

## AN EARTHEN SOLAR COOKER-DESIGN AND PERFORMANCE TEST

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### ABSTRACT

An earthen solar cooker (ESC) has been designed, constructed and tested. Simple and low cost compared to other solar cookers, it is made of a rectangular cavity dug out of the ground, covered with a glass plate. In a series of tests to investigate the feasibility of the ESC, one liter of water was used to simulate food. The temperatures of water and air in the cooker as well as outside ambient air were measured for 3-4 hours. For comparison purposes, a commercially available solar box cooker (SBC) was also tested side-by-side with the ESC. The results show that the ESC can potentially provide a favorable environment for cooking food and pasteurizing water. However, its performance is not as good as SBC's, mainly due to the lack of reflective surfaces in its design.

### INTRODUCTION

Solar energy provides an inexpensive means for cooking meals. Solar cooking could serve as a vehicle to help reduce the rapid consumption of wood as a fuel source among many populations of the world. This in turn would reduce the deforestation and erosion of land.

Although the idea of solar cooking is not new, early promotional attempts at the global level met without much success. Societal and operational problems were among the chief sources of failure (Kuhnke, 1987). Although the societal problems remain as the main obstacle to the adoptability of solar cooking, many attempts such as design of simple and low cost devices have been made to reduce the operational problems. Several types of solar cookers have been documented by Grupp et al. (1987), Kulkarani (1987), Mills (1987),

Ramadan et al. (1988), and Kammen and Lankford (1990).

A relatively inexpensive solar box cooker (SBC) was made commercially available in 1976 which has been adopted by several organizations and villages around the world (Kerr-Cole). (The fabricated kit which requires some assembly costs \$80 and the materials for do-it-yourself cost \$10-15 in 1991 dollars.) The basic construction is a cardboard box within another cardboard box. Cardboard baffles are used in between the boxes for insulation. Aluminum foil covers all interior surfaces. An adjustable reflector made of aluminum foil is attached to the glass lid. In addition to cooking, the SBC has found other applications. Ciocchetti and Metcalf (1984) modified the SBC and showed its utility for pasteurization of naturally contaminated water.

To construct an SBC, in addition to a glass cover and a blackened aluminum tray, 6 m<sup>2</sup> of cardboard and about the same quantity of aluminum foil are needed. Obviously, these materials are not readily available in many parts of the world where solar cooking and water pasteurization would have applications. A need for an alternative cooker which is less dependent on the availability of man-made materials does exist.

This paper introduces an earthen solar cooker (ESC), and documents the results of a series of performance tests that were carried out to investigate its feasibility and utility. The ESC utilizes the earth instead of the cardboard and requires minimal amounts of aluminum foil and cardboard. Advantages and disadvantages of the ESC are listed and recommendations are made regarding improvements. Applications of the ESC are also outlined.

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## CONSTRUCTION OF THE ESC

The ESC is a rectangular cavity dug out of the ground, see Figure 1. The interior dimensions are 57 cm x 46 cm x 23 cm. A layer (2.5 cm) of dried grass clippings serves as an insulation pad above which rests a blackened aluminum tray (0.9 mm thickness). A window type glass held in a wooden frame provides the lid. A notch is cut out at the top perimeter of the cavity where the frame is seated, making the lid flush with the ground. An adjustable reflector, assembled of aluminum foil glued to a cardboard rectangular piece (70 cm x 56 cm), is attached to the frame.

In addition to the glass plate and aluminum tray, only about 0.4 m<sup>2</sup> of cardboard and 0.4 m<sup>2</sup> of aluminum foil are needed to construct an ESC. This is the main advantage of the ESC.

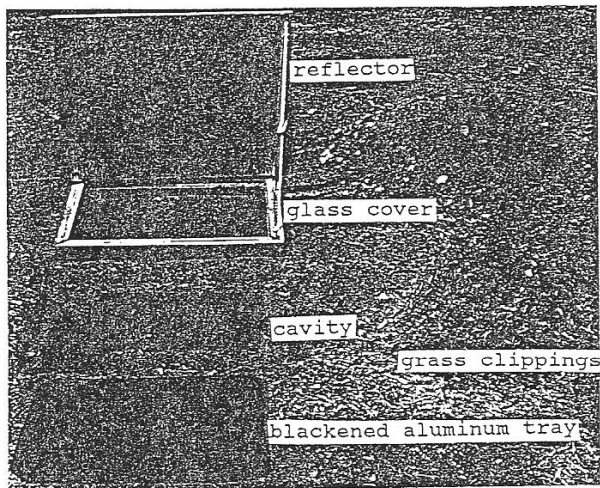


Figure 1 - Earthen Solar Cooker.

## PERFORMANCE TESTS

To investigate the usefulness of the ESC a series of comparison tests with the SBC were carried out. The interior dimensions of the two cookers were identical. The reason for selecting the SBC was its popularity among solar cooking promotional organizations (Solar Box Cookers International and Solar Box Cookers Northwest).

