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Testing of the Burns-Milwaukee's Sun Oven

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Testing of the Burns-Milwaukee's Sun Oven

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Abstract

A Burns-Milwaukee Sun Oven was tested at Sandia's Solar Thermal Test Facility. It was instrumented with five type K thermocouples to determine warm-up rates when empty and when a pot containing two liters of water was placed inside. It reached inside air temperatures above 160 °C (320°F). It heated two liters of water from room temperature to 80°C, (175°F), in 75 minutes. Observations were also made on the cooling and reheating rates during a cloud passage. The adverse effects of wind on operation of the solar oven was also noted.

The Solar Thermal Design Assistance Center (STDAC) at Sandia National Laboratories evaluated a Sun Oven from Burns-Milwaukee at Sandia's Solar Thermal Test Facility in Albuquerque NM. It was designed for single family household cooking. It is targeting developing countries' alternative energy markets where conventional fuels are not available and wood is the primary fuel used for cooking.

Because of the wide variety and types of solar cookers being manufactured it is very difficult to come up with a number, such as a figure of merit, to indicate how each will operate under various weather conditions. The best way to determine how a solar oven will operate is to test it under real life conditions[1,2]. These tests will not determine if a solar cooker is good or bad. It will, however, indicate the usefulness of the solar cooker for its intended usage.

The purpose of this test was to determine the basic operating characteristics of the Sun Oven solar oven. For this report, only the basic tests of heat up rate and maximum temperature attained when empty and the time to heat room temperature water to 80°C (175°F). Further testing was too elaborate for the scope of this test. The solar oven is sized to cook about a two liter volume of food. Therefore, two liters was chosen as the volume of water to heat in the oven.

The Burns-Milwaukee Sun Oven is a box type solar cooker with multiple external aluminum reflectors. Figure 1 shows a picture of the Sun Oven baking bread. The external reflectors reflect sunlight into the cooker that would have otherwise not have used by the cooker. The reflectors increase the solar collecting area, which enable the oven to obtain higher temperatures because of the increased sunlight entering the cooker. It weighs about 21 lbs., has a fiberglass outer shell, fiberglass insulation, blackened aluminum interior, tempered glass front that also serves as a door, and silicone rubber seal for the glass door. Its dimensions are 19" x 19" with an average depth of 11". This solar oven sells for about $150 new.

To measure the temperature inside the solar oven, five type K (1/16" In600 sheathed) thermocouples were used. They were inserted through holes drilled into the side of the oven. This was done so the door, or window, seal would not be affected. Three of the thermocouples (front, middle, and back) measured the inside air temperature and two (side and middle) measured the water temperature. The front air thermocouple was centered on the front side and inserted one inch into the oven. The back air thermocouple was also centered on the back side inserted one inch into the inside of the oven. The middle air thermocouple was placed in the center of an imaginary line connecting the front and back air thermocouples. The thermocouples used to measure water temperature went through feedthroughs in the side of the pan. This preserved the seal between the lid and pot, which reduced the amount of water vapor escaping and, therefore, condensing on the front window. One measured the water temperature close to the side of the pot and the second measured the water temperature at the center. When the water was not present, these two thermocouples measured the air temperature on either side of the middle air thermocouple perpendicular to the imaginary line connecting the front and back thermocouples. The temperatures inside the solar ovens, outside air temperature, wind speed, wind direction, and direct normal insulation (DNI) were measured and stored by a computer data acquisition system every thirty seconds.

Initial testing characterized heat up rate, the highest temperature reached, the temperature profile, and how long the solar cooker can remain in one position before it needs to be turned back into the sun. Figure 2 shows the normal heat up rate for the oven. The Sun Oven will stabilize in temperature in about 50 minutes. The peak temperature was about 170°C (340°F). The oven needed to be repositioned approximately every hour to maintain optimum temperatures. For the remainder of the testing period it was repositioned every 30 minutes.

