KHAN'S SOLAR OVEN

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ABSTRACT

The device was designed and fabricated by the author*, at Chichawatni, District Sahiwal Pakistan. The purpose of designing this device was; (1) to get such a solar cooker which could be used quite easily just like a microwave oven, (2) one could add or pick the cooking pots easily and frequently without wrapping the pots in any transparent bag, and (3) the capacity of the device should be enough to cook meals for at least 10 persons. After initial experiments it was found that the desired results were achieved. The performance records were at par or a shade lower than the cookers normally manufactured in the world. The intercept area of the oven during winter solstice was $0.7896^{\square}$ meters and the maximum temperature achieved was 116.6 ^{o}C. In summer Solstice the intercept area increases to $0.8922^{\square}$ meter**.** It was also observed that this specially designed solar oven did not require frequent tracking, as the partially extended upper reflector lid help widen the tracking period.

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INTRODUCTION

After studying different solar box cooker designs, with respect to their efficiency and feasibility it was decided to design and assemble a solar device, which should be easy to use. It was designed and fabricated as per specifications shown in Appendix 1.
The device was named as, "KHAN'S SOLAR OVEN" (KSO).
The KSO has the following characteristics:

- The oven receives the solar flux from five sides, while the sixth side serves as a door.
- It depends upon the altitude angle that how many sides should be chosen to receive the solar flux.

a) In winter solstice three sides, i.e. (the upper, northern and the lower side) receive the solar flux directly and with the aid of the reflectors.
b) While in summer solstice when the sun shines overhead, four sides, i.e. (the eastern, western, upper and the northern side) receive the solar flux, directly and with the aid of the reflectors.

- All the five sides are covered with double-glazing.
- The cooking chamber is 45cm x 56cm x 30cm = .0756 cubic meter = (2.66 cubic feet). It is made up of metal sheet, colored dull black.
- Partially extended upper reflective lid and the solar reflex receiving sides of the oven extend the tracking period.
- Hot water facility for tea making is also provided in the device.

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RESULTS AND DISCUSSION

A number of experiments were carried out to check the performance and efficiency of the KSO in empty and loaded state at different ambient temperatures during 3-4 hour cooking time and with different cooking stuffs.
In Experiment No.1 the temperature of the heat trapped in empty oven was recorded during the time span of 3 hours, i.e. from 10.00 AM to 1.00 PM at successive intervals of 5 minutes each.
This is shown in table No.1 and depicted in time versus temperature graph (Graph 1). In the start the variation of temperature with time was not linear. However, the stagnation temperature of 109 ^{o}C was achieved after 1 hour and 50 minutes, which retained till the end of the experiment and has shown linear response. This corresponds to the saturated region of the time-temperature curve. In this region the foodstuff can receive the maximum heat energy and is cooked steadily. It is expected that in the summer solstice the stagnation temperature could rise appreciably.

Experiment No. 1
Performed on January16, 2007 at
Chichawatni: Latitude: 30n32, Altitude: 521 feet
Ambient air temperature: 16 ^{o}C at 10.00 AM
Solar Gain: 0.42 **(**kW/m^2) Ref. Appendix II
The graph shows the temperature achieved by KSO (empty) during 3 hours i.e. from 10.00 am to 1.00 pm.
Graph 1:

