Creating a Passive Solar Water Heating System

December 3, 2006

Environmental Science 102

Fall 2006

Created by:

Dan Jacobs

Maria K. Chaconas

Introduction

Challenge:

In this course we all acted as research scientists and environmental engineers to construct this non-electric solar power water heater. This was truly an example of science in that we did not know the outcome from the beginning but instead used the scientific method to predict an unknown outcome and test our hypotheses. The conditions of the experiment were small groups of two to three with limited supplies needed to develop and test a scale model of a water heater. The heater needed to have the ability to heat an amount of water no less than 3 quarts and no more than 3 gallons to make it relatively light and easily movable. The target water temperature is between 37 and 43 degrees Celsius or 100 to 110 degrees Fahrenheit.

The scientific method:

1. Observe the situation or problem.

2. Formulate a Hypothesis that is testable and consistent to the observed situation.

3. Test the Hypothesis

4. Gather Data from tests and analyze if the data disproves the Hypothesis.

5. Modify the Hypothesis and repeat 3 and 4 until a Hypothesis without discrepancies is reached

Hypothesis: **In the research that we have done, we believe the best method to create a successful solar water heater is by using a flat panel collector design with multiple tubes in an area where there is maximum sunlight exposure which will enable our bench scale model to have the ability to move 1 and ½ gallons of water in a circuit, heating the water to a temperature of 38 degrees Celsius or higher.**

Key words:

Here are some of the important terms necessary to understand in order to build a solar water heater.

Thermosyphon: The term use to describe the movement of the water inside the heater and tank. This describes the idea that warmer water is more buoyant and will float above cooler water. When using thermosyphon for a system pumps are not required because the water moves by way of convection.

Convection: Fluids and gasses expand when heated and are less dense so that they will float above the cooler more dense fluid or gas of the same type.

Conduction: This is the movement of heat or energy from one warmer object to another cooler object.

(This is not necessary in construction, but is the method our water heater used.)

Research:

In the research we read many interesting articles and created and annotated bibliography (attached) containing sources and came up with many interesting facts about the solar water heater.

1. Two Types:

Passive: The passive water heater is the type of solar heater that we had the challenge of designing and creating using no electricity.

Active: The active heater used a pump and therefore the heater does not have to be vertical with the heated liquid moving up by way of thermosyphon.

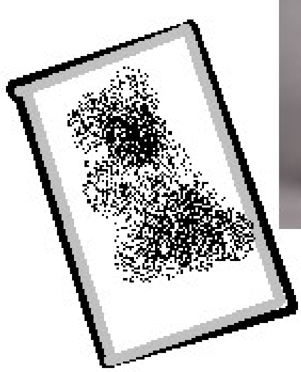
2. The heated water from a passive solar water heater is not usually the water used in the house. Normally the heater is closed loop and transfers the heat into separate water and is only for preheating so that not as much energy is used in a water heater.

Results

Materials used:

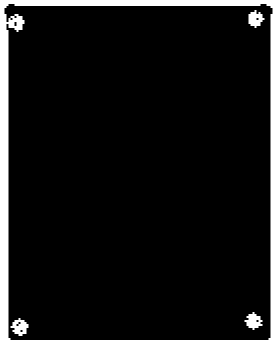
To create our solar hot water heating panel we used the following components; one rectangular, shallow cardboard box 1 foot by 1 ½ feet, two 1 foot long pieces of foam board ½ inch thick, two 1 ½ foot long pieces of foam board ½ inch thick, two thin aluminum sheets 11 X 17 inches, two flexible 3/8 inch plastic tubes 11 inches long, four flexible 3/8 inch plastic tubes 17 inches long, two 3/8 inch flexible plastic tubes 30 inches long, eight plastic T connectors fitting 3/8 inch tubing, one 1 ½ gallon plastic container with screw on lid, four sets of bolts and nuts, one sheet of Plexiglas 1 x 1 ½ feet, masking tape, black spray paint, and extra foam board to cover the plastic container, a metal gasket fitting 3/8 inch tubing.

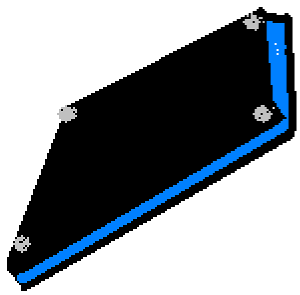
The Step by Step Process:.



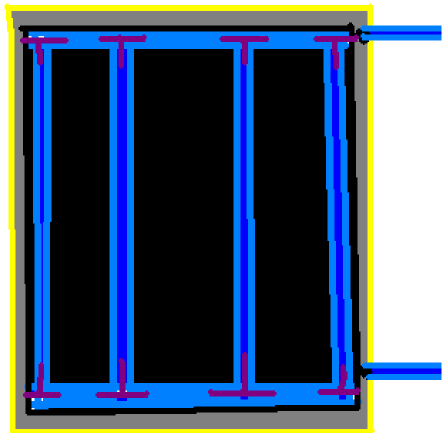
The first step is to hot glue the foam board to line the inner sides of the box. Placing the box in front of you vertically, drill two holes 1 inch from the top and bottom on the right side 3/8 inch in width. Spray paint one side of each of the aluminum sheets, and the inside of the box with the flat black paint and allow time to dry. Make sure to use flat paint and not glossy. This is because glossy paint will reflect more of the heat instead of absorbing it.

Next, take the 11 inch tubes and cut them into four equal sections each (2.75 inches each). Place the T connectors in between each tube section, leaving the right end with out a tube. Using a lighter, heat the left end piece of each 17 inch tube and pinch it together, sealing them shut, making sure there are no holes. Then, connect the 30 inch tubes to the right end T connectors.