Later tests determined the ability of the solar oven to heat up water. A black ceramic coated covered pot filled with two liters of water was used. The oven was preheated for about one hour before the pot filled with water was placed inside. The water and pot were at room temperature before being placed into the oven. Figure 3 shows the results from this test. It heated the water to 80°C (175°F) in less than 75 minutes. The water temperature would reach nearly 100°C (212°F) and would be boiling in the pan. There was enough water vapor escaping from the pan to cover a significant portion of the window with condensation, which limited the operation of the solar oven.

The temperature distribution inside the Sun Oven during testing is shown in figure 4. There was very little difference between thermocouples. The shape of the oven puts all of the thermocouples about equidistant from the window, its seal, and the bottom of the oven. This lends itself to very good temperature uniformity inside the oven.

Wind always has an adverse effect on the performance of solar ovens. Figure 5 shows the inside air temperatures are depressed during high winds and increase during lower wind periods. With the lowered inside air temperature it took longer to heat the water to 80°C (175°F). The figure also shows when the wind reached 14 m/s (31 MPH) the Sun Oven tipped over. Having external reflectors makes it more vulnerable to tipping over in the wind. The fact the oven did tip over should not be of great concern since under normal circumstances a cook would be present and would employ some means to prevent it from tipping over.

The likelihood of it tipping over is determined not only by its speed but also its orientation to the solar oven. The solar oven works best when it follows the sun, so its orientation changes throughout the day. It is very common for the wind to change directions and be gusting throughout the day. It is, therefore, best to assume the wind could tip the oven over and buttress it somehow.

Clouds also have an adverse effect on the performance of the solar oven. Figure 6 shows the effect of several cloud passages on the measured inside air temperatures. The figure shows the air temperatures inside the oven decrease rapidly during very cloudy periods but recover nicely when the sun returns. These data show that during minor cloudy periods the water temperature is only slightly affected. This is to be expected, since water has a much greater heat capacity than air.

These tests show the Sun Oven can obtain sufficient temperatures to slow cook about a two liter quantity of food. It can heat water above 80°C (175°F) in a reasonable period of time, less than 75 minutes. This temperature is important because 80°C (175°F) and higher is required to sterilize water and its contents, such as the food. The Sun Oven can be unstable in high winds. This problem is easily overcome and should not detract from the usefulness of the oven. It is capable of higher inside air temperatures than most box type solar cookers. This allows it to cook more types of food such as breads, which require the higher temperatures.

References

[1]S.C. Mullick, T.C. Kandpal and A.K. Saxena, *Thermal Test Procedure for Box-Type Solar Cookers*, Solar Energy, Vol. 39, No.4, pp353-360, 1987

[2]European Committee for Solar Cooking Research (ECSCR), Solar Cooker Test Procedure, Version 2, November 1993

