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Solar Hot Water Heating Systems (by Yvonne Banks)

Commonly referred to as Solar Domestic Hot Water Systems, solar heating systems are, as determined by a National survey, one of the most cost-effective systems. They can be used for car washes, hotel/motels, restaurants, swimming pools, and laundry mats. Each system uses a variety of renewable resources that reduce environmental carbon emissions, but their effectiveness is based on the surrounding climates. Most have back-up systems containing either gas or electricity.

There are two main types of heating systems: passive and forced. According to ToolBase services, passive systems cost between $1,000 - $2,000 and uses solar energy, but have a lower capacity, whereas the forced systems require a pump to move water from the tank to the collector. According to government studies and surveys, most hot water heating systems, generally, are forced. Reviews of some scientific research show that in order to gain optimal performance, the collectors are to be aligned at a perpendicular angle of about 18 – 50 degrees.

Introduction for Project/Hypothesis (by Ashley Diehl)

We began our project with the hypothesis that if we change the input location on the water tank, the overall temperature of the water inside of the tank will change. Out of four input locations, the main question to be answered was which input location would influence the change the most. The bottom input could very well do this, as elementary learning about the way heat rises would tell us. However, another thing to consider would be the topic of distribution, in which one of the middle inputs (second from the bottom or second from the top), being closer to each half of the bucket, would produce more evenly heated water than the other input locations would. Also worth considering is the flow resistance that heated water would encounter at the bottom of the water tank, where cold water is already being expelled and might slow heat's progression up the tank.

It was a tough call for a little while, but we eventually decided to put our weight behind the bottom input location producing the most heated water, as per the fact that heat rises, through water being no exception. It was also our assumption that heated water going into the bottom of the tank would heat up the rest of the water as it rose, perhaps not evenly, but adequately enough for this location to be the optimum location for the input to be placed. It was from this hypothesis that we began our experiments.

Description of the Design

For our solar-powered water heater, we first started with a bucket to be our water tank. The bucket's dimensions were 14" tall with a diameter of 12" and a volume capacity of 12,500 mL (reduced to 9,500 mL upon the introduction of two 1,500 mL bricks). The locations of the four input valves on this bucket were as follows: bottom input, 1" from the bottom of the bucket; next to bottom input, 4"; next to top input, 7"; top input, 10" (all separated by every third inch). On the back of the bucket, at the same level as the bottom input (1"), only on the opposite side, we placed the output valve for the draining of all cold water.

Our collector was a box, 2 ½ inches tall and 13 ¾ wide. Its length was 18 inches. This box was constructed of wood, had a glass cover of corresponding dimensions, was painted black on the inside and contained within itself four pipes in a honeycomb formation. These pipes came together at A:) the bottom of the box/the side of the box tilting downwards to supply an entry point for the cold water coming from the output on the water tank and B:) the top side of the box/the side of the box tilted upwards towards the water tank.

The water tank itself was set up 16 inches above the table on which the solar collector rested, providing the space needed for heated water to run upwards from the collector and into the water tank. In addition, the tubes leading up to this tank were made of clear, flexible plastic. These tubes would latch onto each input location on the tank as we were testing the location. All other times the input locations remained sealed shut with mini clamps while the active input was the only one with the input tube attached to it.

In addition, the entire rig was set up in a greenhouse in order to obtain maximum light and heat from the sun.

Description of the Process (by Chris Thomas)

Once we had a solar powered water heater formed from these materials, we configured it to run without our variable for a test run. Our rig did warm the water and was working but we did not meet our goal of 100 Fahrenheit. Instead, we reached 36 degrees Celsius, which is 96.8 degrees Fahrenheit. Once we knew the rig was working we went and started to adjusting the rig to suit our variable. The main water tank had only 1 inlet and one outlet, but we drilled 3 more holes in the side of the inlet, each one three inches apart and one right above the other. This gave us four inlets and divided the tank into four parts: the top, 2nd from top, 2nd from bottom, and bottom.

After the inputs were created, we checked for leaks and then set the solar water heater up for a week of testing, but in the start of the testing we had three leaks form and they had to be dealt with, so we put rubber squares over the leaks and put the leaks over a fish tank incase something happened during the week. The week after, the leaks continued to keep us at a standstill so we stopped everything and focused on the leaks. We sealed them shut with caulk and had to let them set for 2 days, then had to wait a week to see if the leaks had stopped. Fortunately, the caulk seemed to help stop the leaks and we went on to get a successful week of data.

We then were able to get two more temperature probes to use in our experiment and we moved the location of our input for a successful week of data. But after two good weeks we ran into trouble with our rig, which had developed an air bubble in the tubes that had stopped the flow of our project, thus completely destroying our week of data.

Our troubles with the solar powered water heater were even further complicated the next week, when the software we were using to collect temperature data of the water, Logger Pro, ceased to function, following which the laptop itself became unusable, which caused us to be unable to take any readings until the week following. Once that was fixed we simply moved the input location and started collecting data again, this time collecting good week's worth of data.