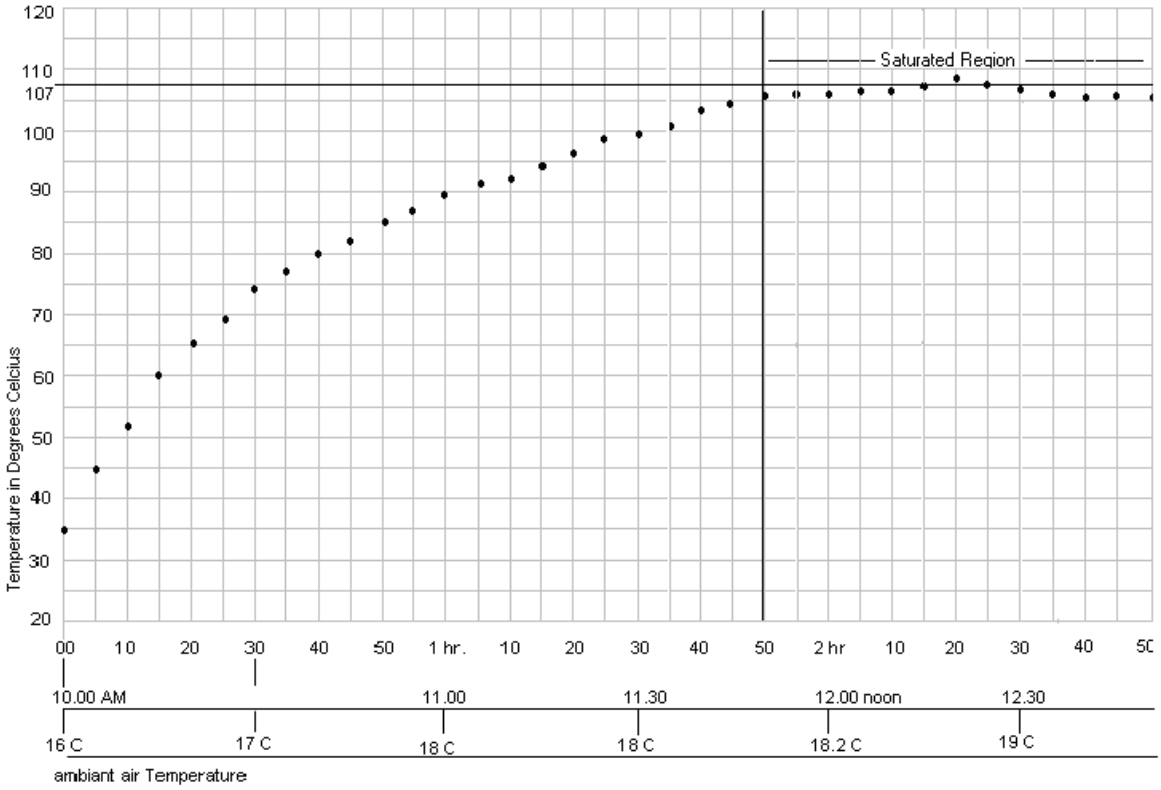


Table1: showing the temperature achieved every 5 minutes intervals

10.00AM	^{o}C	11.00 AM	^{o}C	12.00 Noon	^{o}C	01.00 PM	^{o}C
10.00	35.0	11.00	89.2	12.00	105.8	01.00	108.0
.05	45.0	.05	91.0	.05	106.4	.05	109.4
.10	53.2	.10	92.0	.10	106.4		
.15	60.0	.15	94.2	.15	107.3		
.20	65.2	.20	96.6	.20	108.2		
.25	69.9	.25	98.0	.25	107.2		
.30	74.0	.30	99.5	.30	106.2		
.35	77.6	.35	101.4	.35	106.8		
.40	80.0	.40	103.2	.40	106.6		
.45	82.3	.45	104.5	.45	106.4		
.50	85.0	.50	105.5	.50	106.8		
.55	87.2	.55	105.8	.55	108.5		

Stagnation Temperature = **109.4 ^{o}C** / Saturated region Temperature **= 107 ^{o}C**

Experiment No. 2
January 23, 2007
Ambient air temperature: 16.5 ^{o}C
In Experiment No.2, three different meals, (Chicken, mixed veggies & rice) 250g each were put into the oven in separate pots simultaneously, and were allowed to cook for 3 hours (Table 2). Consequently well-cooked, tender and delicious meal was obtained

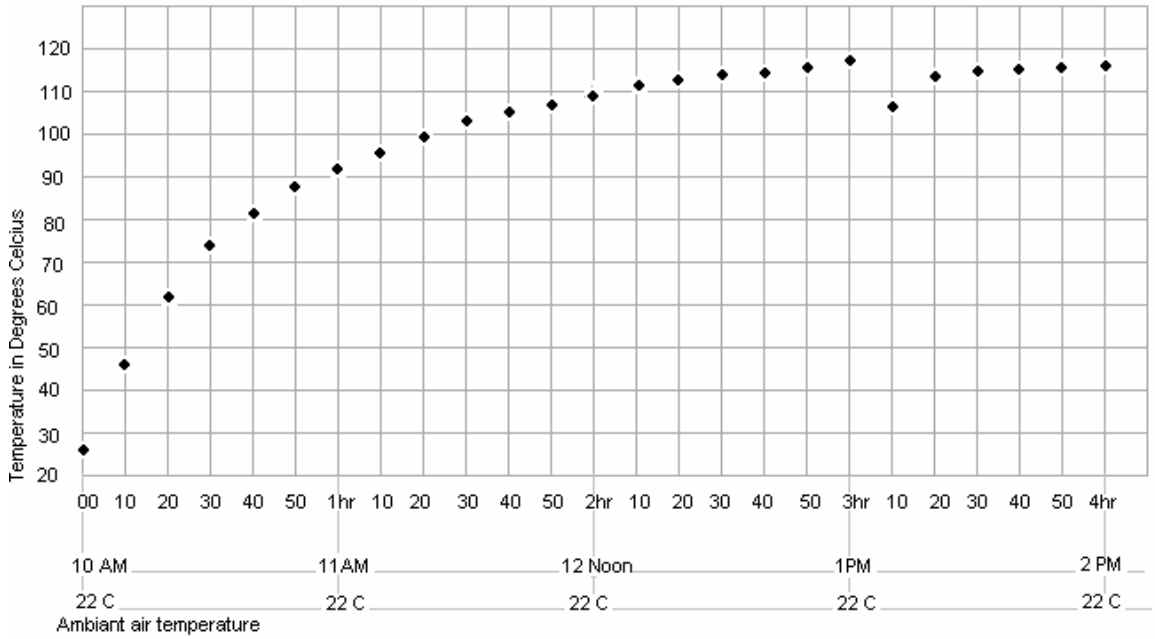
Table 2: 750g of meal was put into the oven, and the results were taken as under:

Meals	time	Remarks
250g Chicken	3 hours	The chicken was tender /delicious
250g mixed veggies	do	do
250g Rice	do	do

Findings:
It was also experienced that cooking with solar oven water in the meals should be used as little as possible. The natural water present in veggies and chicken is quite sufficient to cook.

Experiment No. 3
Friday, January 26, 2007
Meals to be cooked: One mutton leg piece: 1.5 kg. Potato: 500g Sweet potato 500g
Total weight: 2.5 Kg

Graph 2: showing the temperature achieved during 4 hours:



Stagnation Temperature**:** **116.6** ^{o}C

In Experiment No.3, a meal comprising of mutton leg, potatoes and sweet potatoes, total weighing 2.5 kg was put into the oven. It was allowed to cook for 4 hours. The temperature profile recorded in this experiment is shown in Graph 2 and Table: 3. It is comparable with that obtained while the KSO was empty. Graphs 1 & 2 evidently explore the following features of the KSO:

a) The rise of temperature
b) Rate of rise in temperature
c) Final temperature of the oven

These are further elaborated in Table: 3

Table 3:

Time	Tem.	Rise in Tem.	Remarks / Findings
10 AM	27.0 C		
10 Min.	46.0 C	19.00 C	Rise of temperature per unit of time decreases as the temerature rises.
20	62.7	16.7	
30	73.5	10.8	
40	81.4	07.9	
50	87.4	05.0	
11 AM	91.5	04.1	
10 Min	96.2	05.3	
20	99.3	3.1	
30	102.2	02.9	The boiling point was achieved after 1h.25
40	105.3	03.1	
50	107.8	02.5	
12 N	109.9	02.1	
10 Min	110.9	01.0	
20	112.5	01.6	
30	113.6	01.1	
40	114.1	00.5	
50	115.1	01.0	
01 PM	115.8	00.7	
10	109.0	-----	Temperature dropped due to opening of the door
20	111.9	2.9	
30	113.1	1.2	
40	114.3	1.2	
50	115.3	1.0	
02 PM	116.6	1.3	Stagnation Temperature

Final temperature of the oven = 116.6 ^{o}C

CONCLUSION

Above supra experiments with the device **"**KHAN'S SOLAR OVEN**"** (KSO) gave the satisfactory results.

"The performance records are almost at par or a shade lower than the box cookers normally manufactured in India. However this design has an advantage of not tracking system, and has a few more possibilities of improvement" [2].

An early European record of cooking in a solar box was made by Horace de Saussure a Swiss naturalist in 1767, achieved a temperature of 87.5 ^{o}C [1].

In the United States the SBCs, made by the founder of solar box cookers Barbara P. Kerr and Sherry Cole, reached a temperature in between 275^{o} F to 300 ^{o}F (135 ^{o}C-149 ^{o} C) during summer. [1]

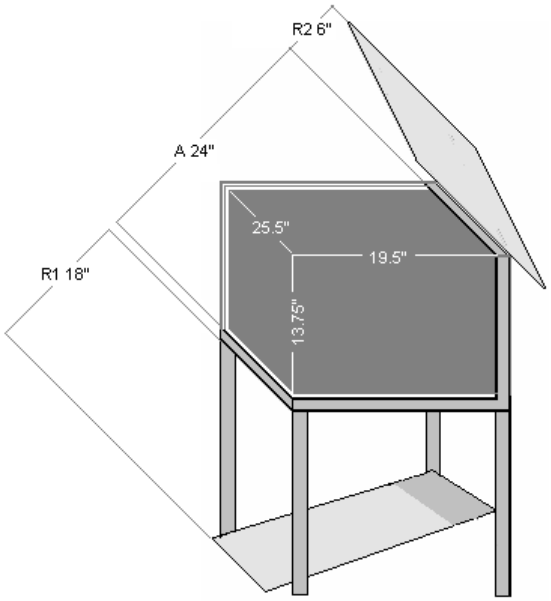
The maximum Temperature achieved by KSO during winter solstice is **116.6** ^{o}C. It is estimated that KSO will reach the above-recorded temperatures during summer solstice. This device is still under experiment and is being improved to gain higher temperatures.