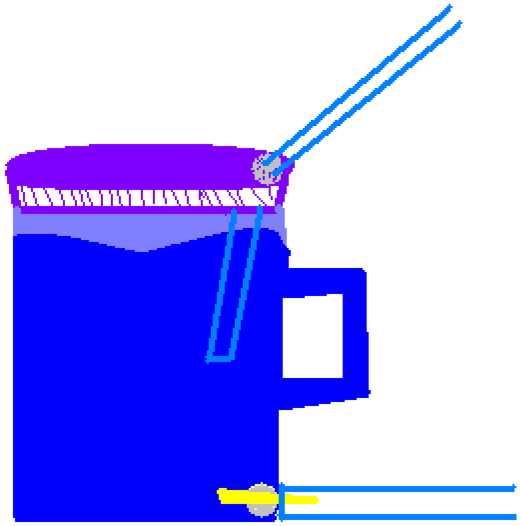




Drill four holes in each of the aluminum sheets on the corners the same size as the bolts and nuts. Place the connected tubes on the painted side of one aluminum sheet and place the other aluminum sheet on top of the tubes with the painted side facing up. Bolt the sheets together making sure to have the nut on the top and the bolt on the bottom so you are able to unscrew the nut incase a problem occurs once it is place inside the box.



To put your bolted aluminum tubes inside the box, make sure the nuts are on the top, and start with the 30 inch size tubes and pull them through the holes you have made in your box on the right side. Then, once you have pulled the tubes completely through the foam padding and the cardboard box, push down on the aluminum, making sure it is flat on the bottom of the box, and fitted tightly inside. Place the Plexiglas on top of the box, and tape it so that it will stay in place.



Take your plastic container and drill a hole on the top, right side of the lid big enough to fit the 3/8 inch tube tightly. Then, drill a hole about two inches from the bottom of the container on the right side small enough to hold the metal gasket tightly. Place the metal gasket inside that hole. Turing the box so that the Plexiglas is facing away from you, connect the bottom 30 inch tube to the metal gasket. Then fit the top 30 inch tube into the lid, sliding it through the lid and into the container, so that the excess tube will be hanging inside the plastic container. Remove the lid, and add water filling the plastic container almost to the top. Replace the lid, and make sure the top tube is inside the water. Place your solar panel in a flat, weather protected area, such as a greenhouse counter, where there is maximum sun exposure. Face the Plexiglas towards the sun. Place your container on some sort of sturdy small box or stool, elevating it so that the bottom of the tank is a little less to equal the height of the top of your solar panel. Take the excess foam board and tape it around the plastic container creating an insulator for the water.

Finally, to be able to read the water temperature, connect two temperature probes, one must be in the water container, so place that probe in the hole in the lid of the plastic container next to your plastic tube, making sure that the probe is in the water. The second probe can be placed inside the box to read how hot the air temperature is inside the box in comparison to the water temperature. This could tell you if you have a leak or problem inside your panel if the air temperature continues to rise and the water temperature does not follow. Stick the second probe in one of the openings next to the tubing connecting the panel to the tank/ container.

The Aspects of a Successful Design

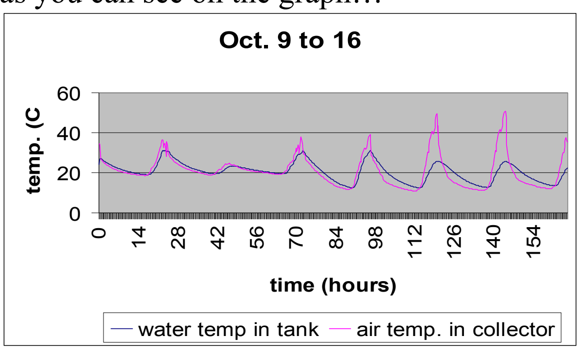
In creating this project because this is a college class, cost and availability were our main concerns. In doing research on the passive solar hot water heating systems, the flat panel was prevalent among those sold on the market, and in the descriptions of many "build it yourself," models that were described in home improvement magazines. In looking at the way these panels were made, it was important to keep the key concepts of the designs while taking under consideration the reality of costs, availability, and practicality.

Space and environment were also issues that needed to be considered. Our projects had to fit in a very small space inside the greenhouse along side of many other systems. The environment was one thing on our side because it was in the greenhouse, so the system was not exposed to any kind of moisture, wind, or any other weather or environmental aspects that could negatively effect out system. The only draw backs to this, is if our system is replicated it must be in a protected area, and also the direct sunlight had to go through the glass of the greenhouse walls, and then through our Plexiglas which causes energy loss. Obviously, the protection is key in the success of our system because of the materials that were chosen.

In researching, the majority of systems on the market used copper piping which would require welding materials, welding knowledge and ability, and also a fairly greater expense. We also took into consideration problem solving issues, such as a leak, and the practicality of that situation if using copper. Copper is expensive, difficult to work with, and if a large enough problem occurred it would have to be taken apart and reassembled with new materials. We did not find this to be the most efficient or effective choice when working on a small scale, and experimenting with the results. The most pragmatic approach was to use flexible, easy to work with, clear plastic tubing. Being inexpensive, easy to replace/ repair, obtainable, and still accurate in following the system's design, it was the right decision for this scale experiment.

