# NOT A DRY SUBJECT: OPTIMIZING WATER TROMBE WALLS


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## ABSTRACT

In this project our group set out to study the optimal water wall thickness of water Trombe walls. We built a controlled environment in which the effects of a heat source on different wall thicknesses (3", 6", 9") could be tested. The environment consisted of three parts: an "exterior" volume containing a heat source, an "interior" volume, and a water wall. The effectiveness of each water wall was measured by turning on a heat source for a predetermined amount of time, then switching it off and monitoring the changes in temperature in the "interior" and "exterior" volumes over time. A time versus temperature graph for each trial showed results that favored the 6" and 9" water wall thicknesses over the 3" water wall thickness.


## 1. INTRODUCTION

Trombe walls are an effective component of passive heating strategies. A Trombe wall consists of a thermal mass, insulated glazing, and an air space. Using direct solar radiation, the thermal mass stores solar gain during the day, then re-radiates the heat into the interior room at night. Although opaque materials such as concrete, adobe, and stone are common thermal masses used in Trombe wall construction, water is also an effective thermal storage device because of its high volumetric heat capacity.

Our interest in water Trombe walls is both scientific and aesthetic. We know that water is a very conductive material and therefore acts as a good thermal mass. It has been used as a thermal mass in many different situations, but information about how much water, what kinds of glass to use, etc. is difficult to come by. Even less information is out there about using water as a mass in a Trombe wall.

Water also has aesthetic benefits. Its translucent properties will allow light to penetrate to the space beyond, and the water itself provides many potential design opportunities. We concluded that before one could effectively design a space using water walls, understanding the optimal thickness would be key.

We adapted the design from a 2008 study conducted by Harlan Justice at the University of Oregon. His work was called "The 'Wet' Window". Justice compared a water wall to a concrete thermal mass, hypothesizing that "the system with the wet window will maintain a one degree Fahrenheit higher interior air temperature than the system with the simplified Trombe wall." The design for our experiment consists of three spaces: one containing a light source, one an empty volume, and one containing water. We based our experimental thicknesses on previous works, including the following: the 2007 MIT Solar Decathlon, which included a water wall using 2.5" thick segments; an article on SolarPowerPanels.ws titled "Trombe Wall for Passive Heating," showing a system using 4" thick water walls; and the Mechanical and Electrical Equipment for Buildings, which states an ideal water wall thickness as 6". Using these three sources as a basis for exploration, we decided to test 3", 6", and 9" thicknesses.

We hope our analysis will provide insight that can inform future designers and builders.

## 2. THE PROBLEM & HYPOTHESIS

Water Trombe walls should be considered a design element, not something to design around or be tacked on at the end of a project. If their properties were better understood, it could be simple to look at a chart and choose the best option available. The problem is that while there is a lot of discussion regarding water as Trombe walls, there are few data, and there are no charts. We propose to add to the data set by exploring the relationship between the thickness of a water wall and the comfort levels it provides. As comfort level is of prime importance we feel that the more consistent an indoor temperature is, the more comfortable an area is. For the purpose of this experiment we will examine the ratio of outside temperature to inside temperature, or "OI", as it is an adequate expression of comfort level in a temperate climate. Our hypothesis is that for each three-inch increase in thickness of a water Trombe wall there will be an increase of .25 OI.

## 3. METHODOLOGY

The system to be explored consists of three parts: an "exterior" space, an "interior" space, and the water wall. Both the interior and exterior spaces are 1 $ft^3$ insulated volumes (1'x1'x1'). The exterior" volume contains the heat source while the interior volume is vacant. The variable to be explored is the thickness of the water wall, so three different thicknesses have been selected. The ratio will be determined by turning on the heat source for a predetermined amount of time, then switching it off, and monitoring the temperature differences from when the light goes on until 19 hours later. (We chose 19 hours because it was the maximum allotment available within our schedules.) Graphing the data for each trial, in a time versus temperature graph, should result in an accurate lag time for each thickness of wall. From these graphs, and from the data points themselves if necessary, we should be able to determine if the OI ratio is greater than .25 higher for each three inch increase in thickness.