After the good week we had a power outage that knocked out a week of data, but things finally started to settle down and we were able to collect the data we needed.

Having collected the data, now comes the part where we tried to make sense of the data and put it into forms that can be easily explained and presented to other people, then stated in a way that can be understood. We divided up the work to what we thought was even and started to turn the data into a good scientific report. We had to make graphs of every week of data and have them in paper format as well as on a flash drive. We also made a graph to summarize all the other graphs, which is a better way to show all that data (see below, following Pat's analysis of these graphs).

Overall, we hit a lot of obstacles but never the less we were able to gain data from all four inlets to the tank and made our charts. However, our rig still failed to reach the aimed-for 100 degrees Fahrenheit target, which means that we did not attain the temperature we wanted, but, over all, reaching 100 degrees Fahrenheit has no real effect on our variable so our test is still valid.

Our test was to find out if the placement of the inlet could affect the overall temperature of the tank. From our data, we have concluded that it does have an effect and that the best place over all was the 2nd from bottom inlet. This had the best overall results for the project. This means that this had the warmest overall temperature throughout the tank and that this inlet is the best to use.

Graph Analysis (by Pat Spliedt)

Over the course of the semester, we successfully collected four data sets. Although each series does not have the exact number of data pieces, they all show the similar trends. By collecting data over an extended period of time, outlying abnormalities are greatly diminished. The aforementioned data sets were over the course of seven days or one hundred and sixty eight hours gathering readings every fifteen minutes. The easiest way to analyze the voluminous data was to put it in the form of a linear graph to more easily understand the ebbs and flows of the temperature fluctuation. In doing so, the four graphs helped as a visual tool to comprehend the results of the week's trial.

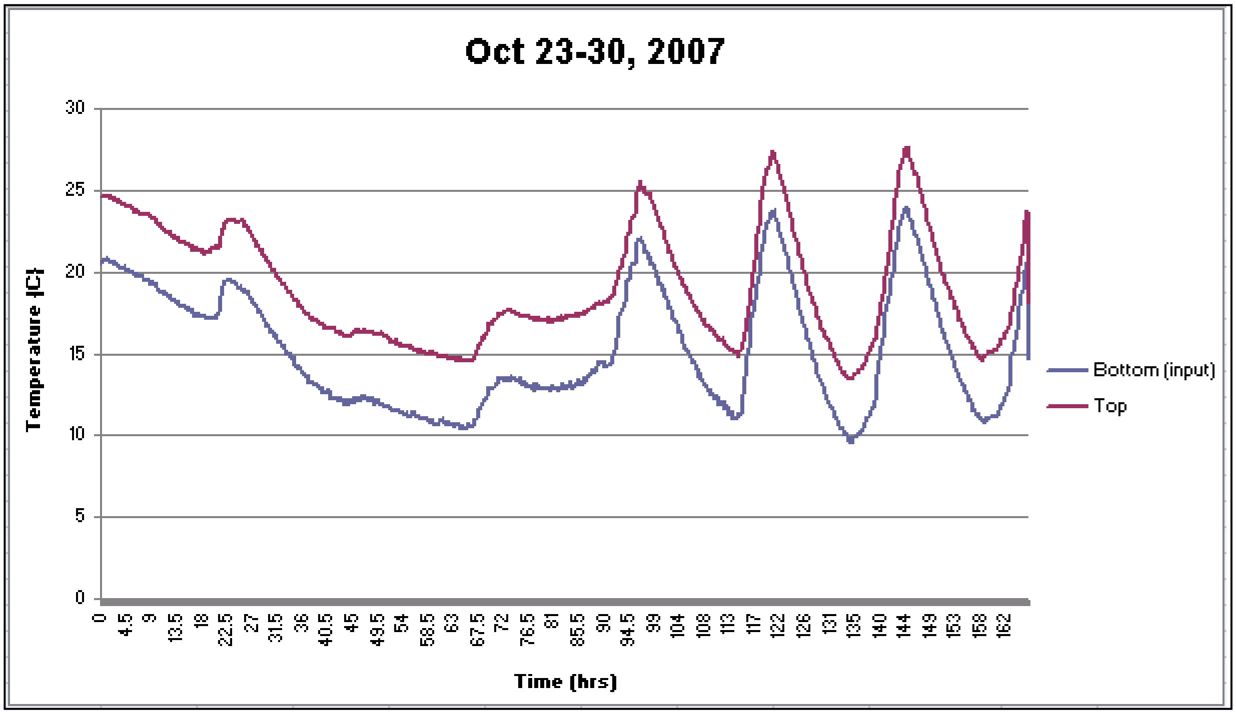
However, the data graphs for each week, though having things in common, did not have one important variable consistent throughout the semester. Each week had several corresponding peaks and troughs, which are attributed to weather and weather-related elements. Just as each day in a particular series had highs and lows formed by the weather, so too did each separate week's data series. Meaning that since each week had different, uncontrollable weather each individual graph could not be compared with the subsequent week's graph because they did not have the same weather variable consistent to the other. To combat this uncontrollable variable, there had to be a means to compare the different data collections without solely relying on weather. Thus, we decided that the best way to prove the hypothesis was to compare the temperature differentials per week from the highest point each week. By subtracting the peak temperature with the corresponding lows, it takes out not only the volumes of data pieces to sift through, but it also eliminates weather from its importance.