Appendix I

Specifications: [3]

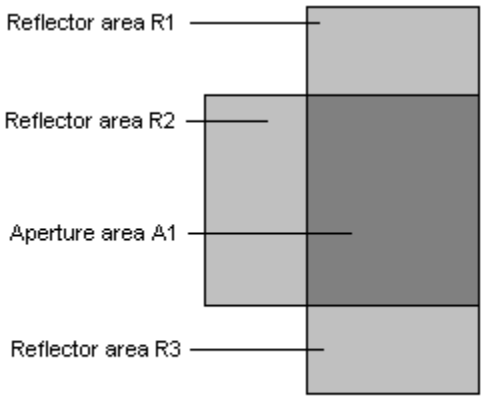
Intercept Area during winter solstice:

January 16, 2007
Zenith angle Z = 53 ^{o}
Aperture area A = 24”x 25.5” = 612$^{\square”}$
Reflector area R_1 = 18”x 25.5” = 459$^{\square”}$
Reflector area R_2 = 6”x 25.5” = 153$^{\square”}$
Intercept Area = A + R_1 + R_2 = **1224**$^{\square”}$
= 0.85416$^{\square}$ **meter**



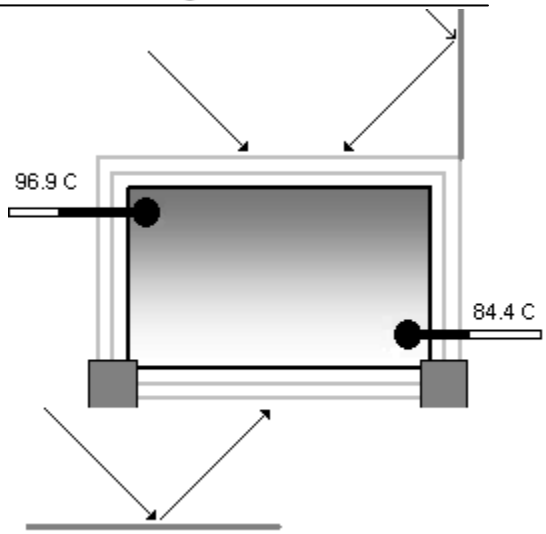
Solar flux receiving area in winter solstice

Intercept area during summer solstice:
Zenith angle Z = 7.5o
Aperture area A = 25.5 x 19.5 = 497.25$^{\square”}$
Reflector area R_1 = 13.75 x 19.5 = 268.125$^{\square”}$
Reflector area R_2 = 13.75 x 25.5 = 349.35$^{\square”}$
Reflector area R_3 = 13.75 x 19.5 = 268.125$^{\square”}$
Intercept area = A+R_1+R_2 +R_3 = **1382.85**$^{\square”}$
= 0.89213$^{\square}$ **meter**



Solar flux receiving area in summer solstice

A temperature difference of 12.5 ^{o}C to 16 ^{o}C was observed in between the ceiling and the floor of the cooking chamber. It is due to the reason that more solar radiation is received from the top vs. the bottom. The sun rays do not enter the cooking chamber and hit the cooking pots, but the sun rays are absorbed into the outer surface of the chamber, and heat enters the oven trough conduction and convection.



Temperature difference top & base of the KSO

Appendix II

Parameters for Solar Cooking*

At **CHICHAWATNI**: Latitude 30.53, Longitude 72.7, and Elevation 521 feet

Monthly Averaged Midday Insulation Incident On A Horizontal Surface (kW/m^2)												
Lat 30.53 Lon 72.7	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-year Average	0.42	0.50	0.60	0.70	0.76	0.77	0.68	0.67	0.67	0.62	0.51	0.41

Monthly Averaged Solar Noon (GMT time)												
Lat 30.53 Lon 72.7	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0720	0724	0718	0710	0706	0709	0716	0714	0705	0656	0654	0702

Monthly Averaged Maximum Solar Angle Relative To The Horizon (degrees)												
Lat 30.53 Lon 72.7	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	38.6	47.0	57.6	69.1	78.2	82.5	80.6	73.2	62.5	51.0	41.2	36.5

*Source NASA [4]

REFFERENCES

1. "The Expanding World of Solar Box Cookers" Copyright © 1999 by Barbara Prosser Kerr.
2. Comments by: Prof. Ajay Chandak. M.Tech. (Mech) IITB. Certified Energy Auditor and Renewable Energy Consultant (India)

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3. *ASAE solar energy committee SE 414 March,2002; approved by the ASAE Structure and Environment Division Standards Committee January, 2003*
4. NASA http://eosweb.larc.nasa.gov/cgibin/sse/grid.cgi

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