### 3.1 Equipment

| Item | Quantity |
|---|---|
| Rigid Insulation | 4' x 8' sheet |
| Glass. Single Paned | 4 panes (24" x 36") |
| Oriented Strand Board | 4' x 8' sheet |
| Silicon-Based Aquarium Caulk | 4 tubes (10 oz. each) |
| 1 ½ Wood Screws | Box of 50 |
| Wood Glue | As needed |
| Halogen Light Bulb, 40W | 1 |
| Data Loggers | 4 |

### 3.2 Methods

Step one: Insulation Preparation

The insulation was first spray-painted with black latex-based paint, then measured and cut to the necessary dimensions. Each segment of the composition must be fully insulated; therefore enough insulation was cut to cover the insides of each OSB box (maintaining a 1'x1'x1' space) and of each of the three water walls. A Japanese razor saw was used for the initial cuts; then a rasp was employed to even out the cuts.

Step Two: "Outdoor" Box

The OSB was fashioned so that a 1'x1'x1' interior space would be maintained, with one wall being a single pane of glass (composing the exterior element of the water Trombe wall), its opposite wall having a 9"x9" access panel (for the heat/light source and data collection), and the other four walls being solid. The insulation was cut precisely to create tightly fitting joints, thereby minimizing infiltration. The insulation was also cut and fitted for the access panel.

Step Three: "Indoor" Box

This box, representing the room space, was also fashioned to the 1'x1'x1' mold. The water wall side of the box was left open, and the other five sides were fully insulated and covered by OSB.

Step Four: Glass Boxes

Each water wall was constructed of glass pieces held together and sealed with aquarium caulk. The caulk was left to cure for 72 hours before continuing. After the caulk cured for 72 hours, water was added to the tanks. The tops were sealed on with more caulk, then wrapped with rigid insulation and OSB.

Step Five: Final Preparations

We used the leftover caulk to seal up any possible points of infiltration. Two data loggers (in case one failed) were put in both the indoor and outdoor boxes, while a fifth was left outside to monitor the climate external to the system. The wall to be tested was sandwiched in between the rooms, and the two joints were sealed with duct tape. The halogen bulb was put in a stable lamp and inserted through the access panel, aimed at the water wall but not touching the data loggers. The access panel was sealed up and the wall system was ready for testing.

*image 1: Completed System With Six Inch Wall*.

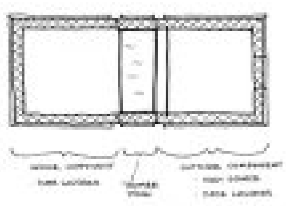


*image 2: Sectional Description of System*.

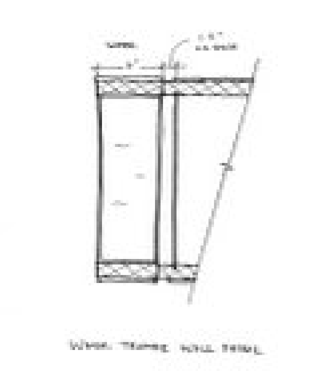


*image 3: Sectional Detail*.

Step Six: Data Collection.

We set the collection interval on the data loggers to six minutes. For each trial, we turned the light on for 5 hours. The data collection extended from the moment the light was turned on through 19 full hours afterward. We started with the six-, and then went to the nine-, and finally the three-inch wall. In between each trial the duct tape was reapplied.

Step Seven: Repeat.

We repeated step six to see if our results were consistent.

## 4. RESULTS

These figures are an average of the data from the two trials. Complete data can be found at the end of this report.

