# Solar Thermal Freeze Protection

*By Eric Skiba*

According to the Solar Energy Industries Association more than 30,000 solar water heating systems were installed in 2010. These types of systems convert energy from the sun into thermal (heat) energy and transfer that energy to a fluid. A warm fluid has endless potential in residential and commercial applications and can be used to heat hot water for domestic consumption, heat homes through hydronics and keep swimming pools warm well into the shoulder months.

Solar thermal collectors for water heating have fluid circulating through them and are typically installed outside. Since a large portion of the country sees freezing temperatures during the year, protecting the fluid inside the collectors from freezing is an important design consideration.

Freeze protection is a common topic of discussion among the solar thermal industry and arguments over the "best" method of protecting a system have been going on for years. Perhaps this is due to the fact that there is no best method. There are many ways to achieve the same end result, but the benefits and downsides of different methods of freeze protection should be considered so that the system operates efficiently and safely.

## Mild climates

Some areas see minor periods of freezing throughout the year. In these areas, where the temperature does not drop below 30°F for more than a few days a year, it is still possible to circulate potable water directly through the collector (direct flow system). If the goal of the system is to heat hot water, circulating potable water directly through the collector is highly efficient. Any time that a heat exchange can be avoided is ideal, but how can this type of system be protected from unforeseen freezing temperatures?

Most modern solar controllers have incorporated freeze protection mechanisms into their programming. These functions operate by monitoring the temperature at the collector and circulate fluid through the collector if the conditions reach a point where freezing could occur. This function uses energy that was previously gained during the day through solar collection or in the worst case, uses traditional fuel sources to provide freeze protection. For mild climates where freezing conditions occasionally occur, the electrical and heat losses of this method are negligible in terms of total annual operation.

During a power outage, however, the combination of no electricity and freezing temperatures can cause damage to a system. One simple solution is to use a valve that opens and causes water to drain from the system. By creating movement through the collector freezing is less likely to occur. These valves must be of good quality since a failure can cause damage to the system and potentially the building.

It should also be noted that certain types of collectors are more susceptible to freezing than others and also may not be approved for contact with potable water. The manufacturer should always be consulted before installing a direct flow system.

## Cold climates

Controller based freeze protection can be a useful method if freezing rarely occurs, but most regions have weather that warrants a more robust method of protecting a solar thermal system. The goal of the design is to provide simple, reliable freeze protection while minimizing costs and reduction in system efficiency. This is achieved by either using anti-freeze to increase the fluid's ability to handle cold conditions or removing the fluid from the elements through the use of a drainback design.

Anti-freeze is commonly mixed with water to lower the freeze point and protect systems from damage associated with cold conditions. Propylene glycol is a standard product which is mixed with water and used in closed loop, pressurized solar thermal systems. The ratio of water and glycol can be adjusted to provide different levels of freeze protection (a 50/50 mix is standard). The glycol/water mix is separated from the potable water through a heat exchanger.

The introduction of anti-freeze and a heat exchanger to the system may have a negative impact on the efficiency. If a heat exchanger is not large enough or is not "solar friendly" this impact can be magnified. Since solar thermal systems operate best at low differential temperatures, the heat exchanger needs to be sized to work with relatively small differences in approach temperatures, sometimes as little as 10°F, and low flow rates when compared to boiler operations.