In an attempt to lower the financial part of the project, we found some household items that worked efficiently. Using a plastic container, such as a cat food container with a screw on lid works very well. In using plastic instead of something made of metal worked in our favor because it did not absorb energy or heat itself which would take away from the energy it takes to heat the water. By insulating this container and the inside of the box with foam board, we found even better results, and a higher average air and water temperature. The sheet aluminum was a key component in our design. By touching the plastic tubing and absorbing heat with the help of the flat black spray paint it helped one as an absorbent, and two as an insulator for the tubes to hold the heat in the panel. The plexiglass was something we felt important enough to not try to cut any corners or costs with. This was seen as a necessity for obvious safety reasons in choosing this over glass, and also for the effectiveness we thought it would have in absorbing and reflecting heat.

Dates	Laboratory Notes	Estimated Temp. range	Changes/ Improvements

		(highest and lowest)	
09/25-10/02	Week 1: tested the probe to see how the computer worked, project not yet assembled		
10/02-10/09	Project not yet assembled. Unable to find the right size T connectors. Cut holes in 11 inch tubing, and using hot glue and epoxy to connect the 17 inch (vertical) tubes to the 11 inch (horizontal) tubes. Larger tubes were used for the 11 in. tubes and smaller tubes were used for the 17 in. tubes due to our original thought that the larger tubes would have to hold more water, and the smaller tubes would work more efficiently in the thermosyphon process due to less air/space where energy could be lost.		
10/09-10/16	Week 2: Project assembled and connected to the lab top. One probe was placed in the water, and one in the collector box to test the air temp. A leak occurred around the 120th hour (on Friday the 13th) as you can see on the graph…  where the air temperature continues to rise and the water temperature significantly drops off.	Water:13-30C= 55-86F Air: 10-50C=50-122F	
10/16-10/23	Took project home to work on the leak, and we decided to completely re-do the tubing not using any glue or epoxy because it only holds temporarily and is not water resistant. Any air hole or water leak is detrimental to the thermosyphon process.		T connectors were added, and the original tubing was replaced with all the same size tubing 3/8th inch.
10/23-10/30	Week 3: At the beginning of the week the water temperature was reaching near our goal as the water reached a temperature of 100 degrees F at one point, but as	Water: 15-38C= 59-100F	Insulation of the water tank.

<table>
<tr>
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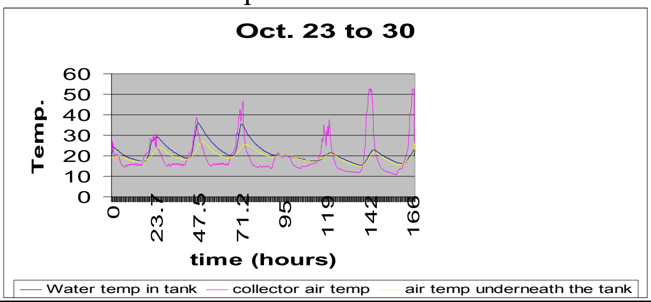
<td>seen on the graph around the 90th hour, there was an obvious loss of flow in the system, meaning a leak had occurred. The leak was found in the bottom left t connector where we had pinched/ melted the end tube together. This must be taken home for further repairs.


</td>
<td>Air: 11-52C=52-126F

Under Tank: 1426C= 57-79F</td>
<td></td>
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<tr>
<td>10/30-11/06</td>
<td>Looking at our new use of T connectors, and the progress we had before the leak disproved our theory about the use of smaller and larger tubes because in reality the T connectors created a smaller opening for the 11in. tubes making them smaller than the 17in. (vertical) tubes. It had the opposite effect of our original theory and seems to work successfully, so we believe the size of the tubes is not an essential detail to the process.</td>
<td></td>
<td>Hot glue was used to fill the ends of the open T connectors along with the sealing of the tubes. Removed the 3rd probe because having it just placed under the tank doesn't show any significant results.</td>
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<tr>
<td>11/07-11/13</td>
<td>Week 4:
At the beginning of the week the probes must have been bumped or tampered with because they were disconnected from our system. They were put back, and began working on Tuesday. Turing our project to the left/ the south had a great impact on the amount of hours where our project was receiving the most amount of sunlight. At one point it reached 100 degrees, and the water was at a higher overall temperature through out the week.</td>
<td>Water: 15-38C=

59-100F
Air: 12-48C= 54-118F</td>
<td>We turned our panel to face more towards the south after noticing that we were not getting the maximum amount of exposure during the morning hours due to the shade of a tree outside of the</td>
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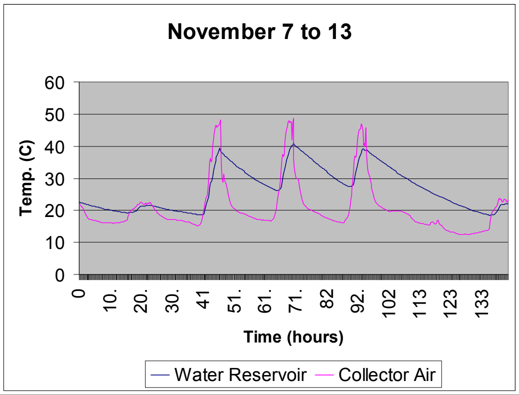
<td>
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<td>greenhouse.</td>
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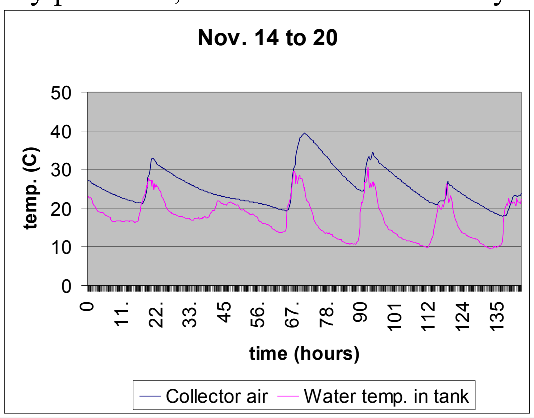
<td>11/14-11/20</td>
<td>Week 5:
This is the first week our project worked with out any problems, and the results were very satisfying.

