

Glazing Peanuts

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ABSTRACT

In our consumer society the ultimate and most lasting product is, without a doubt, the landfill. We produce massive amounts of materials and products that have a functional lifespan of a month or a year and then discard them as waste to decompose for hundreds or thousands of years. Our goal is to discover which materials can be reused so that such destructive cycles can be slowed or even reversed. Responding also to the inefficiency of buildings, we have honed in on Styrofoam. We believe that this material, which is otherwise thrown away, can be used to add insulative value to double pane windows. During the night, especially hot days, or whenever views are not desired, Styrofoam peanuts would drop from within storage units in the walls to fill the gap between the panes of glass to add extra insulation. We plan to test our theory by using a hotbox to determine the R-values of window sections with and without the Styrofoam filler. If we are successful, then we will have discovered a positive use for a destructive product.

1. INTRODUCTION

The evolution of the machine gave the human population tremendous power. The machine simultaneously eased our labor and gave us new forms of material that enhance our relaxation. Almost everything we own has been a gift of the machine, and in return, we have given the machine our loyalty. It would be foolish to deny modern societies absolute dependence on the machine, and backwards to aspire to the rustic ideal of a lifestyle without it.

Combined with human intelligence, the machine can produce massive quantities of designed chemicals. The

production of harmful chemicals at the beginning of the industrial revolution can be justified only by ignorance. However, now that we can see that many of these synthetic materials do not support life, their production has no justification.

So far, we have used the machine to support the linear production of materials. The line begins at natural resources and ends with synthetic materials in an isolated landfill. If the human race is to prosper from the wealth of the earth, then this linear mode of production must be redirected and transformed into a cyclical system. This implies that every synthetic material that we use must be able to be recycled indefinitely, without producing other harmful chemicals in the recycling process. This task is enormously difficult, but must be our prerogative if we value the continuity of our species, and the variety of life on earth. One part of this task is to repurpose single-use materials that are known to be harmful to life cycles.

Expanded polystyrene, commonly known as "Styrofoam," is one of the major forms of plastic waste that has resulted from our haphazard industrial lifestyle. This oil-based plastic takes an estimated 400 years to even begin to biodegrade, and when it does, it degrades into multiple carcinogens that are known to be harmful. Currently, it is not economical to recycle this material so most expanded polystyrene is put into landfills or is blown into the ocean.

Although expanded polystyrene has negative environmental consequences, it also has qualities that make it a valuable resource. Because of its insulating qualities and its resistance to decomposition, the use of ridged insulation boards made out of expanded polystyrene for insulating walls is popular among architects and contractors. However, because the

methods of producing expanded polystyrene propagates carcinogenic byproducts, and we know that harmless alternatives exist, the use of polystyrene must be discontinued.

So the question becomes: What do we do with the polystyrene foam we have? Biodegrading polystyrene produces carcinogens that are harmful to many species of life, including humans, so we can't mix it into the natural systems of the earth. We have to come up with new ways to reuse it. The idea of using recycled polystyrene for insulation isn't unheard of in architecture, but it's definitely not a popular idea. We think it should be! You kill two birds with one stone; you reduce the heat loss and resultant energy consumption of your building, and prevent the contamination of our earth and natural resources.

In order to motivate designers to recycle this toxic material we need to think of aesthetically pleasing solutions. What could be a better way to show off a new sustainable design than to put it in a window? After all, windows are the most significant weakness in a building's thermal envelope. What if you could install a vacuum system that filled your windows at night, and emptied them on sunny days? We want to test the viability of a system like this. We'd like to prove that it works, and we might even get designers to start thinking creatively about how this method can be implemented in future buildings. By providing sound data for designers, we hope that this small idea may have the sort of impact that will help guide us on our still smoggy path to a more sustainable planet.

2. THE PROBLEM & HYPOTHESIS

Windows are often the largest source of heat loss during cold nights, when the warmth from within the house is lost through the panes to the cold outdoors. Even double paned windows cannot prevent a majority of this heat from being lost. Insulating specific types of double paned windows during the night that can protect this heat from escaping, but can also be converted back into a standard see through window, would greatly decrease the amount of heat lost during the night while not interfering with the aesthetic value of the window during the day.

