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Why Waste Heat with a Heat Dump?

At first glance, incorporating an outdoor radiator, a “heat dump”, on a solar heating system seems like a total waste. Your justifiable instinct is to use solar heat as effectively and totally as you possibly can. This is a good instinct, but allow me to lead you through the process by which I arrived at my present design. If your system is anything like mine, I expect you will come to a similar conclusion.

My main design constraints (low power pumps working in concert with the thermosiphon effect) required that I use a propylene glycol (PG) antifreeze solution, and I wanted to keep my antifreeze from overheating and turning acid, so I needed a way to limit the antifreeze temperature in the panels. The overheating problem is expected on nice sunny days when the temperatures are mild, and in the Virginia/West Virginia area you can encounter these conditions even in January. Yet, you still want the system to be able to provide useful heat on days with high temperatures in the teens, and overnight lows below zero F. The problem boils down to this: any adequately-sized system will sometimes make more heat than you can use.

There are several strategies one could use to prevent overheating. The easiest three are bad. The first bad idea is to make a system so inadequate that it has no chance at all to overheat. That would make it so ineffective as a heating system that you might as well not bother. The second bad idea would be to avoid any thermostatic limits … put all the available heat into the home, so that the home itself becomes the heat dump. If the system is adequate for cold weather, this strategy would drive you out of the home on mild days, although it does make sense to set the thermostat as high as you find it comfortable … *the heat is free*. The third bad idea is to attempt to store all the extra heat.

I should defend bad idea three in a bit more detail, since on the face of it, this actually sounds like a good idea, and in fact most solar hydronic systems attempt to do this to at least some extent. The fellow I bought my panels from offered me a 400 gallon storage tank for just this purpose. He thought I was crazy when I declined. I had my reasons. In the first place, I intended from the start to use the thermal mass of the log home, with its concrete floor over 60 tons of gravel, as my thermal storage medium. In the second place, there was no place inside this modest home for a tank of that size. In the third place, the tank offered was a disgusting mess covered with bird dropping and other filth acquired in a couple of decades of barn storage.

My reasons aside, a solar heating system should have some heat storage, and for a hydronic (fluid-circulating) system a tank is not a bad option. Just don’t get carried away. A large insulated tank is a reasonable way to store enough heat to get by for several days to a week, especially if you are working with a home with a good place for a tank (a basement, for example) and which lacks the thermal mass of a log home on a concrete pad. But there are limits to how large a tank one can use. If you attempt to incorporate such a large tank that you will never need a heat dump, realize that this consideration also will mean that it will take ages to get it hot enough to be useful. Secondly, insulation is imperfect. A tank so large that it will never overheat is itself a heat dump. If a reasonable tank were perfectly insulated and the collectors were sufficiently large, the tank would eventually overheat and you would need a heat dump anyway. If the collectors were insufficient, the system would be insufficient as well.

An important consideration for me is the cost of the antifreeze, and the life expectancy thereof. Tanks used with drainback systems circulating plain water don't have this problem, but since I am circulating antifreeze that sells for about $5 a gallon, the thought of using 412 gallons instead of 12 gallons was a huge cost consideration. Assuming the life of the antifreeze is 2 years, I was looking at a replacement cost of around $1000 a year! And attempting to stretch antifreeze life could be false economy, if it meant risking corrosion of my capital equipment.

One could get around this by using PG in the collectors but using a heat exchanger to heat plain water in the tank. I do this with the domestic hot water system. It does require a certain optimism in leaving the system unattended through a winter … a couple of weeks of severe weather with high ice clouds robbing all the heat from the sunshine, or a simple malfunction, could possibly freeze the system. The tank might pull through without freezing, but if you are circulating water from that tank to heat the home, those loops could freeze with expensive consequences. Heat exchangers add complexity and make heat transfer less efficient.

It comes down to this: any finite-sized storage system coupled to collectors large enough to actually heat the home under average conditions will occasionally make excess heat during warm sunny spells. Thus, even if you do go with a reasonably-sized storage tank, if you are using antifreeze constantly in the collector panels you need some system to dispose of excess heat. Several options are available. Here again, I consider one of them to be a bad idea. Look up heat dumps on the internet, and you'll see mention of systems that have a purge valve that dumps some of your coolant. At $5 a gallon, this was a non-starter, plus I've seen propylene glycol kill grass (it may be "non-toxic" but it is a poor substitute for water, and PG takes around 6 months to break down in soil).

