Fabrication and Testing of Box Type Solar Cooker with Different Orientation of Box and Reflector Glass for Effective Performance

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Abstract: Indian subcontinent is blessed with ample amount of sunlight almost all through the year. Roughly 80% of all seasons are sunny of which 50% is dry and hottest. There is a need of switching over to a perennial source of energy reserve as a powerful alternative so as to replace all the fastly depleting fossil fuels. There is much interest in non conventional energy nowadays so as to trap energy from unassuming but promising sources of energy such as Solar, Wind and Tidal energy of which, trapping the heat and infra-red rays from the sun using air and water as mediums, separately and together as a whole is the most easiest and versatile way of energy capture. In order to trap this abundant energy we require an efficient design of a solar concentrator which heats up the ambient in the quickest pace. In connection with this in the present project work a cost effective solar concentrator is made with locally available raw materials which is efficient enough to make water reach steam point and air reach its hottest phase. A thorough dealing with a span of one week observation on the working of the solar cooker is presented in detail.

From the tests conducted, it is suggested to keep the reflector angle in range of 85^0-105^0 in order to get maximum performance of box type solar cooker and also found that the direction of box effects the performance of box type solar cooker. Different tests are conducted for few days with different environmental conditions like heavy cloudy, cloudy and clear day and reported the same. From the results it is found that the maximum temperature obtained is 59^0 C and is raised during clear day. The suggested box type solar cooker is finally found to be simple, eco-friendly and economical.

Index Terms **- Solar energy, box type solar cooker, reflector glass.**

I. INTRODUCTION

The intensity of the solar rays is unpredictable and often plays truant during rainy and winter seasons. The harnessed energy is transferred and poorly stored. This reduces the overall efficiency of the device. The time required to cook the food is increased because of lacking in heat storage.

The use of solar cookers will have a great potential of reducing the suffering of many people from the shortage and high cost of fossil and other sources fuels. It will also reduce the tedious task faces by rural women in search of fire wood for cooking. Several factors including access to materials, availability of traditional cooking fuels, climate, food preferences, and technical capabilities: affect people’s perception of solar cooking. It is in the light of this that the author decided to investigate the effect of solar cooking using box type solar cooker with different orientation and also with different angle position of reflector. The purpose of changing reflector angle position is to make the rays in addition to direct falling rays also additional rays are made to concentrate on cooker by reflecting the rays falling on reflecting glass which in turn improves the performance.

II. DESIGN OF BOX TYPE SOLAR COOKER:

Box-type solar cooker consists of an insulated outer and inner box, metallic cooking tray sat inside the box, double glass lid on the cooking tray, and two reflecting mirrors fitted to the two sides of the lid of the box and an adjustable stand. The cooking tray is insulated on the sides and bottom. The cooker box consists of a top open black painted inner box kept inside of the another box and the space between the two boxes is filled with glass wool insulation .The two reflecting mirrors are placed on the upper side of the box with a gap between them and are in hold by a hinge joint with the cooker box. This is a conventional type of cooker and its length is three times its width and depth is same as that of width.

The cooker is to be placed facing sun, keeping longer side vertically inclined position and the inclination of the cooker box can easily be changed from 15 degree to 45 degrees with respect to the ground by the adjustable stand, attached at the back side of the box.

The reflectors are set along the length of the cooker box cover, one in each side, by hinge and holding strip. So length of reflectors are equal to the length of the glass cover .The widths are equal to the width of the glass cover .The reflectors are inclined at an angle of 115 deg with the face of the box cover.

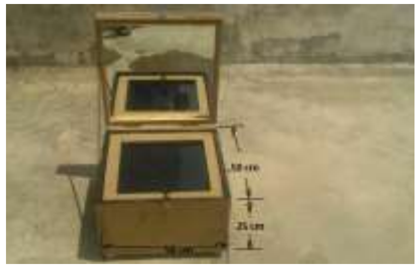


Figure 1 : Schematic Diagram of the Solar Box Cooker.

The face of the cooker is to be placed perpendicular to beam radiation to collect the maximum energy. This perpendicular position can be easily achieved simply by the rotation of the cooker towards the sun with the help of caster wheels ,suitably attached at the bottom side of the cooker and by changing the inclination of the cooker by adjustable stand of the back side .But the position of the reflectors remain unchanged throughout the working period.

Materials Required For Fabrication:

1. 500*500*250 mm Plywood.
2. 24 gauge aluminum sheet
3. Reflector mirror of thickness 3.5mm and height and length 16.4 c.m
4. Transparent Glass of thickness 4 mm
5. Thermocol for insulation
6. Two cooking bowls Capacity is 3 Liters
7. Black Paint.
8. Two Thermocouple.