When the 3" gap between the panes of a 10" by 12" double pane window is filled with recycled expanded polystyrene packing peanuts, that window's resistance to heat flow will increase by more than 8 h ft² F / Btu.

3. METHODOLOGY & EQUIPMENT

Materials:

- One sheet of plywood
- Two ¼" dowels to construct the hotbox without the use of nails because of their ability to serve as thermal bridges
- Two pieces of 10" x 12" glass
- Enough rigid insulation to completely cover the interior of the hotbox 2" thick
- One 100 watt light bulb
- One extension cord
- Enough recycled Styrofoam peanuts to fill the 3" gap between the two sheets of glass
- Enough rigid insulation to fit between the 3" gap of glass and provide a known R-value
- 3 HOBOS to collect data from within both chambers of the hotbox as well as monitor the outside control temperature

Process

We first need to build a hotbox out of plywood with interior dimensions of 11" x 13" x 24", three separate interior chambers, and removable pieces as diagrammed in Fig. 1. The interior of the box must then be covered completely with the rigid insulation, and a place for the heat lamp and extension cord must be accounted for and mounted onto one side of the box. Two chambers must now be created by dividing the 24" length to two 10.5" sections with a 3" middle area enclosed by the two sheets of glass. The glass must be fitted securely into the insulation and sealed with an airtight sealant so as to prevent infiltration as best as possible. The hotbox is now constructed and ready for testing, as seen in Fig. 2.

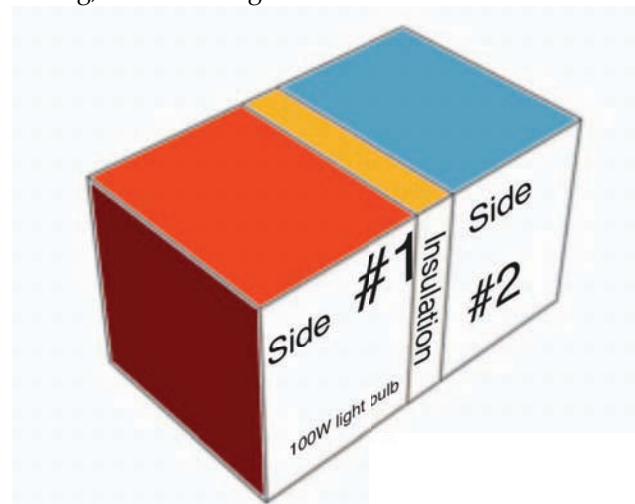


Fig. 1: Diagram of the hotbox used for testing.

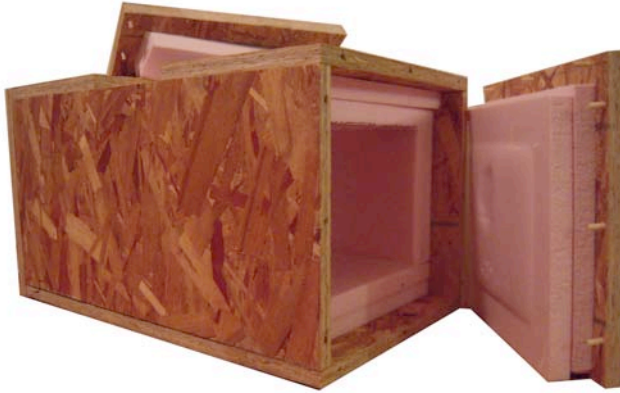


Fig. 2: Photo of the finished hotbox with side #2 and the lid above the 'window' open.

