Solar Solutions

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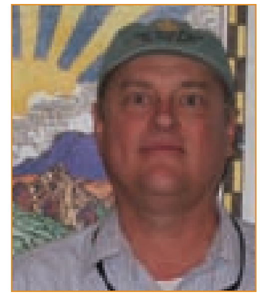

Bristol's six principles of good solar hydronic design

Part 9: The primary check-loop flow center

Any time a homeowner or builder starts thinking about adding solar heat collectors the thought process invariably proceeds along the same lines. First, they think about a solar water heater with one or two collectors. Then they wonder whether some of that heat could be used to heat their floors. If so, then maybe a few more collectors would be worthwhile. Then they wonder how hard it would be to hook up some baseboards to the solar heat. Then, how about the spa or pool or an ice-melt zone? What if we do some of it now and some of it in the future? Every new question requires a change of design, different piping connections, different components, different temperatures and different controls.

In 1997, after going through this same process with dozens of different projects, I decided to try to standardize what I was doing to make it easier to add, delete and change components. The key to doing this is to make things modular so that they can be plugged in or unplugged as the clients change their minds, without requiring any serious re-engineering. I began building all my designs around a "flow center," where all of the circulation pumps plug into a modified primary loop with two pipe connections and could just as easily be unplugged. These days, I have been making the transition to the European-style "flow separator" systems, but my original concept (and the modular controls that go with it) is still valid after more than a decade and well over a hundred installations later. Let's take a closer look at this time-tested primary check-loop solar heating system concept.

The "solar combi-system" dilemma

Multiple heat sources and multiple heating loads can be connected in a bewildering variety of different ways. In our region, the most typical solar-hydronic combi-system includes (1) a solar heat collector array, (2) a gas boiler backup, (3) a domestic water heater and (4) a radiant heated floor. I think of this application as combi-system 101, since I have duplicated these features so many times. There are only four items — two heat sources and two heat loads. Yet, if you present these requirements to three different solar heating suppliers, you will get three very different spaghetti diagrams with tees, motorized valves and pumps in all different locations and some often cryptic control strategies (or none at all) to complete the confusion.

This will lead to the solar nightmare scenario as seen in **Figure 1**, where three different independent installers with three different piping diagrams tried one after the other to assemble this four-collector solar heating system in a small house near Santa Fe - and failed. The bottom of the wall-hung boiler is just visible at the top and two domestic hot water tanks are on either side. I took this photo in 2008, just before installers from my company, Cedar Mountain Solar, removed most of this piping and reconnected it to a flow center, as we always do, and added our control system that goes with the flow center piping.

Figure 1. A spaghetti piping diagram manifested.

Primary loop "flow center" solution

In past years, the primary loop, using closely spaced tees, has been more popular in commercial buildings than in residential. But I found that it has consistent advantages in solar combi-systems as well, and most of our installations are residential. The primary loop offers a plug-in capability where any secondary loop can be connected with only two pipes to any heat sources and other heat loads. The residential solar combi-system is not unlike the multiple boilers and multiple loads found in small commercial applications.

A solar heat array is like an individual boiler that is out of our control but somewhat predictable. It can be put to good use when it is behaving well during the

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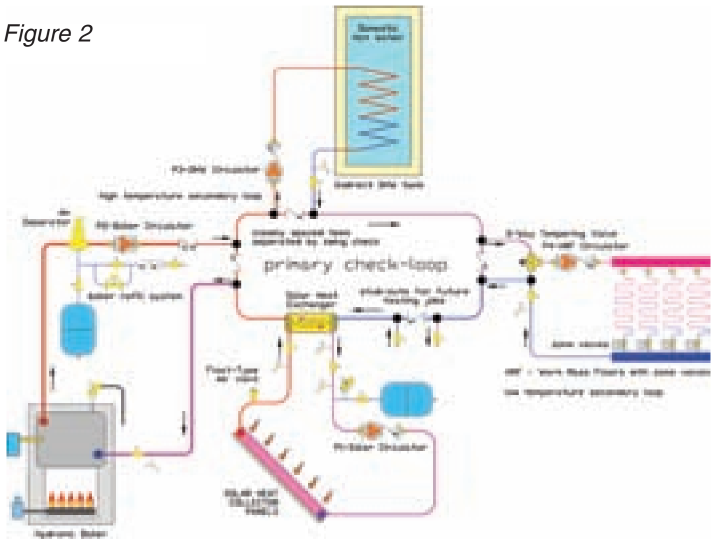
Figure 2



Primary/secondary piping for two heat sources and two heating loads.

sunny hours and bypassed with another boiler when it is behaving badly. When regarded in this way, a solar array can be plugged into the primary loop just like any other multiple boiler but with extra controls to accommodate its independent nature. Why do we put up with a boiler that acts this way? Because the fuel it "burns" is free.