The test location was on the campus of the University of the Pacific located in Stockton, California (latitude = 37°5', longitude = 121°2', elevation = 8.5 m). A total of 12 tests were carried out in the period from 10 June-25 July 1991. The tests were started in the morning hours, between 10 and 11 am local time, and continued for 3-4 hours.

The same amount (usually 1 liter) of tap water, in a baking pan covered with blackened aluminum foil, was placed in each of the cookers to simulate food. The reflector on

each cooker was set at approximately 90°, and the lids were closed off. Grass clippings were used to seal the lid of the ESC.

Temperatures of air and water in the ESC and air or water in the SBC were measured with type T thermocouples (AWG 24) and recorded on a 3-channel strip chart. The thermocouples were positioned in the middle of each cooker (or the water pan). Ambient air temperature was measured with a mercury-in-glass thermometer and recorded every 15 minutes. Total solar radiation on the horizontal surface was measured with an integrating pyranometer (LI-200SB, LI-Cor, Inc.) and manually recorded. A diagram of the experimental setup is shown in Figure 2, while Figure 3 shows the actual setup.

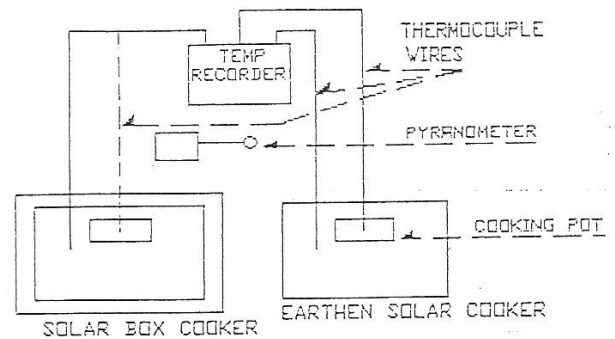


Figure 2 - Diagram of Experimental Setup.

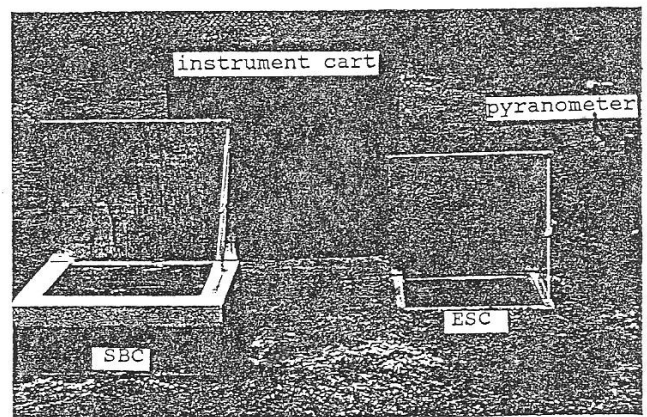


Figure 3 - The Actual Setup.

Several variations from the above general procedure were tried to gauge the effects of various parameters. For example, in one test, the reflectors were removed from the cookers to see if the ESC, in its most basic form, would provide a reasonable cooking environment.

## RESULTS AND DISCUSSIONS

Table 1 shows a summary of the results. Unless otherwise indicated, one liter of tap water was used in each cooker and the reflectors were in position. For all cases the SBC performed better than the ESC in terms of reaching higher temperature. Typically, the air temperature in the SBC was 15°C to 25°C higher than in the ESC. Nevertheless, the results indicate that the ESC could be used to provide a favorable cooking environment. The minimum required air temperature in solar box cooker is 82°C according to Blum (1990), and this was reached in the ESC (except tests # 7 and 11) within 2 hours. In comparison, 82°C was attained in the SBC within 0.5 hour.

The lack of large quantities of aluminum foil in the ESC design is a major contributor for the above mentioned difference in performances between the two cookers. To validate this presumption, aluminum foil was added to the inside wall surfaces of the ESC in one of the tests (#8). The results of that test were similar for the ESC and the SBC, see Table 1.

Figure 4 shows the result of a typical test (#12). The air reached 86°C in 2.5 hours in the ESC and 107°C in 2 hours in the SBC. The maximum water temperature in the ESC was 96°C, recorded at about 3.7 hours.

The usefulness of the ESC, in its most basic configuration (i.e., lack of cardboard and aluminum foil), was also tested (#11). In this test, the reflectors were removed from both cookers. The result is shown in Figure

5. Note that the two cookers performed similarly. The important result here is that the water temperature in the ESC reached and exceeded 65°C. It has been shown that at 65°C naturally contaminated water is pasteurized (Ciochetti and Metcalf, 1984). Therefore, The ESC is capable of providing an environment for such pasteurization.