</td>
<td>Water: 18-39C= 64-102F
Air: 9-30C= 48-86F</td>
<td>Insulation of the water tubes connecting the panel to the tank.</td>
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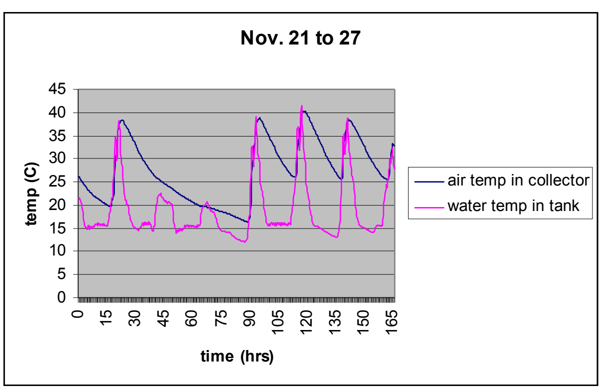
<tr>
<td>11/20-11/27</td>
<td>Week 6:
Project was successful all week reaching an average temperature of 39 degrees C all week (around 102F). The outside temperature was warmer during this week, and the sun was out a lot which helped.

</td>
<td>Water: 12-41C= 54-106F

Air: 15-39C= 59-102F</td>
<td>Another tank of water was added just to see what would happen.</td>
</tr>
</table>

Conclusion

The Data that we have collected in class shows that construction and operation of a solar water heater is not as complicated, or as impossible a task as it first seemed. This also gave us all a great incite on how we can improve our energy consumption and benefit personally through dollars saved on water heating.

After a bit of a bumpy start and one of the team members dropping off the project finally started to come together. Once we got going our group worked very well together and did well getting the materials needed to get the project done. Being the first group to get our system up, and after a few leakage problems the only group to get it running we saw that our efforts in and out of class paid off.

Future research information

1. Always take the best notes you can, our group was a little slack in taking notes and it was definitely hindering our ability to complete this final report.

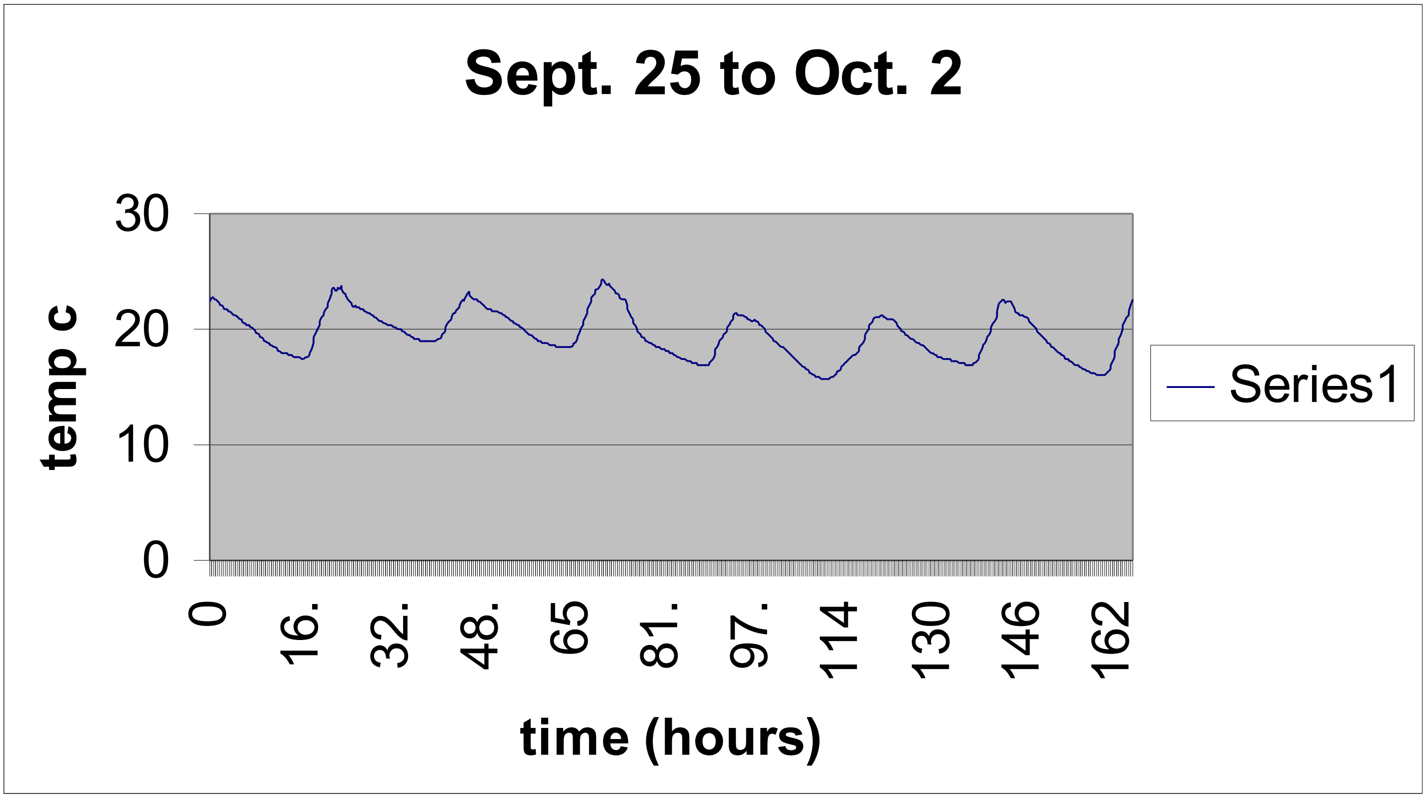
2. When connecting the tubes together, if using plastic tubing always use a fitting, do not try to glue the tubes as they will most likely leak. Try to find an elbow for the corners of the heater (our group had to melt a T fitting so it would stop leaking).