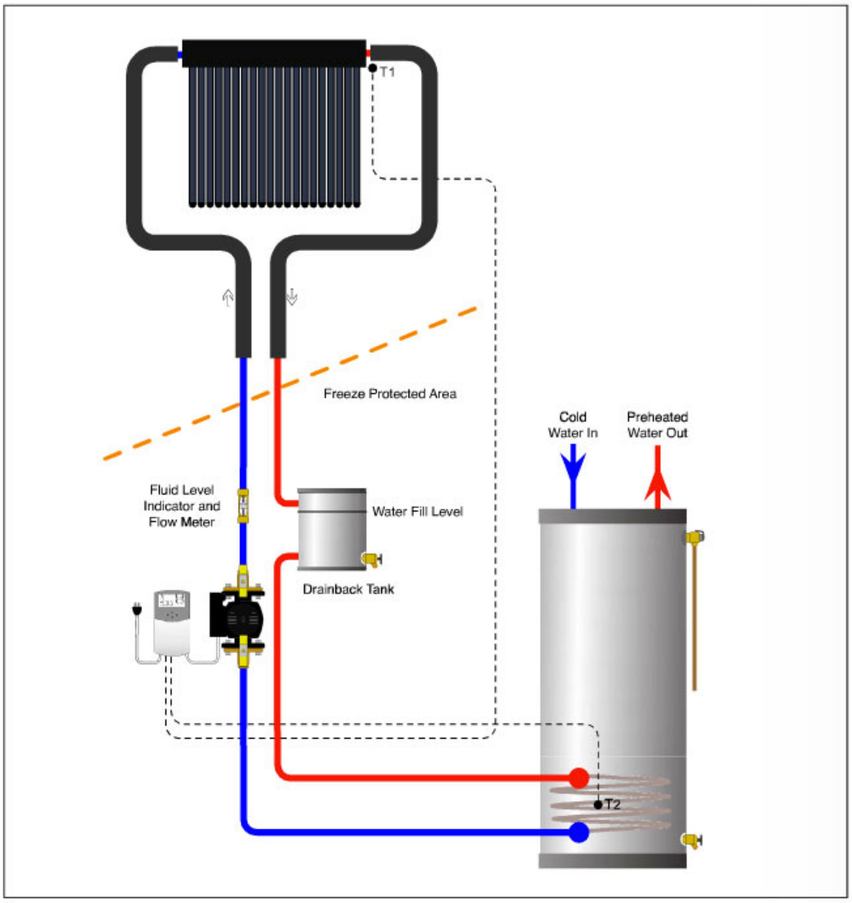
One benefit of using closed, pressurized systems is that there are no substantial piping requirements other than avoiding excessive fluid velocity and increased pressure

*Continued on page 36*

# Thermal

*Continued from page 34*

drop. Also, the power consumption of the pumps can be substantially less than those of a drainback solar system since the pump is only overcoming pipe losses and not vertical lift. This can be especially important in commercial applications where panels may sit a significant height above the storage tanks.



*An example of a drainback system utilizing a hot water storage tank with an internal coil heat exchanger. When the system is not operating, fluid sits inside the freeze protected area. Certain valves and small components are not shown.*

The biggest issue seen in antifreeze based systems is the degradation of system fluid over time. During periods of non-use, or in systems with undersized storage, it is possible for some collectors to sit hot on the roof and reach temperatures over 250°F. This causes some types of glycol to break down resulting in degraded freeze protection capabilities and raised pH levels. This can harm other system components and create the formation of "sludge" which can cause further issues in the system.

In order to combat this issue many manufacturers have begun to produce glycol mixes that are able to handle temperatures up to 350°F. The additives and inhibitors in these products help extend the life span of the antifreeze, but most of the time the addition causes the fluid to no longer meet the FDA's generally regarded as safe (GRAS) guidelines. While still non-toxic, certain codes require that a double wall heat exchanger be used, adding cost and potentially lowering the systems efficiency. Other non-propylene glycol based fluids are becoming available that can withstand high temperatures (over 450°F) but issues such as high viscosity at lower temperatures can cause pumping issues.

