# SOLAR ENERGY

# Steve Baer

# 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.

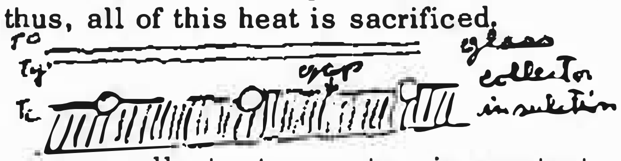
### SACRIFICED HEAT

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 $T_c > T_g > T_o$

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.

$$(T_g - T_o)U_o = H_s + (T_c - T_g)U_c$$

$$T_gU_o - T_oU_o = H_s + T_cU_c - T_gU_c$$

$$T_gU_o + T_gU_c = H_s + T_oU_o + T_cU_c$$

$$T_g = \frac{H_s + T_oU_o + T_cU_c}{U_o + U_c}$$

collector loss to glass $= (T_g - T_c)U_c =$

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

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

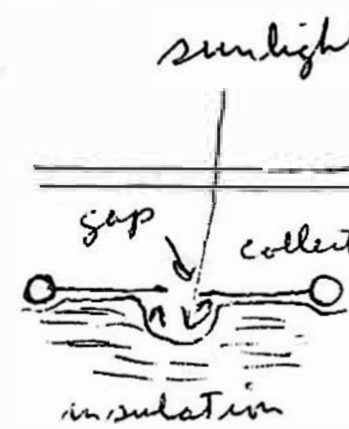
$$\frac{U_c\left(\frac{T_oU_o + T_cU_c}{U_o + U_c} - T_c\right) - U_c\left(\frac{H_s + T_oU_o + T_cU_c}{U_o + U_c} - T_c\right)}{H_s}$$

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

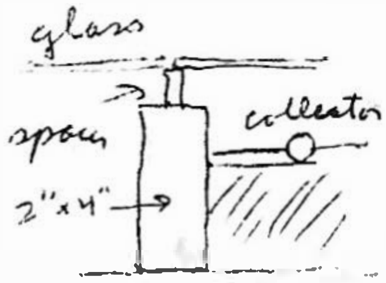
Typical values for Uc and Uo would be $U_c = 1$, $U_o = 2$ so that the cracks between the collecting fins would be only $\frac{1}{1+2} = \frac{1}{3}$ as efficient as the rest of the collector. A ½'' wide gap around the perimeter of a 4' square collector amounts to about 4% of the total area so it is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



he glasing for the collector should, when-
ver.possible be lifted slightly off of its
upports by spacers so that the area taken
p by the supports is largely used as a
ollector rather than "becoming" a dead
pot.






# Steve Baer installment 9

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# Convection

# SOLAR ENERGY

## CONVECTION ENGINES

Gravity is a container which continually ranks its contents, light substances rise to the top, heavy substances sink to the bottom. All liquids change density with temperature (see Fig. 1). Each volume of liquid in a gravitational field is thus an engine whether it is as tiny as a drop of water or as immense as the atmosphere. It is an almost universal property of fluids that they expand upon being heated- the very instrument which tells us temperature, the thermometer, is merely a guage for reading the expansion of the contained liquid.

Thus it is almost universal that if a fluid is heated it rises and if it is cooled it sinks. Our planet with all the liquids captured in its gravitational field (except for the anomalies water and heavy water) is continually moving heat outwards.

The flame burns at the bottom of the tea kettle, the heating element is at the bottom of the hot water tank. The entire contents warm. If one wishes to contain cool fluids, a pool is enough - thus in super markets the freezers are open on the top - a pool of cold air rests within. Citrus growers fight this property of air with fans set within groves that lie in valleys.

