Solar Solutions

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Bristol's six principles of good solar hydronic design

Part 5: The evolution of "direct" active solar heating

Let's review what we have been discussing so far in this series of articles. 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. In my work in solar heating over the past thirty years, I have slowly gravitated towards the concepts that withstand the test of time in my region. The methods that best conform to the six principles and meet the needs of the broader solar heating market include the following:

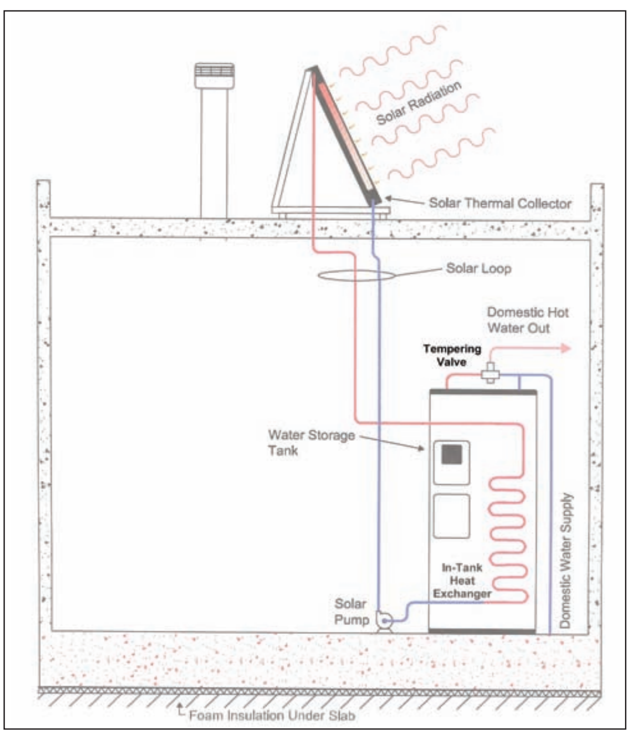
• Solar heat collector systems using closed loop glycol rather than drain-back;

• PV pumped glycol rather than AC pumps on the solar heat collector loop;

• Potable hot water tanks with immersed heat exchangers rather than external exchangers with pumps;

• Reliable automatic solar heat controls rather than manual or simplistic controls; and

• Automatic overheat prevention rather than depending on manual cooling or a relief valve blowing off.



Solar collectors used to directly heat a domestic hot water storage tank.

These ideas and the others discussed in previous articles have become the building blocks of the heating systems we are deploying today.

A fundamental concept that we employ in every heating system we install is the idea of "direct" solar heating. This concept is not widely used yet in the hydronic heating industry, but we have been using it with good results for many years in our local region. You might say that we are the pioneers of Direct Active Solar Home Heating. Let's take a closer look at it now.

What is direct active solar heating?

First, let's get a few definitions out of the way. Passive is the opposite of active. Passive solar heating occurs when solar heat is delivered only by natural means, such as natural convection, radiation, thermal siphoning and other mechanisms found in nature. "Direct gain" passive solar heating is a well-known method of solar home design. When a house is designed with many windows facing the sun (allowing the house to warm up in much the same way a greenhouse does) that is known as direct gain solar heat. The heat is collected into the house in a single step, as it passes through the window into the heated space. Heat gain could not be more direct than that.

Active solar heating occurs when an energy source (besides the sun) that is not provided by nature is used to transfer the solar heat from one place to another. It is typical for active components such as circulator pumps, fans or motorized valves to be used that are powered by AC electricity and sometimes by DC. This outside energy is known to solar designers as "parasitic" energy, because it reduces the net energy savings provided by the solar collector system.

How can an active solar heat collector be a direct system? By delivering the solar heat from the collector in one step. A good example of this is a solar water heater with an immersed heat exchanger in the potable water tank. [*See diagram of the solar water heater, left*]. A glycol pump delivers solar heat directly from the collector into the potable water tank. The existence of the pump and its power source and controller make this an active system. If there were an external heat exchanger or a separate heat storage tank between the collector and the heating load (the potable water) then the system would be more indirect, with more heat loss and lower solar heating contribution. But this is the most direct solar heat delivery possible with an active system.

From water heating to direct active solar floor heating

Clearly, this is a simple and reliable way to build a solar water heater, but it is also possible to apply this system to heat a warm concrete mass floor. In fact, one of the earliest direct active solar heated floors I know of was constructed around

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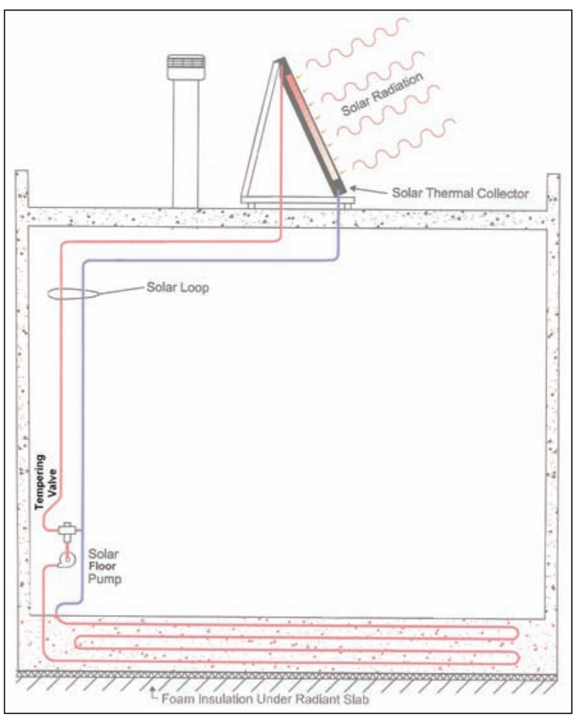
1957 here in Santa Fe, New Mexico, by a local solar pioneer, Peter van Dresser. The idea was to pump heat directly from a solar heat collector into the heat storage mass of a masonry floor. The floor would warm up slowly and stay warm well into the evening on cold winter days. The challenge was to size the collectors and tilt them so that the floor is provided with a quantity of heat that does not cause uncomfortable temperatures at any time of the year. This has a lot to do with the specific heat storage capacity of the masonry material in the floor, which has about 1/2 to 1/3 of the heat storage capacity of the same volume of water. If you take this into account and control the heat in the floor within the comfort range, you realize that maybe you don't need those enormous solar heat storage water tanks that everyone else is using. The floor acts as a "solar accumulator," to use a phrase that's come into favor lately.

