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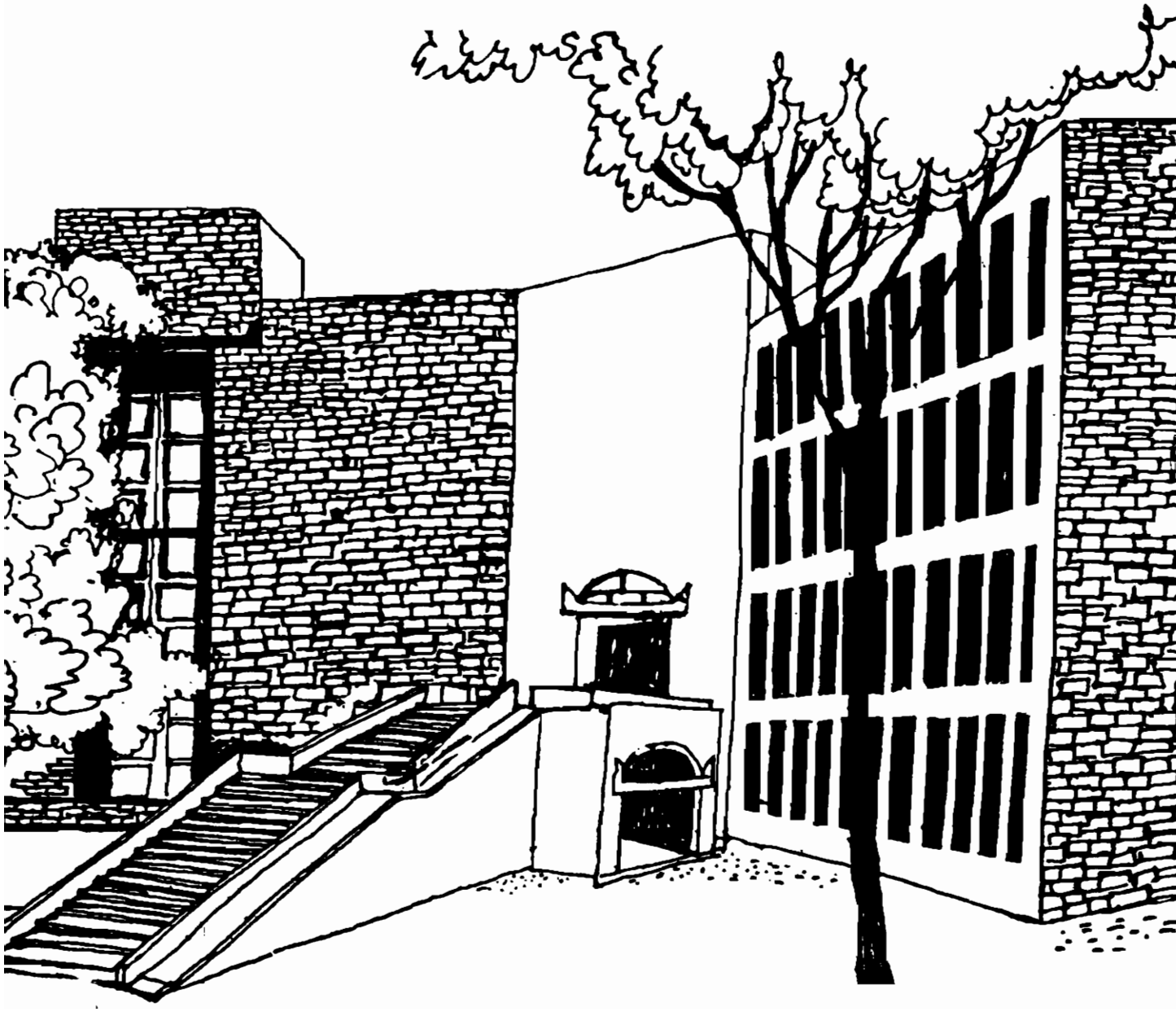

EFFECTIVENESS OF REFLECTIVE INSULATION IN BOX SOLAR COOKER

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Abstract

In this paper, we present comparative performance of box solar cooker fitted with reflective insulation and the cooker with the usual glasswool insulation. It is found that reflective insulation made of **Alseal** with one air space of 25 mm is as effective as glasswool of 50 mm thickness. Increasing the number of air spaces to two does improve the performance, but only marginally. Reflective insulation promises to be an effective substitute for glasswool in cookers. It will permit appreciable reduction in weight and bulk of existing cookers.

