Solar energy has been used from ancient days on wards in India as well as other countries of world..In indian context in MAHABHARATUM written by Sage Veda Vysa usage of solar energy for cooking has been mentioned.In the present book how the basis of sun movement in various seasons waspresented as mentioned in BHAGAVATUM written by sage VedaVysa. From this conclusions has been drawn regarding reflector design..In spite of this temple gopurum Shapes of Indian architecture eas also considered for black trough design..Regarding coatings modern paints has been used .Regading paiting of black vessels olden days paints manufacturing is under study.

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Kota Anjaneya Sarma

New Design of BOX TYPE SOLAR Cooker

parabolic solar cooker

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Write up on Solar Cooker

1. Chapter 1 Introduction to solar energy- pages
2. Chapter-2 :Parabolic surfaces & Paraboloids - pages
3. Chapter-3 Solar cooking
4. New design of Box type Solar cooker-design of reflector & compound parabolic surfaces
5. Design Back up Temperature readings during experiment
6. Performance tests SCI & Pune University test reports
7. Chapter - Advanced reflector design for lessening boiling time

Chapter-1: Introduction to Solar energy

Salutations to almighty, lord of dynasty and sages of India and parents, grandparents, fore fathers and teachers for giving inspiration to think about solar cooking. In Indian culture, Sun is worshipped daily as routine from ancient days onwards. The utility of solar energy was mentioned in Indian epics written by ancient Indian sages. The sun is also worshipped in other cultures of remaining part of world.

The earth rotation and its inclined position will cause days and nights of varied magnitude/lengths depending up on geographical location and varied seasons. Solar energy is intermittent energy source available abundantly in nature .It is not like continuous fuel LPG/wood. It varies with respect to geographical location wise .As distance from equator increases the availability of solar energy varies. It also varies with respect to season also. Its intensity varies with respect to morning, noon and evening. It is of lower calorific value fuel and is expressed in watts/per square meter or Kilo calories per square meter. Solar energy is expressed as solar constant 1000Watts/square meter. The total incident radiation per day is expressed as insolation. For example 5KW insolation means total radiation received per day at square meter area is 5 KW.

Solar energy is converted in to thermal energy or directly into electrical energy. Thermal energy form conversion by absorption (black bodies) or concentrating by reflectors in reflection phenomenon or refraction phenomenon.

In absorption mode the temperature developed depends upon intensity of incident light and it is used for temperature less than 150 degrees Celsius application. In this form of energy cooking, drying/frying pasteurizing can be easily done. Roasting application requires more temperature.

High Concentration of light generates higher temperature more than 150 degrees Celsius and useful for high temperature application. The concentrators used for roasting application of cooking part and for steam generation and other industrial applications.

In electricity conversion photovoltaic panels are used. The electric power generated is of direct current.

In solar energy utilization the reflector or lenses used energy collection size/ area is more to get the required heat quantity and the designed equipment occupies higher space in comparison with LPG stoves or electrical stoves/heaters. More over the designs should be robust to with stand wind loads and reflectors or lenses are to be placed in open areas where sun rays are falling. The frequent dust falling on the equipments is a criteria which reduces efficiency.

In electricity conversion photovoltaic panels are also occupy more space and placed in open areas where sun rays are falling .

The sun movement is of diurnal. The reflectors or Photovoltaic panels are to be aligned with respect to sun position is called tracking.

Tracking is of uni-direction or bidirectional type.

In heat conversion equipments like reflectors/lenses concentrators or other type non imaging concentrators and PV panels are to be aligned to sun in unidirectional or bidirectional for better utilization in extraction of solar energy. If they are kept stationery the energy collection will be less. Tracking is costlier and adds moving parts and maintenance issues are to be addressed as and when required.

The solar energy is intermittent resource but abundantly available throughout the year. Solar energy is of lower calorific value fuel expressed as solar constant 1000Watts/square meter. The total incident radiation per day is expressed as insolation. It is to be used as supportive energy source in parallel with LPG and electricity. In this way reduction of in use of LPG /electricity for present society needs is possible and leads to lessening of environmental damage.

The food boiled/cooked in box type solar cookers is tastier and highly nutrient one.

