Description of the Problem

The insulation in the solar box cookers plays a vital role in performance. The current insulation technique involves using wood shavings in the gaps in the wall and in the bottom of the box cooker. This is done to reduce the convective heat transfer in the walls and floor of the oven. While this is the currently practiced technique for insulation, it is a known fact that the box ovens perform better during their first year of operation than in the years after. One of the theories associated with the diminished performance of the ovens over time is that the constant heat flow through the walls causes the insulation to settle to the bottom, and at that point the insulation would no longer be preventing convective heat transfer in the upper regions of the wall. And with an expected life of 10-12 years, diminished operation after the first year is something that needs to be analyzed. The motivation for this experiment is to essentially prove or disprove theories on the insulation in the box cookers and to improve the design in the most effective and economical way possible. A subteam consisting of Harrison Ko, Drew Hart, Abby Sterle, and Leif Paulson was formed following our trip to Nicaragua in order to begin work on this problem.

Experimental Setup

The idea of the insulation test is to isolate heat transfer through a single wall of a solar oven. Figure 5 depicts an insulated box with some sort of heat source on the inside. The heat inside the box will travel the path of least resistance, and with the other five faces of the box insulated it can be assumed that the majority of heat transfer is going through the experimental wall.

The experimental wall will be built to mimic the walls of a conventional solar oven. The main difference would be the interchangeable interior of the wall. The typical solar oven wall consists of a pine frame with insulation to fill in the hollow space. The experimental wall of this setup will be built the exact same way with the only exception of being able to change the insulation for different tests. This is done to be able to get the most relevant data from the setup.

The insulated box is designed to have the five non-experimental faces have a thermal resistivity far greater than that of the experimental wall. In the case of this experiment, the thermal resistivity is assumed to be similar to that of air. The faces of the experimental box were decided to be...
approximately ten times the thermal resistivity, to ensure that heat will most likely travel through the experimental wall. The high thermal resistance of the insulated walls is very easy to achieve since thermal resistance in series is additive. This allows for the insulated walls to simply be extra thick to increase the thermal resistance.

The experiment will be conducted to obtain the most relevant information possible. The plan is to measure temperature of the inside air, the outside air, and on many locations on the wall. The idea of is to obtain simple data from the air temperature measurements, as well as to obtain a heat gradient from the measurements through the wall.

The two basic factors of how well the solar oven is insulated can be described by two characteristics: the time it takes the oven to heat up to cooking temperature and how well the oven retains the heat. Therefore, the plan is to heat up the inside air of the box until it reaches a typical cooking temperature for the solar box cookers (~300F) and then immediately shut off the heat source. At this point, the time it takes for the inside air to become equal with the outside air can also be measured. These measurements can provide practical characteristics of different types of wall designs and insulation materials.

Initially, the goal of this experimental idea was to be able to obtain an R-value for the experimental wall. After further research however, it was determined that obtaining an official R-value was rather arbitrary, and that as long as the data can be characterized in a logical and scientifically sound manner it can still be applied practically.

**Construction**

Our goal in construction is to make a box apparatus which has five highly insulated sides and a sixth side which is easy to change and manipulate so that a variety of insulation types can be tested. Ideally, the apparatus would mimic the performance of one of the real box ovens in terms of the relevant mechanisms for heat transfer out of the box, so we are using one of the old 30in x 30in box cookers as an internal frame and template. We have available sheets of mineral wool insulation, which is heat resistant and has an R-value around 3.1 which is heat resistant and has an R-value around 3.1 ft²/ hr/Btu. Using three inches of mineral wool on each side gives an R-value contribution of approximately 10. Due to the rough and comparative nature of our calculations, this value need not and cannot be very precise.

We also have sheets of scrap plywood which will serve as an external frame. Our simple construction will consist of the box oven internal frame without the door, surrounded on five sides by three inches of mineral wool and plywood walls to hold it together. The plywood will be held together with L-clamps, and the construction does not need to be precise except that there can be no gaps in the insulation. The final side, which replaces the door of the oven, will be constructed nearly identically to an ordinary box oven wall, except that it must be easy to disassemble to change out the insulation, so we will not use silicone as a sealant. The removable wall will be attached in some way which makes it easy to repeatedly take off and put back on with a tight seal.

Next semester the team will look for an appropriate heating element to place inside the apparatus as a heat source. The power cord for the
heating element and the thermocouple wires will be put through one of the back corners of the insulated box with minimal heat loss.

Future Goals

Since no experiments have actually been run, the future goal of the insulation test is to get the apparatus ready for experimentation and to run experiments. Ideally, the experiment should be set up with computer software that can automate the experiment to obtain consistent results. That software, combined with the finished construction of the experimental wall is currently the most integral factors for the future work of this project.

After the experiment is set up properly, the first tests should be to determine whether the experimental setup is effective or not. This can be done by simply comparing a test with no insulated filling against a test with a much insulated filling (e.g. mineral wool).

Assuming the test works properly, it is important to investigate the problem of the diminishing performance of solar cookers over time. While the theory is that the wood chip filling eventually settles to the bottom of the wall, there is no evidence to support this claim. The first order of business would be to validate the issue with the wood chip insulation.

After validating the problem, solutions should be investigated and tested to determine the most economical and effective solution for the solar box cookers. It is even possible to imagine a completely different wall design arising from this experiment.