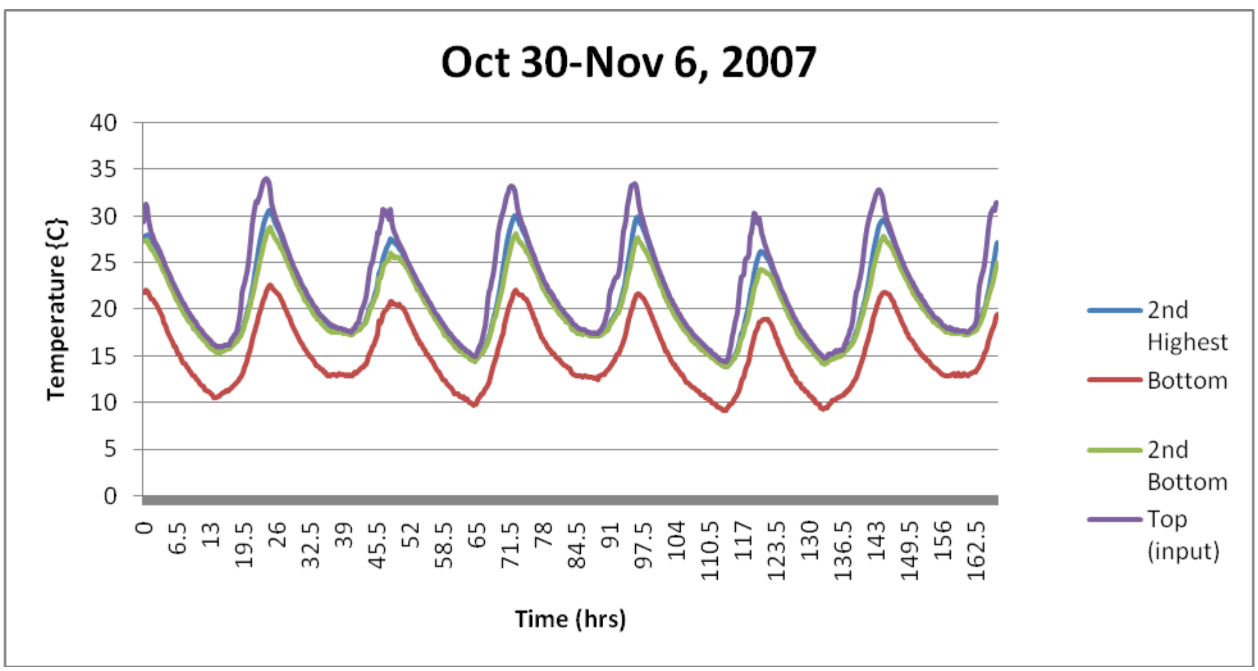
For example, the first week's temperature difference at the top probe location was fourteen degrees Celsius, while the bottom probe temperature differential measured a twelve degrees Celsius discrepancy from peak to low. By comparing each probe location on a particular week, it can be proven which water level is consistently warmer. Then, once the weather variable is eliminated in each week, the remaining data can be compared to all of the weeks.

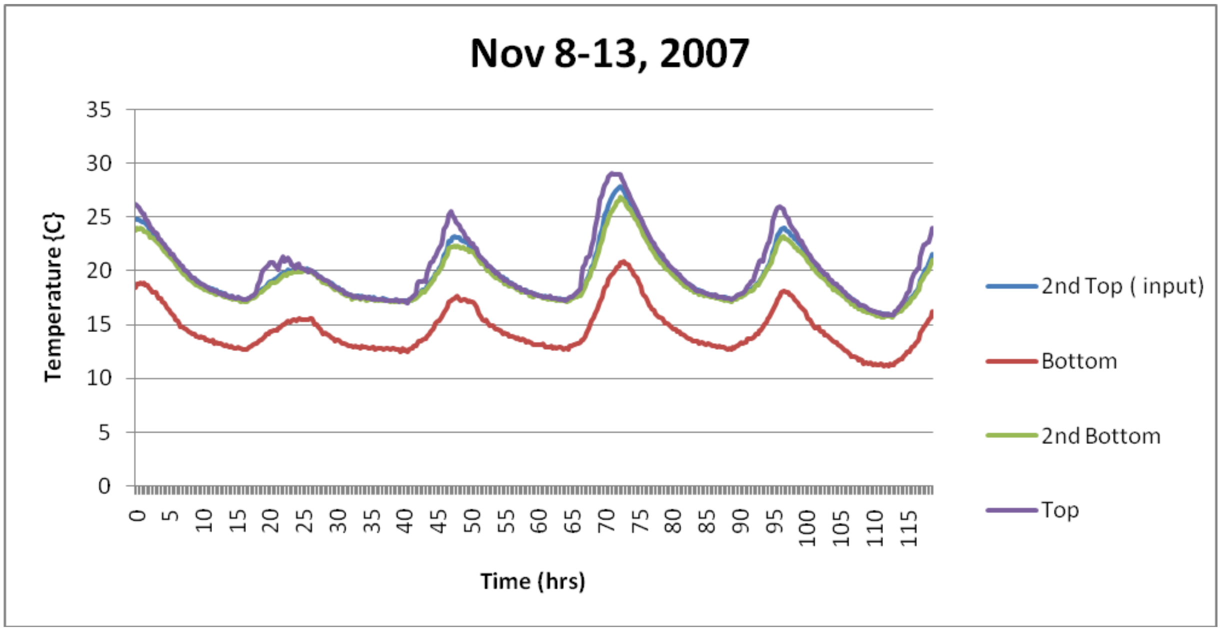
In all four graphs for temperature differential, the top probe temperature always had the greatest temperature difference. This result is consistent with the conclusion that the highest probe point also always attained the highest temperature and mean temperature as well. Thus, the higher the peak, the greater the difference was proven to be.

