Barn or Garage Solar Heater –
Description and Initial Results 2/25/04:
Updated 8/15/04 – see last pages <---

Note: See update of 5/20/04 at end of this doc.

Description:
The collector is 20 ft wide by 8 ft high for an overall area of 160 ft^2 (net area is about 149 ft^2). It is built right on the South wall of the barn/garage – the barn siding is the back wall of the collector. The collector is 6 inches thick, and the front surface is glazed with Polycarbonate panels. Openings at the bottom and top of collector allow air to circulate from the garage into the collector and back to garage. Wire mesh screen suspended inside the collector acts to absorb solar heat and transfer it to the circulating air.

The collector frame consists of a top sill, bottom sill, and 6 verticals that divide the 20 ft width into 5 bays of 4 ft each. The collector is 6 inches deep. The 6 verticals are 2X6s, bottom sill is a 2X6, and the top sill is a 2X8. The top sill is sloped to shed rain. The collector frame is attached to the garage wall by lag bolts from the inside.

The collector glazing is SunTuf corrugated Polycarbonate panels with a UV treatment on the sun facing surface. Each SunTuf panel is 26 inches by 96 inches, and there are 10 panels all told. Pairs of 26 inch wide panels are joined on a 1X2 to make the 4 ft panels for each bay (the panels overlap by 1 corrugation where they are joined).

There are 20 openings or vents that connect the garage space to the collector space. The bottom row of ten vents let cool garage air enter the collector, and the top row of ten vents let air that has been warmed by the collector flow back into the garage. Circulation is by convection (no fan). Each vent is 0.5 ft^2 (4 X 18 inches). Ten flapper valves made from light plastic sheeting are used to prevent back-flow through the collector at night – these are installed on the garage side of the top row of 10 vents. Half inch hardware cloth is installed under the flapper plastic sheets to prevent the flappers from being sucked into the vent opening at night.

Figure: Collector entry and exit vents from inside barn

Figure: Flapper valves

Black metal window screening is used for the absorber. The absorber is installed about half way between the glazing and barn siding. The vents and absorber are arranged such that cold air enters low on the South side of the absorber, and must flow through the absorber and to exit high on the North side (back) of collector.

Figure: Lower sill with summer vent holes – lower vent and absorber screen support are visible above the sill.

Summer ventilation (to prevent overheating) is provided by two 2 ½ inch holes in the top sill of each 4 ft bay, and two 2 ½ inch holes through the bottom sill in each 4 ft bay. These are covered over for winter, and opened for summer.

Materials:

The cost of materials was $300 (about $2 per ft^2!!). Everything for the collector can be bought at your friendly Home Depot or Lowes or ...

Item	***Qty***	***Description***
Glazing	10	Corrugaged Polycarbonate panels 26X96 inches (SunTuf)
Glazing Supt	40ft	Horz glazing support "wiggle strips" (SunTuf)
Fasteners	150	Glazing attachment screws with EPDM washers (SunTuf)
Glazing Supt	5	1X2 by 8ft mid panel supports
Glazing Supt	6	Aprox. 1.5 by 1 inch beveled to fit corrugation(ripped from 2bys)
Verticals	6	2X6 by 8ft
Bottom Sill	2	2X6 by 12 ft
Top Sill	2	2X8 by 12 ft
Lag screws	32	5/16ths by 3.5 inch lag scews with washers
Absorber	40ft	Black alum window screen
Sealant	5	Tubes of Silicone caulk
Vent Covers	20	Scrap ½ inch MDO for summer vent covers
Misc		Staples, screws, nails, paint, lumber scraps