The diagram in **Figure 2** shows the configuration that has become my basic standard piping configuration for more than a decade for combi-system 101. There are a number of additional benefits when using this system in real-world installations. It provides the ability to extend the primary loop through attic or crawl spaces to remote areas of a building to pick up or deliver heat from other mechanical rooms. This is especially useful in many remodel situations. It allows expansion from the 101 system to additional heating sources and more heating jobs with just the addition of another double-tee connection point. When using the same piping layout on every job, the installers require less training and, with the repeated practice, achieve better consistency.

Primary loop modifications: heat exchanger and check valve

Step back for a moment and review our real objectives for solar heat. We want to deliver solar heat to any job that needs heat, giving solar heat priority whenever it is available. If we intercept it and use it immediately as it arrives, the energy loss associated with heat storage, extra pumping and multiple heat exchangers is eliminated. If solar heat is used directly (instead of stored) as soon as it arrives, the delivered solar thermal efficiency is maximized.

Figure 2 shows how I have modified the common primary loop with a heat exchanger and some swing check valves in order to more fully meet these objectives. The location of the heat exchanger allows all the cool return fluid to absorb solar heat before reaching the backup boiler. If the solar circulator is not running, primary fluid passes through the heat exchanger with no temperature change. The control system then allows the boiler to do the required heating. Solar preheating of the boiler is also easily achieved.

The swing check valves are straight-through flow types and offer little resistance to the flow in the primary loop. They allow each secondary pump, independently or in concert with the others, to induce one-way flow around the primary loop without the need for a dedicated primary pump. When allowed to do so by the thermostatic controls, any secondary pump may be used to circulate through the solar heat exchanger to deliver solar heat directly to its heating job. Spring check valves in every secondary loop prevent unwanted creeping flow, unless that secondary pump is running.

Solar heat can be delivered directly for storage in the DHW tank or directly for storage in

Figure 3. A non-spaghetti primary/secondary installation.

the mass of the radiant warm floors. As I mentioned in an earlier article, two-stage room thermostats can be used to distribute solar heat to the coolest rooms and control the heat storage temperature of the mass floors within a comfort range.

Figure 3 shows a Cedar Mountain Solar installation in Taos, N.M. that is similar in size and scope to the unfortunate project seen in Figure 1. Notice the comparative simplicity offered by the check-loop flow cen-

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Figure 4. Wall-mounted solar collectors heat the primary loop shown in Figure 3.

ter. The solar collectors feeding heat to the system in Figure 3 can be seen mounted vertically on the exterior wall of the building shown in **Figure 4**. The photo in Figure 3 includes a view of the solar heat exchanger (lower left), the boiler connection (upper left), the HRF mass floor secondary loop (bottom) and an air separator at the top. You can also make out our control system in a gray box with three Tekmar digital temperature controls on it and some Taco relay boxes to control the pumps and zone valves.

Temperature sequencing

Heat sources are sequenced along the primary loop in order of increasing temperature production, and heat loads are placed in order of declining temperature requirements. This is important in any simple primary loop system, because the cool return fluid mixes with the hot supply fluid at every secondary connection. So, the DHW gets its heat before continuing around the loop to the HRF mass floor. A baseboard secondary would be placed before the HRF tap, and swimming pool heat can be taken after the HRF connection.

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.

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.

Piping variations

Stub-outs may be placed anywhere along the primary loop to accommodate additional heating sources or heating loads. (e.g., hot tubs, heated pools, wood boilers, ground source heat pumps, hot water fan convectors, etc.) Typical bypass valves, isolation valves and boiler drain locations for easy maintenance are not all shown in Figure 2, but some of these can be seen in Figure 3. Air vents in actual installations may need to be located at high points in the piping, especially where flow is diverted downward. Loops may be mounted on vertical walls or suspended horizontally below the ceiling. Swing checks must never be mounted in the flow-downward position. Three-way thermo-mechanical mixing is provided at any secondary where plastic pipe is employed. No plastic pipe is ever used anywhere near the solar loop or the solar heat exchanger.

Control variations

The example control system seen in Figure 3 uses Tekmar controllers (Models 152 and 155) to send solar heat to the DHW tank, turn off the boiler when the solar is hot enough, control two-stage heat banking in the warm mass floors and control overheating in the solar collectors during periods of low heat demand.

Without changing the piping, different functions can be accomplished simply by adding different controls. For example, if the DHW tank was oversized, solar heat can be removed from it for floor heating at night. This is an optional control that we often install, especially where baseboard convectors are involved. Also, I have mentioned night sky radiant cooling (NSRC) in my previous articles; this can be used to cool the tank or the mass floors by adding a cooling control that runs the appropriate pumps at night. I hope to discuss controls in more detail in the future.

Flow center systems are evolving

The check-loop flow center is something that any experienced mechanical installer can build from scratch with easily accessible components from local suppliers. Lately, more European companies such as Caleffi, PAW, Oventrop and others have been offering pre-assembled pump stations, manifolds and flow separators that can be configured to do the same job as my old check-loop system. The time savings in labor can be remarkable when using this new modular equipment and so, I have been gradually changing over, as project budgets allow. ■

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