A second option was attractive, but rather complex, and it was more expensive than I liked: cover the panels when there is excess heat coming in. I do this manually during the summer, but for heating season use, the system should be automated. I considered some sort of louver system, which could certainly be done, but is complex, probably prone malfunction in ice or snow, and would block part of the sunlight. A retractable awning system is not out of the question, and they are available for decks, sun porches, and greenhouses. Again, the expense made it less attractive than what I finally settled on.

Some sort of hydronic heat radiator system on a closed loop seemed worth considering, and in fact, many users of hydronic solar heat collectors use this strategy. There are several options to my version that have some merit.

If you have a swimming pool, it is an ideal heat dump. Just rig a long enough loop of tubing in it and you can dissipate any amount of excess heat you care to, and possibly stretch your pool season a bit in the process. Water-to-water heat exchangers are simple and highly effective. Plastic tubing has enough thermal conductivity for the job if you use enough of it, and is easily fabricated into any shape that suits you. Solar is often used for pool heating. PG is pretty safe … if you can afford enough that a leak would constitute a dangerous contamination of your pool, you're a lot wealthier than I am.

If you are considering putting in a new paved driveway or sidewalk, you can rig some loops of tubing (PEX, the same stuff as is used in my radiant heat floor, is a suitable type) under the pavement. With a little luck, this may even help you melt snow on the pavement. You could even just bury tubing in the ground, but I'd recommend doing so sufficiently deeply that it is not easily damaged. Modern "geothermal" systems use such a system of buried tubing as a heat source/sink.

I don't have a pool, and was not planning any paving operations, so I opted for a compact fluid-to-air heat exchanger. These are also commonly used. One article I saw reported using old cast iron radiators in an attic. I thought wistfully of the hoard of old hot-water radiators my dad stored in our garage back when I was a kid. However, with no attic to hide them in, plus their weight, volume, and tendency to rust, these were not a good option for me, even if I still had access to them.

I considered plain copper pipe, but then I did the calculations for the amount I would need. It turns out that, while un-insulated copper pipe will radiate heat, it takes a huge amount of it to get rid of the heat from even a single 4 x 8 ft solar collector.

I finally turned to hydronic baseboard radiator tubing. This is also copper pipe, but equipped with heat fins. I about choked when I saw the price, but it is so much more effective than plain copper pipe, and the other options were even more expensive, that it finally started to seem like a good idea. The plot below compares ½ and ¾ inch copper tubing to Slant/Fin E-75 Finned Tube (from their Fine/Line 30 specification). The data Slant/Fin offers supposes that the tubing is enclosed in their baseboard covers. I shopped around and found a more affordable substitute of comparable construction. In practice, my open radiator seems to be exceeding the performance numbers below considerably.

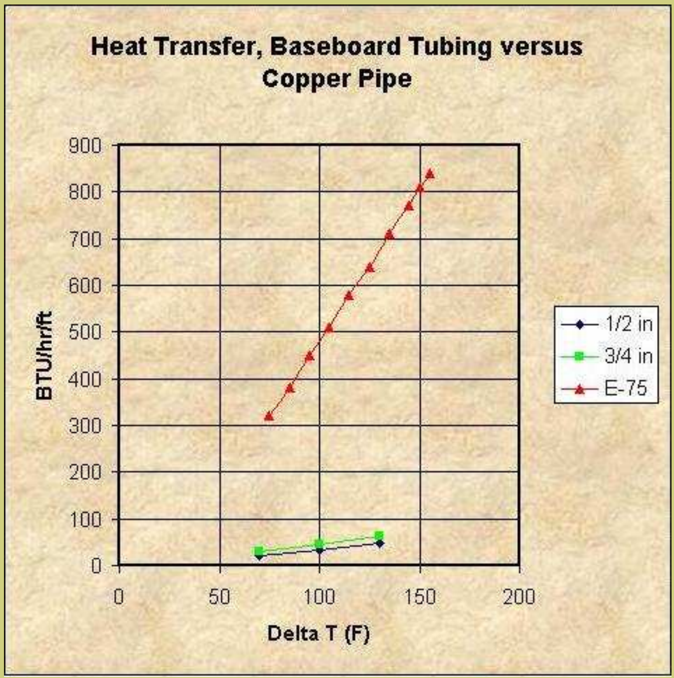
The plain copper tube data are from:

http://www.engineeringtoolbox.com/copper-pipe-heat-loss-d_19.html

Slant/Fin has excellent technical literature on their website, including this:

http://www.slantfin.ca/documents/327.pdf

My Excel model based on these data is a tad crude, but I will be happy to share it. It uses flow data to estimate the temperature gradient on a length of tubing.