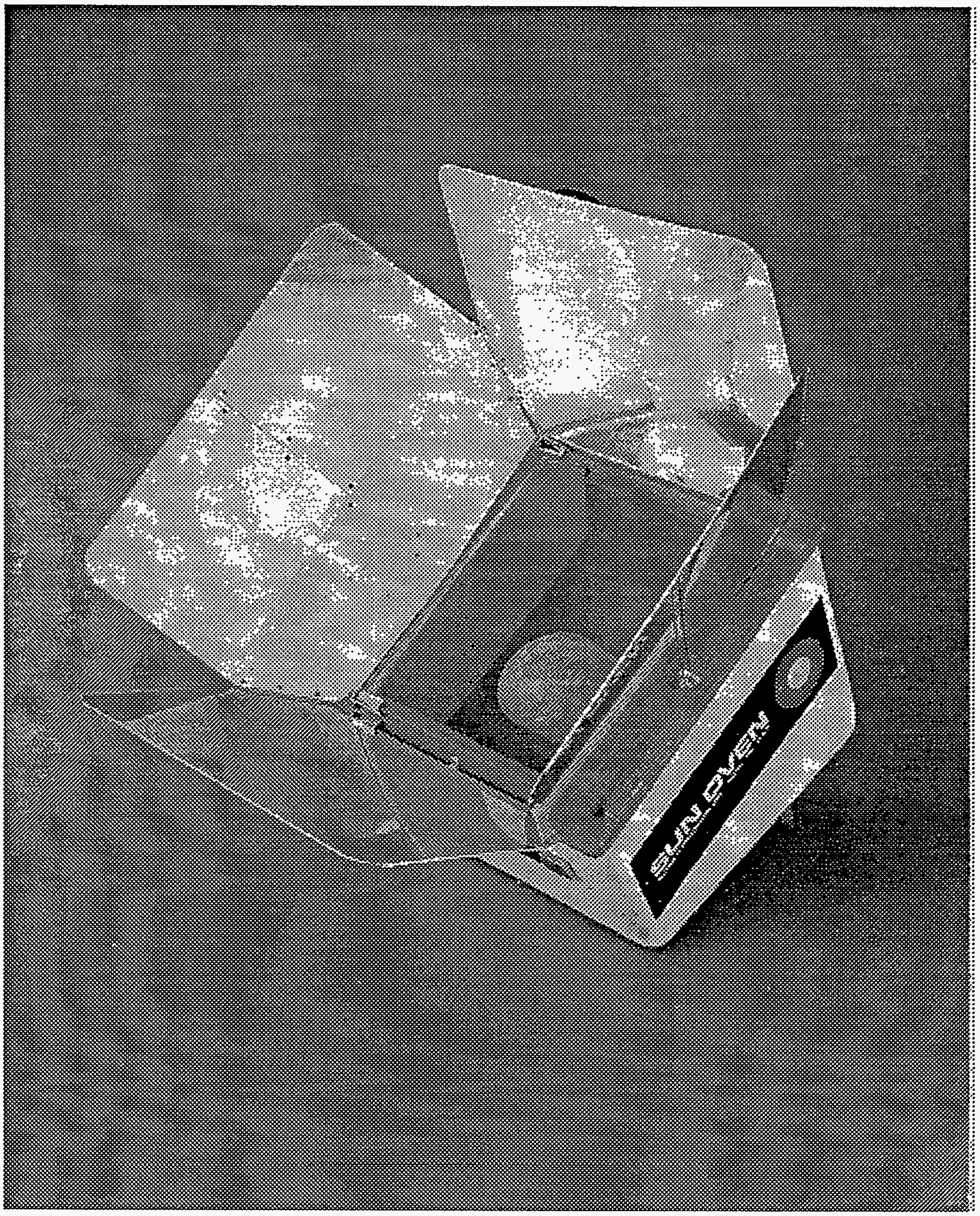

Figure 1: Photograph of the Sun Oven baking bread. Note the external reflectors.