III.EXPERIMENTAL SETUP

The experimental tests on the solar cookers were carried out during the successive days from the 9-02-2017 to 14-02-2017. Each experiment starts from 9:00 am in the morning to 16:00 pm in the evening. The electrical and electronic parts were tested and calibrated before being used on the various designs on both solar cookers. The first part of this research work concentrated on testing of two box type cookers: traditional black painted cooker and black pained with coal cooker as shown in Figure 1. Both cookers are fixed at a position towards the south. The second part is testing the coal black painted cooker with a tracking system to the sun movement. Figure 2 shows schematic diagram of three dimension of the solar cooker installed on a horizontal sun tracking system. It shows the base, motor and bearing and sun cooker.

This project consists of mainly 5 parts

1. Wooden box
2. Transparent glass
3. Reflective glass
4. Aluminium sheet
5. Cooking bowl

1. Wooden box:

In order for the box to reach interior temperatures high enough for cooking, the walls and the bottom of the box must have good insulation (heat retention) value. Good insulating materials include: aluminum foil (radiant reflector), feathers (down feathers are best), spun fiberglass, Rockwool, cellulose, rice hulls, wool, straw, and crumpled newspaper. When building a solar cooker, it is important that the insulation materials surround the interior cooking cavity of the solar box on all sides except for the glazed side --

usually the top. Insulating materials should be installed so that they allow minimal conduction of heat from the inner box structural materials to the outer box structural materials. The lower the box heat loss, the higher the cooking temperatures.

2. Transparent glass:

In the field of optics, transparency (also called pellucidity or diaphaneity) is the physical property of allowing light to pass through the material without being scattered. On a macroscopic scale (one where the dimensions investigated are much, much larger than the wavelength of the photons in question), the photons can be said to follow Snell's Law. Translucency (also called translucence ortranslucidity) is a super-set of transparency: it allows light to pass through, but does not necessarily (again, on the macroscopic scale) follow Snell's law; the photons can be scattered at either of the two interfaces where there is a change in index of refraction, or internally. In other words, a translucent medium allows the transport of light while a transparent medium not only allows the transport of light but allows for image formation. The opposite property of translucency is opacity. Transparent materials appear clear, with the overall appearance of one color, or any combination leading up to a brilliant spectrum of every color.

3. Reflective glass :

Figure 2: Reflective glass

Materials which do not transmit light are called opaque. Many such substances have a chemical composition which includes what are referred to as absorption centers. Many substances are selective in their absorption of white light frequencies. They absorb certain portions of the visible spectrum while reflecting others. The frequencies of the spectrum which are not absorbed are either reflected back or transmitted for our physical observation. This is what gives rise to color. The attenuation of light of all frequencies and wavelengths is due to the combined mechanisms of absorption and scattering.

1. Aluminum sheet:

Aluminum sheet is used to maintain the heat with in the solar box .the size of the aluminum sheet is 24 guage,the amount of sheet required is based on the size of the wooden box.

4. Cooking bowl:

Figure 3: Cooking bowl

Cooking bowl is used to cook food by using solar thermal energy .Here cooking bowl is made by aluminum, is more effective than that of steel .the quantity of cooking bowl is 3 Liters.

IV.WORKING PROCEDURE WORKING:

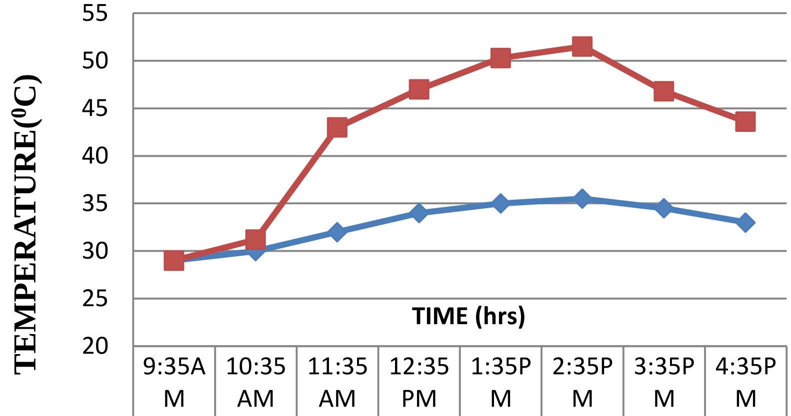
A solar box cooker is basically a large box with a glass lid that will function as an oven. However, the heat losses over a larger surface area will partially offset the additional gain through having a greater heat collecting surface. What is usually done to compensate for this is that a glazed surface cover and reflectors are used to increase the apparent collector area. These reflectors can be made from a variety of materials and their primary purpose is to reflect sunlight through the glazing material and into the cooking space inside of the box.