To begin testing:

- Place HOBOS in both chambers of the hotbox at the inner left corner, as well as a third HOBO in the same room but away from the hotbox to keep a control record of the surrounding temperature
- Turn the devices on to begin collecting data
- Secure the lid and sides of the hotbox as quickly and securely as possible
- Collect data for 5 minutes to get a control temperature of the interior of the box
- Turn the lamp on
- Collect data for 10 minutes with the lamp on
- Turn the lamp off
- Collect data for an additional 20 minutes as the hotbox cools
- Open all chambers of the box and read out the HOBO loggers
- Leave all three of the chambers open until the interior of the box, as well as the insulation, returns to room temperature

Repeat the testing process 3 times to gather multiple sessions of data that can be used to rule out fluke test results and to find strong averages of measurements. This is the control data that will be used to compare to the data gathered from testing the glass with the Styrofoam peanuts in place.

- Remove the lid of the hotbox
- Compactly fit recycled Styrofoam peanuts into the 3" space between the panes of glass

Repeat the testing process 3 times under the same conditions as the first, now with the Styrofoam peanuts in place, in order to gather the data that is most important to this case study. Once finished:

- Remove the lid of the hotbox

- Remove all of the Styrofoam peanuts from the space between the panes of glass
- Place two pieces of rigid foam insulation between the glass (totaling R – 7.8)

Repeat the testing process another 3 times so that there will be known R-value results to compare our unknown Styrofoam peanuts to.

Once all testing sessions are complete, the changes in temperature within the hotbox when the "window" is empty, when it is filled with recycled Styrofoam peanuts, and when it is filled with a known R-value insulation, can be compared and a conclusion as to whether or not the Styrofoam made an impact, or how great an impact, can be drawn.

4. RESULTS

4.1 Change in Temperature: Side #2 of Hotbox Uninsulated (airspace)

In these first tests the hotbox was run with no insulation. These three tests show clearly in Fig. 3 that with no insulation, there is a dramatic increase in temperature on the side opposite the lamp (side #2) with little to no lag time. Without insulation, the glass, airspace, and air films have a combined R-value of 4.4. One factor that may be amplifying the increase in temperature is the light absorbed by the insulation of the side opposite the lamp. Some of the light must be absorbed and radiated out as heat.

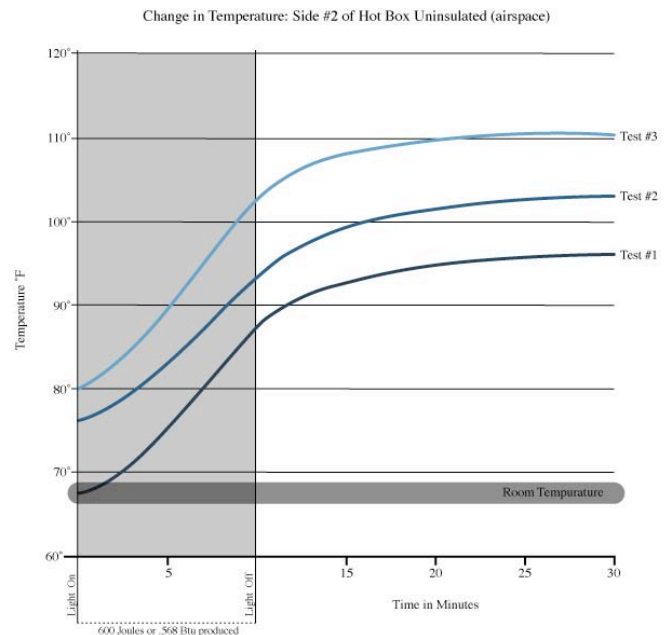


Fig. 3: Test results with no insulation between glass.

4.2 Change in Temperature: Side #2 of Hotbox Insulated with Packing Peanuts

Filling the 3" gap between the glass panes of the hotbox with packing peanuts reduced heat loss dramatically. Without the peanuts the change in temperature was around 28° F. With them, the change in temperature was reduced to just 5° F. Also, there appeared an apparent lag in heat flow. Side #2 lost heat until after about 5 minutes when it reached equilibrium, visible in Fig. 4, then started to gain heat. Because the insulative peanuts resisted the heat flow so effectively, side #1 heats up much more quickly than it did during tests without any insulation between the glass panes.