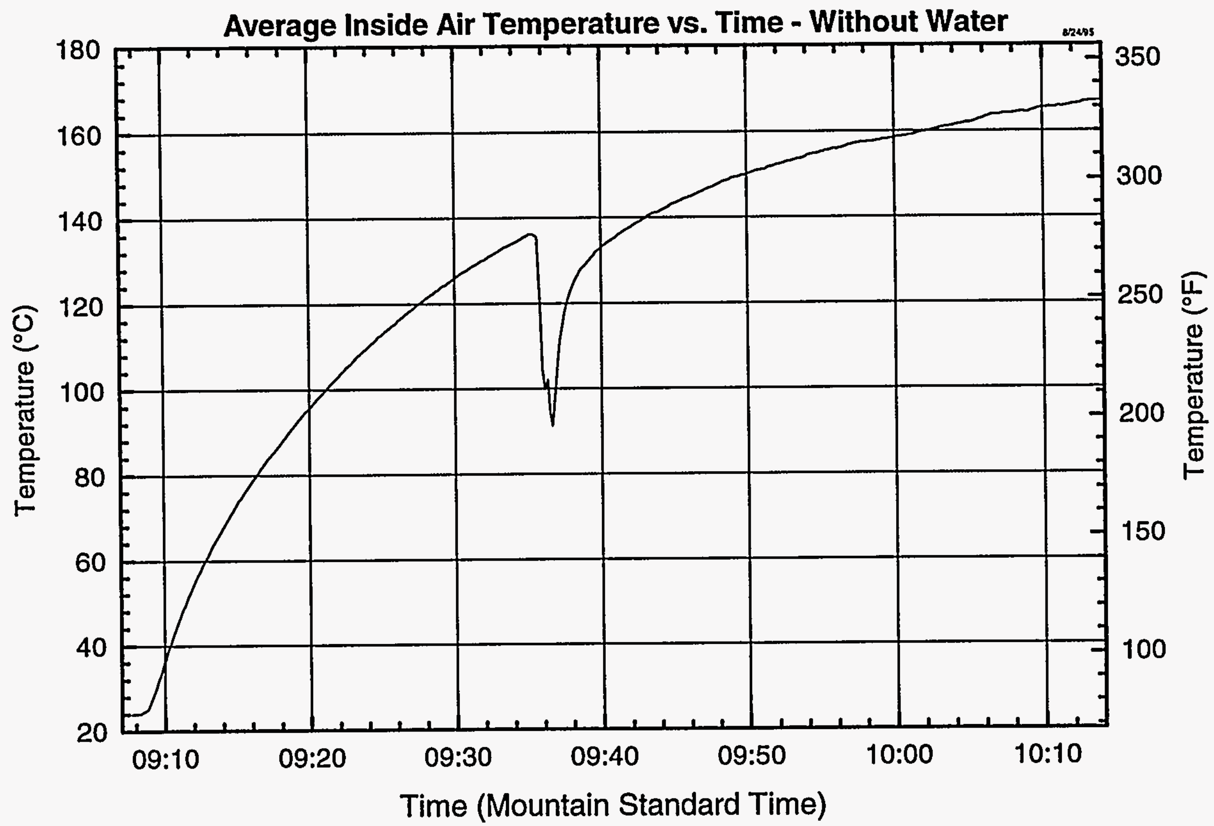

Figure 2: Ave. air temperature vs. time showing heat-up rates without water. The average of all five thermocouples is shown. Note the break at 9:36. The window, or door, was opened to observe how fast the oven recovers when opened during cooking.