The box cooker consists of some type of heat trapping enclosure, which usually takes the form of a box made of insulating material with one face of the box fitted with a transparent medium, such as glass or plastic. This enables the cooker to utilize the greenhouse effect and incident solar radiation cooks the food within the box.

The insulating material allows cooking temperatures to reach similar levels on cold and windy days as on hot days, as well as having an added benefit of blocking any leakages that could potentially seep through and damage the cooker. A dark cooking pot is recommended for cooking as it absorbs the maximum amount of heat and allows for higher cooking temperatures.

V.RESULTS AND DISCUSSIONS

Graph on 9-02-2017 for heavy cloudy day:



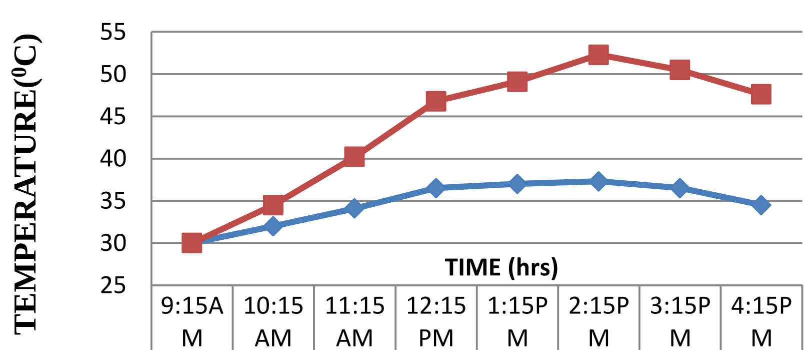
TIME (hrs)	9:35AM	10:35 AM	11:35 AM	12:35 PM	1:35PM	2:35PM	3:35PM	4:35PM
Outside Bowl Temp	29	30	32	34	35	35.5	34.5	33
Inside Bowl Temp	29	31.2	43	47	50.3	51.5	46.8	43.6

Graph 1: Variation of inside & outside temperature of bowl with respect to time.

Graph 1: shows the variation of inside and outside temperature of bowl with respect to time on heavy cloudy day .it is observed from the graph that the outside and inside temperature of bowl increases initially from morning 9:35 am to afternoon 2:35pm.also it is observed .that raise of the temperature outside the bowl is fall less than raise of temp inside the bowl. The maximum raise in temperature outside the bowl is found to be 6.5 ^{0}C where as inside the bowl it is found to be 22.5 ^{0}C.

During first one hour that is 9.35 to 10.35AM only slight raise in temperature is observed and there after a sudden raise is observed. This is because it need some time for the air entrapped in the after the air particles activated and results in absorption of higher heat Energy.

Graph on 10-02-2017 for heavy cloudy day:



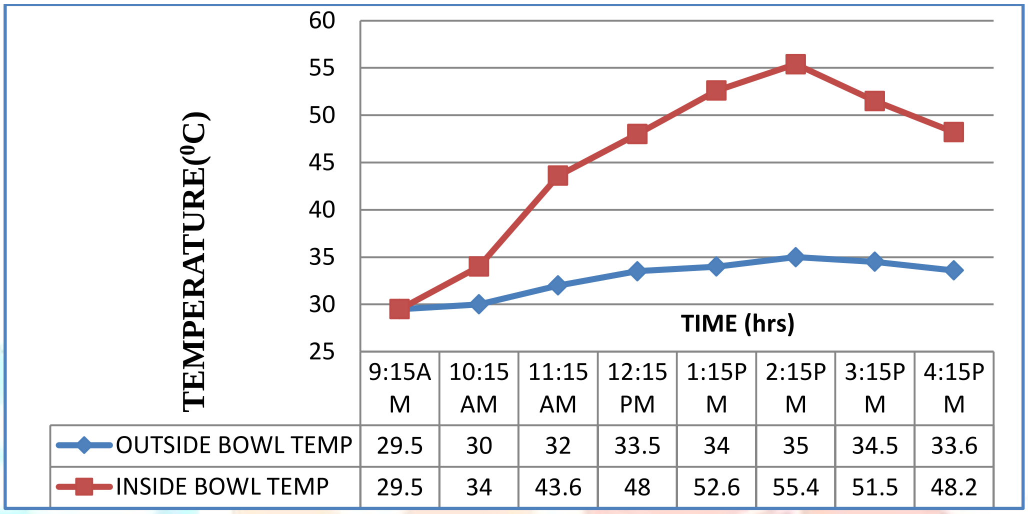
TIME (hrs)	9:15AM	10:15 AM	11:15 AM	12:15 PM	1:15PM	2:15PM	3:15PM	4:15PM
OUTSIDE BOWL TEMP	30	32	34.1	36.5	37	37.3	36.5	34.5
INSIDE BOWL TEMP	30	34.5	40.2	46.8	49.1	52.3	50.5	47.6

Graph 2: Variation of inside & outside temperature of bowl with respect to time.