Systems that do not regularly experience stagnation are in less danger of fluid degradation and may require minimal maintenance. If a system is designed properly with

*Continued on page 56*

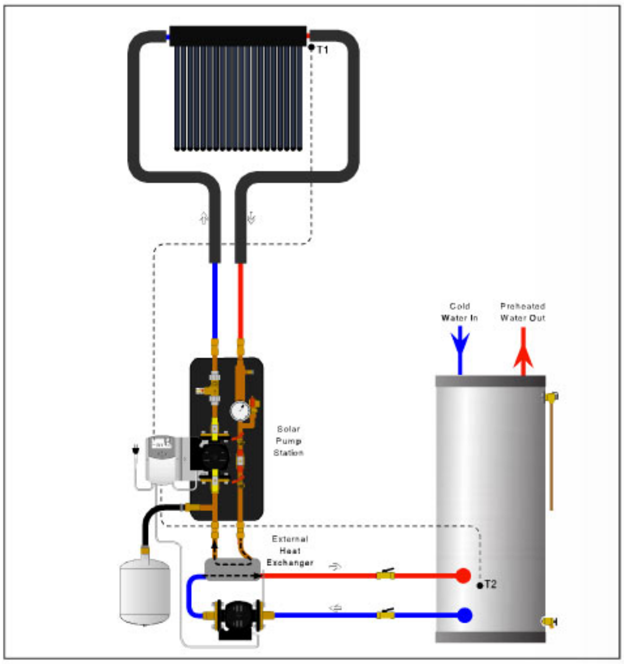
# Solar Thermal Freeze Protection

*Continued from page 36*

enough storage and is not oversized, closed loop systems can work well and run at high efficiency for years. However, it may sometimes be difficult to avoid such conditions and sometimes an oversized system is required. An example would be a system that is contributing to a heating load as well as hot water, or a commercial system that has high loads during the week and almost none over the weekend. For such systems it may be prudent to utilize a drainback method of freeze protection to avoid the issues associated with pressurized anti-freeze systems.

A drainback system runs at low or atmospheric pressure and uses water as the heat transfer fluid. This can help improve the system efficiency since water's thermal properties are more ideal for use in transferring heat. A heat exchanger is still required since the pressurized potable water system must be separated from the lower pressure solar system, so it is important that this heat exchanger be properly sized and designed.

When the system is not operating (no available solar energy and the tank is at maximum temperature) the fluid in the collector, supply and return lines drain empty of water. The water that drains from the system is stored in a drainback tank that is located in a freeze protected area. If the collector is sufficiently hotter than the bottom of the main storage tank, the solar pump will turn on and lift the water up the supply piping pushing the air out of the collector and return line into the drainback tank. As this happens the piping begins to fill with water and eventually will operate similar to a closed loop system once all the air is removed from the piping.



*An example of a solar thermal system using an external heat exchanger. The preheated water leaving the tank is then distributed through a conventional water heating system. Certain valves and small components are not shown.*

In order for a drainback system to function properly as a freeze protection mechanism, it must drain completely. All the piping has to slope back to the drainback tank at a sufficient pitch (¼" per foot) to ensure that fluid does not get "hung up" in a section of pipe exposed to freezing conditions. This can be difficult on certain jobs such as ground mounted systems where there may not be enough of a height difference between the collector and the drainback tank. One important element to the operation of the system is that air must be able to reenter the system otherwise it will not drainback. If this is not able to take place, a vacuum will hold fluid in the exposed piping and freezing can occur. It should also be noted that due to the design of the internal flow paths, certain types of collectors simply will not drain completely and therefore cannot be used in these systems.

A drainback system will also require slightly more energy since the pump has to lift the water up and through the collectors. This energy cost can be minimized through certain piping designs so that once the piping is flooded with water, the system operates with similar pumping requirements as a closed system.

All types of freeze protection have important considerations that must be addressed when installing a solar thermal system. Keeping a system from freezing is only one part of the design. Sufficient research of system types should be carried out before a final method is chosen so that the best method for that installation is carried out. Each application is unique and differing methods of freeze protection have been used in many installations, some of which have been in service for over 20 years. Proper design, installation and equipment selection will help ensure that the system runs safely and efficiently. ■

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