Horizontal Pond Domestic Hot Water Heater

This is an experimental concept for a solar domestic water heater. It consists of a horizontal pond of water that is glazed on top and insulated on the bottom and sides. A long coil of pipe is immersed in the pond. The cold water intake to the house hot water heater tank passes through the immersed coil of pipe to pre-heat the water before it enters the water heater tank. In operation, the pond water is heated by the sun during the day, and warms up to 130F or so. The water inside the pipe coil is heated at the same time. When a hot water tap is opened in the house, the warmed water from the immersed pipe coil flows into the house hot water tank. Depending on how much the pond heats the water, the heating element in the hot water tank has less heating to do (or maybe nothing to do). The immersed coil of pipe might hold 2 or 3 gallons (or even more), so the initial 2 or 3 gallons of water in the water draw will be heated to the full temperature of the pond. After this initial flow has gone through, the coil of pipe acts like a heat exchanger to transfer heat from the pond water to the cold water flowing through the pipe coil.

The prototype horizontal pond shown in the pictures (below) is about 4 ft by 6ft and about 4 to 5 inches deep (a pond for actual use should probably be more like 4X8 or 4X10). The top surface of the pond is glazed with one layer of transparent bubble wrap (which floats on the pond water), plus one layer of SunTuf corrugated polycarbonate glazing. The bubble wrap is taped around the edges to reduce the loss of water vapor. The pond itself is framed with 2 by 8 lumber, and insulated with 2 inch (R10) rigid foam insulation. The pond is lined with 2 layers of 10 mill black poly film to provide a leak proof container. The pond is filled to a depth of 4 to 5 inches with plain water. Running through the pond is a coil of ¾ inch polyethylene pipe. The pipe coil in this prototype is about 90 ft long.

The things I like about this collector are:

- Its very easy to build – e.g. the frame is four boards and 8 nails. It might take an afternoon to put together and another afternoon to install.
- Its very cheap (less than $100 – even less if you do a little scrounging). I would guess that the payoff period is less than a year.
- All of the materials to build it are readily available at your local hardware and lumber stores.
- It is aesthetically unobtrusive. Basically if you put some low plantings around it, you wouldn't see it at all (just make sure the plants don't grow:-).
- Its very simple – no pumps, controllers, antifreeze, air purgers, expansion tanks, or other clap-trap.

The concept is very much like the traditional batch solar water heater (a great design IMO). Compared to a traditional batch heater, it eliminates the need for a pressurized tank. The pressurized tanks for batch heaters seem to be hard to get at a reasonable price, and this is a problem for anyone wanting to build a simple cheap batch solar water heater. This horizontal variation is also less aesthetically intrusive. While I think the big black bread box batch heaters have a certain functional beauty, many people (my spouse included) think they are really ugly-- this flat version is hardly visible at all.

On the not so good side:

- The materials used will likely need some protection from full summer sun. The HDPE pipe has a maximum service temperature of 140F, and the pressure rating has dropped to about half the rating at 73F. In full summer sun, the pond temperature might exceed 140F if no steps are taken to protect it. Since the pond has a lot more thermal mass than a conventional fin and tube water collector, I would not expect it to get as hot as these do, but it might still get hot enough to damage the HDPE pipe or the PE liner. Throwing a piece of shade cloth over the collector in the summer would probably lessen the solar gain enough to prevent overheating (and you don't have to climb up on the roof to put the shade cloth on). If the HDPE pipe does not hold up to this service, then PEX pipe might be an alternative, as it has higher temperature ratings.

- I am not sure what the building code folks might think of the hot water supply line passing through a pond of stagnant hot water?
- Some of the materials used in the horizontal pond heater may not outlive you. If long life is a big goal, you could use an EPDM liner, a PEX pipe coil (or even copper), and replace the bubble wrap glazing with another layer of polycarbonate or glass.
- The non-optimal collector tilt angle of 0 degrees will result in less hot water per square foot of collector. Most hot water collectors are tilted up at an angle about equal to the local latitude, which is normally the best angle for year round solar radiation. But, the penalty in incident radiation for making it horizontal is not that great (only about 10% at 30 deg lat – see tables at end).