Introduction

All makes of box cooker marketed in India presently use glasswool to insulate the absorber tray. This is also true for cookers fitted with auxiliary electrical heater. The usual thickness of insulation is 50 mm, both on the sides and bottom. Although glasswool is a good insulation material, there are two problems associated with it. *First*, it contributes 5 to 8 per cent to the weight and even more to the bulk - since about 10 cm of the outer dimension (51 cm) is due to space needed to put the glasswool. *Second*, being manually placed, there is always variation in the density of packing and total amount used. It could vary from 600 gm to more than 1 kg. Too loose or too dense a packing, can both affect the insulation efficiency adversely. In order to remove the problem mentioned above, we have tried out reflective insulation. Preliminary results of this experiment are presented in the paper.

Reflective Insulation

Reflective (also called 'low emmissivity') insulation employs highly reflective surface and air space to retard heat flow. Such insulation is used in cold storage wall, ovens, furnaces, houses, ships, etc.[1]. Effectiveness of reflective insulation (RI) is illustrated by two situations shown in **figure 1**.

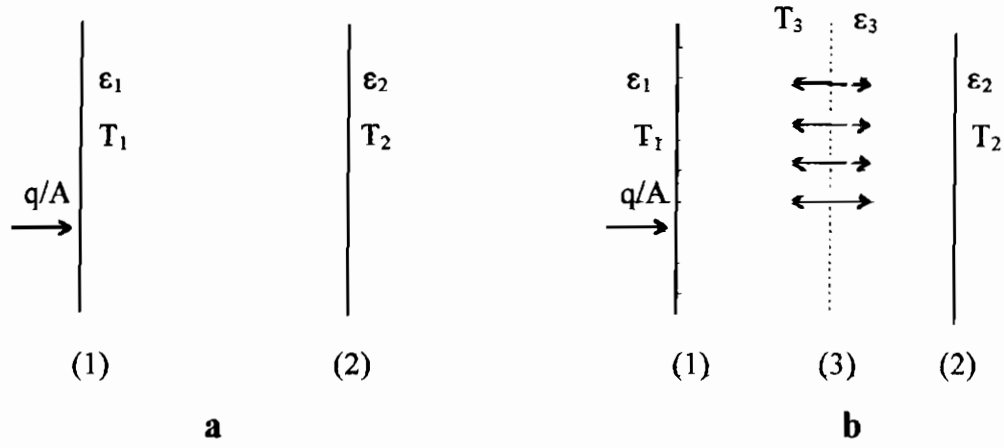

Fig-1 : Reflective Insulation: Illustration

Figure 1(a) shows two parallel surfaces, (1) and (2), separated by a gap exchanging energy. Net radiative heat transfer between the two, assuming these are very large, is given by equation-1.

$$\frac{q}{A} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \qquad \text{..... (1)}$$

where,

q	Net heat transfer between surface 1 and 2 per unit time
A	Area of surface
σ	Steffan Boltzmann constant
T_1	Temperature of surface 1, °K
T_2	Temperature of surface 2, °K
ε_1	Emmissivity of surface 1
ε_2	Emmissivity of surface 2