I ran the numbers on the tubing above, assuming the maximum coolant temperature I wanted and the likely range of outdoor temperatures. It made sense to cover the collectors during summer when ambient temperature was high and the heating system was not needed. It became obvious that higher flow would greatly improve heat dissipation by making the entire length of the tubing work at close to the delta T of the inlet end. I wound up with a design to service two collectors. The heat dump shown is comprised of eight 8-foot lengths of ¾" finned baseboard tubing running in parallel. In fact, the ½" version of this product would work almost the same, except that it would have needed mechanical support to span this distance. Figures 1 and 2 show the final array installed, sloped to encourage thermosiphon (fluid convection) and angled so that the staggered tubes catch the coolest air. The tubes are rotated so that their open air channels are as close to vertical as possible. The array fit nicely behind the frames for the two panels.

Figures 1, 2. Heat Dump (baseboard radiant tubing).

I needed a valve which would open the heat dump loop with minimum fuss. I considered using an automotive thermostat, although mounting one would require some custom machining. Unfortunately, most are set for too high a temperature for my needs. A quick test of one of these showed that they were not worth fooling with.

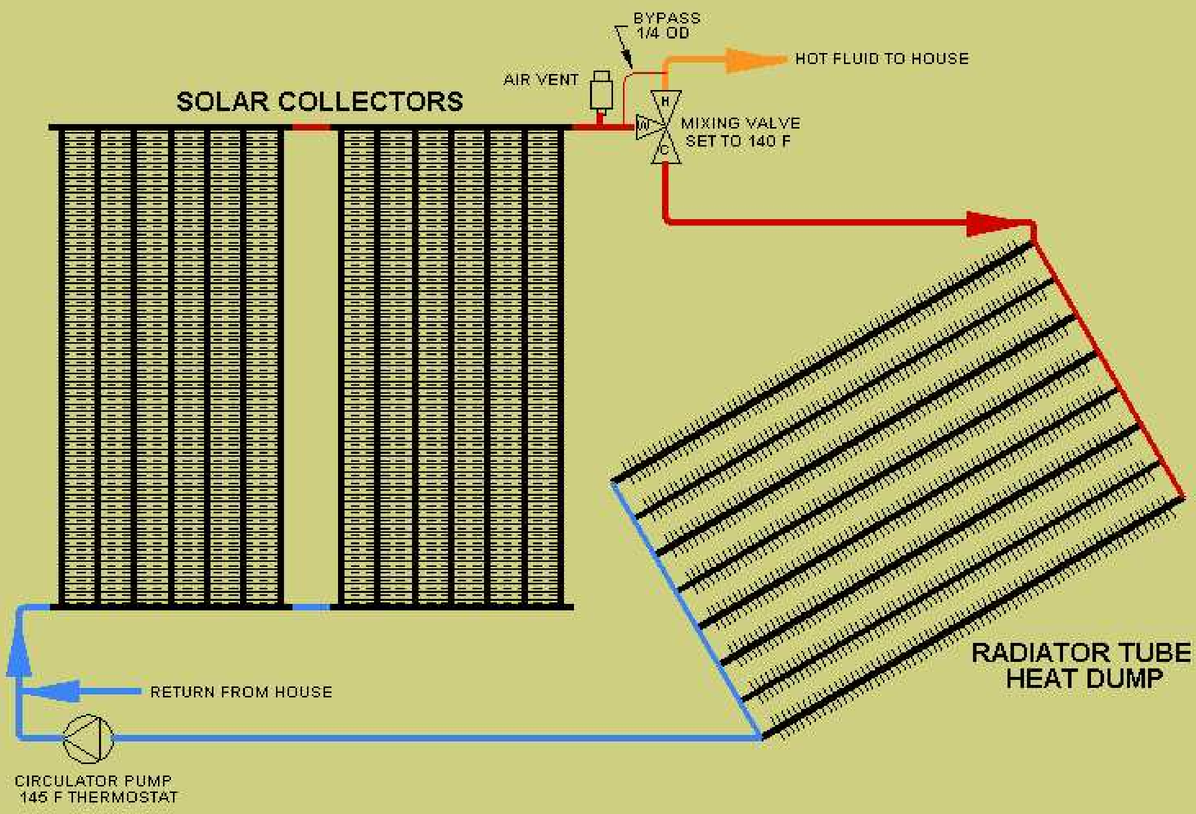
A second thought was to use hot water heater pressure-temperature relief valves. A quick test showed that they need pressure as well as temperature to open. These were not going to work at all with just convection, and would need more pump than I wanted to budget the power for.

