressure gauge will indicate the assembly pressure.

If the system holds a pressure of about 50 psi for 30 to 60 minutes, you can be assured of its integrity. If the pressure gauge falls during this time and the leak is not apparent, a solution of soap and water can be applied with a spray bottle to detect very small leaks. Soap bubbles will appear at the leaking joint(s).

When you feel that the module is leak-free, the entire assembly should be fastened to the module backing and the backing fastened to the wall with screws or lag bolts. Four screws or lag bolts, one at each corner, should be enough since the whole apparatus only weighs 30 to 40 pounds (17–18 kg).

The piping to and from the collectors and storage tank can be soldered with the module in place. Some installers prefer to use unions at connections to major system components, such as the closed loop module or the heat exchanger. Unions are merely a convenience for maintenance and repair if removal or replacement is anticipated.

SDHW Closed Loop Parts List

At a minimum, a SDHW closed loop installation with collectors placed on a roof, will require the parts listed below.

Solar Collector(s)

Solar collectors capture the heat from the sun and are the main components of the system. In addition to your collectors, you will need mounts and hardware, roof jacks, silicone caulking, and roof sealant. (See “Installation Basics” *HP94*.)

Pump(s)

A closed loop system uses a low head, centrifugal circulating pump with a cast iron, stainless steel, or bronze body and is able to pump at least 0.5 to 1 gpm (2–4 lpm) for each 4 by 8 foot (1.2 x 2.4 m) collector. If your system has an external heat exchanger, you will need an additional circulating pump on the water side of the heat exchanger. This pump should have a bronze, stainless steel, or high-temperature plastic body. Be sure you have pump-to-pipe flanges if you use flanged pumps. (See “Installation Basics” *HP94*.)

Differential Control

A differential control activates the system whenever useful solar heat can be collected. It senses the difference in temperature between the solar collectors and the storage tank and turns the pump on or off accordingly.

You will also need two sensors and a 120 VAC receptacle and cord set, unless the control includes a cord set. Thermostat wire for the control sensor wiring should be #20 or #22 (0.5 or 0.3 mm^2), two-conductor jacketed cable. Use stainless steel hose clamps for fastening the sensors to the pipes. Connect the sensor wires to the sensors with electronic solder, coat with silicone sealant, and cover the connections with small wire nuts. (See “Installation Basics” *HP94*.)

Heat Exchanger

The heat exchanger, which transfers the heat from the solar heated antifreeze to the domestic water in the storage tank, can be either external or inside the tank. (See "Heat Exchangers" *HP92*.)

Storage Tank

Solar hot water is typically stored in a tank that is separate from the backup water heating system. Your storage tank may come with or without an integral heat exchanger.

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Parts List, Continued

Expansion Tank
A #15 bladder-type expansion tank is sufficient for fluid volumes up to 4.7 gallons (18 l). For greater volumes, you may use multiple tanks, or a #30 is sufficient up to 12.5 gallons (47 l).

Pressure Relief Valve
A pressure relief valve rated at 50 to 75 psi is usually adequate to protect the closed loop piping.

Pressure Gauge
A pressure gauge that registers in the range of 0 to 100 psi will work.

Coin Vent or Automatic Air Vent
Coin vents are preferred. Automatic air vents may be problematic outdoors in freezing climates. Manual coin vents are adequate for closed loop systems where no makeup fluid is automatically introduced into the system. (Makeup water is a common feature in large hydronic heating systems where water is automatically introduced into the system to make up for losses or leaks over time. This is not common in solar water heating systems.)

Boiler Drain Valves
You will need two boiler drain valves for purging and filling the system.

Check Valve
Spring-type check valves are recommended to prevent forward or reverse flow at night. However, swing-type check valves are recommended for use with PV powered DC pumps, which may not generate enough force to open a spring-loaded check valve.

Miscellaneous Plumbing Parts
You will need some 3/4 or 1 inch Type M copper tubing and various copper elbows, tees, adapters, and unions as required. You will also need solid wire solder (type 95/5; don't use rosin core solder intended for electronics) and flux, high temperature pipe insulation, insulation covering, and propylene glycol—approximately 1 gallon (4 l) per collector.

Options to Think About
Consider adding dial thermometers or choosing the option of digital temperature readouts on the control if available. Another nice option is the addition of three ball valves for the hot water bypass assembly. Ball valves are preferable to gate valves because the position of the handles indicates whether the valves are open or closed.

A pressure relief valve and air vent is installed at the highest piping point in the system—the outlet of the solar collector(s).