Now consider **figure 1(b)**. A shield (surface 3) made of highly reflective surfaces has been installed between surface 1 and surface 2. The shield does not add or remove heat from the system. It does, however, retard the heat exchange between the first and second surface. Using network theory the total resistance to flow of heat from surface 1 to surface 2 can be easily obtained **[2], [3]**. Total resistance to heat flow

$$R = \left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{2-\varepsilon_3}{\varepsilon_3}\right) \qquad \text{..... (2)}$$

where

R Resistance to heat flow

ε_3 Emmissivity of surface 3

Note, now the total resistance to heat flow has increased by an amount

$$\frac{2-\varepsilon_3}{\varepsilon_3}$$

Accordingly, heat transfer will be retarded. The extent of reduction will depend on the emmissivity of the shield. For instance, if all three emmissivities are equal say ε,

$$\text{Resistance without shield} = \frac{(2-\varepsilon)}{\varepsilon}$$

$$\text{Resistance with shield} = 2\,\frac{(2-\varepsilon)}{\varepsilon}$$

Thus, installation of one shield of the same emmissivity as the two other surfaces will reduce heat transfer to half of what it was without the shield. Further reduction can be achieved by increasing the number of air spaces, by choosing a shield that is highly reflective (low emmissivity), and to an extent by increasing the width of air space.

Cookers used in Study

Three cookers were used in this study. One was the standard "**Geeta**" cooker, a popular make of Gujarat. The other two were modified versions of it; the change being only in insulation material. The modified prototypes are referred to here as "**GS-1**" and "**GS-2**". Specifications of all three are shown in **table 1**. The commercial name of reflective insulation used in GS-1 and GS-2 is "***Alseal***". It is water and fire resistant, single-sided, light-weight, adhesive-bonded, fully-scrim reinforced reflective aluminium foil laminate. It weighs only 95 to 105 gsm. Its reflectivity is 95 per cent. Alseal comes in the form of 1000 mm wide sheet. One side of the sheet is highly reflective.

Schematic diagram of GS-1 is shown in **figure 2**. Alseal sheet was formed into a tray, 25 mm larger than the absorber tray. The sheet is easy to work. A sheet of 585.5 x 585.5 mm was cut from the roll to make the insulation tray. Edges were formed by putting a steel strip along the edge-line and creasing it slightly. The wall part was then just lifted up and made vertical. A slight extra material at the upper end of the vertical edges was folded flat and fastened to the walls by means of **"fevicol"** adhesive. Top of the insulation tray was fixed on a wood baton of 25 x 25 mm. Top of the absorber tray was also fixed to the inner-face of this baton. The air space between the absorber tray and the insulation tray was thus made reasonably air-tight to reduce convective losses. Another wooden baton of 25 x 25 mm was put under the insulation tray bottom to give it support. The air space between the absorber tray wall and the Alseal tray was 25 mm wide with shiny surface facing the absorber tray..

In the second prototype (GS-2) also, Alseal tray was formed in the same way as before. In this case, Alseal sheet was two times larger to start with. It was then folded on to itself to make a sheet of 585.5 x 585.5 mm size with both sides shiny. Adhesive was applied in the middle to fasten the two sides firmly and uniformly to eliminate air spaces. This effectively provided two air spaces--one between the absorber tray and Alseal tray,

other between Alseal tray and outer casing as shown in **figure 3**. No glasswool was used in GS-1 and GS-2.

Comparative Tests

All three cookers were tested at Sardar Patel Renewable Energy Research Institute (SPRERI), Vallabh Vidyanagar. Empty cookers were placed simultaneously outdoors on horizontal surface with reflective mirrors shrouded. Temperature of the centre of the absorber tray of all cookers was tracked from 10:00 A.M. to 4:00 P.M. via a data-logger. Tests were done for three consecutive days in the month of March 1999. **Table 2** shows the absorber tray temperature of all three. The table also shows the difference in temperature between Geeta and GS-1, and Geeta and GS-2.