To increase the usage of solar energy the new design of box type solar equipment was worked out from concept, design, manufacture, assembly, testing was done for guaranteed performance. As this done at residence without laboratory/educational institute support there is approximation and suit at site process adopted in this design. In this design in normal sky more than one time boiling is ensured and frying/drying is done. The design procedure/technology is simple and easily adoptable for common man knowhow. This cooker reflector tracks the sun and to be rotated once in a day only at noon to take care of sun movement towards west. The utensils and the materials are normally available in local market.

Chapter-2: Solar thermal cooking

Cooking food is an art and tradition oriented one depending up on tastes and choices of individuals and occasions. Conventional cooking is done with animal dung (dried form), agricultural crop residues like rice husk, dried leaves etc., wood, char coal, LPG or electricity of increasing order of calorific value fuels. Wood calorific value is of 4500Kcal per ton. Charcoal is of higher side than wood. In this way LPG is the highest of carbonaceous fuels. But solar energy is of lower calorific value fuel comparison to these fuels. In this solar cooking time of cooking is slightly more than these fuels.

In normal cooking heating is done at bottom of utensil. The heating system (wood burning oven/electrical heater/LPG stoves) is kept inside kitchen. Through conduction process of metal surface, convection of liquid inside the food vessel heat is transferred. In this cooking attendant attention requirement is very much required during cooking. If attendant is not there, the food will burn and change in chemical properties food occurs. Nowadays pressure cookers are used to avoid burning of food. In pressure cooker due raise temperature by increasing of pressure occurs. But in both the process the soaking of food at 60 to 70 deg Celsius for less time..

In solar box type cooker cooking due to low temperature (less than 150 deg Celsius) burning of food will not take place. In this cooking, boiling starts from top to bottom. This is because the temperature is more at top and less at bottom. Attendant requirement is very less. The soaking of food at 60 to 70 deg Celsius takes place for more time. This food is tastier and all vitamins, enzymes are preserved. It is highly nutrient food and easily digestible by all age groups. With solar cooker, cooking is to be done outside the kitchen where sun rays are falling. By ensuring the boiling without wastage of food and more than one time boiling solar cooking will get popularized in the society.

Chapter-3: Parabolic surfaces& Paraboloids study

Parabolic surfaces and paraboloids and their role in solar energy applications Introduction: The parabola observations mathematically as follows.

If we consider a parabola: Square Y=4aX (a is focal point of parabola)

X	Y	X	Y
0	0	36a	± 12a
a/4	± a	49a	±14a
a	±2a		
4a	±4a		
9a	±6a		
16a	±8a		
25a	±10a		

If we observe the above readings of ordinates increases steeply up to certain limit of X ordinate(X=a) and afterwards Y ordinate increment is less as X ordinate increment up to(X=16a) and after this limit the increase of Y ordinate w.r.t to X ordinate is becoming too less. Parabola is of 2dimensional figure. If it is rotated about axis passing through focal point paraboloid forms, it is of 3 dimensional figure.

Study of parabolic surfaces:

As per Physics parabola formula: Square Y=4aX.

The light rays when fall on parabolic surface all the rays concentrated at focal point. In parabolic surface rays falling surface below focal point rays deflected/reflected upwards. In parabolic surface rays falling surface above focal point rays deflected/reflected downwards.