3. Always be sure there are no bubbles anywhere in your system and that it is completely closed. Bubbles in the tubes will stop any flow that was currently in

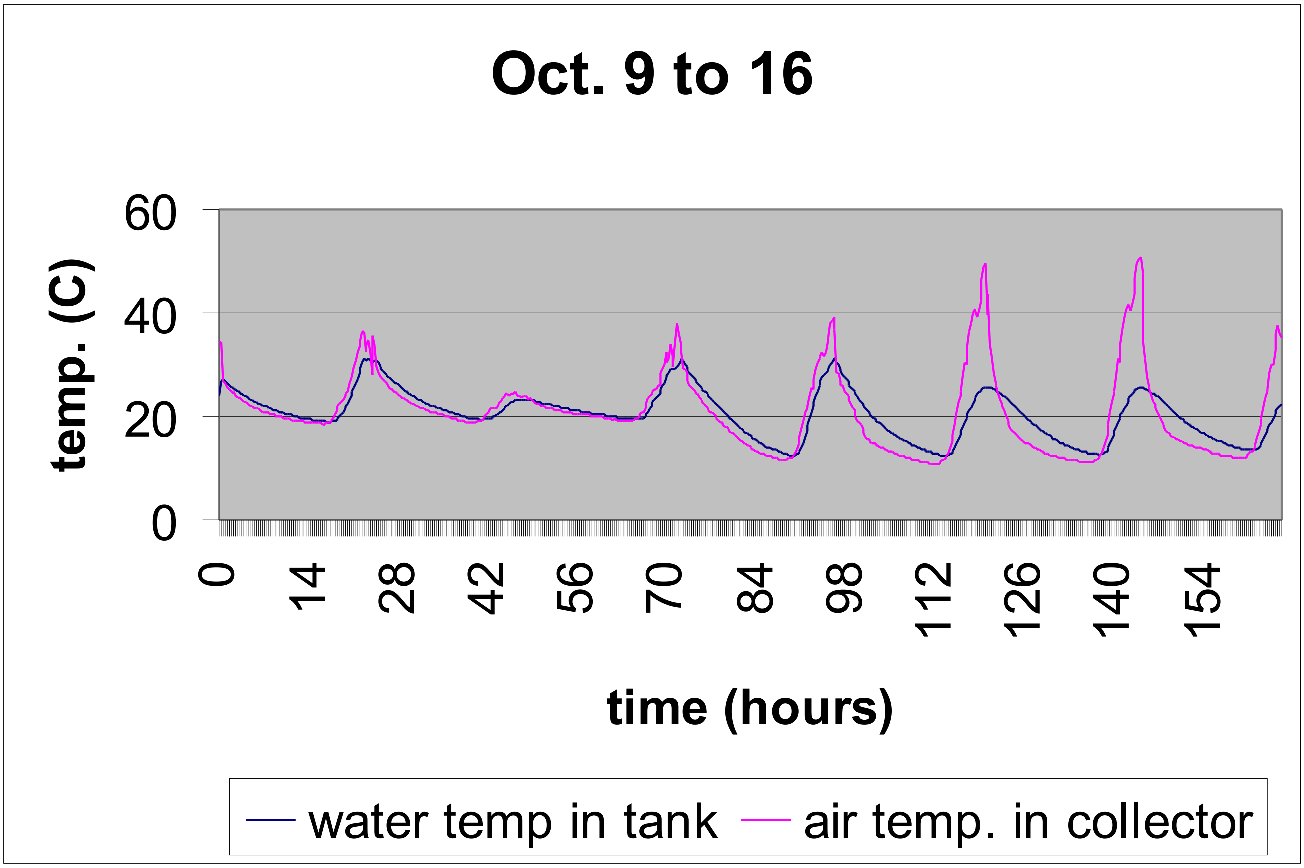
place.

4. When using a manifold kind of heater, the top and bottom tubes do not necessarily have to be larger than the vertical tubes. (Because of the T fittings in the top and bottom each individual vertical tube was actually larger than either of the horizontal tubes but it did not seem to affect the performance substantially).