I've run simulations for several climates using the TMY weather data base files, and for southern US like latitudes and climates, the concept should work just as described above. These the low colatitudes have high average sun elevations, which means lots of radiation on horizontal surfaces. In addition, the warm ambient temperatures reduce losses at night – night losses can be high because of the large glazed area. For winter use in more northern climates, the concept needs some help. On the prototype (located in Montana), I am currently using a hinged lid that insulates at night and reflects more sun on the pond during the day. While this manual actuation arrangement is probably not going to satisfy many people, a more automated version might be developed. With an insulating lid, good insulation around the pond, and a reflector it is an all weather device that will heat water year round (the output in the coldest couple months of winter will be modest, but this is also true of most solar water heaters). Good insulation and burial of the pipe lines between the house and pond would also required for cold climates.

Poly Pipe Heat Exchanger:
I did an initial test of the performance of the pipe coil as a heat exchanger (see plot at end of this writeup), and the results were not wonderful. Basically, with 120F pond temperature, 47 deg supply water, and a flow rate of 1.75 gpm, the water flowing through the pipe was warmed from 47F to 77F. While this is helpful, it probably wants to be about twice this good. Need to work on improving this – more pipe – better pipe to pond geometry --- maybe Nick's notion of multiple coils of half inch pipe, which improves the immersed volume and the surface area to volume ratio while not increasing head losses. Increasing the volume of water in the pipe would be especially good, since this water will always be heated up to the full pond temperature. Any other ideas?
I may have sabotaged the effectiveness of the pipe coil by putting in some extra layers of poly film on the bottom of the pond to protect the liner from getting abraded by the pipe coil supports – these extra layers tend to float up and reduce pond water circulation

around the pipe coils (not sure how much of the problem this was – I need to try again with this problem fixed).

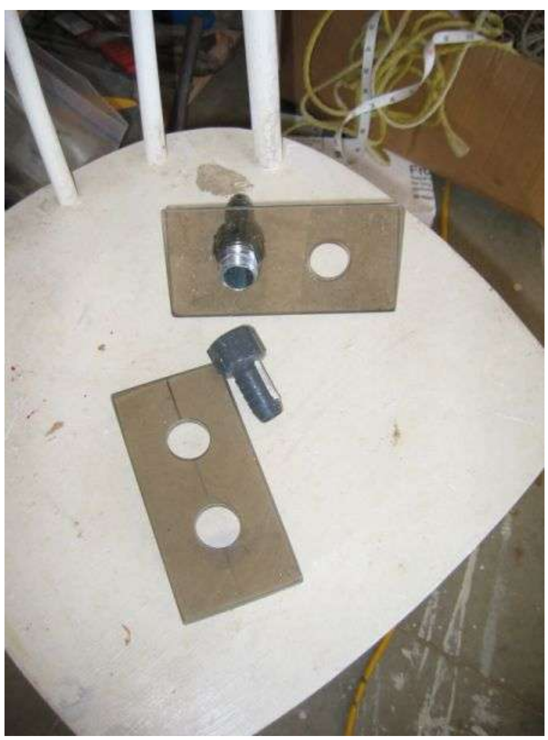
Pictures:
The 4'X6' prototype without the cover and reflector, but with interested onlookers. The prototype is primitive, made mostly from leftovers from other projects.

Prototype with the insulating cover and reflector. The glazing is a layer of bubble wrap floating on the water surface and sealed at the edges, plus a layer of corrugated SunTuf polycarbonate over that. Its a bit amazing to me to walk out through the snow, pull up the corner of the glazing, and find the water is to hot to keep your hand in! The reflector is made from some scraps of aluminized mylar plus some aluminum foil when I ran out of the mylar. The reflector/cover is a sheet of 2 inch rigid "pink" foam with a sheet of hardboard glued to the top.

