# Solar Solutions

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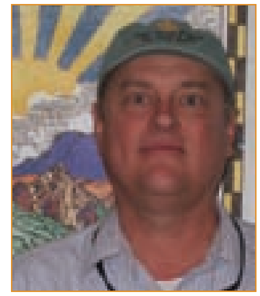

## Bristol's six principles of good solar hydronic design

# Solar overheat protection

Solar overheat can be problematic. Even a fully functional closed-loop glycol solar heating system can overheat. This is most likely to happen when there is plenty of sun, but the heat is not being used. This can happen for many reasons, but most commonly when the heat is not needed because all the heating loads are satisfied, or because of a pump failure (or power failure) in the heat storage or distribution system. Heat begins to build up in the solar collector loop when it is not carried away to a useful heating job. Flat plate collector temperatures exceed normal design limits and then eventually reach maximum stagnation conditions unless overheating can be controlled or at least slowed down. The conditions that can initiate overheating may happen only once a year or even less often, but when it does happen, the results can range from annoying inconvenience at best to major heating system failure at worst.

**Minor overheating**

A minor episode of overheating is often accompanied by the sound of steam hammering in the solar heat collector, the propylene glycol starts to cook and may begin to turn brown in color, a plume of steam may appear at any open float vent and the pressure relief valve may begin to drip or spurt glycol and the temperature and pressure (T&P) valve on the water storage tanks may begin to dribble. The volume of liquid glycol that is displaced by the steam in the collector will try to seek refuge in the glycol expansion tank. If the expansion tank is large enough and was installed with the proper air pressure, this may prevent much of the glycol from leaking out the pressure relief valve. After sunset when the steam condenses, and the air pressure forces the glycol back into the solar loop, the system may actually continue to run normally, so long as the electric power, pumps, valves and controls are not damaged and the glycol pressure has not dropped to zero.

This type of overheating is not uncommon behavior for older solar water heaters when their owners are on vacation. When nobody is using the solar hot water from day to day, there is no cold makeup water provided to cool the water storage tank, which can overheat after a few days of clear, sunny weather.

> In this series of articles, I have been making the case that the key ingredients for solar/hydronic design and installation can be divided into six categories, listed below, roughly in order of their importance.
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> 1. RELIABILITY
> 2. EFFECTIVENESS
> 3. COMPATIBILITY
> 4. ELEGANCE
> 5. SERVICEABILITY
> 6. EFFICIENCY
>
> The success of any solar hydronic home heating installation depends on the often-conflicting balance between any of these six principles. Finding the balance between them defines the art of solar heating design.

**Major meltdown**

It is important to design solar heating systems to prevent these small overheating events because it only takes a few minor events to add up to a major failure. Every time the glycol cooks at stagnation temperatures it becomes a little more acidic. If it is allowed to cook thoroughly, it can turn to the consistency of brown molasses, which can clog the collector tubing. Steam and extremely hot glycol will tend to ruin the rubber seals in the air vents, relief valves, pump gaskets and expansion tanks, resulting in the inevitable glycol leak. If cheap plastic foam pipe insulation is used anywhere near the overheated solar pipes, it will melt and flow off like candle wax. Nearby electrical wires and sensors often are ruined by the high temperatures, and gauges can be ruined as well. If the overheating episodes are allowed to continue (even intermittently), it is only a matter of time before the glycol leaks out, the circulator pumps seize and the catastrophic failure is complete.

The glycol fluid in this system is just as critical as the Freon in a refrigerator. Systems must be designed and installed ideally so that the fluid never leaks out and the flow is never blocked by steam or air. If we make our solar water heaters as reliable as a typical refrigerator, we are doing a good job. Reliability, in my opinion, is the most important feature required for market acceptance and customer satisfaction, which is why it is listed as "Principle #1."

**Past approaches**

In the early days of active solar water heaters, the focus was on producing solar heat, not cooling issues. So, when cooling problems were encountered, the reactionary response was an afterthought rather than part of the original design:

- The solar pump shuts off when there is no need for heat and bigger and bigger expansion tanks are added to try to contain the stagnation pressure.
- When the solar water tank gets too hot, the T&P blowoff is used to cool it with make-up water. Cross your fingers and hope the T&P valve stops leaking later.
- Seasonal covers are fabricated to shade the collectors during the hot season. These must be manually installed and removed along with the screens and storm windows, and the annual swamp cooler or air conditioner covers.
- Manual valves or controls are added for night siphoning or heat dumping which must be activated by hand whenever overheating is expected.

While all of these approaches can be made to work, none of these are acceptable under the principles that guide us here, especially Principles 1, 3, & 4. None of these cooling strate-

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gies is ultimately Reliable enough, Compatible with customer expectations, or Elegant enough to be widely accepted in today's market.