Graph 2: show the variation of inside & outside temperature with respect to time on anther heavy cloudy day. It is observed from the graph that temp raises from 9:15AM to2:15PM and decrease there after. But it is observed that for first 2to3 hours the raises in temp is less and reaches a significant level only from 12PM.

During first one hour that is 9.15 to 10.15AM only slight raise in temperature is observed and there after a sudden raise is observed. This is because it need some time for the air entrapped in the after the air particles activated and results in absorption of higher heat Energy.

Graph on 11-02-2017 for cloudy day:



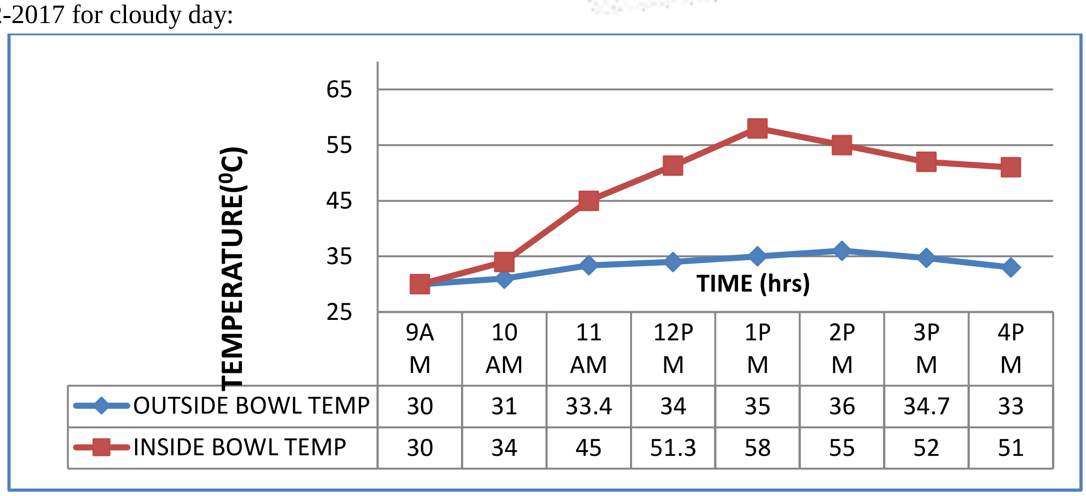
	9:15AM	10:15 AM	11:15 AM	12:15 PM	1:15PM	2:15PM	3:15PM	4:15PM
OUTSIDE BOWL TEMP	29.5	30	32	33.5	34	35	34.5	33.6
INSIDE BOWL TEMP	29.5	34	43.6	48	52.6	55.4	51.5	48.2

Graph 3: Variation of inside & outside temperature of bowl with respect to time.

It is seen from the graph the raise in temp inside the bowl starts increasing from starting onwards from 9:15AM and temp raise in this case is higher than that of the temp rise on during heavy cloudy day. The max temp raise inside the bowl is found to be 25.9 ^{0}C, though temperature decreases from 2.15PM, it is observed that only a drop of 7.2 ^{0}C takes place up to 4.15PM, because from morning to afternoon the air entrapped in the casing gets heated and so even outside temp decreases the warm, trapped air boostup the process upto some extent &these by the performances of heat absorption is higher than the expectation (based on outside temp)

During first one hour that is 9.15 to 10.15AM only slight raise in temperature is observed and there after a sudden raise is observed. This is because it need some time for the air entrapped in the after the air particles activated and results in absorption of higher heat Energy.

Graph on 12-02-2017 for cloudy day:



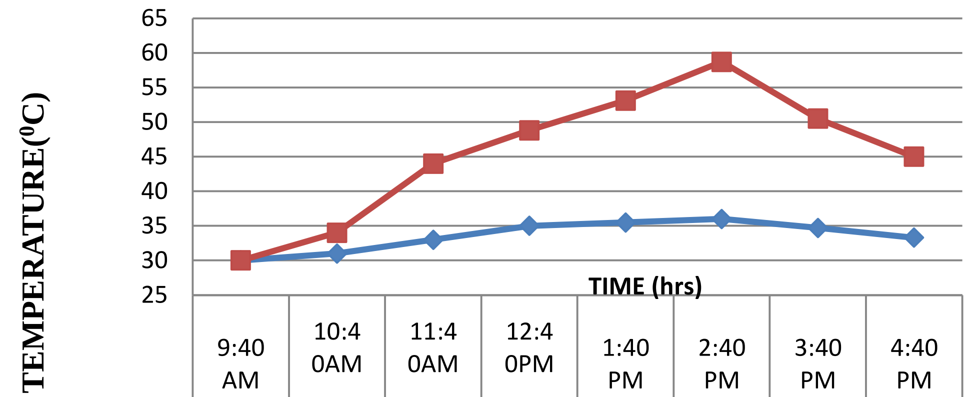
	9AM	10 AM	11 AM	12PM	1PM	2PM	3PM	4PM
OUTSIDE BOWL TEMP	30	31	33.4	34	35	36	34.7	33
INSIDE BOWL TEMP	30	34	45	51.3	58	55	52	51

Graph 4: Variation of inside & outside temperature of bowl with respect to time.

It is seen from the graph the raise in temp inside the bowl starts increasing from starting onwards from 9AM and temp raise in this case is higher than that of the temp rise on during heavy cloudy day. The max temp raise inside the bowl is found to be 23 ^{0}C, though temperature decreases from 2PM, it is observed that only a drop of 6^{0}C takes place up to 4PM, because from morning to afternoon the air entrapped in the casing gets heated and so even outside temp decreases the warm, trapped air boost up the process up to some extent &these by the performances of heat absorption is higher than the expectation (based on outside temp).

During first one hour that is 9AM to 10AM only slight raise in temperature is observed and there after a sudden raise is observed. This is because it need some time for the air entrapped in the after the air particles activated and results in absorption of higher heat Energy.

Graph on 13-02-2017 for clear day :



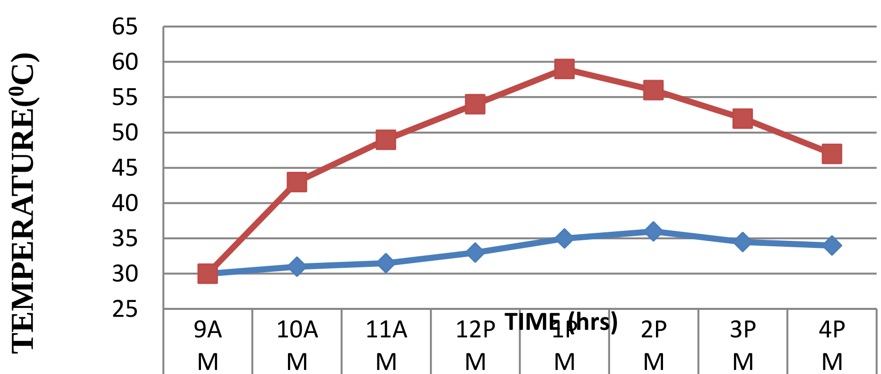
	9:40 AM	10:40AM	11:40AM	12:40PM	1:40 PM	2:40 PM	3:40 PM	4:40 PM
OUTSIDE BOWL TEMP	30	31	33	35	35.5	36	34.7	33.3
INSIDE BOWL TEMP	30	34	44	48.8	53.1	58.7	50.5	45

Graph 5: Variation of inside & outside temperature of bowl with respect to time.

It is seen from the graph the raise in temp inside the bowl starts increasing from starting onwards from 9:40AM and temp raise in this case is higher than that of the temp rise on during clear day. The max temp raise inside the bowl is found to be 28.7^{0}C, though temperature decreases from 2.40PM, it is observed that only a drop of 6^{0}C takes place up to 4.40PM, because from morning to afternoon the air entrapped in the casing gets heated and so even outside temp decreases the warm, trapped air boost up the process up to some extent &these by the performances of heat absorption is higher than the expectation (based on outside temp).

During first one hour that is 9:40AM to 10:40AM only slight raise in temperature is observed and there after a sudden raise is observed. This is because it need some time for the air entrapped in the after the air particles activated and results in absorption of higher heat Energy.