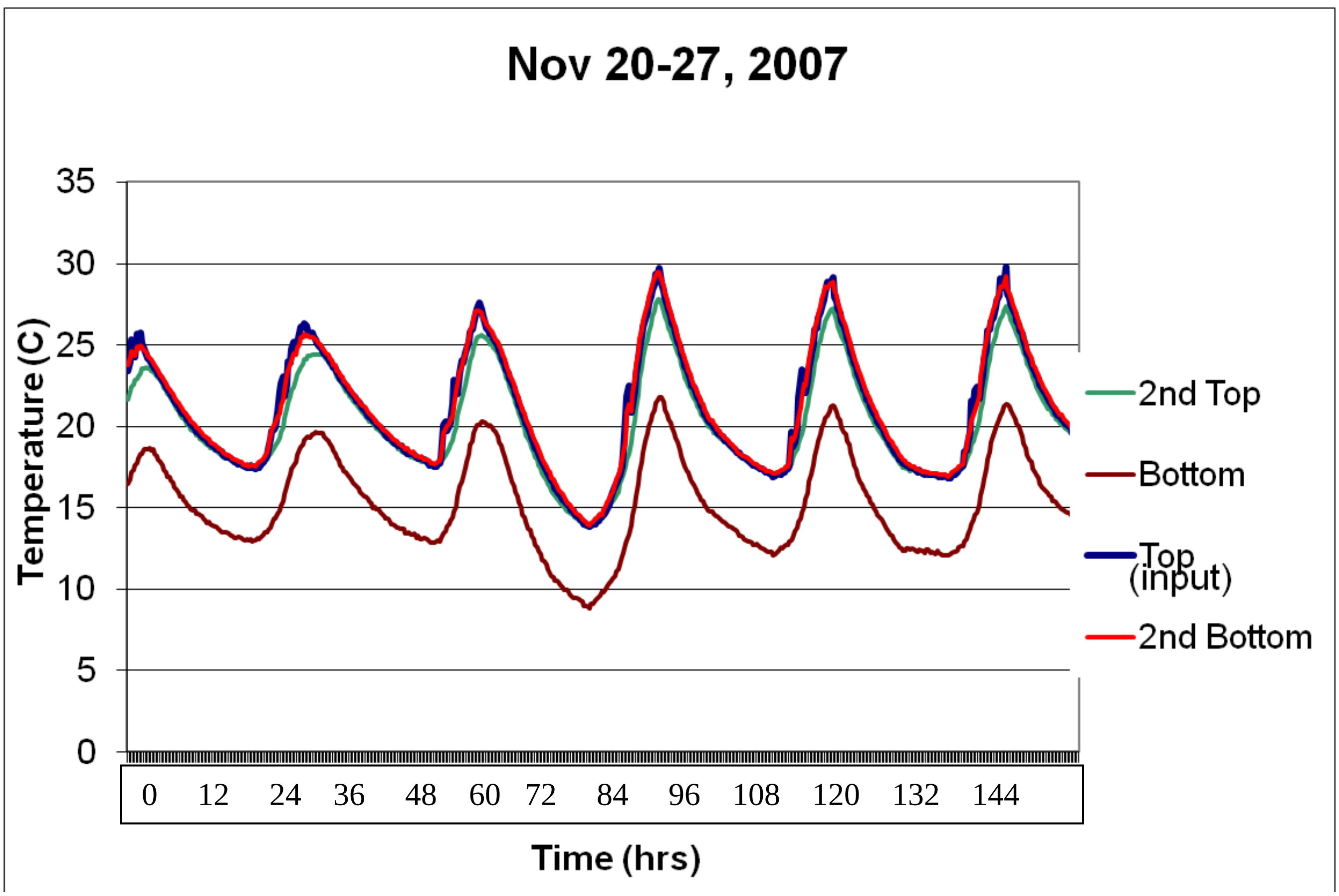
The input valve also proved to be a critical component to the temperature efficiency as well. Although, the bottom location and the top location proved to be the lowest and highest average temperatures respectively, having the input tube at the next to bottom proved to be more beneficial in regards to achieving higher temperature on average rather than the next to top input. This tendency is represented with graphs illustrating both the highest peaks and the average peak per level for the semester.