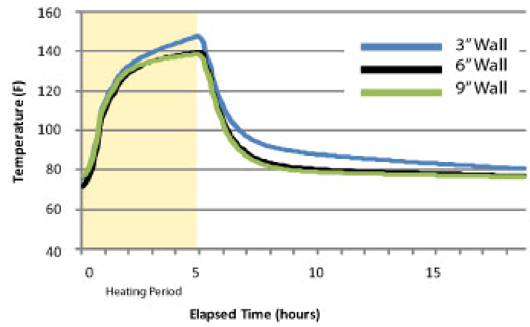



*figure 1: External Volume. Average temperature (in °F) over elapsed time (in hours) curve, as measured by HOBO data loggers, of the heating and cooling periods of the 'external' side of the water Trombe wall system.*

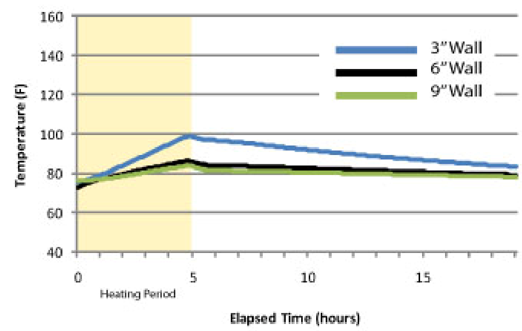



*figure 2: Internal Volume. Average temperature (in °F) over elapsed time (in hours) curve, as measured by HOBO data loggers, of the heating and cooling periods of the 'internal' side of the water Trombe wall system.*

## 5. DISCUSSION

Our hypothesis--that for each three inch increase in thickness of a water Trombe wall there will be an increase of .25 OI--was not supported by our data. A graph of OI versus Elapsed Time (*figure 3*) shows that the difference between any two walls was never greater than ~.02, when the light was turned off. Several interesting things can still be interpreted from the data. Although it was not the direct linear relationship that we hypothesized, it is evident that the three-inch wall did not regulate the temperature as well as its thicker counterparts. The temperature of the water within the three-inch wall increased at a much greater rate than that of the six- and nine- inch walls. This is demonstrated by the fact that the slope of the temperature over time curve (*fig. 2*) for the three-inch water wall was much greater than that of the six- and nine-inch walls. The three-inch wall also allowed a greater amount of heat to penetrate the indoor room at a greater rate than the other two rooms. Once the heat source was removed, the temperature of that indoor room also fell at a greater rate, indicating that it is simply a less effective Trombe wall. This less effective Trombe wall would allow for greater variation in room temperature, which would probably create a less comfortable environment. The slopes of the temperature over time curve (*fig. 2*) for the six- and nine-inch water walls, though distinct from each other, were both very flat in comparison to the three-inch wall curve. From this we can infer that they had a much longer lag times than the thinner wall and seemed to store and radiate the heat much more effectively.

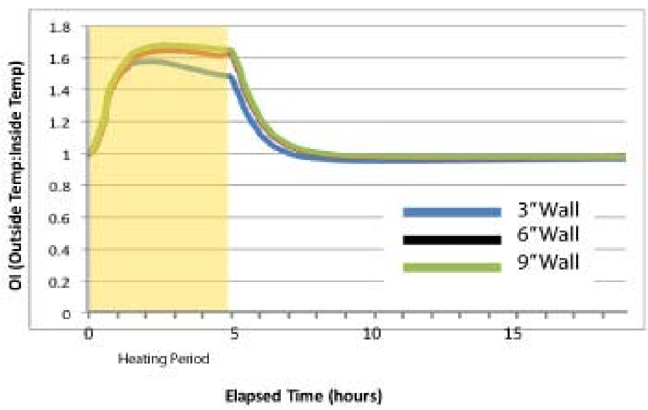



*figure 3: Ratio of Outside temperature to Inside Temperature. Representing the OI versus the elapsed time (in hours), of the heating and cooling periods of the water Trombe wall system.*

Another notable observation about the curves in figures 1 and 2 is their atypical shape. Forty-five minutes after the light turned off, the exterior side has a typical 1/x curve and the "indoor" side expresses a linear relationship. However, during that 45-minute period the heat source seems to have kind of a plateau-drop off effect mirrored by the indoor side, but the indoor side is much less precipitous.

All three lines have linear slopes, and after 12 hours of cooling they still don't intersect. If they had intersected, it would have meant that one of the thicker walls was warmer than one of its thinner counterparts, which might have supported our hypothesis. Extrapolating the data, it looks like the six-inch and nine-inch walls would cross at about 15 hours post-radiation, and the three-inch wall would cross the nine-inch at about 26 hours post-radiation. Most importantly, the shapes of all three graphs were so similar that lag-time differences were observed as insignificant.