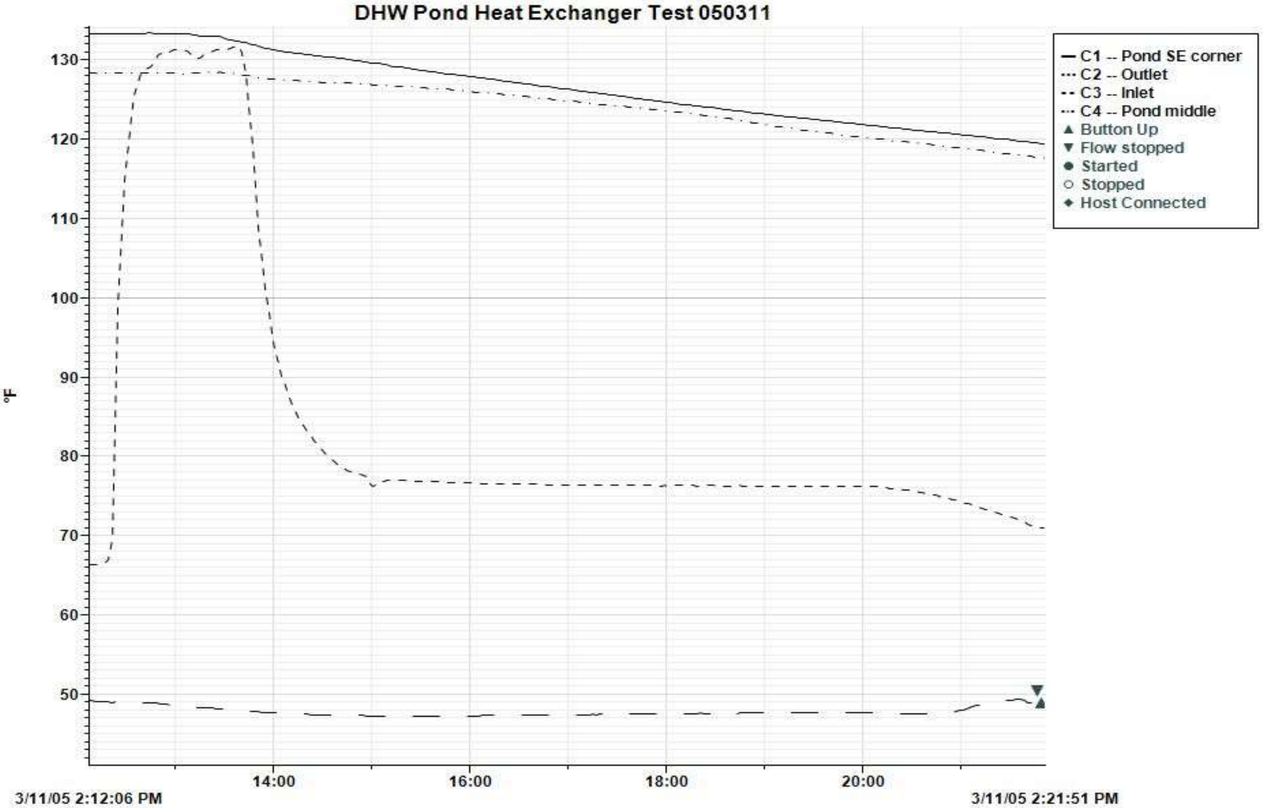
The basic box before the poly liner was put in. The insulation panel sits right on the ground.

The pond box with 2 layers of 10mil black poly liner and the ¾ dia HDPE pipe coil. Getting the poly tubes to behave fairly well was the most time consuming part of the construction. Nick Pine's idea of using multiple coils of half inch HDPE might give better performance, and make for an easier installation?