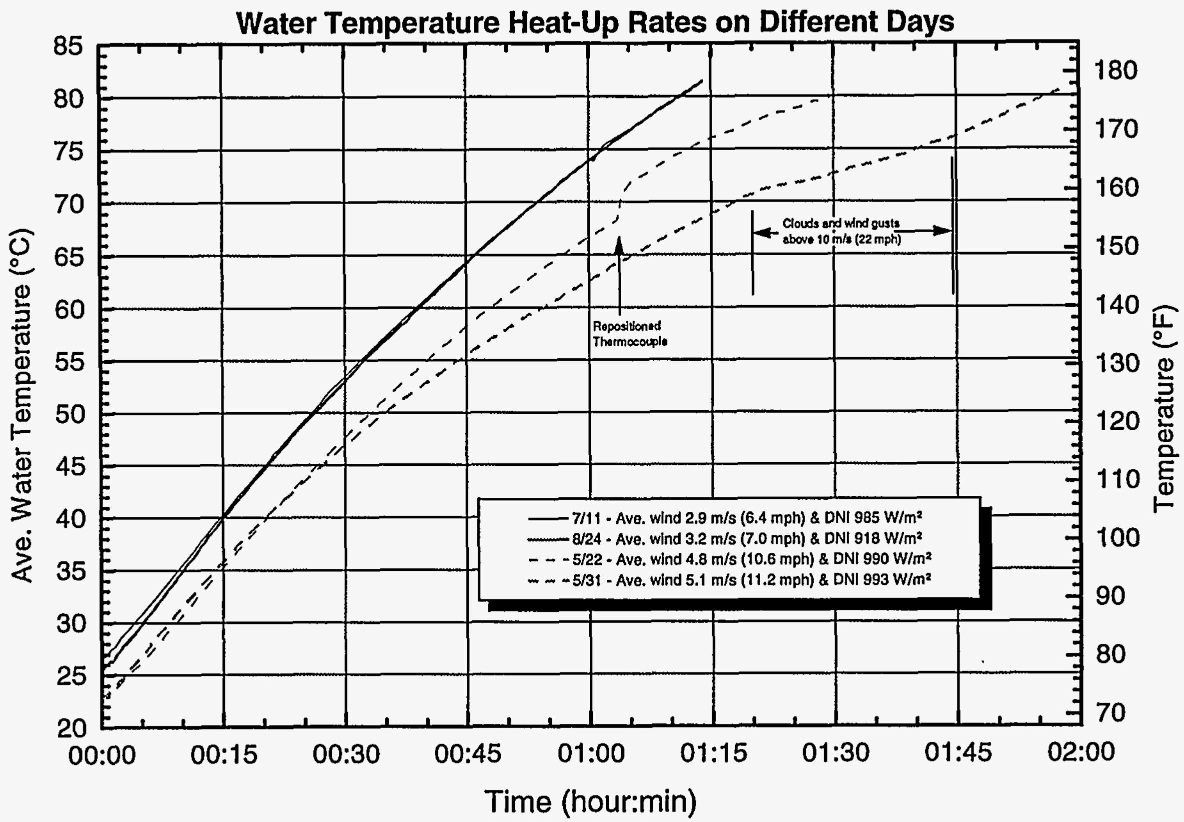

Figure 3: Average water temperature vs. time heating two liters of water. The tests on 5/22 and 5/31 had the thermocouples going through the window seal. The other tests had the thermocouples going through the sides of the oven. Note how even a small break in the door seal changes the heat-up rates.

