Testing of the Burns-Milwaukee's Sun Oven

T.A. Moss

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

Approved for public release; distribution is unlimited.
Testing of the Burns-Milwaukee's Sun Oven

T.A. Moss
Solar Thermal Technology Department
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-0703

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.
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

 Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
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\textsuperscript{12}. 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\textdegree{}C (175\textdegree{}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


2European 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.
Intentionally Left Blank
Distribution:

A.S.E. Americas, Inc.
Steven T. Slavsky
4 Suburban Park Drive
Billerica, MA 01821-3980

AAA Solar Service and Supply, Inc.
Chuck Marken
2021 Zearing Avenue, NW
Albuquerque, NM 87104

Agua y Energia Electrica
Grupo - Fuentes Alternas
Sociedad Del Estado
Gabato 3713
1826 Remedios de Escalada
Buenos Aires, ARGENTINA

All Indian Pueblo Council
Tim Jeffrey Chavez
Pueblo Office of Environmental Protection
3939 San Pedro N.E., Suite B
Post Office Box 3256
Albuquerque, NM 87190

All Indian Pueblo Council
Mark Thompson
Pueblo Office of Environmental Protection
Post Office Box 3256
Albuquerque, NM 87190

Alliance to Save Energy
Malcolm Verdict
1725 K Street NW, Suite 509
Washington, DC 20006

American Solar Energy Society
Larry Sherwood
2400 Central Avenue, Suite G-1
Boulder, CO 80301

Arizona State University
Byard D. Wood, Ph.D., P.E.
College of Engineering & Applied Sciences
Tempe, AZ 87287-5806

Bright Ideas Cooperative
Peter Clay
3090 King Street
Berkeley, CA 94703

Burns-Milwaukee, Inc.
Thomas J. Burns
4010 West Douglas Avenue
Milwaukee, WI 53209 (5)

California Energy Commission
Promod Kulkarni
Energy Technology Development Div. R&D Office
1516 9th Street
MS-43
Sacramento, CA 95814-5512

CDESON
Jorge Villaescusa Celaya
Reyes y Aguascalientes (Esq)
Col. San Benilo
Hermosillo Sonora, 83190
SONORA

Centro Investigaciones Energeticas
J.M. Figarola
Medioambientales y Tecnologicas
Instituto de Energias Renovables
Avda. Complutense, 22
28040 Madrid,
SPAIN

CIEMAT - Madrid
Manuel Macias Miranda
Instituto de Energias Renovables
Avda. Complutense, 22
E-28040 Madrid
SPAIN

Citizens Conservation Corp.
Steve Morgan
530 Atlantic Avenue
Boston, MA 02210

Col. Universidad
Ing. Rafael Cabanillas
Enrique B. Michel #11
Hermosillo, SONORA,
MEXICO

Commonwealth of the Northern Mariana Islands
Juan M. Babauta
2121 R Street, N.W.
Washington, DC 20008

Conservation and Renewable Energy System
Ben Wolff
6918 N.E. Fourth Plain Blvd., Suite B
Vancouver, WA 98661
Consortium/Energy Efficiency
Lawrence Alexander
303 Congress Street, Suite 600
Boston, MA 02210

Council of Great Lakes Govs
Frederic Kuzel
35 E. Wacker, Suite 1850
Chicago, IL 60601

County of Hawaii
Steve Burns
Dept. of Research and Development
25 Aupuni Street
Hilo, HI 96720

County of Maui-Energy Division
Kalvin Kobayashi
250 S. High Street
Wailuku, HI 96793

Dept. of Business, Economic Dev. & Tourism
Maurice H. Kaya
Energy Program Administrator
335 Merchant Street, Room 110
Honolulu, HI 96813

Direccion Sectorial de Energia
Apartado 126/2021
San Francisco, Guadalupe
San Jose, COSTA RICA

Diseno Solar y Arquitectura Bioclimatica
Everardo Hernandez
A-P 69-738
D.F. C.P. 04460,
MEXICO

Division of Energy and Intergovernmental Affairs
Nathaniel Robinson
101 South Webster, 6th Floor
P.O. Box 7868
Madison, WI 53707

Ecotecture
Jasper O. Hardesty, AIA
803 Loma Linda SE
Albuquerque, NM 87108

ECOTOPE
David R. Baylon
Energy Efficient Solutions
2812 E. Madison
Seattle, WA 98112

Energy Foundation
Bill Keepin
75 Federal Street
San Francisco, CA 94107

Environmental Technology & Education Center (ETEC)
Jon Nimitz, Ph.D.
3300 Mountain Road NE
Albuquerque, NM 87106-1920

Federal Conservation & Renewable Energy Referral Service
P.O. Box 8900
Silver Spring, MD 20907

Florida Solar Energy Center
Library
300 State Road, Suite 401
Cape Canaveral, FL 32920-4099

Guam Energy Office
Jennifer Sgambelluri
P.O. Box 2950
Agana, 96910
GUAM

Hawaii Energy Extension Service
Andrea Beck
Dept. of Business & Economic Development
Hawaii Business Center
99 Aupuni Street #214
Hilo, HI 96720

Indo-American Credit Corporation Ltd.
Amit N. Shsh
Ambawaki Bazar
Ambawadi, Ahmedabad
(Guj.) -380 006, INDIA

Industrial Credit & Investment Corp. of India, LTD.
P. H. Vaidya
169, Backbay Reclamation Road No. 3
Bombay 400 020,
INDIA

Molokai Ranch
David Nakamura
Four Waterfront Plaza
Suite 96
500 Ala Moana Boulevard
Honolulu, HI 96813