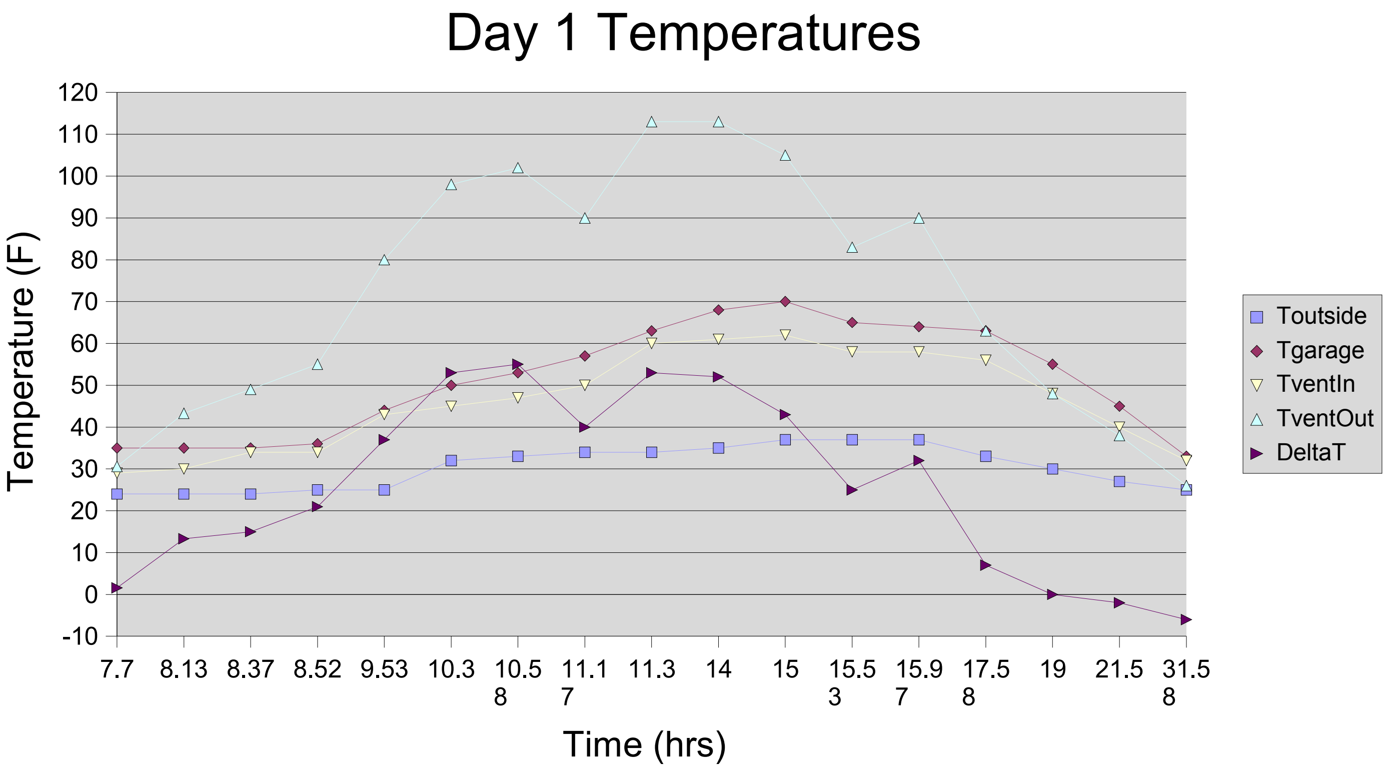
Labor:
It took the equivalent of 3 full 8 hr days to build and install (and the loss of 2lbs of excess body weight).

Performance:
It has only been running for 4 days as I write this, but it looks like it is going to do fine.