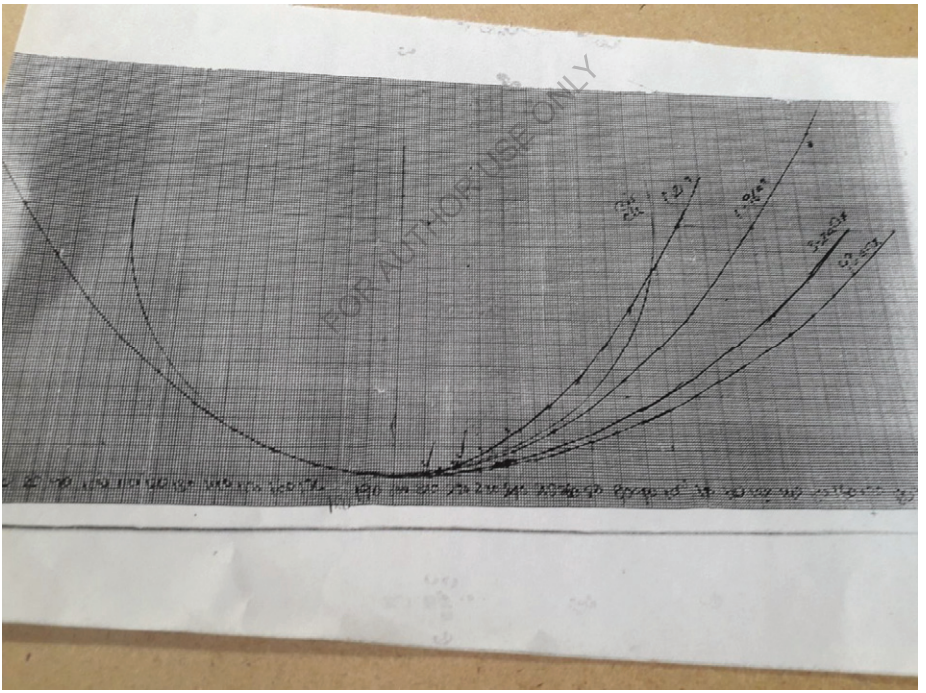
The curves plotted on graph paper are attached in figure-1

If 4aX is replaced with perfect squares like 1.21aX curve plotting is shown in graph paper.

If 4aX is replaced with perfect squares like 1.96aX& 3.24aX curve plotting is shown in graph paper.

Curves are indicating that the shape is less access to scatter/diffusion radiation of light.

**Fig -1 graph;



The above figure indicates different parabolas generated4aX is replaced with perfect squares like 1.21aX, 1.96 aX&3.24aX.

As the focal point increases parabola widens and accessibility for reception of radiation increases.

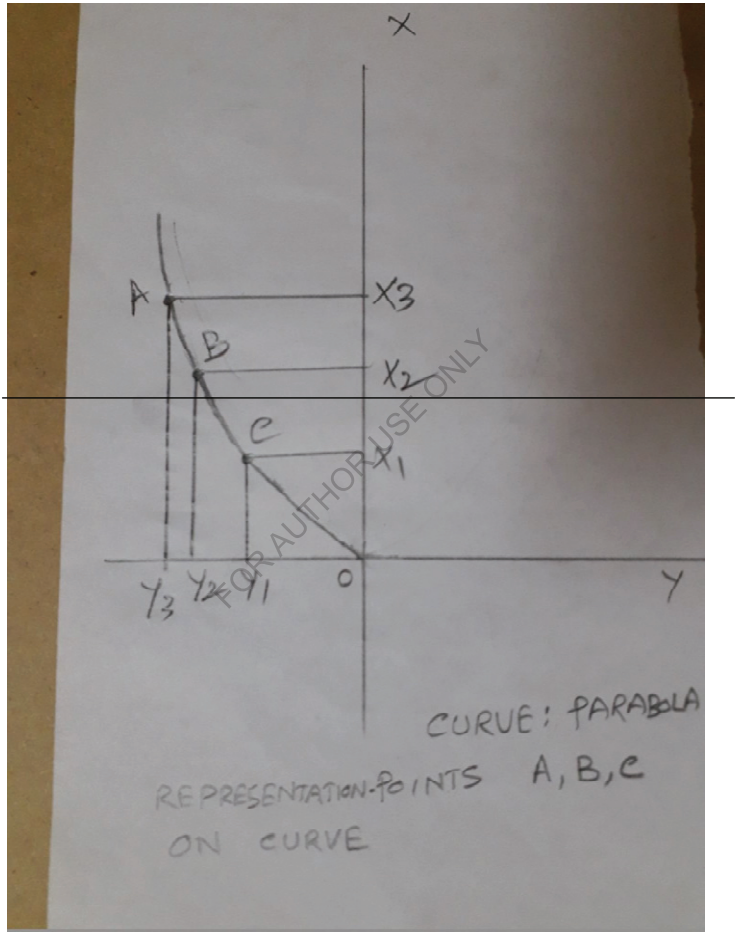


Fig-2

In the above drawing at point C (X1,Y1) ordinates At point B (X2,y2) at A(X3,Y3)

For making good profile the difference of straight line length and curve length should be bare minimum. Straight line length of points A&C is equal to arc length of points A&C. This can be achieved by fixing the intervals of Y ordinates (difference in between Y2 & Y1, Y2 & Y3). The length of curve at B&C, B&A of curve and straight line lengths of points B&C and B&A difference will be bare minimum. The minimum interval (difference of Y2-Y1&Y3-Y2) is key factor and also decides the shape deviation with respect to mathematical equation to actually fabricated model.