## RECOMMENDATIONS

One source of difficulty in all tests was ensuring good packing of grass clippings around the lid of the ESC. Good packing is absolutely required since in its absence the cavity would not be sealed, and therefore the infiltration would prevent substantial temperature rise in the cooker. To help alleviate this problem an ESC with a hinged lid (permanently attached to the ground) could be designed.

It would also help if a layer of plants material could be used to cover the side walls to improve the insulation value of the ESC. Typical soil has a larger thermal conductivity than that of the cardboard; therefore, any attempt to reduce the conductivity of the walls of the cooker would improve the performance.

The next line in the development would be to find a natural substitute for the glass cover since glass, like aluminum foil, may not be readily available in some parts of the world where the solar energy applications of cooking and pasteurization are so great.

TEST	DATE	TEST DURATION hour	MAX TEMPERATURE (°C)				AMBIENT AVG AIR T	W/m2 AVG RAD	REMARKS
			AK	WK	AE	WE			
1	10 June	3.00	104		89	92	33.3	947	
2	12 June	3.00	109		84		28.4	872	
3	13 June	3.00	103		86	90	27.5	884	smoke covered sun for 1st hr
4	25 June	4.00	107		86	92	24.3	891	
5	2 July	3.67		100	110*	96	36.8	913	calm day
6	10 July	4.00		100	86	85	29.8	910	2 lit in each
7	16 July	4.00		91	76	76	27.9	876	2 lit in each, reflectors off
8	18 July	3.00	101		95	100	28.6	893	alum foil on all inside walls
9	19 July	3.50	105		86	95	25.7	838	
10	23 July	4.00	111		92	98	29.8	881	
11	24 July	4.00	86		79	86	28.7	891	without reflectors
12	25 July	3.75	107		86	96	29.3	886	

AK ... air temp in the SBC  
 WK ... water temp in the SBC  
 AE ... air temp in the ESC  
 WE ... water temp in the ESC  
 AVG RAD ... average solar radiation on a horizontal surface

\* ... thermocouple in contact with the water pan

Unless otherwise specified, for all tests  
 used 1 lit of water in each cooker  
 reflectors were in place  
 used grass for sealing the ESC  
 light wind was present

TABLE 1 - Summary of Results.

ambient air temperature (°C)

max = 33

min = 26

avg = 29

average solar radiation (10:45-2:30) = 886 W/m<sup>2</sup>

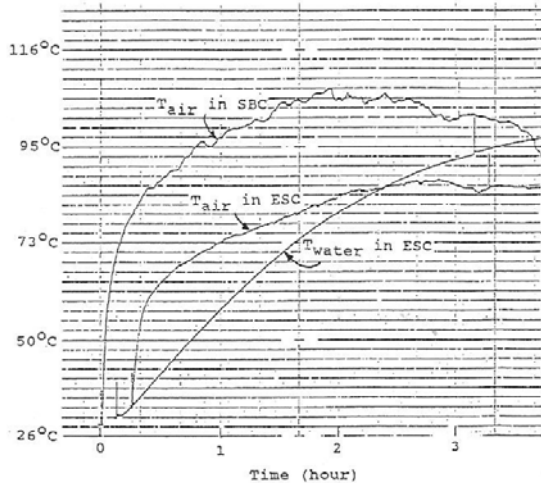


Figure 4 - Result of Test # 12, 25 July 1991.

Note: The scale is matched to the thermocouple.

ambient air temperature (°C)

max = 32

min = 25

avg = 29

average solar radiation (10:30-2:30) = 891 W/m<sup>2</sup>

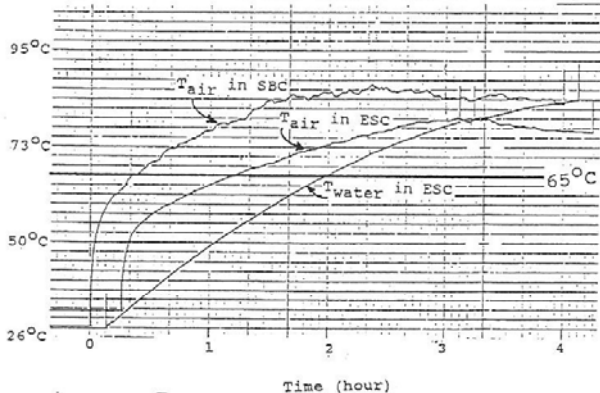


Figure 5 - Result of Test # 11, 24 July 1991.  
(Reflectors were removed from both cookers.)

#### CONCLUSIONS

An earthen solar cooker (ESC) was designed, constructed and tested. The objective was to investigate the utility of

this very simple and inexpensive solar cooker. For comparison purposes, a commercially available solar cooker (SBC) was also tested side-by-side with the ESC. Water simulated the food. Results showed that the ESC has the potential of being used for cooking purpose although its performance was below that of the SBC. It was also shown that the ESC, without any cardboard or aluminum foil, can be used as a device to pasteurize naturally contaminated water.

#### ACKNOWLEDGMENTS

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