Detail of point where ¾ pipe penetrates the lining.
Detail showing the fittings, nipple, and plastic plates used to make a leak proof penetration of the lining. The lining is sandwiched between the two plastic plates, which are squeezed together by the two threaded fittings threaded on a short nipple. A little silicone caulk is used between the plastic spacers and the lining.



Pipe Coil as Heat Exchanger Test:



This plot shows the performance of the 90 ft coil of ¾ poly pipe as a heat exchanger.

Line C2 shows the outlet temperature on the pipe (after it has passed through the pond).
Line C3 shows the inlet temperature of the water (from the well)
Lines C1 and C4 show the temperature for two locations in the solar heated pond of water.
The time scale is in minutes.
The flow rate was measured by repeatedly noting the time it took to fill a 2 gal bucket.
The average flow rate was 1.75 gpm.

For the initial about 1 minute the outlet temperature is the same as the pond temperature. This is the water that has been sitting in the pond and has had time to warm up to the full pond temperature. After the first minute, the outlet temperature drops down to about 77F for the rest of the draw. The water going through the pipe coil is being heated from the inlet temperature of 47F by passing through the pond water to an outlet temperature of 77F (a rise of 30F). While this is nice, it would be nicer to get more heat transfer, and get the outlet temperature closer to the pond temperature. Ideas would be appreciated.

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These tables show the difference in radiation of a tilted at latitude surface to a horizontal surface.

Radiation on Horizontal Surface:
The two sample outputs below show radiation on a collector located at latitude 30, with one horizontal and one tilted at 30 deg. At this low latitude, there is only about a 10% difference.

```
Month by Month Summary of Sun on Collector
(100% sunny weather)

  Collector Area:         1.0 (sqft)
  Collector Azimuth:      0.0 (deg) measured from South
  Collector Tilt:        30.0 (deg) measured from horiz
  Latitude:              30.0 (deg)
  Altitude above SL:      0.0 (ft) Above Sea Level
```

Date ----		Sun ----------------			Collector -----------------------		
Month	Day	Direct Normal	Di- fuse	Total	Direct	Difuse	Total
1	21	2537	147	2684	1920	137	2058
2	21	2896	173	3070	2150	162	2312
3	21	3031	215	3246	2217	201	2418
4	21	3071	299	3370	2082	279	2361
5	21	3096	376	3472	1934	351	2284
6	21	3066	410	3476	1853	383	2236
7	21	2995	407	3402	1872	380	2252
8	21	2894	352	3245	1976	328	2304
9	21	2829	263	3092	2081	245	2326
10	21	2731	198	2929	2043	185	2227
11	21	2468	155	2623	1872	145	2017
12	21	2409	138	2547	1803	129	1932
Sum		34022	3134	37156	23802	2924	26726

Radiation in BTU/day

```
Month by Month Summary of Sun on Collector
(100% sunny weather)

  Collector Area:         1.0 (sqft)
  Collector Azimuth:      0.0 (deg) measured from South
  Collector Tilt:         0.0 (deg) measured from horiz
  Latitude:              30.0 (deg)
  Altitude above SL:      0.0 (ft) Above Sea Level
```

Date ----		Sun ----------------			Collector -----------------------		
Month	Day	Direct Normal	Di- fuse	Total	Direct	Difuse	Total
1	21	2537	147	2684	1234	147	1382
2	21	2896	173	3070	1592	173	1766
3	21	3031	215	3246	1920	215	2136
4	21	3071	299	3370	2117	299	2416
5	21	3096	376	3472	2208	376	2584
6	21	3066	410	3476	2215	410	2625
7	21	2995	407	3402	2147	407	2554
8	21	2894	352	3245	2015	352	2367
9	21	2829	263	3092	1812	263	2075

10	21	2731	198	2929	1507	198	1704
11	21	2468	155	2623	1200	155	1355
12	21	2409	138	2547	1082	138	1221
Sum		34022	3134	37156	21050	3134	24185

Radiation in BTU/day