Graph on 14-02-2017 for clear day:

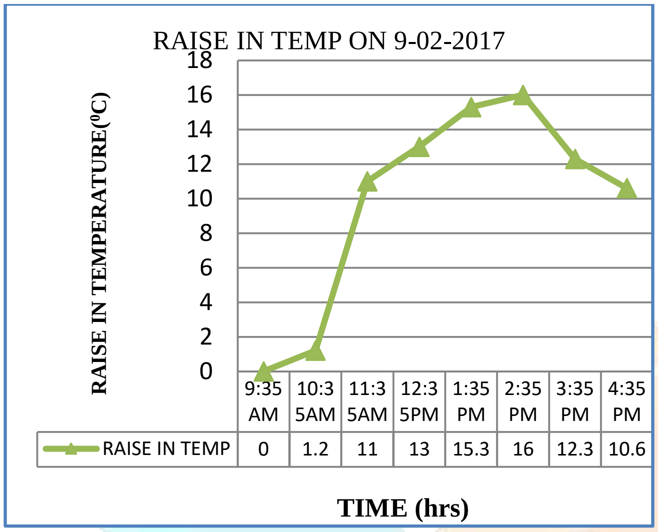


	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM
OUTSIDE BOWL TEMP	30	31	31.5	33	35	36	34.5	34
INSIDE BOWL TEMP	30	43	49	54	59	56	52	47

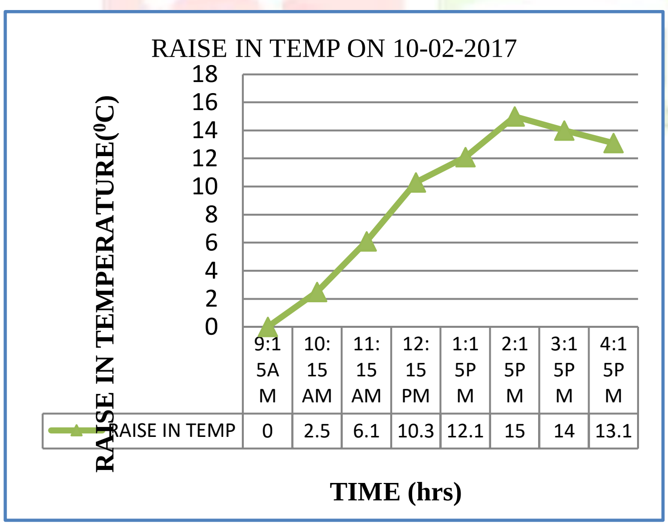
Graph 6: Variation of inside & outside temperature of bowl with respect to time.

It is seen from the graph the raise in temp inside the bowl starts increasing from starting onwards from 9AM and temp raise in this case is higher than that of the temp rise on during clear day. The max temp raise inside the bowl is found to be 29^0C, though temperature decreases from 2PM, it is observed that only a drop of 6^0C takes place up to 4.15pm, because from morning to afternoon the air entrapped in the casing gets heated and so even outside temp decreases the warm, trapped air boost up the process up to some extent &these by the performances of heat absorption is higher than the expectation (based on outside temp).

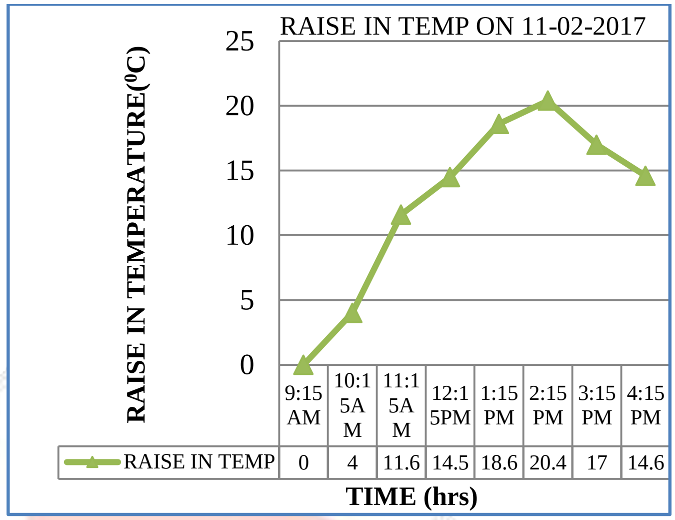
During first one hour that is 9AM to 10AM only slight raise in temperature is observed and there after a sudden raise is observed. This is because it need some time for the air entrapped in the after the air particles activated and results in absorption of higher heat Energy.



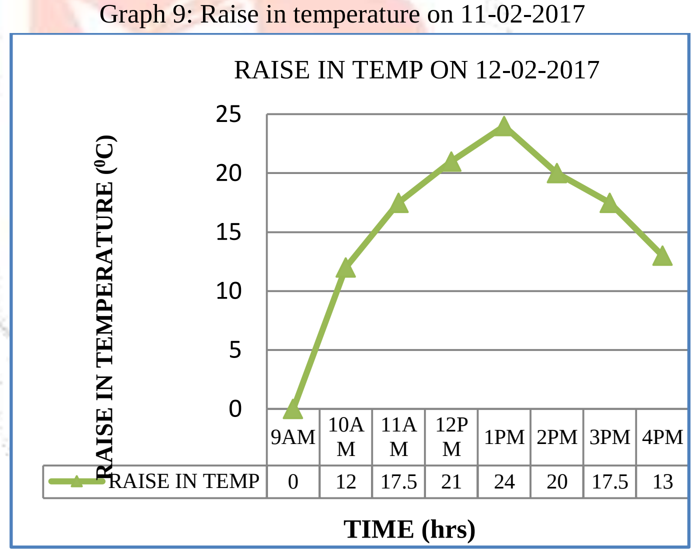
Graph 7: Raise in temperature on 9-02-2017