Weekly Data Graphs

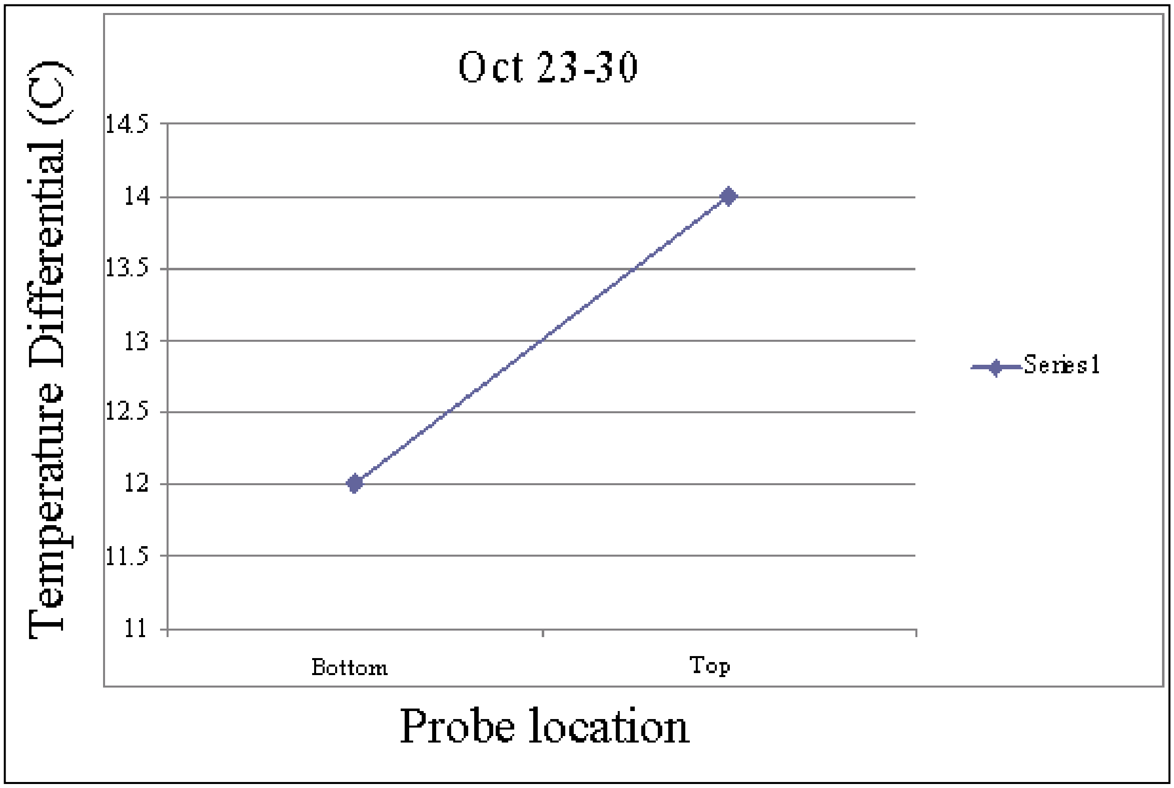


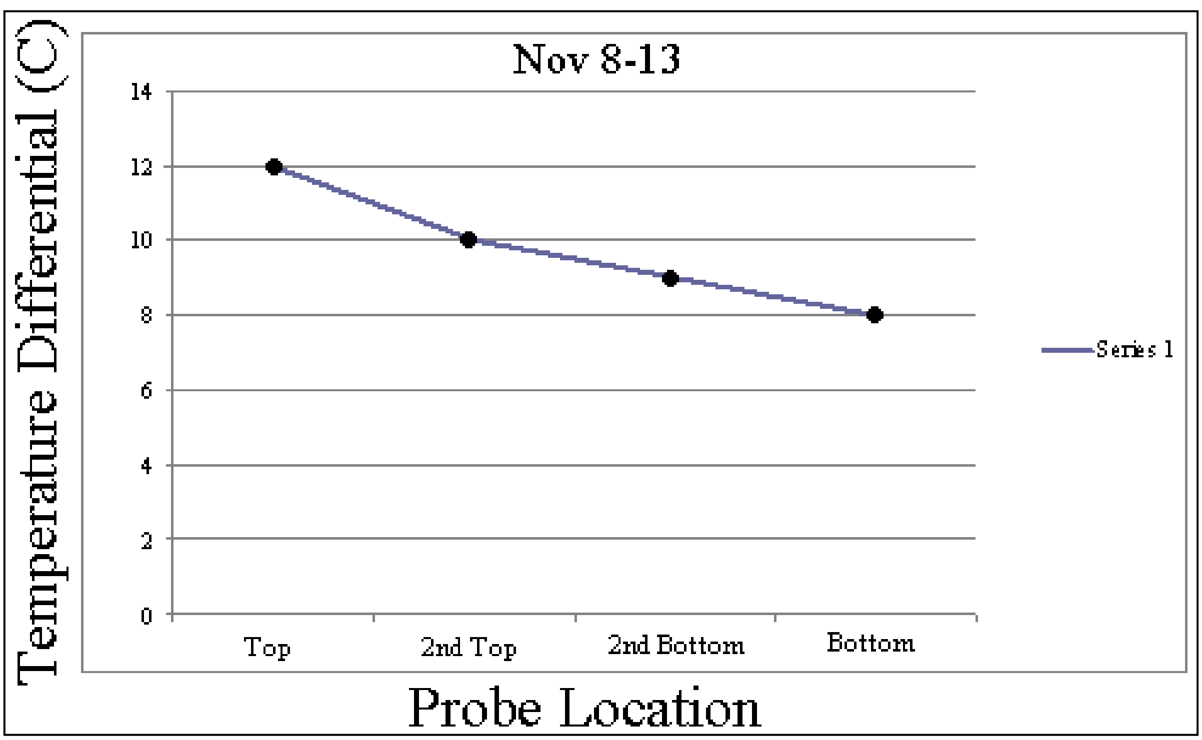


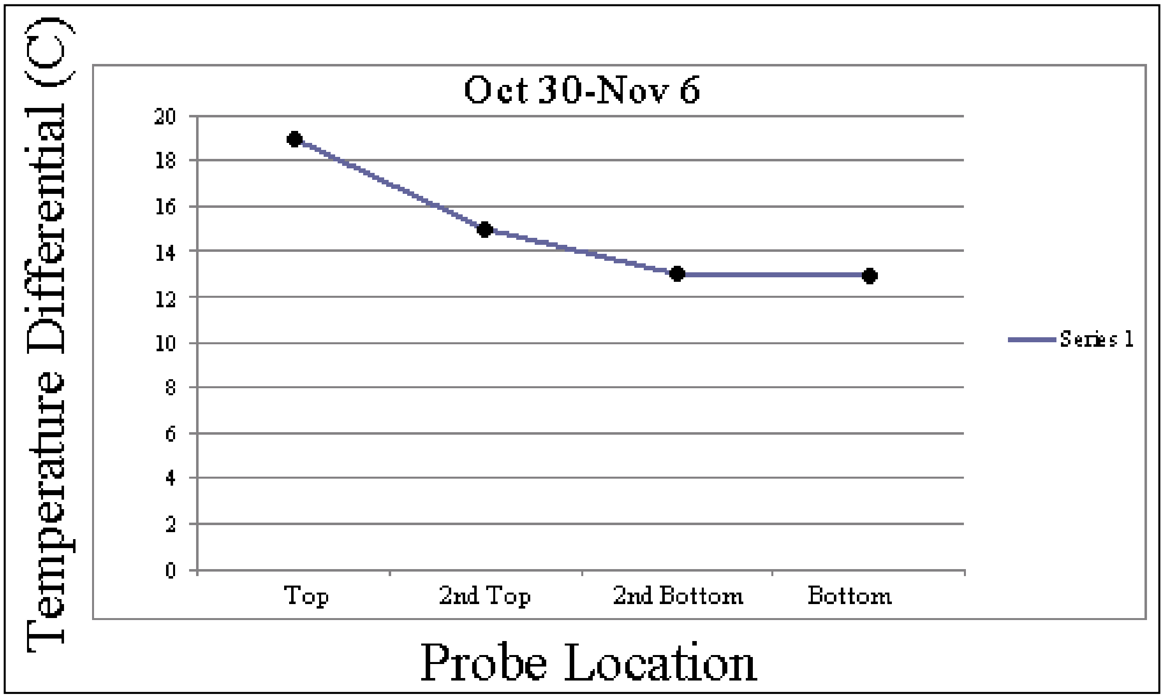

Nov 8-13, 2007
Temperature (C)
Time (hrs)
2nd Top (input)
Bottom
2nd Bottom
Top

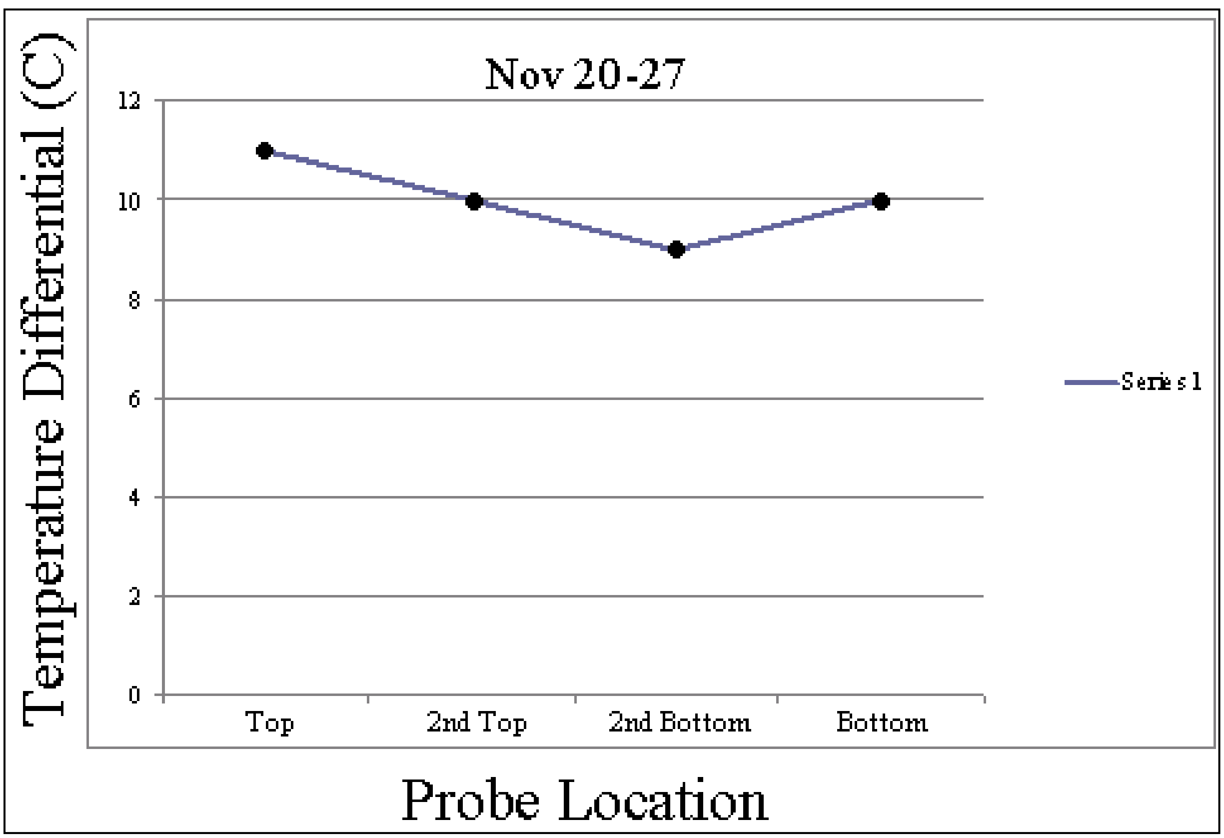

Nov 20-27, 2007
Temperature (C)
Time (hrs)
2nd Top
Bottom
Top (input)
2nd Bottom

Weekly Temperature Differential Graphs

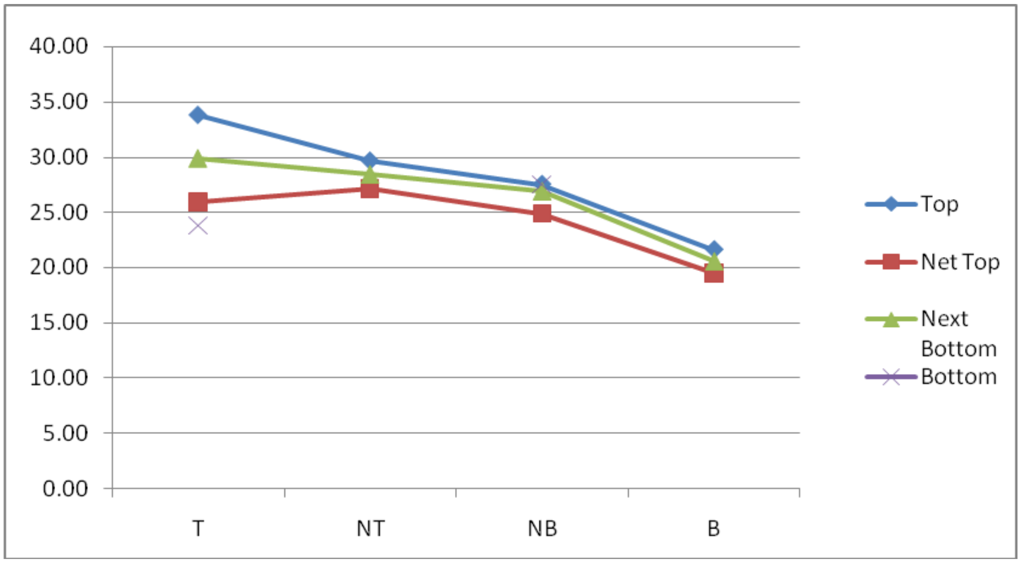




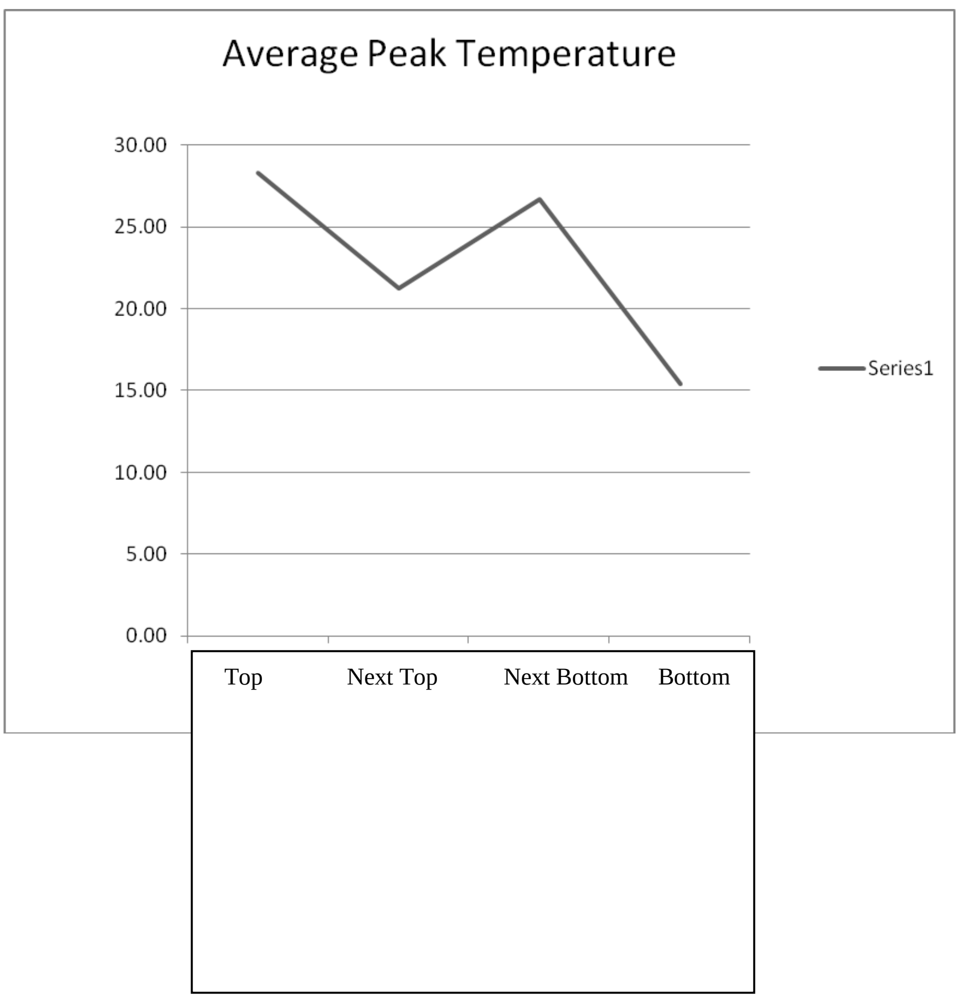

Temperature Differential (C)
Oct 30-Nov 6
20
18
16
14
12
10
8
6
4
2
0
Top
2nd Top
2nd Bottom
Bottom
Series 1
Probe Location


Temperature Differential (C)
Nov 20-27
12
