Releasing Solar Heat

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Which hydronic heat emitters work best with solar thermal systems?

In past *Solar Heating Report* articles, we've discussed systems for capturing solar energy for domestic water heating and space heating. The "golden rule" in designing such systems is to keep the operating temperature of the collectors as low as possible. This is true for both evacuated tube and flat-plate collectors, although the latter is especially sensitive to increases in entering fluid temperature.

With respect to space heating, the operating temperature of the collector array is largely determined by the distribution system the solar subsystem connects to.

Traditional hydronic heat emitters such as fin-tube baseboard are usually sized to the relatively high water temperatures available from conventional boilers — 160- to 200-degree F supply water at design load conditions. Expecting any solar collector array to efficiently and consistently produce such temperatures in the dead of winter is unrealistic.

One might argue that using additional baseboard would bring the required supply water temperature down. This is true. The graph in Figure 1 shows the output of typical residential fin-tube baseboard over a range of water temperatures.

The output of fin-tube baseboard at an average water temperature of 120 degrees F is about 160 Btu/hr./ft. of finned element. That's about 33 percent of its output when operating with an average water temperature of 180 degrees F. The implication is that more than three times the baseboard would be required in the building if the supply water temperature under design load was limited to 120 degrees F. Few buildings have the wall space for this much baseboard; even fewer owners would find this amount of baseboard aesthetically acceptable. Clearly baseboard is not well-suited for use in solar combisystems.

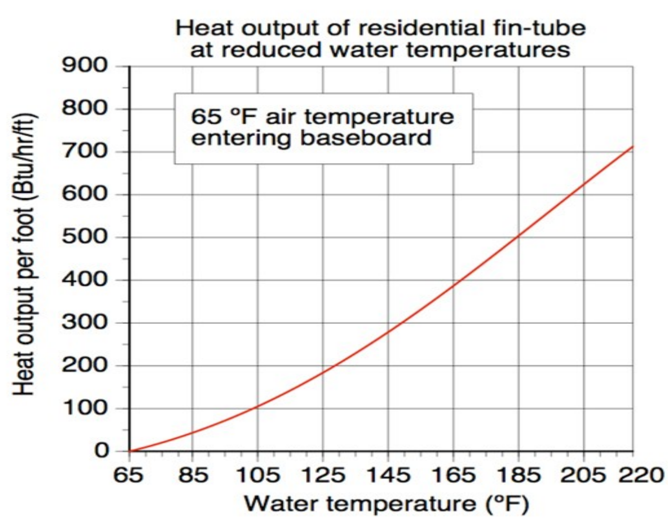

Figure 1

Is Floor Heating The Answer?

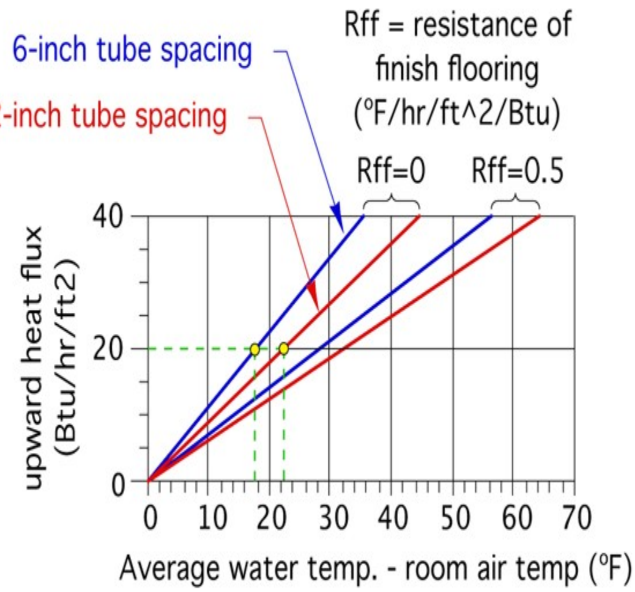

Figure 2

Many of those who have used slab-type floor heating may wonder why this question is even asked. After all, slab-type floor heating, with low-resistance finish flooring, has one of the lowest water temperature requirements of any hydronic heat emitter. The graph of Figure 2 indicates that a bare slab with 12-inch tube spacing can emit 20 Btu/hr./ft.2 when the average water temperature in the circuit(s) is 22.5 degrees above room temperature. For a room maintained at 70 degrees F, this means an average circuit water temperature of 92.5 degrees F could maintain this output.

The supply water temperature would likely be 5 to 8 degrees higher (97.5 to 100.5 degrees F). Tightening tube spacing to 6 inches reduces these temperatures about 5 degrees, an even more favorable situation for the solar collectors. So why wouldn't heated floor slabs always be the obvious choice for use with solar combisystems?

The answer lies in the building itself. If it is well-insulated and designed for passive solar gain, the building's thermal characteristics can conflict with the time-delayed response of heated floor slabs.

Consider the following situation. An eco-friendly home is being constructed with southerly exposed windows totaling 8 to 10 percent of its floor area. These windows will flood a beautifully stained and sealed concrete floor slab with solar energy during sunny winter days. The slab will readily absorb this energy and store it for release after the sun has set and on into the night. This is classic "direct-gain" solar architecture.