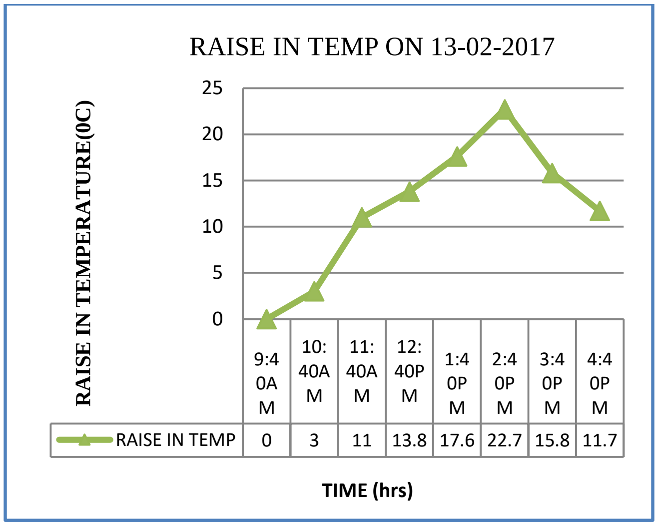
Graph 8: Raise in temperature on 10-02-2017



Graph 9: Raise in temperature on 11-02-2017

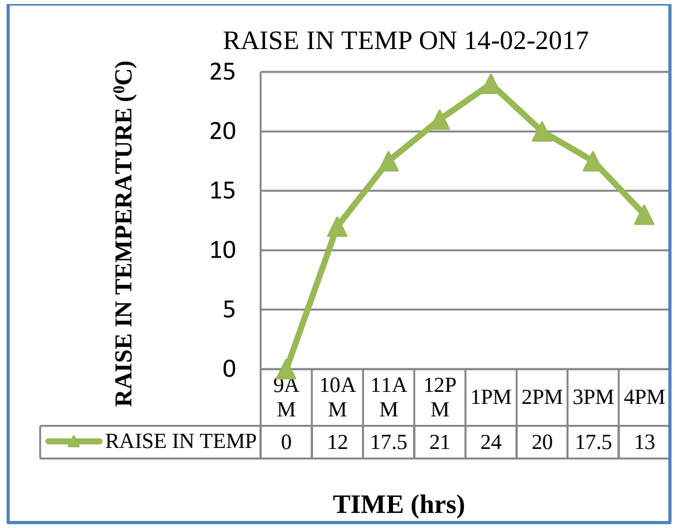


Graph 10: Raise in temperature on 12-02-2017



	9:40AM	10:40AM	11:40AM	12:40PM	1:40PM	2:40PM	3:40PM	4:40PM
RAISE IN TEMP	0	3	11	13.8	17.6	22.7	15.8	11.7

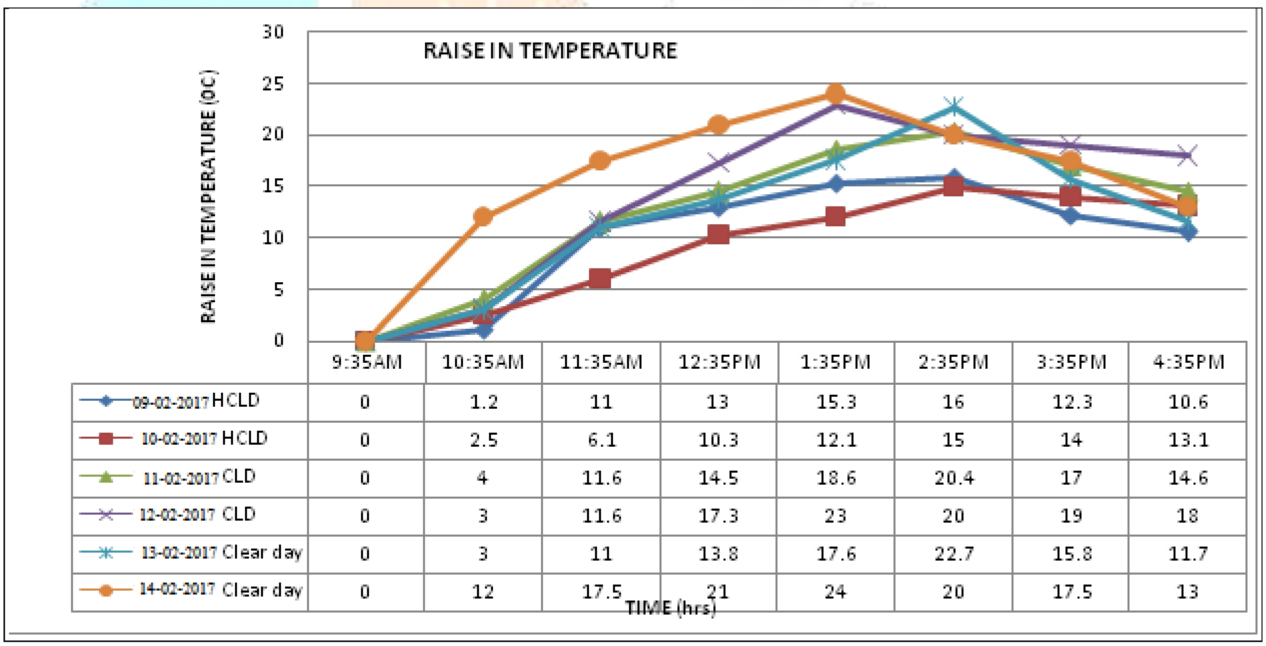
Graph 11: Raise in temperature on 13-02-2017



	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM
RAISE IN TEMP	0	12	17.5	21	24	20	17.5	13

Graph 12: Raise in temperature on 14-02-2017

Graph for raise in temperature for all days:



	9:35AM	10:35AM	11:35AM	12:35PM	1:35PM	2:35PM	3:35PM	4:35PM
09-02-2017 HCLD	0	1.2	11	13	15.3	16	12.3	10.6
10-02-2017 HCLD	0	2.5	6.1	10.3	12.1	15	14	13.1
11-02-2017 CLD	0	4	11.6	14.5	18.6	20.4	17	14.6
12-02-2017 CLD	0	3	11.6	17.3	23	20	19	18
13-02-2017 Clear day	0	3	11	13.8	17.6	22.7	15.8	11.7
14-02-2017 Clear day	0	12	17.5	21	24	20	17.5	13

Graph 13: Graph for raise in temperature for all days

In the graph: HCLD: Heavy cloudy day CLD : Cloudy day

From the graph it is observed that the temperature increases with time from morning 9AM to mid afternoon and decreases up to 4PM. It is observed that the temperature raise low on heavy cloudy day that is 10-02-2017. Where as it is higher on clear day 14-02-2017.

During cloudy day the temperature raise is 43.75% higher than that of temperature rise during heavy cloudy day (the maximum temperature raise is during clear day is 50% higher than that of heavy cloudy day 4.34% higher than that of cloudy day).

VI.CONCLUSIONS