**Improving what you already have**

To improve the overheat protection on an existing glycol (flat plate) solar water heater you might first consider using what you have to better effect. If you already have an instant hot water circulator pump, make sure it turns on before the hot water storage tank gets too hot. A thermal snap disk control or set-point thermostat can be used to do this automatically. This can dissipate excess heat from the tank remarkably well. This type of control can also be used to run the flat plate solar collector coolant pump at night automatically.

It is not a bad idea to install an oversized expansion tank to help prevent glycol loss if and when the collector experiences minor stagnation. The liquid acceptance volume in the tank should be at least equal to the fluid volume of the solar collectors themselves. Keep in mind that repeated stagnation will always result in premature system component failures.

Some newer solar DHW controllers (differential thermostats) have night cooling capability (vacation mode) so make sure yours is programmed to take advantage of this, or consider upgrading your older controller. Keep in mind that night coolant pumping is not effective with most evacuated tube collectors since they are not designed to work in reverse.

The solar coolant pump is the most critical component needed to provide overheat protection to the collectors, so consider making it non-interruptible. We do this by using PV (solar powered) solar circulators, but battery backup systems also could be used like those made for computers. If the solar pump continues to circulate even when the other heat storage and distribution pumps have temporarily stopped, you can gain a vital time delay before the system stagnates.

**Our most common strategies**

In the past decade I have designed and installed hundreds of solar water heaters and "combi" solar home heating systems. Most of these were installed in recent years by my company, Cedar Mountain Solar Systems. All of these systems use closed loop propylene glycol piping systems employing photovoltaic (PV) coolant pumps and flat plate solar heat collectors. The combi systems typically include a solar domestic hot water tank and some radiant heated mass floor zones all heated with the same solar collectors (and the same backup hydronic boiler. See previous articles for diagrams). Many of the combi systems also include hydronic baseboard radiator zones, hot tub or heated pools, ice melt zones and other heating loads all connected to the same solar heat collectors.

1. Night collector cooling is used on nearly every glycol water heater, sometimes augmented with instant hot water circulator heat dissipation control. A small DC power supply is switched on to power the PV pump for night circulation. If you lose 20 degrees (e.g. dropping from 170F down to 150F) overnight, you are not likely to overheat the next sunny day. Temperature set points and differentials can be adjusted to fit the user's situation.

2. Collector tilt is considered on every combi solar home heating installation, sometimes augmented by a carefully

designed roof overhang for summer shading of vertical wall mounts. Seventy-five degrees is a typical south-facing solar collector tilt for a full combi home system (with no heated pool) in northern New Mexico. This steep tilt favors winter collection and rejects much of the mid-summer heat.

3. Heat banking controls are included on every combi solar heating system, as well as heat dissipation (a.k.a. dumping, shedding) controls. Heat banking controls allow extra solar heat to be stored in the mass floors, water tanks or heated pools only as long as a high-limit comfort temperature is not exceeded. Heat dissipation controls maintain the collectors at a safe high temperature even when the heat is not needed for any useful heating job. Garage floors or ice melt zones are often used for heat dissipation.

### Other survival strategies

In addition to our three most common strategies described above, there are other approaches to overheat protection.

Most of these issues are not inherent to drain-back systems since drain-back collectors fill with liquid only when the solar pump is running. The use of a drain-back system is a valid solution for the installer who wishes to avoid most overheat protection problems altogether. (See previous articles for my reasons for choosing closed loop glycol systems exclusively.)

Ask your preferred solar equipment supplier what is new in cooling. Solar manufacturers have been thinking about this for awhile now, and along with new controls, some have come up with other interesting products. For instance, Apricus, Butler Sun Solutions and Zomeworks each manufacture passive heat dissipation equipment that works by thermal expansion fluid diversion into a cooling fin system. They are each very different from one another. The Zomeworks product, called the "Tide Tank," has a long successful track record for use in home water heaters, and a new stainless steel version is now available.

Also, collector manufacturers are beginning to think about cooling. Some vacuum tube collectors (e.g. Thermomax) have a high limit temperature shut-off built into each tube and EnerWorks provides a flat plate collector model that includes a heat activated ventilation system built into the frame.

In general, when choosing critical components for the solar loop like float vents, pressure relief valves and expansion tanks, use only "solar" components rated for high temperature glycol and high pressure survival. Some common hydronic components may leak after the first exposure to solar stagnation.

Choose cooling methods that can be adjusted to keep all valves, seals, pumps and fluids below their maximum operating temperatures. Do not assume what those temperatures are. Look them up in the manufacturer's literature. Use only high temperature resistant brands of propylene glycol manufactured specifically for solar heating systems. Not all glycol is created equal. ■

***Bristol Stickney**, partner and technical director at Cedar Mountain Solar Systems in Santa Fe, N.M., has been in the solar heating industry in a variety of roles for more than 30 years. His new start-up, SolarLogic LLC, is developing the next generation of solar heating controls.*