Connecting to the Heat Exchanger
Connecting the preassembled module to a tank with an integrated heat exchanger is rather straightforward. The heat exchanger outlet (cold) feeds the pump inlet, and the collector outlet connects to the heat exchanger inlet (hot). The tank's standard water inlet and outlet connections should be fitted with dielectric unions where copper pipe connects to the steel tank. This prevents galvanic corrosion between dissimilar metals.

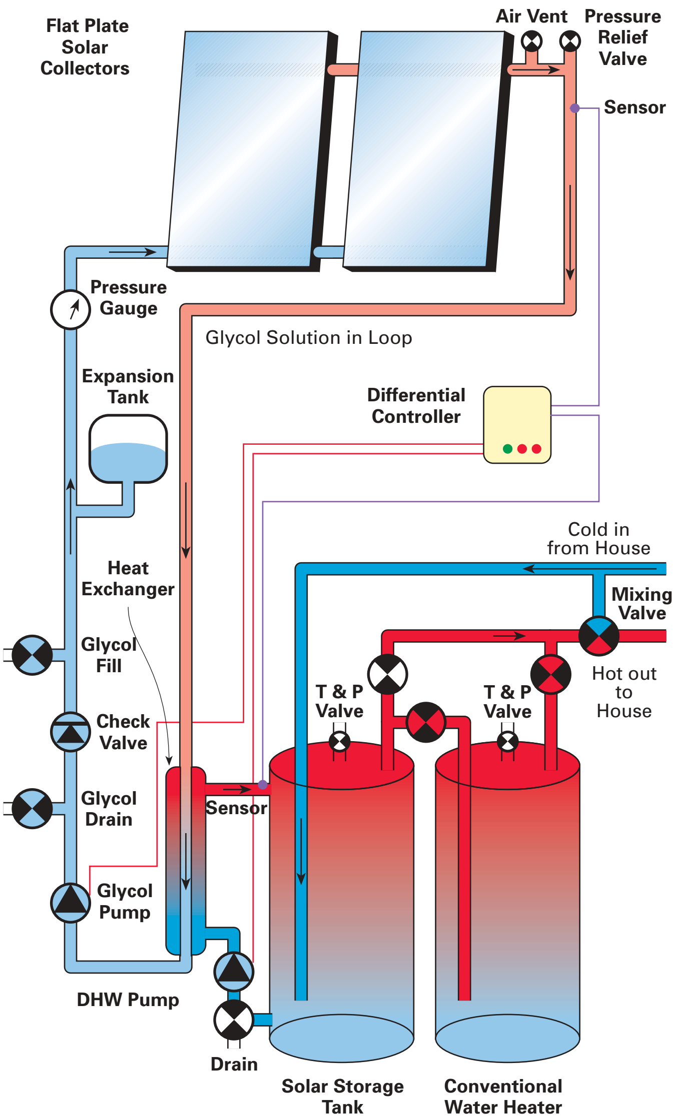
A temperature/pressure relief (TPR) valve must be installed on the storage tank if there are any valves between the storage tank and the conventional water heater. The outlet of the TPR valve should either discharge at a floor drain, connect with a tee to the TPR discharge of the conventional water heater, or be piped outside. If you pipe it outside, make sure the open end faces downward and is at least 6 inches (15 cm) and not more than 24 inches (61 cm) above ground level.

One and Two-Tank Storage Systems
Most SDHW systems use a separate tank to store solar heated water. This is in addition to the backup auxiliary water heater. Cold water supply from the house will feed the cold inlet of the solar tank. The hot outlet of the solar tank will feed the cold inlet of the auxiliary gas or electric water heater. You can install a bypass valve assembly as shown in the diagram to bypass the auxiliary tank during months when the sun heats 100 percent of your hot water.

You may consider installing a single tempering valve downstream from the tanks to avoid sending exceedingly hot solar heated water to the tap during those bountiful sunny and warm months. But tempering valves can be a problem in areas with hard water. The spring in the valve that mixes the water can become clogged in a few years, and the valve interior may need to be cleaned or replaced.

For smaller systems with an external heat exchanger and electric backup, you can save space by modifying a single, oversized, standard electric water heater to function as both backup and solar hot water storage. See the "One-Tank" how-to article in next issue for directions on making these modifications.

Complete SDHW System with Tank Storage



For situations with limited space, you also might consider using a tankless or on-demand heater for auxiliary backup. In this case, the hot outlet of the solar storage tank feeds the inlet of the on-demand heater. For this configuration to work, you must be sure that the on-demand heater is able to sense the incoming water temperature and regulate the outlet temperature. This way it will only operate to the extent that the solar preheated water needs to be boosted in temperature. The AquaStar "S" model functions in this way and is therefore compatible with solar water heating systems. (See "Solar Hot Water, Homebrew Style," *HP88*).