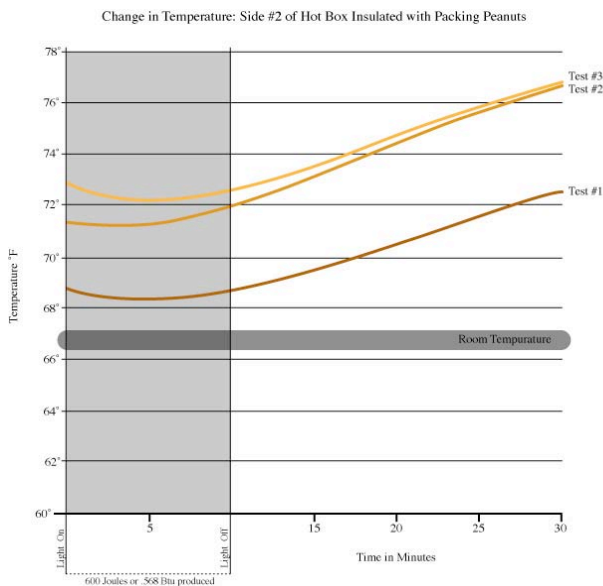


Fig. 4: Test results with packing peanuts between the glass.

4.3 Change in Temperature: Side #2 of Hotbox Insulated with Ridged Insulation

The packing peanuts seemed to work very effectively, but they could not match the effectiveness of 2 sheets of ridged insulation (R-7.8 total). With the ridged insulation, the temperature rose only 1.8° F on average within the 30 minutes of testing. The time lag was about 3 times that of the packing peanuts, taking around 15 minutes for side #2 of the hotbox to reach equilibrium and to start taking on heat.

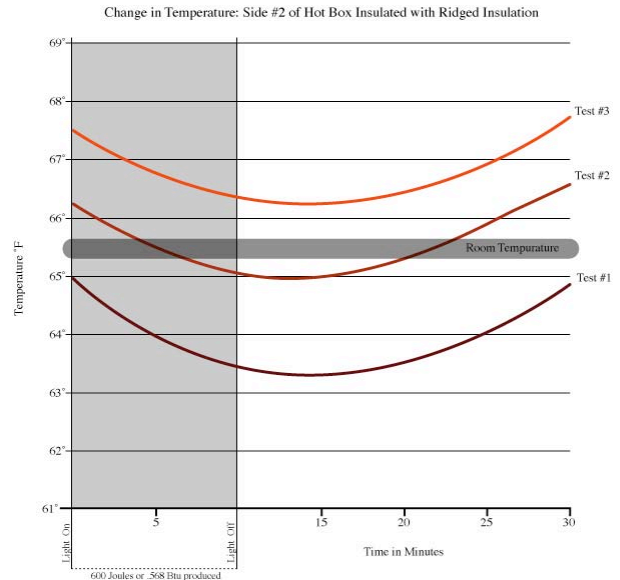


Fig. 5: Test results with rigid insulation between the glass.

4.4 Mean Change in Temperature: Side #2 of Hotbox

Fig. 6 shows the change in temperature as a function of time, demonstrating the average heat flow. Without insulation, side #2 heats up steadily while the light is on, but heat gain immediately decelerates when the light is turned off. When the airspace is filled with packing peanuts however, the temperature hardly increases while the light is on, and heat gain slowly accelerates after the light is turned off. This lagging effect is even more dramatically illustrated by the ridged insulation. Side #2 doesn't even reach equilibrium of heat loss and heat gain until 3-5 minutes after the light is turned off.