From the experimental results conducted on fabrication and testing of box type solar cooker the following conclusion are drawn

1. Temperature inside and outside bowl increases with time from 9:35AM to 2:35PM and decreases thereafter.

2. The temperature raise increment during heavy cloudy day and cloudy day increases slowly during starting, whereas the same takes place with in small time during clear day.
3. The maximum raise in temperature is inside the bowl is 24^0C and is obtained on clear day i.e. 13.2.2017 and 14.2.2017.
4. 77.5% of increase in temperature is obtained during heavy cloudy day.
5. 90.5% of increase in temperature is obtained during cloudy day.
6. 96.1% of increase in temperature is obtained during clear day.
7. Based on the changing of direction of solar box and angle of reflector glass. The temperature raise is increases for the following direction and angle with respective time.

TIME	DIRECTION OF SOLAR BOX	ANGLE OF REFLECTOR GLASS
9:35AM	NORTH-EAST	90^0
10:35AM	NORTH-EAST	85^0 –90^0
11:35AM	EAST	90^0
12:35PM	10^0 FROM EAST	95^0–100^0
1:35PM	10^0 FROM SOUTH	98^0 –100^0
2:35PM	10^0 FROM SOUTH	100^0 –105^0
3:35PM	SOUTH – WEST	105^0 –110^0
4:35PM	10^0 FROM WEST	105^0 –110^0

8. In the afternoon though the temperature outside bowl fall in down, it is not affecting much on the temperature of inside the bowl due to warm entrapped air.
9. The maximum temperature raise is during clear day is 50% higher than that of heavy cloudy day and 4.34 % higher than that of cloudy day.
10. Inside bowl temperature raise is 4.5 times greater than that of outside bowl temperature.

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