Tankless water heaters may need cleaning after a few years in locations with hard water. If you need to clean automatic coffee makers with vinegar frequently, this same type of periodic maintenance may be required with a tankless water heater.

Collector Loop Fluids

When the collectors are securely mounted and all components are assembled and wired as shown in these drawings and according to the manufacturers' instructions, you are ready to test the whole system for leaks, purge it, and fill it with an antifreeze solution or synthetic oil.

The most common fluid used in closed loop systems is a 50-50 solution of propylene glycol and water. This will give freeze protection down to approximately –30°F (–34°C). Propylene glycol is similar to car antifreeze (ethylene glycol), but is nontoxic. Ethylene glycol is not recommended, but may be used in systems with double-walled heat exchangers. You should be aware of its toxicity and the potential danger from possible future leaks.

Most propylene glycol is distributed with inhibitors or buffers that prevent it from turning acidic over long periods of time. These inhibitors (aluminum hydroxide is a common one) can break down at high temperatures (above 280°F; 138°C). When the buffers are gone, the glycol solution can turn acidic. A higher temperature (325°F; 163°C) propylene glycol is available, but the boiling points of both of these glycols are the same—approximately 225 to 250°F (107–121°C), depending on system pressure.

Synthetic oils have an advantage over glycol solutions because they will not boil under any temperatures produced by flat plate solar collectors. They make a system maintenance-free in this respect. The disadvantages of silicone oil are reduced efficiency due to its lower specific heat, limited availability, and high cost. A gallon of 50-50 glycol solution costs an average of US$7 to US$10. Silicone oil can cost US$75 a gallon or more.

Two other synthetic oils have been used in closed loop systems, bray oil and dyala oil, but the use of these requires a heavy caution. Neither of these oils is compatible with the butyl rubber used in O-rings, gaskets, and the bladder in expansion tanks. These oils need special O-rings and gaskets made from Viton, a material manufactured by Dupont. Expansion tanks are no longer made with bladders of this material, and that poses a significant installation problem when considering these synthetic oils as an option.

Purging & Checking for Leaks

Other options are available for purging and filling the system, but the method employed most often uses a charge pump capable of creating more than 15 psi pressure in the closed loop. It must also be capable of lifting the charge fluid as high as the collectors. A charge pump can be as simple as a drill-operated pump found in many catalogs and home centers. This type of pump has hose fittings on either end, and connects easily to the system's boiler drain valves. Three washing machine hoses, two common garden hoses, and a five-gallon bucket or other suitable container completes a minimum setup for purging and filling the system.

A closed loop SDHW system will have many solder joints, and it is a good idea to clean the system out before charging it with an antifreeze solution. To do this, you will need a garden hose or two to drain the system if the component module is located where you don't want water on the floor. Washing machine hoses have female thread hose connections on both ends. Using two of these hoses, connect one end of each hose to the two boiler drain valves. Connect the other end of each washing machine hose to each of the boiler drain valves. The other end of each washing machine hose is connected to one of the garden hoses. One garden hose is connected to a hose bibb to supply water, and the other is used to direct the discharge water outdoors or to a drain after it has been circulated through the system.

The supply water from the hose bibb is circulated through the boiler drain fill valve located downstream from the check valve. The arrow of the check valve should point to the fill valve. The water can only go one way, and will eventually return through the other boiler drain (discharge) valve located upstream from the check valve. If the sun is shining when you purge the system, the collector will heat the water a bit and help clean out the flux, in addition to purging any other debris that might be in the system.

When the water appears at the discharge hose, let it run at full flow for a few minutes to get the air out of the system. You may then shut off the upstream (discharge) boiler drain and slowly close the downstream (fill) boiler drain where the water is being introduced. Watch the pressure gauge and let the house pressure bring the system up to about 25 to 40 psi. Then shut the valve completely.

Turn the differential control to the "on" position and make sure it is plugged in. If the system is wired correctly, the pumps should start up, even without sunshine. If the sun is shining, you will be able to feel a difference in temperature between the pipes to and from the collectors. This assumes that most of the air was forced out of the system by the garden hose water. You can then let the system run for a few minutes or longer if you wish—the hotter it becomes, the better it will clean out any flux left in the system. While the system is circulating the water, you can disconnect the downstream supply (fill) garden hose from the hose bibb, after tuning it off.

