Phase Change Material

Product Overview

Solar water heating basics

Water is a suitable means of collecting and storing thermal energy. In standard solar water heating processes water maintains its properties as a liquid and stores one BTU for each pound of water raised 1ºF. Each gallon of water contains 8.33 lbs of water. It therefore takes 8.33 BTU of energy to increase one gallon of water 1ºF. Typically it takes approximately 500 BTU of energy to raise one gallon of water 60ºF (120ºF-60ºF) which is the difference between the supply water temperature entering the water heater and the desired hot water temperature at the fixture.

Water heaters are rated by energy factor (EF). This number represents the amount of energy consumed at the water heater burner inlet to achieve the desired hot water delivery at the fixture. This number is typically 0.58 for natural gas water heaters which is the minimum federal efficiency standard for water heaters. This means that for every gallon of hot water used at the fixture 860 BTU (1.72 x 500) of natural gas must be consumed.

An average family of four consumes at the fixtures about 80 gallons of hot water every 24 hours. The amount of natural gas consumed by this average family is
860 BTU / gal x 80 gal / day x 365 day / year = 25,112,000 BTU annually which in turn represents burning about 250 cubic feet of natural gas.

In terms of CO_2 greenhouse emissions there are 11.7 pounds of CO_2 released into the atmosphere for each 100 cubic feet of natural gas burned. The annual CO_2 emissions from the average family's water heater is therefore 250 x 11.7 = 2,937 pounds of CO_2.

Storage Design Basics

There are three parts to a solar hot water system; collection, storage and distribution.

The common wisdom in sizing storage is to store one day's solar collection in an insulated water tank. The other rule of thumb is to use a ratio of about 1 – 1.5 gallons of water storage for each square foot of flat plate solar collector.

This method of sizing does not account for the thermal efficiency of the solar panels, closed loop heat exchanger effectiveness, or the azimuth and tilt of the collectors. Most experienced solar installers will refer to the issue of solar storage to collector sizing as an art rather than an exact science.

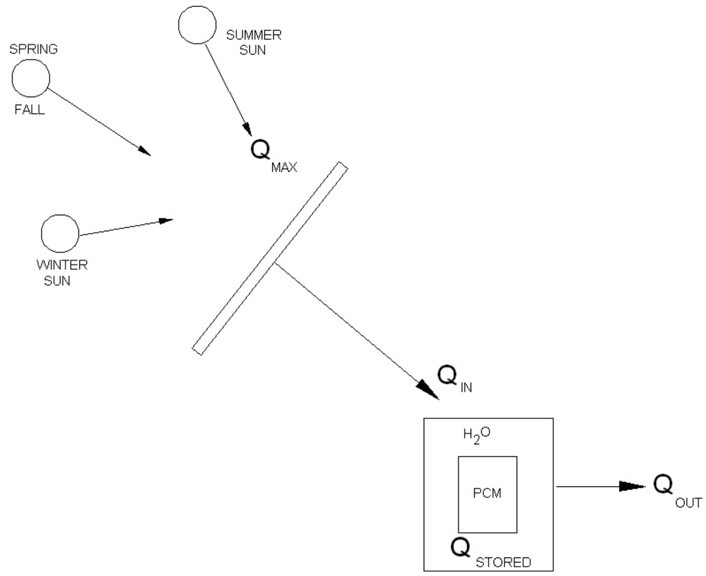
Closed loop systems are particularly sensitive to summertime temperature extremes and require means to dump excess heat to prevent the system from overheating and shortening the life of the system. Many installers are intentionally "de-rating" their systems by switching from high performance black chrome collectors to black paint to minimize this problem.

The introduction of phase change material (PCM) into the design of the solar storage tank makes the solar process more of an exact science and improves the performance and longevity of a solar water heating system. PCM changes from a solid to a liquid by absorbing large amounts of heat energy during this process. The temperature maintains a constant temperature during this process until all of the material is liquefied. This is called latent heat of fusion. The process is reversible and when the material is cooled the heat is released at the same temperature as it melted. The phase change temperature of the material can be selected based on preferred operating temperatures.

Designing with PCM

Performing an energy balance is simply calculating the energy input from the collectors during daytime solar conditions and storing the energy for release and distribution until the solar energy can be replenished the next sunny day. The best way to look at the storage process is to have one eye the extreme conditions of summer collection with the other eye on the poorest winter conditions.

The angle of the collar panel and the angle incident modifier and the operating efficiency of the solar collector as well as the latitude should define the maximum solar insulation expected to be used and stored from the solar system.



HEAT STORAGE MODEL

Determine the amount of PCM required using TRENDSETTER® Evacuated Tube Solar collectors with a 40 Gallon Water Storage Tank

The following average solar conversion values can be used for TRENDSETTER® Solar collectors:

Cold Blue Sky Winter Day = 60%

Mild Blue Sky Spring/Fall Day = 70%

Hot Blue Sky Summer Day = 90%

On cloudy overcast days reduce above by 30%

Summertime

A south facing solar collector situated at 40ºN Latitude tilted 30º with the horizon on June 21st the average solar insolation value is 2423 btu/ft^2 /day. Multiplying by the conversion efficiency of x 69.7% and a 90% summer day factor yields a collector output of 1520 btu/ft^2 /day.