10
8
6
4
2
0
Top
2nd Top
2nd Bottom
Bottom
Series 1
Probe Location

Peak Temperature per Level During Semester



Average Peak Temperature for Semester



Conclusion

The information that we have gathered from the graphs has mostly disproved our hypothesis. Instead of the bottom input producing the most overall heat, it is the second from the bottom input that has achieved this status. This suggests that the upward rise of heat does have some influence over the overall temperature of the water, but it also implies that this is not all-inclusive.

In this case, the bottom input location appears to not have been as effective as the one above it, presumably because of the water having to resist the cold water washing downwards into the output valve on the opposite side of the tank from this position. From the optimum location of being second from the bottom, this gave the water enough room to rise up and heat up the rest of the tank, while also not having to interfere with the downward rush below.

And so, our conclusion: when given a water tank with four entry points for a solar water heater, each at approximately 1/4, 2/4, 3/4 and 4/4 levels on the bucket (measuring from the bottom), it is best to use the 2/4 spot for inputting the heated water.

Recommendations

A final thought worth considering is that the volume of the tank used might also have an effect on optimum input location. If, say, a tank is large enough so that the output and the input valve are far enough apart, the bottom input location may very well be the best place for overall temperature increase, simply because there may be less resistance from downward flowing water in such a situation. This is not something our unique experiment gave us a chance to test, as our water tank was rather small, and it would be interesting to see if a greater girth for a water tank would produce different results.

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