If we wish to cool a house we can place a loop of tubing through the house and then onto the roof and fill the loop with liquid (throughout this discussion I am omitting any mention of heat transport by radiation or conduction - heat is an enormous subject- radiation or conduction are equally as important as convection.) During the day the sun shines on the portion of the loop that rests on the roof, the liquid within grows hot - where does the heat go? It stays on the roof since the hot liquid is lighter than the cool liquid within the shaded portion of the loop. During the night heat radiates into space. Sometime after the earth spins the house into its shadow the roof will be cooler than the inside of the house - now convection starts. The house gives heat to the loop and its fluid. The fluid rises to the roof, loses its heat to the night sky, grows denser by shrinking and circulates back down within where it again picks up more heat. A combination engine-refrigerator. Perhaps it is difficult for us to think of convection as an engine since it doesn't break down or wear out. Doesn't wear out? We are brought up with the idea that everything wears out. But the very framework within which such questions are posed has permanence, and among its constituents are gravity and the expansion of liquids on being heated. The two together coupled to a heat source which is blinked on and off provide innumerable engines which function endlessly and tirelessly. Then we have readily available engines which can cool buildings, (provided there are low enough night time temperatures) but what of the reverse; can we exploit one of these convection engines to heat our building? We can if our heat source is below the building. This is generally inconvenient; our source of heat (unless we have built on top of a warm springs) is sunlight and it falls on the walls and the roof of the structure rather than the floor. Then if we wish to convert heat downwards we need a liquid that convects backwards, a reverse juice.

Is there such a juice? Water below the temperature of 39 degrees F and deuterium oxide below 52 degrees F are reverse juices. I know of no others. Rubber contracts on being heated but it is a solid rather than a liquid. The reverse juice can hide heat - this quality of water, instead of convecting heat to the stars, to hide heat below 39 degrees F, protects pond life every winter.

Could we use water's property as a reverse juice to prevent freezing of collectors at night?

In the construction of water heaters I have mentioned several times the necessity in cold climates such as Albuquerque to have a two liquid system where an anti-freeze mixture circulates through the collectors instead of water. If water freezes in a pipe it can burst the pipe because the ice is 8% larger than the water it is formed from. Water is at its most dense at 39 deg. F - a quick examination of the diagram of a typical water heater (Fig. 2) shows that there should be no problem of freezing in the collector even without the two liquid system for water before it gets to 32 deg. F, expands slightly and would thus rise to be replaced by heavier water at 39 degrees F. Water really does act this way if it has enough space to move in. Ponds freeze at their tops. I have measured the temperature of water at the bottom of a number of frozen ponds near Taos and found it to be between 39 and 42 degrees F. Then it would seem we could rely on this property to keep our heat collector which is below a supply of warm water above 32 degrees F. Every time water got close to this freezing temperature it would swell slightly and escape upwards toward the storage tank where it would be warmed and shrink and sink to replace colder water again. The problem with utilizing this property is that the expansion and contraction between 39 degrees F and 32 degrees F is very slight and the convective forces are thus weak. To supply enough heat to a collector by this reverse convection on a cold night would require large flow channels. In normal collectors

