# SOLAR ENERGY

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## installment 8

### SOME DETAILS OF COLLECTOR DESIGN

## HEAT CONDUCTION - The More the Better

When you are designing something it is important to know what you must be careful about and where you needn't be careful. Rafts are extremely simple to build. You can add anything you want - so long as it will float.

Bridges are not like rafts; enough weight added in the wrong place can break the bridge. Building a heat conductor is more like building a raft than a bridge. Anything added in parallel to a path along which heat is being conducted is an aide to the transport of the heat. So that in fabricating a heat exchanger, if you had some scraps of metal leftover you might just solder or weld them on to the exchanger rather than throw them away.

## HEAT COLLECTORS MUST BE AWAKENED IN THE MORNING

Everything in the collector has to be warmed up in the morning to a useful temperature only to cool back down again at night. This is wasted heat. Often this warming must occur more than once a day since clouds frequently interrupt the sun and let the collector cool during the day. If you multiply the weights of the parts of a heat collector by their specific heats you can find how much heat must be invested in warming a collector up in the morning. A heat collector for a hot water heater may fall to 15 degrees F. during the night and have to rise to 115 degrees F. before it contributes any heat to the tank. Thus, if there is a thermal mass in the collector equivalent to 1 lb. $H_2O$/sq. ft. which is equivalent to a sheet of steel ¼" thick, 100 BTUs/day will be used just to wake up the collector in the morning. Intermittant cloudiness can cause frequent minor versions of this throughout the day. One standard design of heat collector is a sheet of corrugated galvanized iron rivited to a flat back-up sheet and with headers at either end. This is a very efficient collector design. The heat must never travel any farther than the thickness of the metal since liquid is circulating behind the entire sheet. The one draw back this design has is that there is considerable mass of liquid which is slow to warm up.

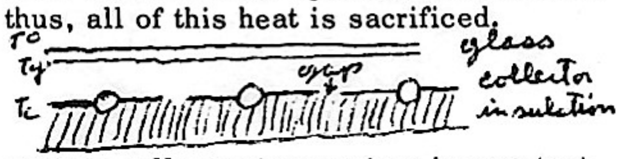
## SACRIFICED HEAT

There are some quite subtle relationships between different parts of heat collectors. For instance, what happens if we drill a hole in a metal fin of a heat collector - or, if we simply leave spaces between fins or at the edges of a heat collector? If we paint the gaps black we know that the energy received there is going to go towards heating the collector and then it seems natural that some of it will find its way into the circulating fluid - where we want it. It is fascinating to realize that in many cases this is impossible. The heat picked up in such gaps cannot, itself, flow into the circulating liquid, but, instead, is sacrificed to heat the glass allowing a traction equal to

$$\frac{U\,\text{collector}}{U\,\text{outside} + U\,\text{collector}}$$

of the heat sacrificed to be collected.

Why can't this heat, or part of it, be collected directly? In such a collector - under normal circumstances - the glass is colder than the metal fins, the outside air is colder than the glass, the temperature of the inside air is between that of the fins and the glass. A gap in such a collector, although it will become the hottest part of the collector, has no way to give its heat directly to the fins. It cannot "see" the fins and thus radiate heat to them because the fins are beside it rather than in front of it. It cannot conduct heat to the fins because the hot material is insulation and thus a poor conductor. Instead the hot gaps heat the air they are in contact with and also the glass is front of them by infrared radiation. Both the air and the glass are cooler than the collector fins and so once heat has fallen to this temperature it cannot flow uphill to the collector - thus, all of this heat is sacrificed.




assume collector temperature is constant - Tc

outside temperature is constant - To

temperature of glass - Tg

assume Tc > Tg > To

assume gap area small compared to total area and evenly distributed

heat sacrificed to glass - $H_s$ BTUs/sq. ft./hr. $H_s$ is the quantity of heat that would normally be collected over the area of the gaps if the collector extended over them.

$U_o$ - U factor between outside and glass

$U_c$ - U factor between glass and collector

The heat lost by the glass to the outside equals the heat sacrificed to the glass plus the normal losses from the collector to the glass.

$$(Tg - To)\,Uo = Hs + (Tc - Tg)\,Uc$$

$$TgUo - ToUo = Hs + TcUc - TgUc$$

$$TgUo + TgUc = Hs + ToUo + TcUc$$

$$Tg = \frac{Hs + ToUo + TcUc}{Uo + Uc}$$

collector loss to glass = (Tg - Tc) Uc =

$$\left(\frac{Hs + ToUo + TcUc}{Uo + Uc} - Tc\right)Uc$$

collector loss to glass with Hs = 0 minus collector loss to glass with Hs > 0 divided by Hs equals portion of sacrificed heat usefully collected

$$\frac{U_c\left(\frac{T_oU_o + T_cU_c}{U_o + U_c} - T_c\right) - U_c\left(\frac{H_s + T_oU_o + T_cU_c}{U_o + U_c} - T_c\right)}{H_s}$$

$$= \frac{U_c H_s}{(U_o + U_c)\,H_s} = \frac{U_c}{U_o + U_c}$$

Typical values for Uc and Uo would be Uc = 1, Uo = 2 so that the cracks between the collecting fins would be only $\frac{1}{1+2} = \frac{1}{3}$ as efficient as the rest of the collector. A ½" wide gap around the perimeter of a 4' square collector amounts to about 4% of the total area so it is a matter to give some attention.

## TRAPPING SUNLIGHT

The performance of gaps can be increased by indenting the insulation behind the gap so that the ray of sunshine heats a space much of which is bounded by the collector fins. In this way some of the heat can flow directly into the collector fins.