## 6. CONCLUSIONS

Our data do not support our hypothesis. There is a correlation between water Trombe wall thickness and a ratio of outdoor to indoor temperature, but that ratio is not linear, and does not increases .25 per three inches of wall thickness.

The thinner water Trombe wall allowed the "indoor room" to increase temperature at a faster rate, reach higher overall temperatures, and maintained high temperatures for a greater length of time than the thicker (six- and nine- inch) walls. Similar trends were noticed between the six-inch and nine-inch water Trombe walls: the six inch water Trombe wall allowed the "indoor room" to increase temperature at a faster rate, reach higher overall temperatures, and maintained high temperatures for a greater length of time than the nine inch wall. However, the temperature difference between the exterior volumes associated with the six and nine inch walls was minimal. A greater amount of heat transfer appears to have occurred through the three-inch wall than through than the six- and nine- inch walls.

## 7. LESSONS LEARNED

In the future we might consider lengthening the test period and more accurately simulating day-night differences. If the heat cycle was started begun again before the interior temperature dropped near its base line, a more steady, realistic interior climate might be achieved. However, the temperature in the exterior space continues to rise until the heat source is removed. Our hypothesis or our methods (or both) would have to be modified to account for this.

More research might be done on the thicknesses of walls between three and six inches to see if there is a critical mass of water at which the results significantly shift. It would also be interesting to study the effect of differing qualities of heat on the six-inch and nine-inch thicknesses.

Under these conditions it appears that a water Trombe wall, to be effective, must be at least greater than three inches in thickness. Also, it seems redundant for the thickness to be greater than 6"six inches. It would be useful to explore thicknesses between 3" and 6".

## 8. REFERENCES


1. Justice, Harlan et al. “The Wet Window”. University of Oregon, 2008.

2. Stein, Benjamin et al. Mechanical and Electrical Equipment for Buildings, 10th ed. John Wiley & Sons, Hoboken, NJ:2006

3. “Solar Wall (or Trombe Wall).” Build it Solar, the renewable energy site for do-it-yourselfers. Gary 05/14/2006. February, 9 2009. http://www.builditsolar.com/Projects/SpaceHeating/SolarWall/SolarWall.htm.

4.  “Trombe Wall.”  Energy Efficient Building Technologies.  February 9, 2009. http://www.eebt.org/Trombe.html.

5.“Trombe Wall for Passive Heating.”  2009.  February 9, 2009.  http://solarpowerpanels.ws/solar-power/trombe-wall-for-passive-solar-heating.

6.“Water Tubes.”  Solar Space Heating.  Kachadorian, James. 1997.  February 9, 2009. http://images.google.com/imgres?imgurl=http://www.westernsolarinc.com/Water%2520tubes.jpg&imgrefurl=http://www.westernsolarinc.com/prod03.htm&usg

APPENDIX

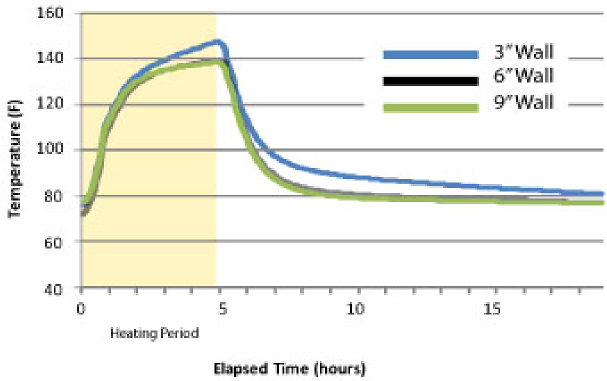



*figure 4: External Volume, Trial One. Temperature (in °F) over elapsed time (in hours) curve, as measured by HOBO data loggers, of the heating and cooling periods of the 'internal' side of the water Trombe wall system.*