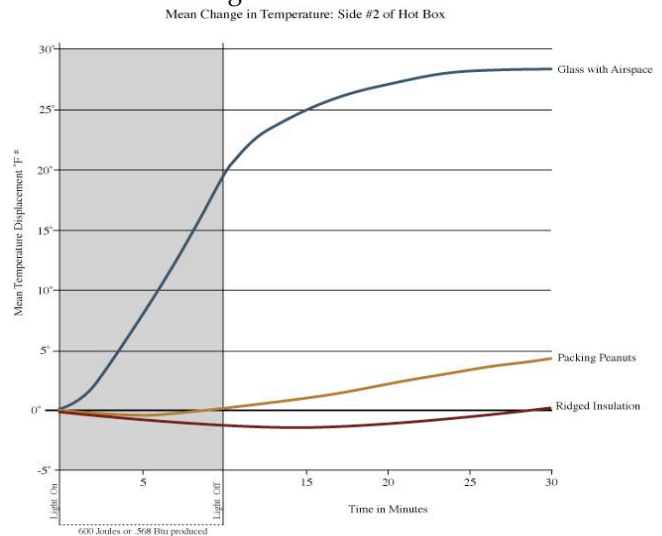


Fig. 6: Average temperatures of all three test results, where 0° represents the initial temperature on side #2 of the hotbox.

5. CRITIQUE AND ANALYSIS

5.1 Critiquing the Methodology

Our experiment was simple and consisted of few variables. We desired to test only the insulative value of a specific material and so it was easy to control for this variable. We needed simply to create a controlled environment in which we would test our material, a known material, and a void to then compare the results. As a control throughout the series of tests, we measured the room temperature outside of the hotbox and found that the variation in temperature was no more than four degrees between any two tests and that in most tests the temperature varied by within a half degree. The variation of external temperature relative to the insulative value of the hotbox was slight enough to ignore.

The most significant confound in our experiment, we believe, was the time frame that we had given to each test. We have observed that any test following another test of the same material would start and end with a higher temperature. Our theory for this slight discrepancy is that we had not given the hotbox enough time to reach an equilibrium state. There must have been excess heat from the previous tests that has affected the results of the following tests. Regardless, the curve of our graphs remained relatively consistent; suggesting that the environment we created was well isolated from unpredictable forces that would skew the data.

Another slight confound, however, was that the heat lamp used in our preliminary tests had melted a small amount of material in the center of the section, thus creating a gap which would allow heat to flow more easily into the other side of the box. Because of this, we switched out the 250-watt heat lamp for a 100-watt standard light bulb to make the environment less extreme and hopefully our results more reliable. In a real life situation, such direct radiation and extreme temperatures would not be likely so these failures are of little significance to the potential real world application of our study. Aside from the problems we had faced with the short time frame and the extreme temperature, the experiment ran quite smoothly and there were no other observable factors that would have had a significant impact on our results.

5.2 Analysis of the Empty Glass Test

The graphs displaying the results from the empty glass test are about what would be expected. As soon as the light is turned on, the temperature begins to increase and accelerates slightly at the beginning but

levels off into a steady rate. As soon as the light is turned off, the temperature continues to increase but does so at a decreased rate which becomes slower and slower. What is most likely accountable for the continued increase after the light is turned off is the uneven distribution of energy, with a higher amount located near the bulb and less near the data loggers. As the heat from the bulb flows toward the areas with less energy, the sensors read an increase even though the total amount of energy remains constant. At about eight minutes after the light is turned off, the temperature on the lamp side begins to decrease while the temperature on the other side continues to increase. The temperature on the lamp side remains higher than the temperature on the other side but begins to converge after the light is turned off. When there is no net increase in energy, the hotbox has a chance to come to equilibrium. The empty space between the planes had a calculated R-value of about 4.4 and did provide some resistance to heat flow.

5.4 Analysis of the Packing Peanuts

The graphs of the packing peanuts looked quite similar to those of the rigid insulation. The major difference was the point at which the temperature transitioned from a decrease in temperature to an increase in temperature. Where it had taken about fifteen minutes for the insulation to transition from a decrease to an increase, it had only taken the packing peanuts about five.

Another difference was the amount of illumination that the peanuts allowed through to the other side. Where the rigid insulation allowed absolutely no illumination, the peanuts did allow some light to pass through, demonstrated in Fig. 7. Though the thermal factor is impaired, this may provide designers with an aesthetic advantage. As was stated earlier, the heat lamp melted a small amount of material. If the temperature was more similar to real life conditions, this gap may not have occurred and the results may have shown higher insulative efficiency.