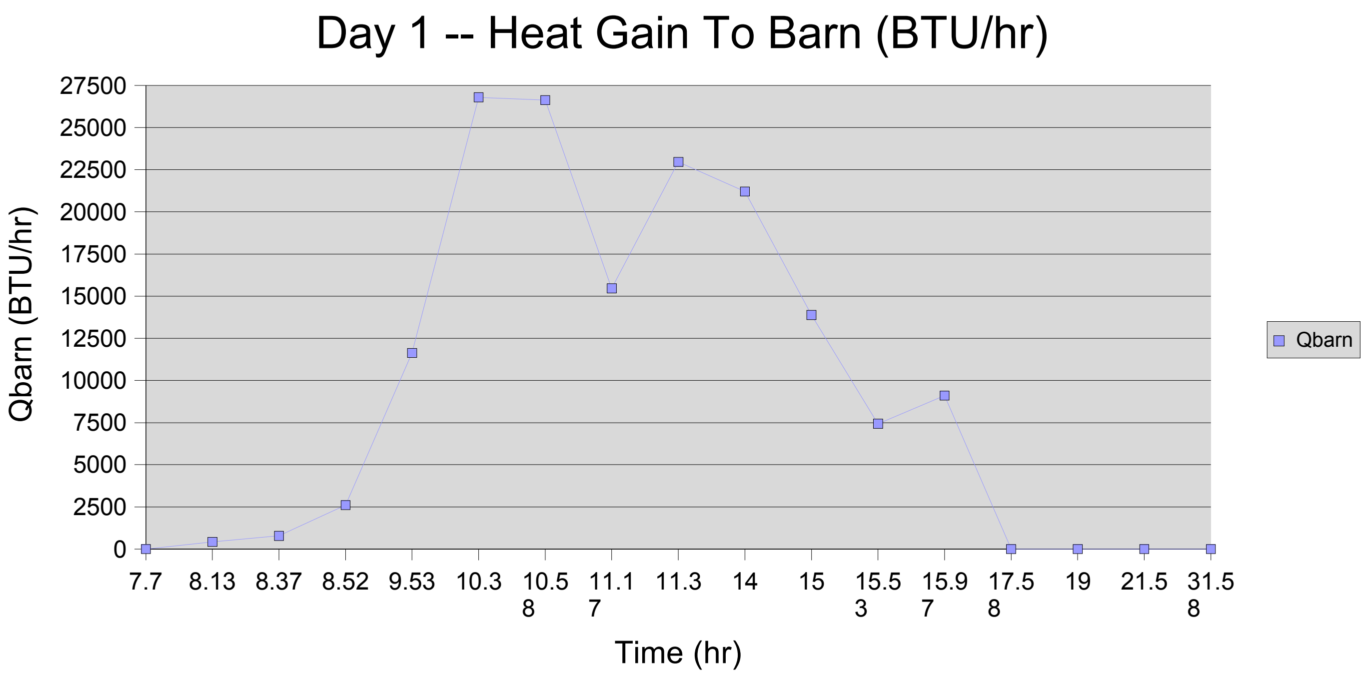
One thing to note is that at this time of year, the mountain to the East cuts off about the first 40 minutes of sun in the morning. In addition, the "South" wall of the barn actually faces a bit East of South, so the collector is in shade earlier in the afternoon than if it faced due South. In spite of this it seems to be doing well.

Also, all of the measurments were done with pretty crude tools. The temperature measurments were done with a bunch of identical alchool type dime-store thermometers (except for the stagnation temps, which were measured with a thermocouple attached to a DVM that supports temp measurments). The The vent exit velocities were measured with a Kestrel 1000 wind meter (it uses a 1 inch dia turbine on sapphire bearings). Kestrel claims to read down to 50 ft/min – so vent velocites velocities were getting near its limit. The velocity was measured at left, mid and center positions on the vent and averaged – this was then adjusted to account for the decrease in velocity at the top and bottom edges of the vent. I plan to do a more careful setup later, and take measurments over an extended period.

Day 1 (2/21/04):
The first day was clear, and a bit warmer than usual for this time of year. The collector heated the garage to 70 F during the day (including the 2nd floor) – I was insulating on the 2nd floor, and had to open some windows to cool it down a bit. The nighttime garage temperature fell to 33F, which was about 8F above the outside temperature low.



Horz axis is hours (e.g. 10.3 = 10:18am)
Toutside = Outside temperature (F)
Tgarage = Garage temperature
TventIn = Temperature of air entering collector
TventOut = Temperatue of air exiting collector
DeltaT = TventOut – TventIn
Hour 31.5 means 7:30 am the next morning.