Figure 4 shows the temperature of Geeta and GS-1; **figure 5** that of Geeta and GS-2. The temperatures are so close that it is difficult to appreciate the difference, which is more easily seen in **figure 6.** It is seen that GS-1 attains marginally higher temperature than Geeta. This remains so till about 1:00 P.M. after which, Geeta achieves marginally higher temperature. After 3:15 P.M., GS-1 again shows higher temperature. On the whole, however, the difference is only marginal. The reasonable inference therefore is that Alseal with just one air space of 2.5 cm insulates the absorber tray as effectively as glasswool of 5 cm thickness.

We had expected that GS-2 would perform significantly better than GS-1 since it had two air spaces. However, the performance of GS-2 was more or less similar to GS-1. Initially till about 1:30 P.M., there is greater difference in temperature of GS-2 and Geeta than was between GS-1 and Geeta. After 1:30 P.M. however, GS-2 appears to lose more heat that GS-1. The result is surprising, and calls for further investigation.

Conclusion

Preliminary results indicate that Alseal holds promise as a substitute for glasswool in solar cookers. It will permit making the cooker lighter and less bulky. It will also make possible more uniform installation of insulation than is the case in glasswool.

Further improvement in thermal performance may also be possible by (a) increasing the number of air spaces to three or more, (b) increasing the width of air spaces, (c) trying out other reflective insulations available commercially with still lower emmissivity.

Acknowledgement

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Table 1
Specification of Box Solar Cookers used in Study

Particulars	*Geeta*	*GS-1*	*GS-2*
Weight	11.6 kg		
Outer dimension	520 x 520 x 210 mm	same	same
Shape	Square	same	same
Glazing			
Numbers	2 (plane glass)	same	same
Spacing	22 mm	same	same
Thickness	3 mm	same	same
Aperture			
Upper	470 x 470 mm	same	same
Lower	450 x 450 mm	same	same
Cooking Tray			
Size - Upper	443 x 443 mm	same	same
Lower	410 x 410 mm	same	same
Material	Al	same	same
Thickness	0.6 mm	same	same
Depth	80 mm	same	same
Paint	Dull-black	same	same
Outer Box			
Material	Al	same	same
Thickness	0.6 mm	same	same
Size	520 x 520 x 210 mm	same	same
Finish	Smooth, Even	same	same
Sealant			
Material	Woollen-felt	same	same
Thickness	2 mm	same	same
Insulation			
Material	Glasswool	**Alseal**	**Alseal**
Thickness - Back	75 mm	One air space 25 mm	Two air spaces 25 mm each
- Side	45 mm		
Reflecting Mirror			
Size	492 x 485 mm	same	same
Thickness	3 mm	same	same
Solar Reflectance	97%	same	same

Table 2
Temperature at the Centre of Absorber Plate (Empty Cooker, V.V.Nagar
Mean of two days, March 9 & 10, ^{0}C)

	GEETA	GS-1	GS-2	GTA-GS1	GTA-GS2
TIME	AVG	AVG	AVG		
10.00	26.32	26.60	24.35	-0.28	1.97
10.10	37.72	44.92	45.58	-7.20	-7.86
10.20	59.47	63.38	63.75	-3.91	-4.28
10.30	73.40	75.60	75.75	-2.20	-2.35
10.40	82.85	83.20	84.40	-0.35	-1.55
10.50	91.85	92.65	93.45	-0.80	-1.60
11.00	97.05	98.25	98.90	-1.20	-1.85
11.10	101.00	102.85	103.25	-1.85	-2.25
11.20	105.40	107.95	108.10	-2.55	-2.70
11.30	109.05	111.05	111.30	-2.00	-2.25
11.40	112.55	114.20	114.50	-1.65	-1.95
11.50	115.25	116.75	117.15	-1.50	-1.90
12.00	117.35	119.05	119.35	-1.70	-2.00
12.10	120.05	121.65	121.75	-1.60	-1.70
12.20	122.70	123.65	123.60	-0.95	-0.90
12.30	124.40	125.05	124.90	-0.65	-0.50
12.40	125.70	126.00	125.75	-0.30	-0.05
12.50	126.60	126.75	126.35	-0.15	0.25
13.00	127.35	127.55	127.00	-0.20	0.35
13.10	127.35	127.55	127.00	-0.20	0.35
13.20	128.50	128.25	127.45	0.25	1.05
13.30	127.90	128.00	127.05	-0.10	0.85
13.40	127.80	127.20	126.25	0.60	1.55
13.50	126.90	126.50	125.40	0.40	1.50
14.00	126.55	125.70	124.35	0.85	2.20
14.10	125.80	124.80	123.35	1.00	2.45
14.20	124.55	123.55	122.00	1.00	2.55
14.30	123.15	122.00	120.35	1.15	2.80
14.40	121.85	120.80	118.90	1.05	2.95
14.50	120.40	119.25	117.05	1.15	3.35
15.00	118.55	117.55	115.10	1.00	3.45
15.10	116.05	115.35	112.80	0.70	3.25
15.20	113.80	112.65	110.00	1.15	3.80
15.30	110.45	110.05	107.10	0.40	3.35
15.40	97.90	107.40	104.20	-9.50	-6.30
15.50	77.80	104.45	100.90	-26.65	-23.10
16.00	67.87	101.40	97.65	-33.54	-29.79