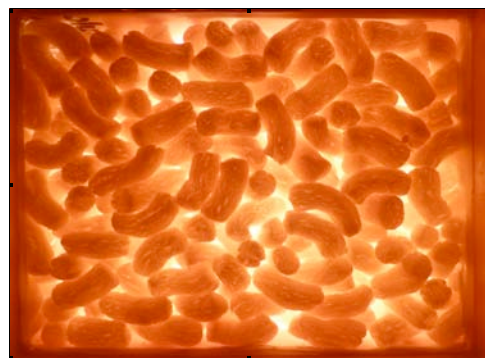


Fig. 7: Side #2 of the hotbox when the light in side #1 is turned on, illuminating the packing peanuts.

5.3 Analysis of the Tested Insulation

Our graphs for the rigid insulation had a surprising curve. The temperature in the far side of the box began with a descending curve and continued throughout the duration that the light was turned on and even several minutes after the light was turned off. Eventually the temperature did increase, but the initial and continued decrease in temperature was not expected. This does however confirm the suspicion that there was excess heat from previous tests that had yet to leave the box. Even after airing out the box for several minutes before the test, the insulation must have had more energy than the air within the box and had reemitted this heat after we sealed the volume. After the insulation and the volume of air had reached equilibrium, the heat could only then escape to the colder exterior on the five sides of the volume not including the glass and insulation. The five sides that were then losing heat must have outweighed the heat coming in from the glass and insulation, which at the beginning would have been very little, as the two volumes of the box began in equilibrium.

5.5 Analysis of the Variations between Materials

As our method of approximating the unknown R-value of the packing peanuts, we used a scale to compare the known values of the rigid insulation and the empty glass. The rigid insulation was calculated to be 7.8 and the empty glass about 4.4. The value of the packing peanuts fell between the two values but was much closer to the rigid insulation than to the glass. Thus, by a simple comparison of the graphs we would approximate the R-value to be about 7. We noticed that the packing peanuts transitioned between its decrease and increase of temperature much faster than the rigid insulation, but what we also noticed was that after the transition had occurred, the two materials had allowed for a similar rate in the increase of temperature on the far side of the box.

The actual R-value of the peanuts might be more similar to the rigid insulation than our graphs show, but the air between them and the light that they let through might account for the earlier transition in heat gain. In general, the light allowed through for each test may have had a significant impact on the results of the study. R-value is independent of light and the emissivity of our materials and the radiation from the bulb may have had a significant impact on our experiment. It would be interesting to see what would happen if we had shielded all light in at least one test for each material. In sum, we have found that the packing peanuts do have a substantial insulative value, but it is not quite as high as we had originally hoped.

6. CONCLUSIONS

Our insulated double paned window performed very well compared to a standard double paned window. We did not, however, manage to prove our hypothesis correct. The goal R-value for our window system was R-8, better than the rigid insulation that was used as a comparative test. Unfortunately, the system fell just shy of the goal, achieving about an R-7 rating. This is still a significant improvement from a standard window system, and is also a very conceivable system.

Recycled Styrofoam peanuts are available in large quantities and often free of charge or very inexpensive. They are lightweight, so a mechanism to move them in and out from between the panes of glass would require little effort and energy, and will serve as extra insulation within the walls when they are stored out of sight when the window is in use. Uses of the insulation can also be easily reversed during hot weather. The Styrofoam can be lowered during the day to keep out the hot outdoor weather while also keeping the cool air indoors contained. Our proposed system would greatly reduce the energy uses of buildings with minimal effort or expensive modifications, and needs to find its way into conventional construction methods to help decrease our environmental impact on the world.

7. ACKNOWLEDGMENTS

Thank you Adrian Ho for helping us uncover the mystery of unknown R-Values.

Thanks to Patrick Moran and Alex Johnson for enduring countless hours of melted Styrofoam-induced states of mind.

8. REFERENCES

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