SOLAR WATER HEATING

Overview

The two most common types of solar water heating collectors are flat plate and evacuated tubes. Due to the many variables inherent with solar, sizing a solar heating system isn't a simple matter. Latitude, solar orientation, budget, heat loss, type of collector, domestic hot water requirements, esthetics, and performance expectations are all factors needing careful consideration. Systems are usually designed based on a summer load so that issues of overheating never arise. However, with unlimited funds, a roof covered with collectors can provide 100% of all hot water needs, but a more realistic modest "starter" system consisting of two or more absorbers can still supply an important boost to water heating. The basic mechanical components (pumps, heat exchanger, controls, etc.) remain the same regardless of how many collectors may be added later.

Evacuated tube collectors are an entirely different approach to solar water heating. Instead of many water filled copper pipes, these collectors use multiple vacuum filled glass tubes, each with a tiny amount of antifreeze hermetically sealed within a small central copper pipe. When heated by the sun, this antifreeze converts to steam, rises to the top of the tube, transfers its heat to a collector header, then condenses back into liquid and repeats the process.

Because heat doesn't easily transfer through a vacuum, more than 90% of the thermal energy hitting the absorber plate stays within the evacuated tube and passes to the collector header. Evacuated tubes are also modular. Although rarely necessary, one or more tubes can be removed and replaced without affecting the other tubes in the array. There is no actual liquid transferred from the evacuated tube to the collector header...just heat. Evacuated tubes can also start absorbing heat earlier in the day than flat plates due to their convex design and the tiny amount of antifreeze within the tube is freeze protected down to -50 degrees below zero.

From a value perspective, flat plate collectors are always going to be a better proposition than evacuated tubes. However, the decision on which technology to use will depend on the application. There are applications where evacuated tubes make sense and vice versa.

How It All Works

There are three main configurations for solar water heaters.

1. The **open-loop** uses a **heat exchanger and anti-freeze** to transfer thermal energy to a storage tank filled with potable water, provides domestic hot water, solves freeze issues, and allows the system to be powered by a very low wattage pump. Solar water heating can also be used as a source of heat. The percentage of antifreeze to water is determined by the lowest possible temperature in your region. A 50/50 mix will generally protect down to -29 degrees. As a rule, use as much water in the mix as you can get away with because water transfers heat better than antifreeze.

2. A **drain-back** solar system is a non-pressurized volume of water in a closed circuit that, as the name implies, drains back from the panels, down to a storage tank, at the end of every heating cycle. The advantage of a drain-back system is built-in freeze and overheating protection. Because water only enters the panels after they've heated up, and then drains back when the panels cool, freezing is impossible. During the summer when the solar storage tank is fully heated, no water will be sent to the panels to "stagnate", so no damage can occur from overheating.

   Disadvantages to this type of system:

   a. need for a high head pump (and the higher initial cost and higher daily operating costs that go with it) because, unlike a pressurized closed loop system, the pump must be powerful enough to push water from the solar storage tank, against gravity, up to the panels. A pump this size requires 245 watts during operation. As a comparison, a standard solar circulator in a pressurized closed loop system uses just 45 watts.
   b. the solar collector array and your loop ***must*** be installed at a slight angle. A minimum slope of ¼" per foot must be designed into the support structure to guarantee that all the liquid in the collector drains back to the storage tank.
   c. heat from the non-pressurized solar tank should only be transferred, via an external heat exchanger, to the main pressurized tank when there's enough heat available in the solar tank to make the transfer worthwhile. In other words, only when the water in the solar tank is **hotter** than the water in the main water heater (i.e. back-up heater) will heat be transferred over. As a result, there will be times (especially during a cloudy winter) when the solar tank is filled with potentially useful, but only semi-warm water. This can be addressed by using a solar storage tank with one or more internal heat exchangers.

3. The **Batch Collector** is any kind of collector that stores a large amount of water within the collector itself and can be as simple as a flat black 55 gallon drum mounted to the south facing side of a roof, or as elaborate as a set of black, 4" diameter water filled tubes mounted in a 4' by 8' insulated box (like any other collector) and encased under low emissivity glass. Their defining characteristic is a quantity of water stored within the collector itself, and not necessarily down below in a storage tank. Though in most cases a secondary storage tank is incorporated into the system to act as a back-up. Another common variation is the "thermosiphon" collector. Essentially a batch collector plumbed to a manifold of copper tubes embedded within a copper absorber plate, the thermosiphon collector requires no electricity to move the water. Instead, it uses the natural tendency of hot water to rise, and cooler water to fall, to create a convective circulation of fluid (see photo below).