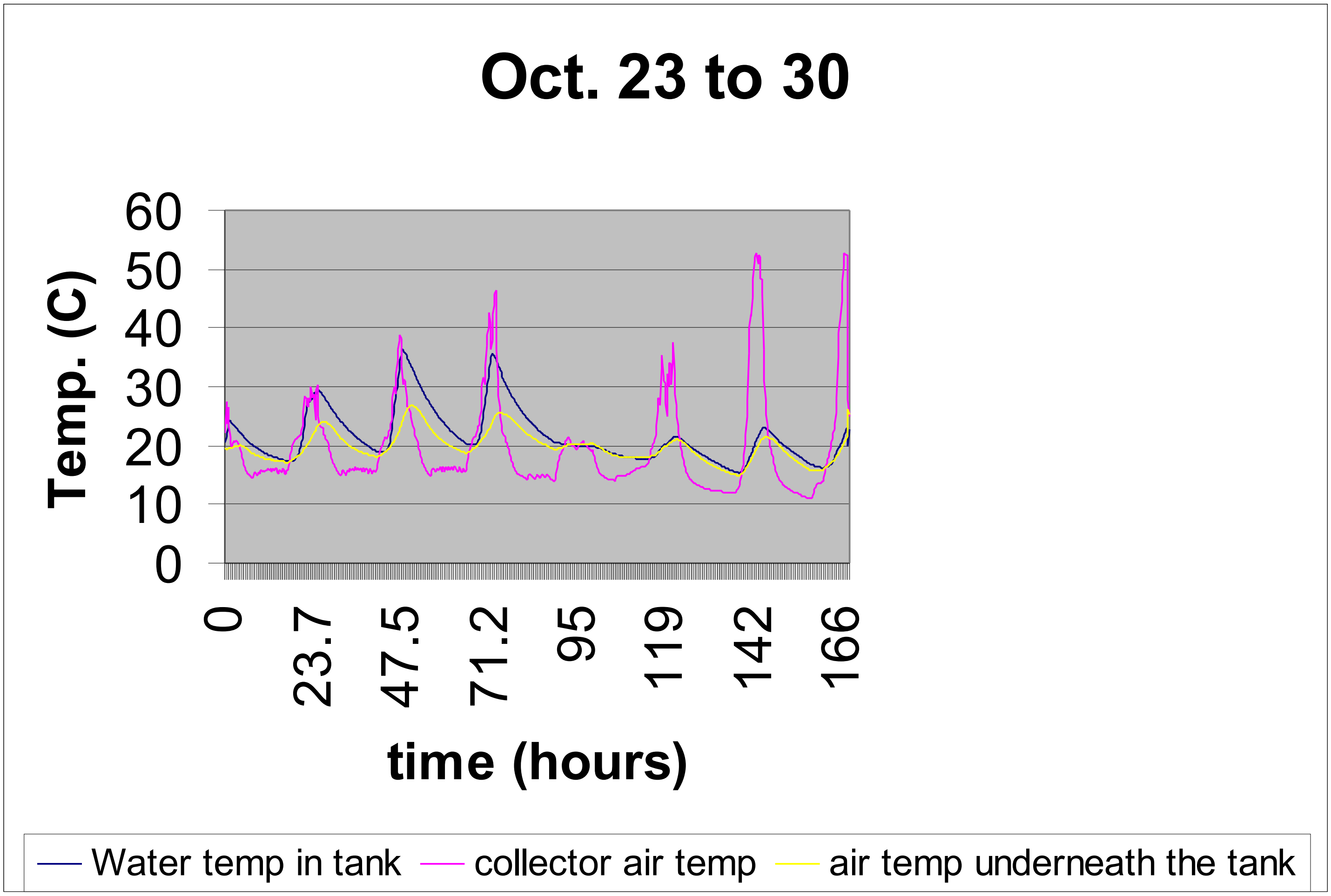
5. Make sure you communicate with your team and be sure to check the progress and check for leaks during the week, and not only during class.