The net daily output for a 30 tube array is 25.8 ft^2 x 1520 btu/ft^2 = 39,216 Btu/day / 500 btu/gallon = 80 gallons of water raised from 60ºF to 120ºF

Water Storage Capacity (Q_{OUT} = 0)

$Q_{in} = Q_{Stored}$

39,216 btu = 40 gal x 500 btu/gal + PCM_{stored}

PCM $_{stored}$ = 39,216 – 20,000 = 19,216 btu

Wintertime

A south facing solar collector situated at 40ºN Latitude tilted 30º with the horizon on December 21st the average solar insolation value is 1480 btu/ft^2 /day. Multiplying by the conversion efficiency of x 69.7% and a 90% summer day factor yields a collector output of 619 btu/ft^2 /day.

The net daily output for a 30 tube array is 25.8 ft^2 x 619 btu/ft^2 = 15,970 Btu/day / 500 btu/gallon = 32 gallons of water raised from 60ºF to 120ºF

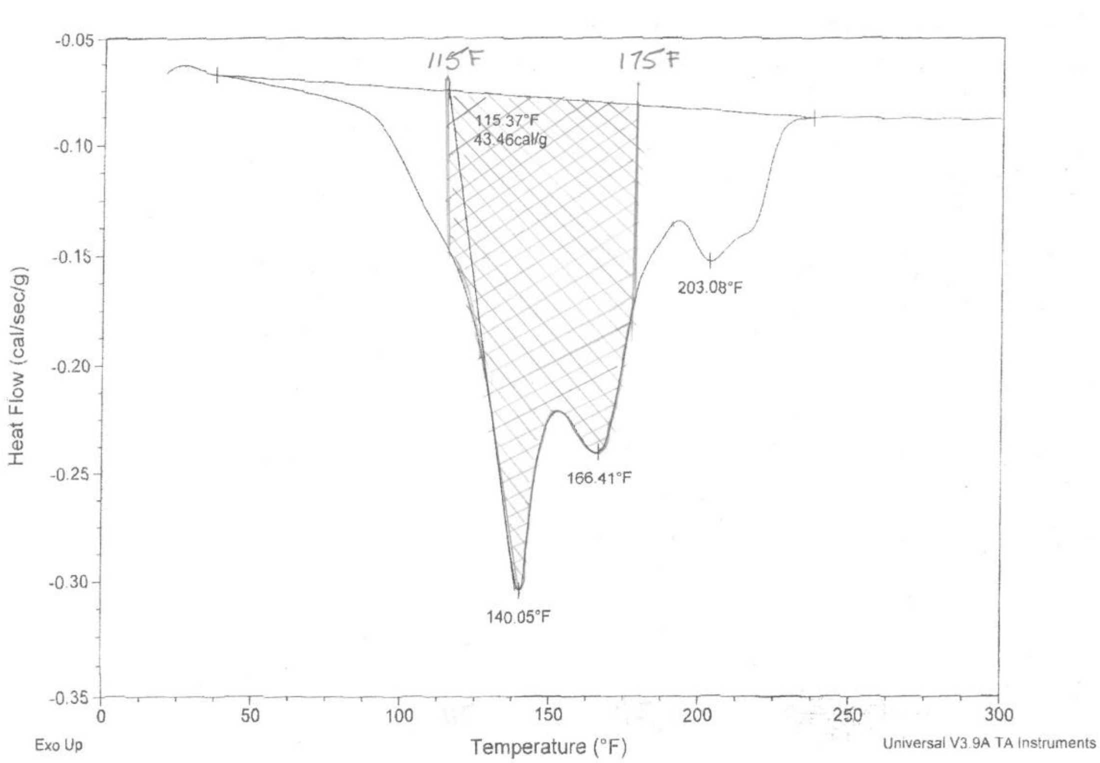
Water Storage Capacity (Q_{OUT} = 0)

$Q_{in} = Q_{Stored}$

15970 btu = 40 gal x 500 btu/gal + PCM $_{stored}$

PCM $_{stored}$ = 15970 – 20,000 = 0 btu

Below is a graph of test data for PCM chosen as appropriate for the application at hand. The desired heat storage range for the PCM to operate is between 115ºF and 175ºF. The hatched area under the curve represents the latent heat stored by the PCM



_____ pounds of PCM is required to be added to the 40 gallon thermal storage tank to absorb 19,216 btu of thermal energy between 115ºF and 175ºF in the above scenario.

Conclusion

- Solar storage tanks using only water are typically sized to store the heat generated during maximum solar conditions but are oversized for most of the year.
- PCM allows a reduced sized solar storage tank to operate at proper storage capacity year round
- PCM acts like thermal mass to smooth out thermal spikes