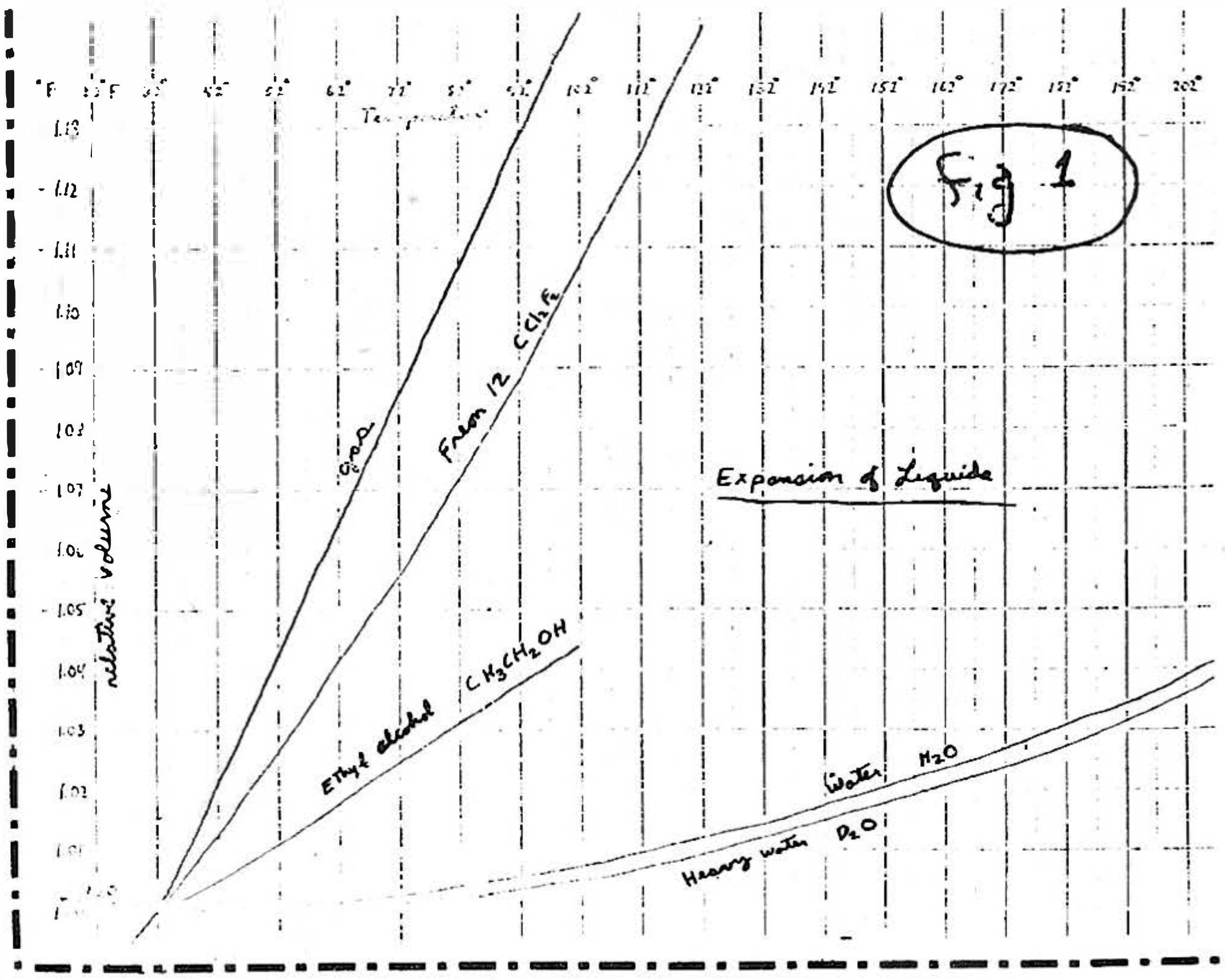


fig 1

this reverse convection dies because of flow constriction. The slightest failure of this reverse convection causes icing which then further restricts the flow and causes the complete failure. As far as I know no one has experimented with this particular problem. The advantages for such a collector would be great since there would be no heat exchanger and during the day the collector would deliver heat to the tank at its own temperature rather than at a lower temperature which is always the case if the heat must flow through an exchanger. A disadvantage to such a system would be the drain of heat during the night from the storage tank to maintain the temperature near 39 degrees F. This would not be a serious problem in many climates that have only occasional heavy frosts.



NEXT ISSUE: MORE ON CONVECTION

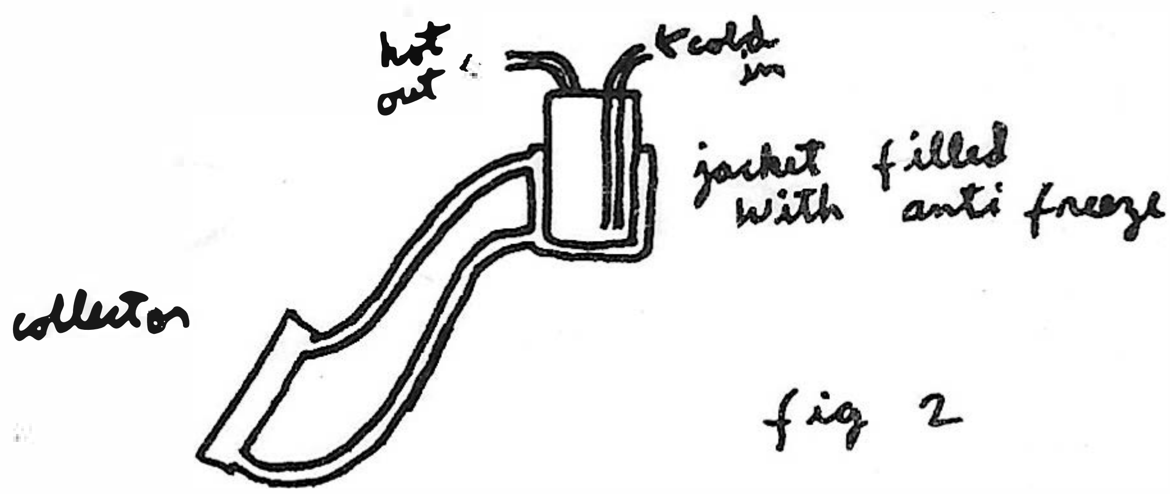


fig 2