Electronic and Mechanical Components

Two **sensors**, one at the collector and one at the bottom of the solar storage tank, monitor fluid temperature. When the temperature at the solar collector is 5-20 degrees (you decide which exact temperature works best for you) greater than the temperature at the bottom of the storage tank, pumps on either side of the heat exchanger are activated. One pump (collector) sends heat to the heat exchanger; the other pump (storage tank) draws the heat off and sends it to the storage tank.

Because the storage tank is filled with drinkable (i.e. potable) water, the heat exchanger guarantees that antifreeze and water never mix...only heat is transferred from one fluid to the other.

There are basically two (2) types of heat exchangers: internal and external. Obviously, the internal heat exchanger only requires one pump because the water surrounding the submerged heat exchanger coil draws off the heat through natural conduction.

Which is best? As always, many factors come into play. Tanks with **internal** heat exchangers are more expensive, around $1,600 while systems using an **external** heat exchanger run about $800.00.

Flat plate **external** heat exchangers are also more efficient, because the water and antifreeze flow in extremely close proximity between alternating stacks of stainless steel plates (see photo below) a very highly efficient heat transfer results.

In contrast, an **internal** heat exchanger immersed in the solar storage tank, transfers heat at a much slower rate due to the lesser amount of surface area in direct contact with the surrounding water. On the other hand, the heat entering an internal heat exchanger has nowhere to go BUT the surrounding water. An external heat exchanger (if left uninsulated) transfers some of its heat to the surrounding air. Of course, this can be okay if the surrounding space is an area you want to heat.

Back-up Heat Source

In all SWH applications a **back-up heat source** is required. The options for back-up heating are two-fold. The back-up heater can be a standard **tank type** water heater and be fueled by gas, oil, or electricity...or a gas fired **on-demand** water heater.

Storage

All solar hot water systems rely on thermal storage in one way or another. Flat plate panels or arrays of evacuated tubes, or a combination of the two, are sized to generate a given percentage of hot water needs during the sunlight hours, and then it's stored in a thermal medium of some sort. Usually, this thermal medium is plain water because, quite simply, water is the best material on Earth for storing heat. A close second would be a dense, solid material like concrete or stone.

Mixing Valves

An important component to any solar hot water system is the mixing valve. This is because, unlike traditional water heaters, solar water heaters can generate generous amounts of hot water during periods of abundant sun and limited hot water usage. The mixing valve keeps any super heated water in the storage tank safe for domestic and floor use.

Besides that, it's never a good idea to allow your panels to sit with the sun beating on them, getting hotter and hotter, building pressure, straining joints, and undergoing lots of thermal expansion and contraction. If the sun is available, use it!

The Heat Dump Package

Nevertheless, depending upon summer hot water use, solar orientation, cloud cover or lack of it, there may be times when no amount of storage capacity can absorb the heat produced by the array and the panels enter a state called "stagnation".

Basically, stagnation occurs when the solar storage tank heats up to maximum temperature early in the day; movement through the solar collector stops, and the fluid in the system sits under the sun getting hotter and hotter. The result is a high pressure, high temperature condition that can damage the system over time by subjecting it to extremes of expansion and contraction. In addition, when antifreeze is superheated every day for weeks at a time, it tends to break down and become acidic, thereby transforming into a corrosive substance that circulates through your system slowly damaging its components. To prevent this, some sort of heat dump should be incorporated into any solar heating system with stagnation potential.

The Differential Controller

Solar thermal systems generally use a special relay called a **Differential Controller**. As the name implies, this relay activates a pump or pumps when a span (or difference) between two temperatures is achieved. In other words, when the temperature at the solar collector is X degrees hotter than the temperature at the bottom of the solar storage tank, the differential controller activates the necessary pumps and draws that useful heat into the system. Transferring heat from a hotter to a cooler tank in order to equalize the temperature in both tanks and increase total storage capacity is another common use for a differential controller.

Two sensors (storage tank and solar array) are required for a proper "differential". One sensor is attached to a pipe near the bottom of the solar storage tank. The second sensor reads the water temperature as it leaves the solar collectors. Both sensors must be insulated (with fiberglass or foam) to prevent ambient temperature from influencing the reading. It should be noted that a sensor clamped to a hot pipe will NOT accurately read the actual water temperature. In fact, the water will generally be 15 to 20 degrees warmer than the sensor indicates.

Fortunately, for the purposes of a well functioning solar hot water system, actual water temperature is not important (unless, of course, it's too tepid for a hot shower). What matters is the **difference** between the water temperatures at the two locations. After all, if the water is actually hotter than what the sensor indicates, so much the better.