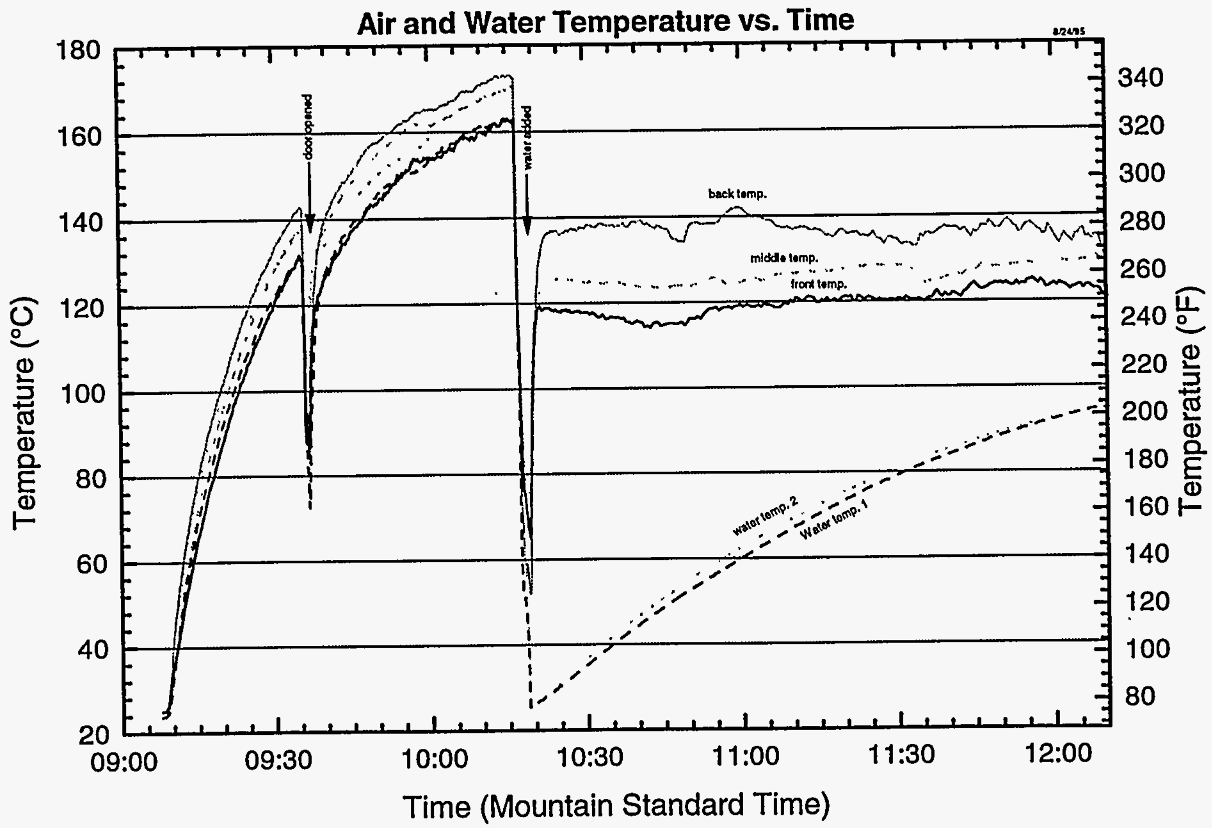

Figure 4: Air and water temperature distribution inside the oven during a typical test.

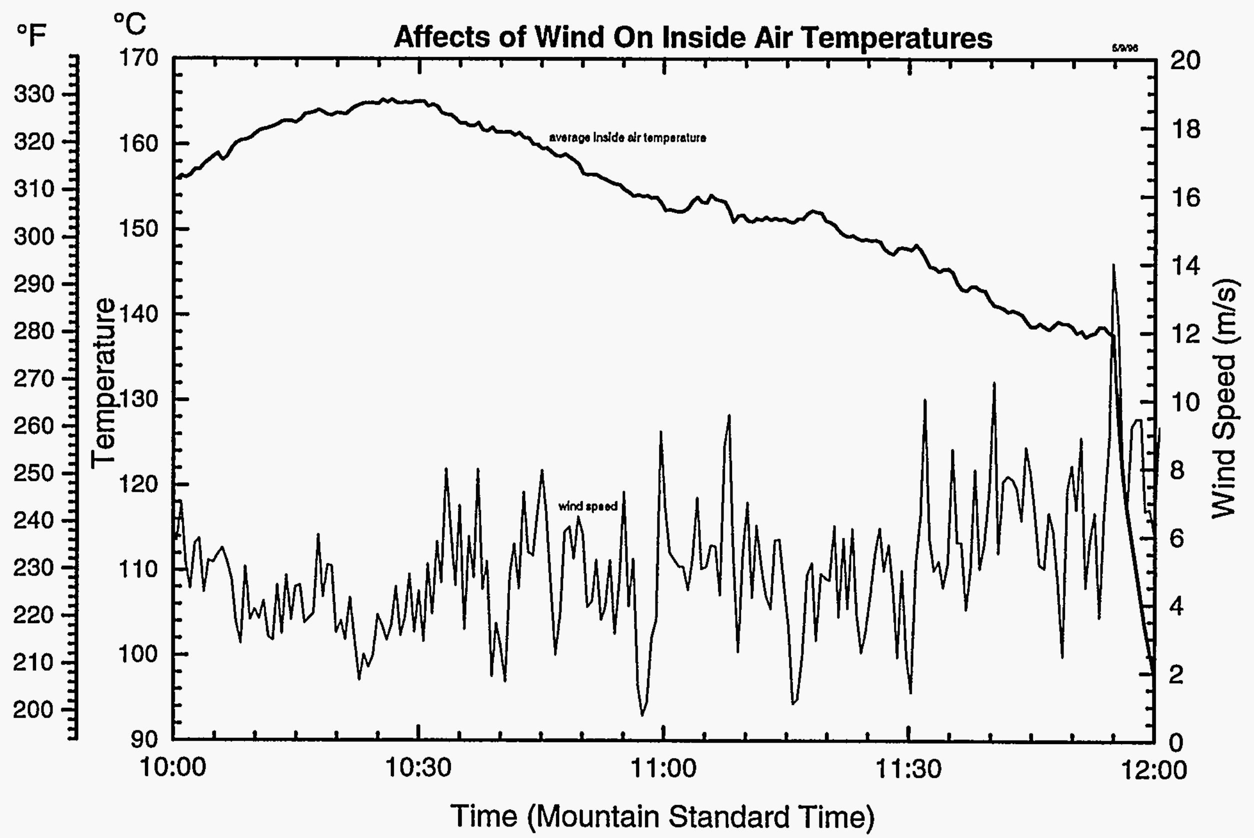

Figure 5: Temperature and wind speed vs. time showing the effect of wind on the inside of the solar oven.