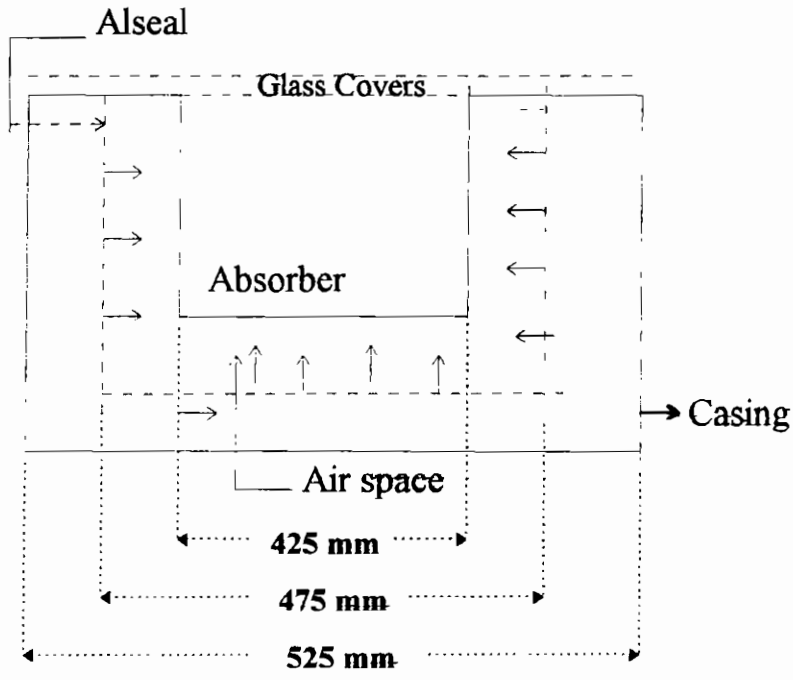

Fig-2 : Schematic Diagram of Modified Cooker (GS-1)

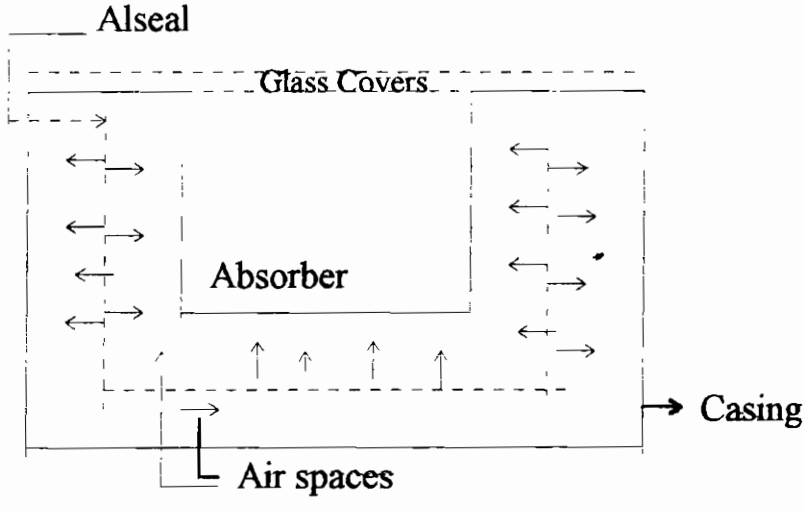

Fig-3 : Schematic Diagram of Modified Cooker (GS-2)