Back in '57, van Dresser was using solar hot air collectors and air ducts in his mass floor. His direct active heating idea became even more practical as hydronic tubing became more widespread and pumps and controls became more advanced. By 1985, as chief engineer at the Coyne Solar Company, I was building solar hydronic heated floors that resemble the system seen in the diagram (*below*). Several other local builders throughout the 1980s and '90s were trying similar things. In our climate, a well-insulated mass floor can be heated with about 10 - 15 % of the floor area in collectors, and the collectors work quite well when mounted vertically on a south-facing wall. The vertical tilt keeps them from overheating in summer, because the high summer sun angle prevents them from gaining heat. The low winter sun angle provides maximum solar heat to a vertical collector during the cold season.



Solar collectors used to directly heat a mass radiant floor.

Most people want it all

By the late 1990s, I began dealing less with individual warm floors or single water heaters and getting more demands for both, with an integrated backup system as well. At first, I did what every heating system designer does: I drew custom piping diagrams for each job with tees and motorized valves and agonized over flow directions and check valves and such. This type of design can still be seen in current manufacturer's installation literature. I have come to refer to it as the "Spaghetti Diagram School of Solar Design."

I graduated from the Spaghetti School around 1997, inspired by a class given in Glenwood Springs, Colo., by Dan Holohan, who was teaching about primary/secondary piping. I realized that most of the components for residential heating systems could be treated as modules and plugged together with two pipes. After that, my diagrams began to look more like the diagram on page 38, using a primary loop to connect everything together and every secondary loop connected with two pipes. Modular design is already popular in Europe and manufacturers such as PAW, Caleffi, Precision Hydronics, Watts Radiant and others are offering more modular components in the U.S. market all the time.

Another advantage of modular design is that the control system becomes more standardized. If the plumbing modules plug in and out with two pipes, the controls can be designed to do the same thing. It is really the con-

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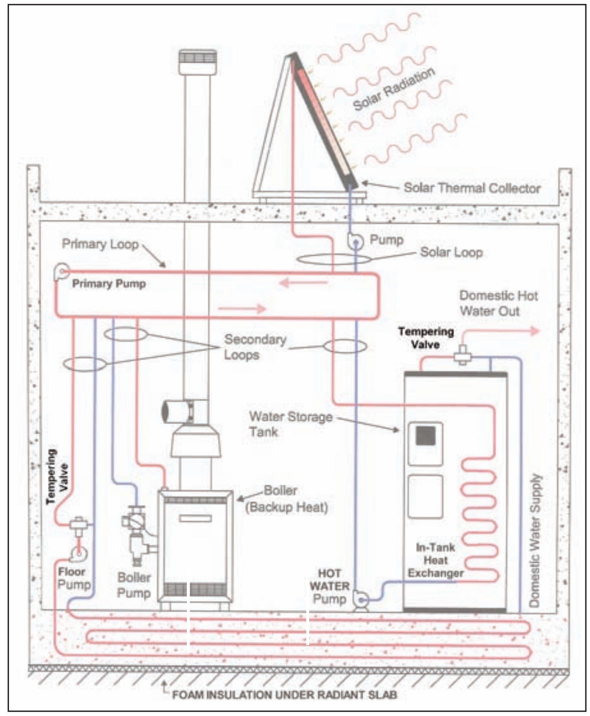
trols that make direct solar floor heating possible. If we could not control the solar heat in the mass floors accurately, within the range of human comfort, we would have to add more big solar heat storage water tanks to absorb the extra heat. Since these tanks are expensive and add complexity to the piping and wiring design, I like to avoid them.

I have found that controlling the solar heat storage in the mass floors is easier and less expensive to install than big solar heat storage tanks nearly every time. At my company, Cedar Mountain Solar, we build our own control systems that do this job. We use 2-stage room thermostats to allow the solar heat to provide a slightly higher setpoint than the boiler heat. And we use the primary loop and the normal zone valves to send the solar heat to wherever it is needed most. The collector is tilted more toward vertical if little heat is needed in summer and tilted back more if there is a big water heater load or a swimming pool.

In this way, we can eliminate big solar water storage tanks in virtually any house that has well insulated hydronic heated mass floors. We have done hundreds of houses like this over the years, and it seems like a natural for the hydronic heating industry as a whole to adopt this approach on a wider scale.

Regional conclusions may vary

Final collector-to-floor area ratios and collector tilts are very climate-dependent and are also dictated by the number and type of heating loads attached to the solar heating system. I hope to go into more detail in future articles. ■



Primary/secondary piping allows easy integration of multiple heat sources with multiple heating loads.

Bristol Stickney, partner and technical director at Cedar Mountain Solar Systems in Santa Fe, N.M., has been designing, managing, engineering, repairing and installing solar hydronic heating systems for more than 30 years.