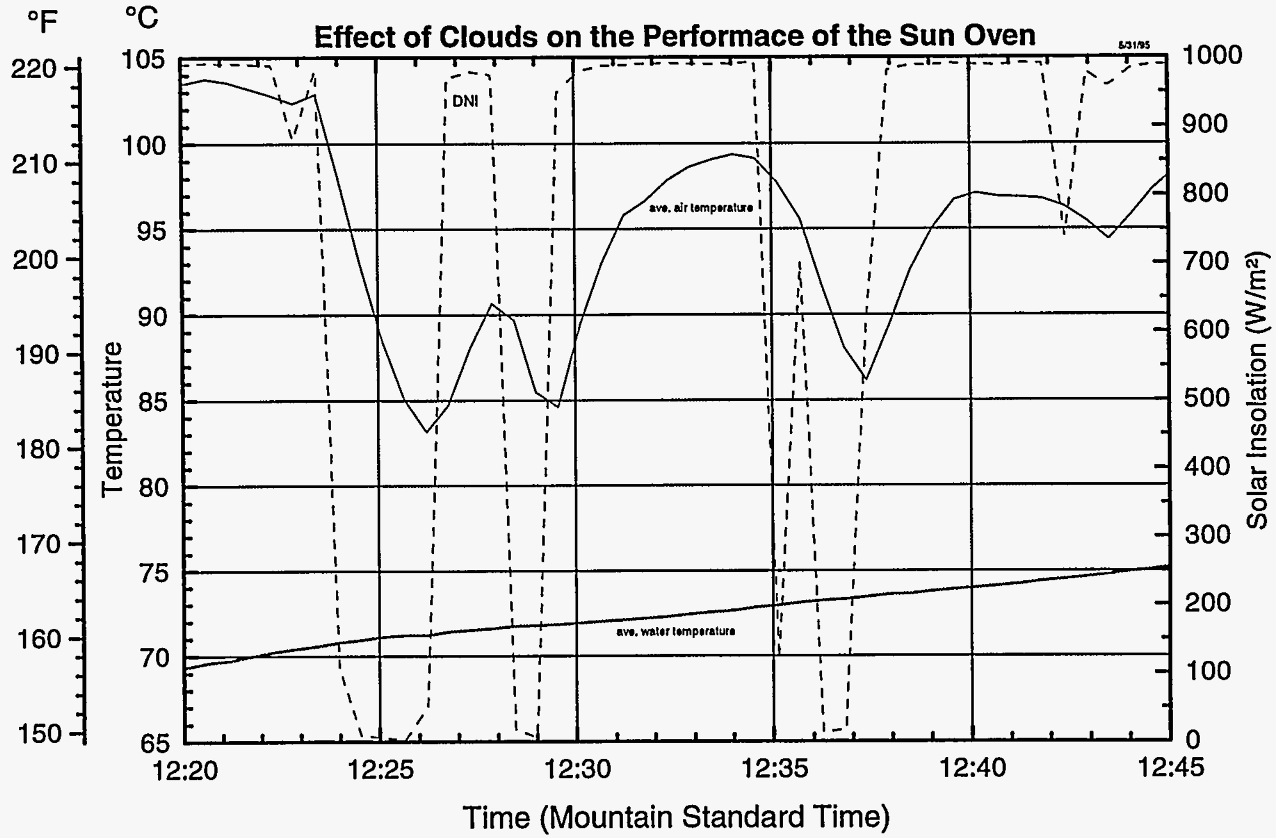

Figure 7: Average air temperature and Direct Normal Insulation (DNI) vs. time showing the effect of clouds on the performance of the solar oven.

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