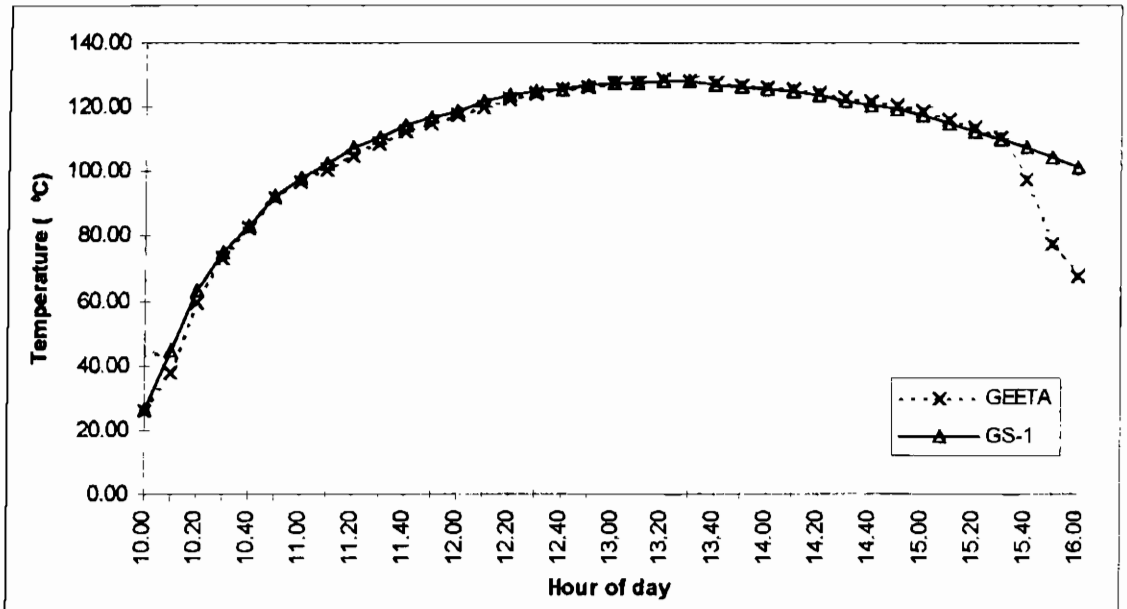

Fig-4 Temperature at the Center of Absorber Plate (Empty Cooker) V.V.Nagar, Mean of Two Days (March 9 & 10)