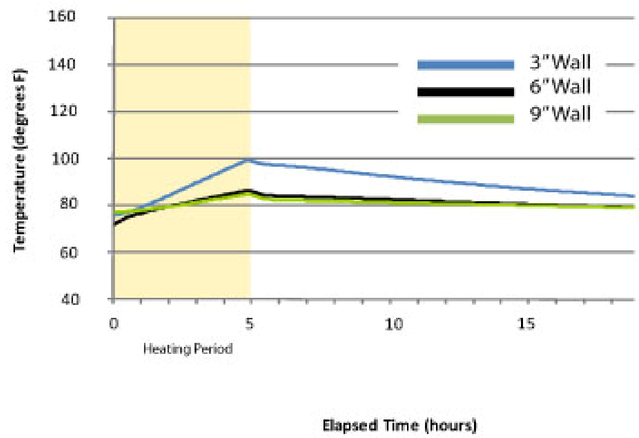



*figure 6: Internal Volume, Trial One. Temperature (in °F) over elapsed time (in hours) curve, as measured by HOBO data loggers, of the heating and cooling periods of the 'internal' side of the water Trombe wall system.*

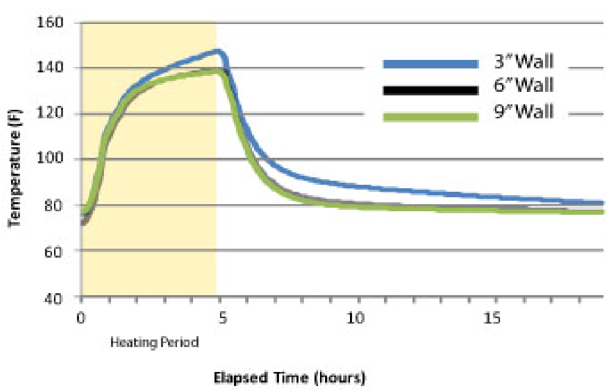



*figure 5: External Volume, Trial Two. Temperature (in °F) over elapsed time (in hours) curve, as measured by HOBO data loggers, of the heating and cooling periods of the 'internal' side of the water Trombe wall system.*

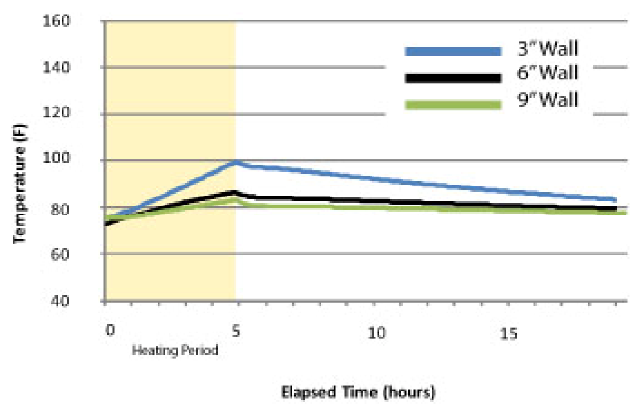
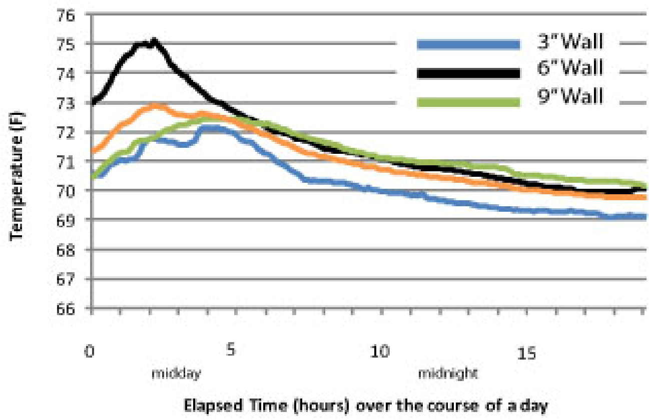



*figure 7: Internal Volume, Trial Two. Temperature (in °F) over elapsed time (in hours) curve, as measured by HOBO data loggers, of the heating and cooling periods of the 'internal' side of the water Trombe wall system.*




*<u>figure 8: Temperature Outside of System</u>. Temperature (in ℉) over elapsed time (in hours) curve, as measured by HOBO data loggers outside of the water Trombe wall system.*