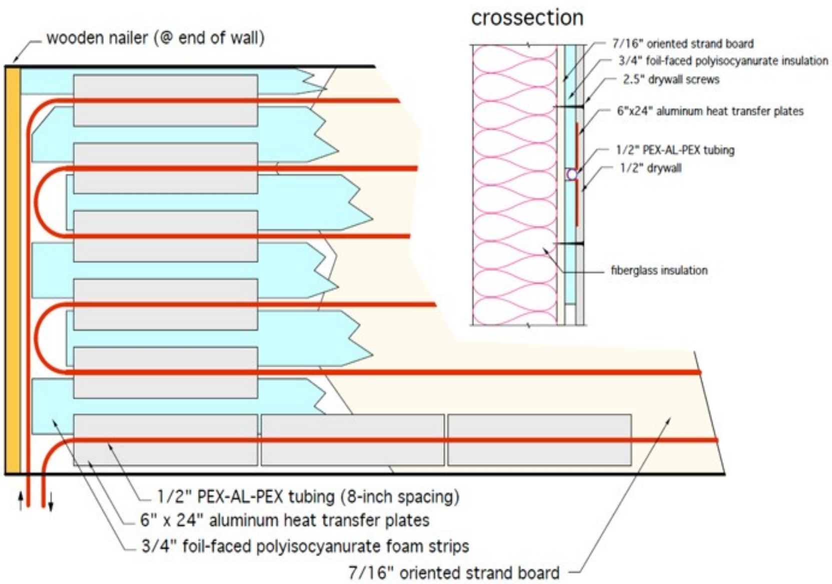

Figure 3

Wanting to take advantage of generous state and federal tax incentives, the owner also decides to include a solar combisystem in the building project. He reasons that the warm water it generates can circulate through PEX tubing embedded in the floor slab during early morning hours after the passive energy gains have dissipated, as well as during times of low solar gain. An auxiliary boiler is included to ensure the floor doesn't cool off waiting for the sun to return.

Now imagine a cold winter night when the embedded tubing and boiler are doing their thing to keep the floor toasty. By 7 the next morning, it's 0 degrees F outside and the floor surface temperature is a barefoot-friendly 83 degrees F. No problems so far.

The sun rises on this clear and cold morning, and by 9 a.m. there's significant solar energy shining through those windows. The thermostat has stopped flow through the floor circuits since the indoor air temperature is now about 73 degrees F. However, just because flow through the floor has stopped doesn't mean that heat output from the floor also stops. The floor surface is still about 10 degrees warmer than room air and most of the interior room surfaces. The floor continues to release heat even as the room temperature climbs to 80 degrees F.

By early afternoon, the interior room temperature reaches 87 degrees F. The owner has stripped down to a T-shirt and opened windows to prevent any further rise in interior temperature.

This all happened because the floor slab was already "charged" with heat when the sun came out in the morning. As such, it was incapable of absorbing additional heat from solar gains and the building quickly overheated. The net effect was that much of the direct solar gain was lost through ventilation to prevent the building from turning into an even warmer sauna.

So What's The Answer?

The ideal hydronic heat emitter for the scenario described above would operate on low water temperatures and have very low thermal mass.

One possibility is a low-mass radiant wall constructed as shown in Figure 3.

The majority of this panel’s thermal mass is the 1/2-inch-thick drywall, which, on a square footage basis, has about 9 percent of the thermal mass of a 4-inch-thick concrete slab. Low mass means faster response.

Site-built radiant walls can be inconspicuously integrated into building surfaces, such as the heated stair banister wall shown in Figure 4.

Figure 4: A heated stair banister can provide warmth inconspicuously

Another excellent solution is low-mass panel radiators such as those shown in Figure 5.

Figure 5: Panel radiators offer an excellent solution to provide warmth in these systems. (Photo credits: Myson (left) and Runtal (right).

Most panel radiators have low water volume relative to their rated output. This characteristic, in combination with low metal weight, makes them fast responders when turning on and, even more importantly, when turning off.

For example, a typical fluted-steel panel radiator 24 inches high by 72 inches long by 4 inches thick contains about 2.1 gallons of water and has an empty weight of about 127 pounds. Its total thermal mass is equivalent to 3.4 square feet of 4-inch-thick concrete slab.

Panel radiators can be sized for relatively low operating water temperatures. For good solar collector efficiency, I suggest nothing higher than 120-degree F average water temperature under design load conditions.

As was the case with fin-tube baseboard, size has to be significantly increased to adjust for lower operating temperature. A typical fluted-steel panel radiator operating at an average water temperature of 120 degrees F in a 70-degree F room releases about 30 percent as much heat as it would operating at an average water temperature of 180 degrees F.

A 200-square-foot room in a building with a design heat loss of 20 Btu/hr./ft.2 would need a panel capable of releasing 4,000 Btu/hr. A panel radiator 24 inches square by 4 inches thick could supply this output if operated at an average water temperature of 180 degrees F. However, a radiator 24 inches high by 72 inches long by 4 inches thick would be required to meet this load if operated at an average water temperature of 113 degrees F.

Under partial load conditions, the supply water temperature would be reduced using outdoor reset control. At an outdoor temperature of 30 degrees F, the 24-inch by 72-inch by 4-inch panel described would only require an average water temperature of about 95 degrees F. The lower the system's operating temperature, the higher the efficiency of its solar collectors.

Hydronics technology is the "glue" that holds solar combisystems together. Contemporary hydronic heat emitters such as low-mass radiant walls and panel radiators, although not designed exclusively for solar combisystems, are nonetheless excellent performers in such applications.

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