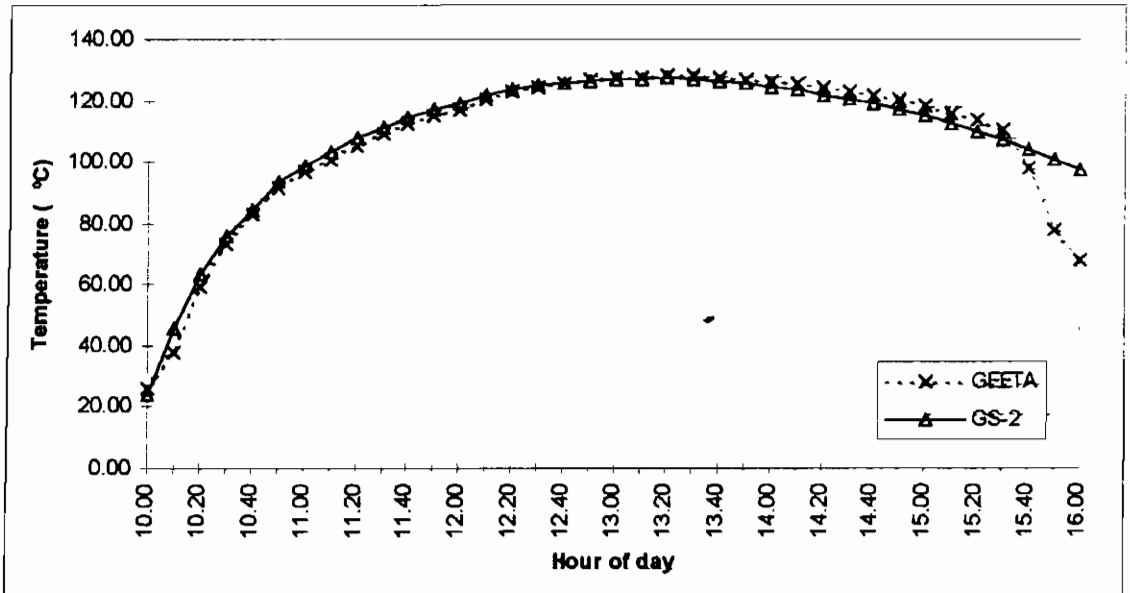

Fig-5 Temperature at the Centre of the Absorber Plate (Empty Cooker) V.V.Nagar, Mean of Two Days (March 9 & 10)

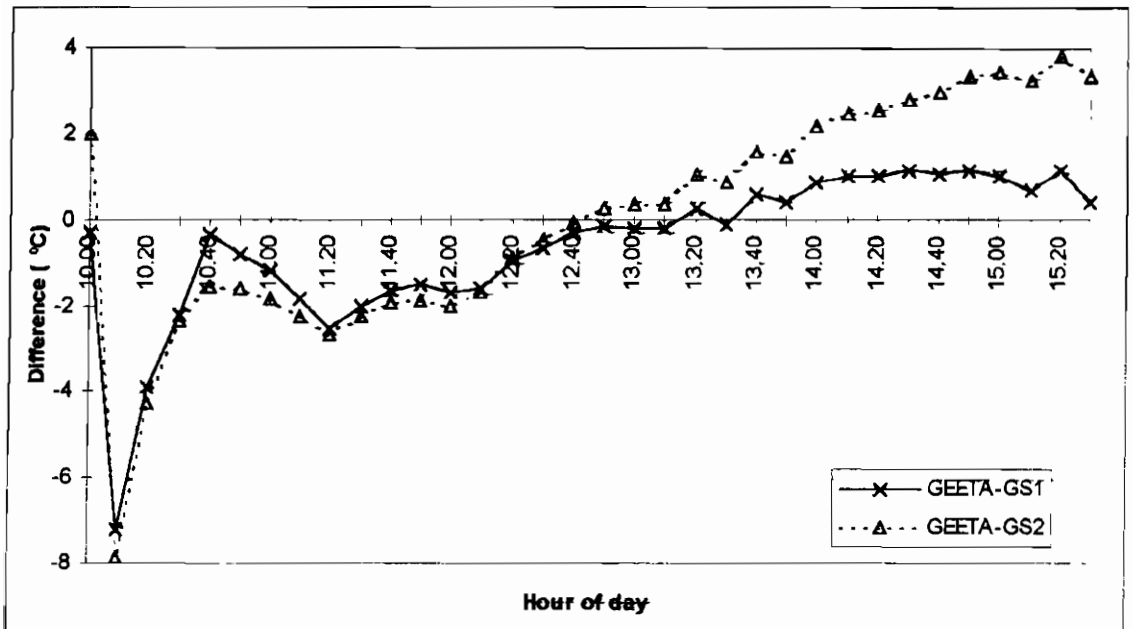

Fig-6 Geeta vs GS 1 & 2

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