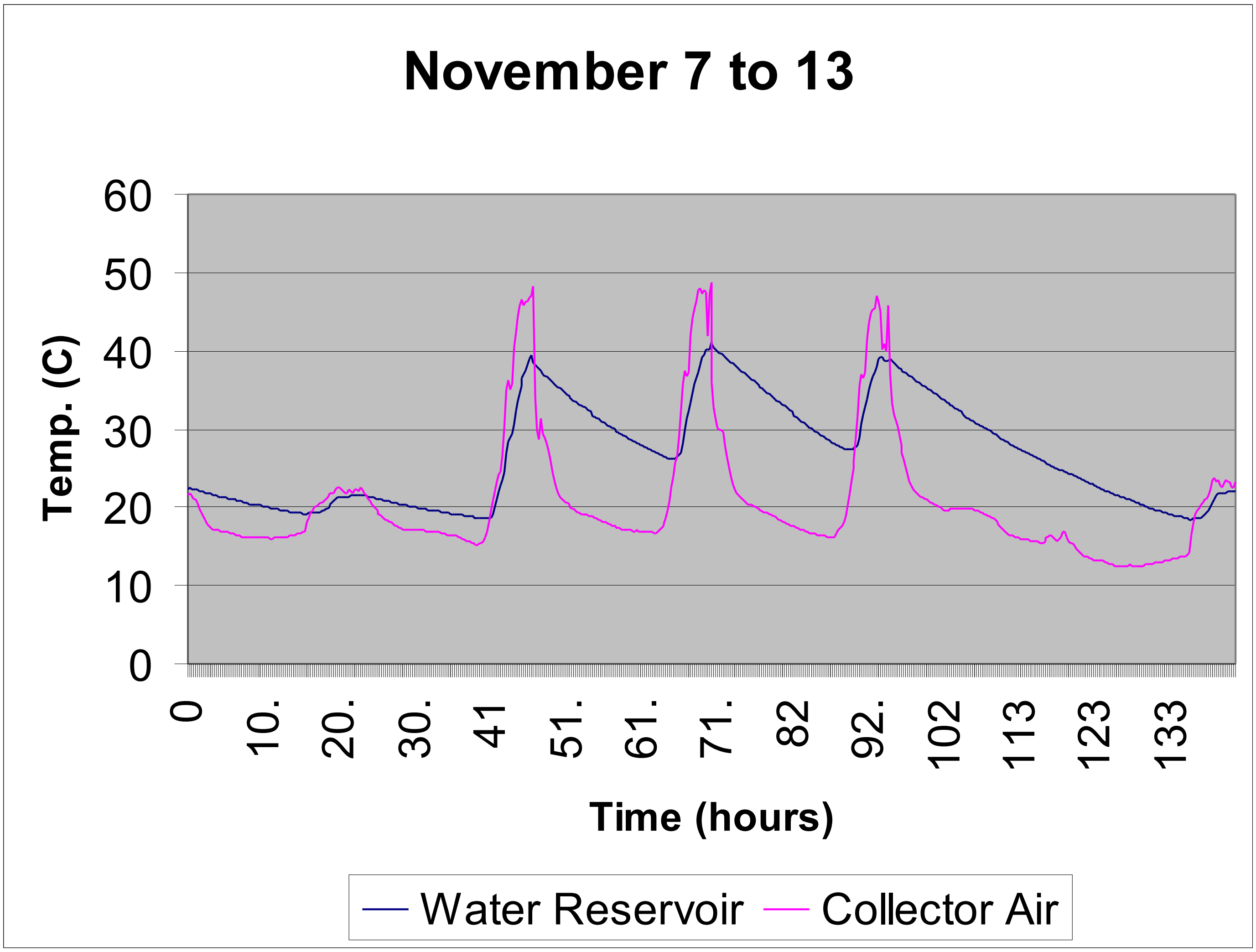


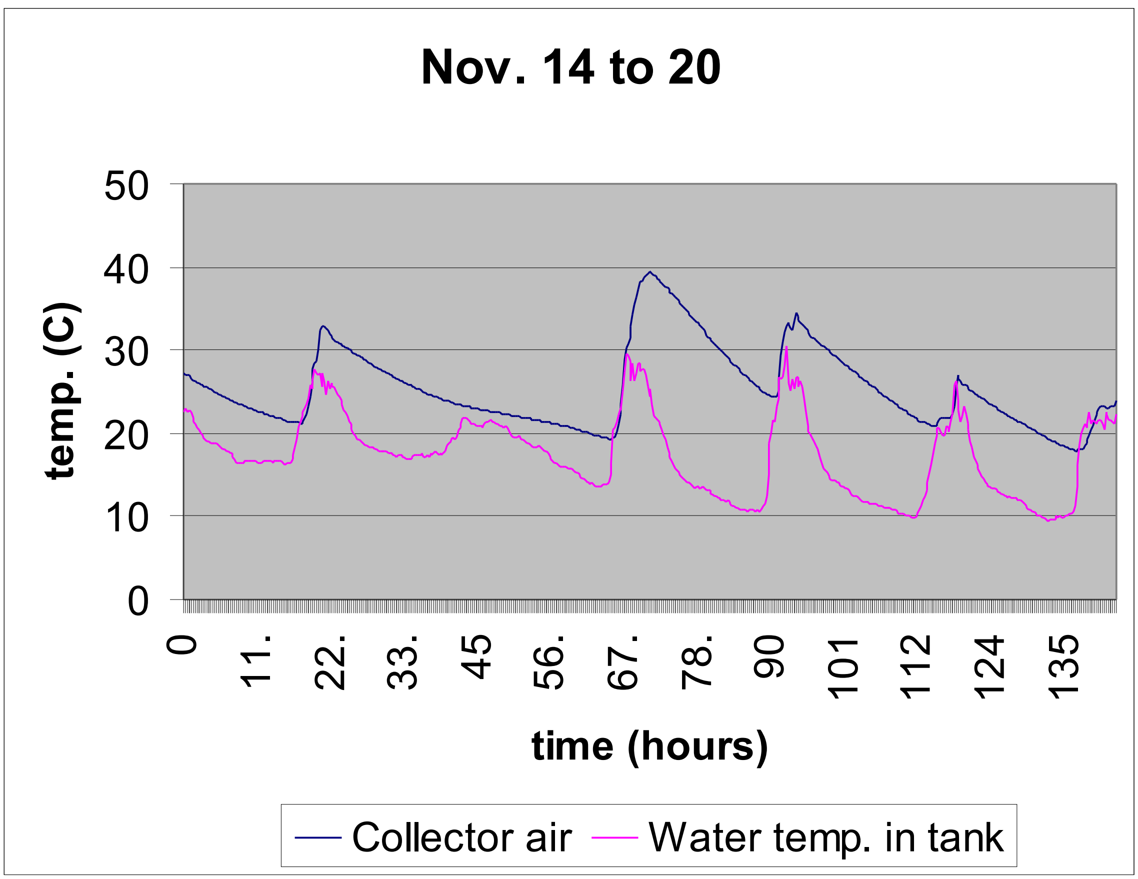
Sept. 25 to Oct. 2
30
20
10
0
temp c
0
16.
32.
48.
65
81.
97.
114
130
146
162
time (hours)
Series1