A solution was found in the line of AM-1 thermostatic mixing valves offered by Honeywell. It was already clear that I would need two low-temperature versions of these. I needed to regulate the fluid going to the radiant heat floor to 90 F, and the domestic hot water system was capable of reaching scalding water temperatures on sunny days, so needed a valve to regulate the tank outlet to 120 F or lower. I tried one of these configured to the odd arrangement required for the heat dump, and found that it worked splendidly. Thus emboldened, I sweet-talked Yorkshire Plumbing Supply into ordering one for me. The specs on the valve I wanted, intended only for heating systems, was outside of anything they or their suppliers normally stocked, and it was ordered straight from the manufacturer. The AM101R-US-1 adjusts from 80-180 F, and suited the bill nicely, with an open CV of 3.9 and intended for a maximum flow of 12 GPM. Such a valve, fully opened, would offer little restriction to convection.

AM-1 thermostatic mixing valves have three ports. The normal configuration uses a hot (H) supply and a cold (C) supply mixed to provide a regulated warm (W) outlet. For use as a heat dump valve, I connected the collector panel outlet to the W (mixed) connection. If the fluid from the panel is cooler than the set temperature, the valve opens the H connection, so I plumbed the H side to the house. If the water at W is hotter than the set point, the C side begins to open, so C hooks to the heat dump. Providing your heat dump capacity is adequate to pull the temperature back in range, the H side of the valve should remain partly open, and you still have hot fluid supplied to the house. If the fluid exceeds a level safe for the second valve, you want the flow to the house shut off.

This is an off-label application for the valve, but it has been working sweetly for two years now and there is no reason the valve should not work this way. It is necessary to engineer the system so that it has adequate cooling though. If sufficiently overheated, the heat sensing mechanism in the W port could be damaged, but setting the valve for 140 F makes it highly unlikely it can ever exceed its rated temperature, even if the pump failed to come on. My unpressurized system will only have a head pressure of 20 ft once the second floor loop is installed and the reservoir is moved there. It is hard to picture that anything dangerous could result.

At a couple of spots in the system, I use short lengths of ¼” OD, ⅛” ID tubing as bypass loops. One of these circumvents the W to H ports of the heat dump valve, and the other bypasses the house heating loop just inside the house walls. These provide a slight convection path so that at least some fluid movement always occurs in the panels. This assures that hot water from the panels can reach the heat dump valve even if all the other valves are shut down. The house bypass also helps keep warm water in the hot line to the house, reducing the time to deliver heat when demanded. The bypasses cause little heat loss, as the lines are all well-insulated, and any heat thus transported is recycled to the return side.



I have set the heat dump valve to 140 F. It could be set higher, but the hot inlet side of the 120 F AM-1 valve that regulates floor temperature is not intended for inlet temperatures above about 140 F. I have a 145 F fixed-temperature snap thermostat attached to the panel outlet pipe, so that if convection fails to dispose of enough heat, a solar-powered Laing pump kicks in. This pump does run occasionally, although more frequently the system seems to get by on just convection. This particular Laing pump had a spring-loaded check valve on its outlet, which blocked convection on the initial trials. The check valve was easily removed, and is not needed in this configuration, as backflow is entirely unlikely.

Overall, the heat dump works better than my modeling predicted, almost certainly because the finned tubing performs better in open air than in the baseboard covers it was designed for. The configuration satisfies the KISS (Keep It Simple, Stupid) principle I like to employ whenever I can. If I could imagine a simpler, more reliable, and more affordable solution, I would be writing that up instead of this.

The next phase of the system will be to install the second floor heating system. I anticipate using hydronic baseboard heating on the second floor, using finned tubing similar to that in the heat dump, housed in the covers intended for them. The baseboards can run at 140 F easily, and in fact would be fine even above 180 F. The second floor loop will have its own thermostat and pump, and will tap off just before the 90 F mixing valve that feeds the first floor radiant heat system. I will add the last pair of 4 x 8 ft collector panels when the new loop goes in, and expect to add capacity to the heat dump when I do so. However, I am expecting the baseboard radiators, by utilizing heat the radiant heat floor must reject, will lessen the use of the heat dump a bit.

After all, you really hate to dump heat if you can find a way to use it.