The plot shows heat gain RATES to the barn through the day in BTU/hr.
The total gain for the day was about 131k BTU (equivalent to about 2gals of propane burned at 70% efficiency). The dips are caused by intermitent clouds passing over – mostly thin clouds.

Based on:
Qbarn = (deltaT)(Cp)(Wflow) BTU/hr -- rate of heat delivery to barn from collector.
deltaT is temp diff from entry vent (lower) to exit vent (upper) (F)
Cp is specific heat for air
Wflow is the weight flow from the exit vents (lb/hr)
Wflow = (Volflow)(den)
Volflow = (Velocity)(Area)
Velocity is the area weighted avg of three reading across vent, with a correction for falloff at edges.
Area is (10 vents)(0.5 ft^2/vent)
den = 0.059 lb/ft^3
This is density of air at 5000 ft altitude and 100F

Days 2 through 4 behaved in a similar way, but did do somewhat better on difference in temperature between the barn and outside first thing in the morning.

In general, the collector managed to get daytime temperatures to the mid to high 60's (about 25F above outside). By the time of the early morning low temperature, the garage was about 10 to 15F above outside temperature. This is just about what the objectives were.

Two screen absorber:

One of the bays has two layers of window screen rather than 1 to see if this makes a better absorber. The two layer one seems to be doing better. The temperature rise is a few degrees better, and the vent exit veloicties are also better. The stagnation temperature for the two screen absorber is also higher. Maybe I should change them all to two screen? Or to?

Stagnation Temps:
I measured the stagnation temperatures for two of the bays by blocking off the top vents with insulation. The conditions were absolutly clear skies, little wind, and with the sun azimuth directly on collector.

Stagnation temp for 1 screen absorber	155F
Stagnation temp for 2 screen absorber	172F

These were mesured with a thermocouple attached to a DVM. The thermocouple measurements agreed well with my regular thermometer up to the max of 130F that my regular thermomters are good for.

The SunTuf panels deflected as much as 2 ¼ inches inward during these tests. This did not appear to do any harm, but it seems like a lot of deflection.

Economics:
The solar collector cost $300 in materials.

The alternative would be to heat with propane. The cost of a propane heater would probably have been a bit less than the cost of the solar collector(?), but the ongoing cost of porpane would have been at least $150 per year -- probably more. So, the payback period is a couple years on materials cost. Or, you can look on it as investing $300, and getting an inflation protected, tax free return of 50%. Pretty good any way you look at it?

Overall Assessment:
Overall, I think it is going to work well.
Its really nice to actually do a solar project on my own house after thinking about it for a long time. I'm all ramped up to try some more – I have this idea for a cold climate batch hot water heater ... :-)

The pros:
- Simple (not much to go wrong or watch over)
- Easy to build
- Long life and little maintenance (I think)
- Low Cost initial cost (a tenth the cost of commercial panels?)
- Good economic return on the initial investment (in saved fuel)
- Output can be adjusted by turning bays off or on – summer output can be made zero.
- My wife doesn't think its ugly (or at least not too ugly)
- Does not impact use of garage (I can still pile stuff against wall, but now its not junk, its thermal mass)
- Does not require changes to the garage structure (i.e. No window framing ...)
- No greenhouse gas.

The Cons:

- Summer vent system needs some improvement (too much work each season)
- It hurts a bit to cut holes in the wall (but you get over it)
- It might benefit from more thermal mass and/or more insulation to keep night temp from dropping as much?

Thanks:
To the alt.solar.thermal bunch -- your suggestions helped a lot.
I would be glad to hear any comments or suggestions for changes or improvements.

Gary
2/25/04

Update 8/15/04

Construction:

I made a few changes to the collector in July as follows:

Changed all of the absorbers to be 2 layers of window screen instead of one layer – this was based on the test mentioned above in which the collector with 2 layers of screening did better than one layer. See also the info below on 3 layers vs 2 layers.