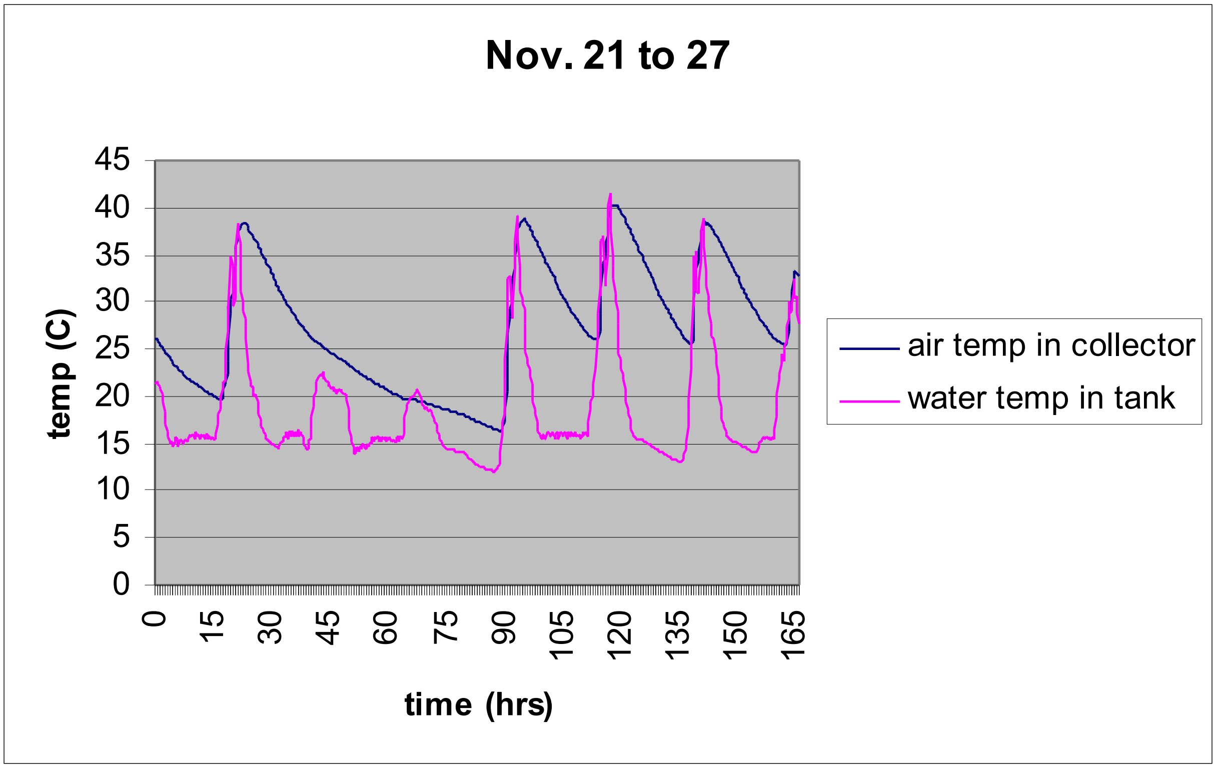
Oct. 9 to 16
60
40
20
0
temp. (C)
0
14
28
42
56
70
84
98
112
126
140
154
time (hours)
water temp in tank
air temp. in collector


Oct. 23 to 30
Temp. (C)
60
50
40
30
20
10
0
0
23.7
47.5
71.2
95
119
142
166
time (hours)
Water temp in tank
collector air temp
air temp underneath the tank


November 7 to 13
Temp. (C)
60
50
40
30
20
10
0
0
10.
20.
30.
41
51.
61.
71.
82
92.
102
113
123
133
Time (hours)
Water Reservoir
Collector Air



Nov. 14 to 20
50
40
30
20
10
0
temp. (C)
0
11.
22.
33.
45
56.
67.
78.
90
101
112
124
135
time (hours)
Collector air
Water temp. in tank



Nov. 21 to 27
temp (C)
45
40
35
30
25
20
15
10
5
0
0
15
30
45
60
75
90
105
120
135
150
165
time (hrs)
air temp in collector
water temp in tank

References

Hackleman, Michael. (1998). 7 solar water heating system designs. Backwoods homes magazine. Retrieved Sept. 16, 2006, from http://www.backwoodshomes.com/articles/hackleman65.html

-Showed pictures and minimal descriptions of what company produced solar heating systems look like.

Mother earth news a homemade solar water heater. (1979). Retrieved Sept. 16, 2006, from http://www.motherearthnews.com/top_articles/1984_January_February/Build_an_Integral_Passive_Solar_Water_Heater.html

-Describes how to build and install an integral passive solar water heating referring to the materials needed, and how it works. This was interesting, but used a pump which does not apply to our project.

Now more about passive solar. (2005). Retrieved Sept. 16 2006, from http://www.gemstones.nowmore.net/passive_solar.htm

-Describes some key concepts, history, types, techniques, and designs of passive solar heating.

Passive Solar Home Plans. (n.d.). Retrieved Sept. 16, 2006, from http://www.jc-solarhomes.com/passive_solar.htm

-A look at solar home plans and descriptions of affordable solar water designs. Trying to get you to buy the book, but can link to other sites.

Pine, nick. (1996, May 29). Help with solar passive hot water storage. Message posted to http://groups.google.com/group/alt.solar.thermal/browse_thread/thread/1d51c6bda44aaa91/4ab4e39314cd0b61?lnk=st&q=Pine%2C+nick+1996+passive+solar+water+heating&rnum=1#4ab4e39314cd0b61.html

-A Q & A about building a passive solar hot water heating system in a house. No pictures.

Reyna, Gary. (2005). Build it solar. Retrieved Sept. 16, 2006, from http://www.builditsolar.com/projects/waterheating/water_heating.html

-The Florida Solar Energy Center describes several types of solar energy systems, their parts, and in what climates they are best used in. Also includes articles from home Power magazine which are very helpful. Best site.

Southborough website design. (2005). What is solar energy. Retrieved Sept. 16, 2006 from
http://www.makeitsolar.com/solar-energy-information/index.htm

-A science fair project design, and a look at how solar power works. Very simple/elementary site, but has short building descriptions which were helpful.

Sun heat workshop.Retrieved Sept. 16, 2006
http://www.jc-solarhomes.com
-Talks about solar heating projects, and again trying to sell a book, so little information, but still somewhat useful.