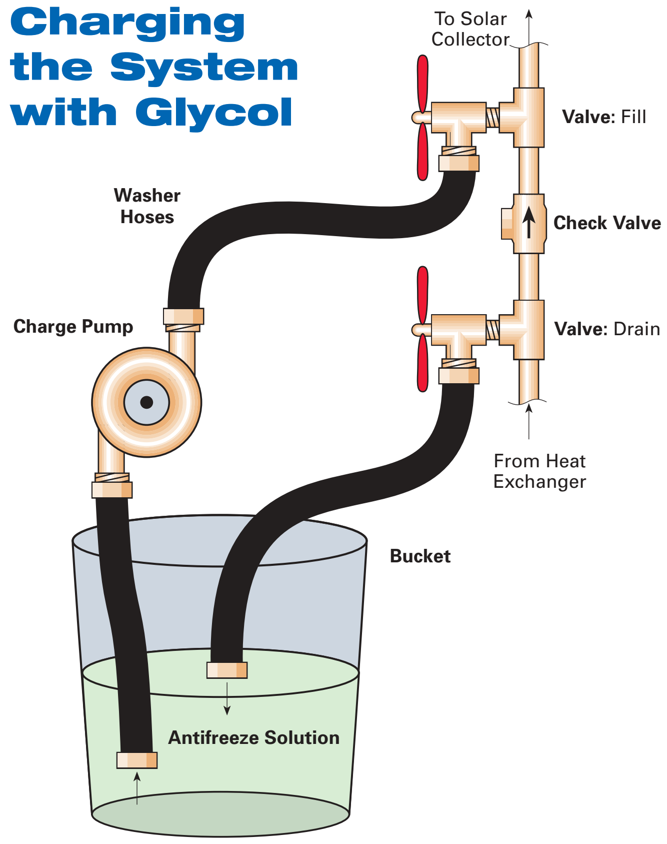
This is also a good time to visually inspect all joints in the system for leaks. When the water has circulated for at least thirty minutes, turn the control to "off" and immediately open both boiler drain valves to allow the water to drain from the system. To drain all the water out, you may need to open the air vent at the collectors to introduce air at the top of the system.

Charging the System with Antifreeze

Fill the bucket with a 50-50 solution of water and propylene glycol. You will almost always need about 2 gallons (7.6 l) of solution per collector (1 gallon of glycol) but the quantity will vary with the collector manufacturer, size of the collector, and size of piping in the system. Make sure to have a little extra if in doubt.

You will now only use the washing machine hoses. One hose is connected to the supply boiler drain valve, downstream of the check valve, with its other end connected to the charge pump output. Another hose goes from the pump to the bottom of the bucket, and the third hose goes from the discharge boiler drain valve, upstream from the

Charging the System with Glycol



check valve, to anywhere in the bucket. You may need to elevate the bucket so that both hoses can reach it. The hose attached to the pump will need to reach the bottom of the bucket.

Open both valves all the way. Start the pump. Solution in the bucket will be sucked up into the closed loop. You will know that the system is full when the solution returns to the bucket from the other hose. The return hose will contain a good deal of air that is being forced out of the system. Let the fluid circulate until the return hose is flowing smoothly with no air bubbles. Close the upstream (discharge) valve at this time. The flow in the return hose will stop and the pressure will increase.

Keep the pump on until the system pressure is about 15 to 25 psi and then shut the fill valve downstream of the check valve. Shut the pump off. Turn the control switch to the "auto" position, and if the sun is shining, the pump(s) should turn on. Leave the hoses connected. The system will normally still have a small amount of air at the top. This air can be released if you have installed a coin vent or automatic air vent at the top of the system. Unscrew the coin vent or push on the stem in the Schraeder valve of the automatic vent until only liquid appears. Be careful—it might be very hot, depending on the amount of sunlight.

Follow-up & Maintenance

Installation follow-up starts with casual observation during the first couple of weeks after starting the system up. The system should turn on shortly after the sun comes up, but exact times are hard to gauge. The turn-on time changes with the seasons and the temperature of the cold water. The system should also turn off before sundown. Micro-bubbles of air are usually present in the water used in the antifreeze solution, and these will tend to gather at the very top of the piping. A couple of weeks after the system is started up, the coin vent should be opened slightly to release any accumulated air. If you used an automatic air vent, this should have purged the air automatically.

A good, quick check of your system operation may be made at the pipes coming to and from the collectors. When the sun is shining and the water in the storage tank is cold or cool, there should be a very noticeable difference in the temperature of the two pipes. If not, there is something wrong with the system. We'll discuss what might be wrong in a future article in this series.

We have covered the practical installation considerations of a closed loop type of solar domestic hot water system. This is one of the most common types of systems with reliable freeze protection. In subsequent issues of *Home Power*, we will follow up with installation of the drainback-type SDHW system and the troubleshooting, maintenance, and repair of both these types of systems.

Access

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