Added two horizontal support members for the glazing. These new supports run perpendicular to the glazing corrugations. The first is placed about 2.5 ft above the lower sill, and the other is placed about 2.5 ft below the upper sill. The members are ¾ by ¾ inch straight grain wood. The verticals that separate each bay are notched to allow the new support members to be flush with the outer surface of the verticals.

This change was made to control the deflection and buckling of the Polycarbonate glazing panels as they heat and cool. This deflection does not appear to harm the panels, but I suppose it might over time. The new supports completely eliminate this problem – the glazing is flat as a pancake no mater what the temperature.

This picture shows the collector with the new horizontal support members.

Summer Overheat Protection Schemes:

With summer, I closed the vents that connect the garage to the collectors to prevent overheating of the garage. This means that (if nothing is done) the collectors are operating at stagnation all the time. I tested two methods of preventing overheat, and compare them to just letting the collector run at stagnation below.

It should be mentioned that Mother Nature helps out quite a bit in protecting against summer overheat for a vertical panel. In the winter the sun is low, and its rays are nearly perpendicular to the glazing, but in the summer the sun is much higher, and the suns rays make a much larger incidence angle on the panel. For example, at 40 deg latitude in late Dec 1650 BTU fall on each sqft of a vertical panel facing South, but in late June, only 610 BTU fall on a sqft.

On Feb 21, with an ambient temperature of about 30 F, I measured a stagnation temperature of 172F -- or, 142F over ambient. On Aug 14 with an ambient of 89F, I measured a stagnation temperature of 162F – or, 73F over ambient. So Mother Nature helps a lot.

The following table shows the results for three different strategies for controlling summer collector temperatures. The strategies are:

Do Nothing:

Close the vents to the garage, and let the collectors run at stagnation.

Outside Venting:

Close the vents to the garage, and open vents in the upper and lower sills of the collector to allow outside are to enter the bottom of the collector, and exit the top of the collector.

For each 4ft wide bay of the collector, there are two 2.5 inch holes in the lower sill and two 2.5 inch holes in the upper sill.

Overhang:

Close the vents to the garage, and add an overhang that shadows all or part of the panel. In my case, I rigged a test overhang of cardboard that extended out about 2.5 ft on one of the collector bays. This shadows about 2/3rd of the panel in August, but almost none of the panel in mid winter.

I did not try covering the panel with shade cloth or the like. But, I am sure this would be effective.

I tested all of these schemes at the same time, by just using one bay of the collector for each scheme. I also ran one of the collector bays with the garage vents open for reference.

The ambient temperature for the test was 89F – I had hoped to do it on a hotter day, but we just haven't had much hot weather this summer. My latitude is 46 deg N.

Scheme:	Temperature	Delta from Base
Do Nothing	162F	Base
Outside Venting	152F	-10F
Overhang	133F	-29F
Normal Operation	122F	-40F

Doing nothing actually works pretty well with a max temperature of 162F -- for my climate, I think this might be fine even with somewhat higher ambient temperatures.

The overhang works well. Even with only 2/3rds of the panel shadowed at midday, it lowers the temperature by about 30F to 133F.

The outside vents only lowered the temperature by 10F, but (in hindsight) I should have made them larger. One scheme would be to have much larger vents in the top sill (say 1 ft^2 per collector bay), and omit the vents in the lower sill. This way, air would be pulled in from the garage via the lower garage to collector vents, and exit out the top of collector via the external vents. This would be solar chimney ventilation of the barn. I think you might get something like (5 vents)(1 ft^2/vent)(140fpm vent vel) = 700cfm.

Three Screen Absorber:

The earlier test showed that 2 layers of absorber screen are better than one, so would 3 layers be better yet?

I did one bay with three layers screen, and the tentative results seem to be that there is very little gain. I will try this again when I get my more accurate velocity measurement instrument.

Gary

8/15/04

If there is an interest in (free) plans and a construction procedure for this thing, let me know.

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