Paraboloid can be considered into number of frustrum cones of radius as follows:

The top cone radius is (y) r at height x, next immediate bottom cone radius is r-delta r(r minus delta r) and the height of cone is x-delta x (x minus delta x).

In this way all frustum cone radii and heights can be nomenclature upto x=0 and y=0(The length of arc is square root of sums of difference square of x ordinate and y ordinates-slant height of frustum cone).

* In this way if cross section is changed into square shape the length of top square side is 2r and height is x, next immediate bottom square side at delta x height is 2(r- delta r) [(r minus delta r)].In this square sides and heights can be nomenclature up to x=0 and y=0

*If cross section is changed into rectangle l (length),b(breadth) at height x and immediate bottom rectangle length will be(l- delta l) [(l minus delta l)] and breadth will be (b- delta b).In this way nomenclature can be done upto x=0& y=0

*In this way by changing the cross section from circle to rectangle paraboloid becomes parabolic surface.

In the same way spherical surfaces also can be explained.

By changing from circle cross section to square section the compound parabolic surface (as shown in fig-1 the surface area of the shape will increase and useful for designing the absorber type solar heat conversion equipments. In this way without tracking, the solar household appliance can be designed. In this model effect of shade factor is bare minimum, acceptance angle is high .Incident area to surface area ratio is higher which increases thermal efficiency and higher temperature generation. In this type without tracking time duration of receiving the sun will increase when compared with box type cooker. By applying high absorptive and low emissive coating like black chrome, aluminum oxide and copper oxides the temperature generated can be increased still further. By placing a mirror facing towards south the efficiency will increase in comparison to box shape as used in box type cookers. In this way solar energy can be utilized for house-hold purposes/application.

Tracking:

Paraboloid/parabolic surface is to be tracked foe suitably for solar energy concentration. The parabolic surfaces are used for communication antennas and for solar energy equipments.

Advantages:

PARABOLIC PROFILE /SHAPE CAN FOCUS DIRECT BEAMS OF LIGHT AT FOCAL POINT AS PER APPLICATION OF PHYSICS.

The dish antenna used for receiving/transmitting signals can be manufactured in this method for better accuracy of profile and size can be reduced for communication industries.

It is useful in lighting industries for better illumination for area covered. This is useful for fabricate process perfect parabolic surfaces.

This can be used for concentrating photovoltaic systems generation for achieving maximum electrical energy generation with tracking facilities. By implanting photovoltaic cells on the surface (trial could not taken.

Pilot models paraboloid and compound paraboloid (shown in Photos Fig 3&4) are of MS make. Paraboiloid was nickel coated for reflection and compound paraboloid is black coated.

Data collected through concentration by paraboloid type reflectors (fig-3)

Fig-3

Fig-3: Paraboloid type reflector has been developed with dis diameter major420 mm& minimum 140 mm height

The following are temperatures at focal points on 22nd and 29 January 2006.At 1000 hars 140 degrees celcius, 1230 hrs 200 degrees, 1430 hrs 180 degrees and at 1600 hrs 120 deg celcius

Fig4

Test Resuts (Fig-4) compound parabolic surface black coated, when kept in sun (22nd and 29 January 2006.) at mid noon peak inside temperature developed is 80 degrees, at 1030 hrs 60 degrees and at 1430 hrs 65 degrees found inside as the top surface is covered with two table top transparent glass covers 3 mm thick kept at 15 mm apart without providing thermal insulation at surface (outsides & bottom (outer) surfaces without proper tight sealing at top side. A mirror was placed facing towards south face.

In this way it can be concluded compound parabolic surfaces are useful in absorption application .By changing the material to aluminum the temperature raise is more in comparison to mild steel because of higher thermal conductivity and temperature is sustained for cooking as long as sun rays are available.

Conclusion:

1. By changing circular cross section in to square or rectangle the 3 dimensional figures easily manufactured.

2. The required curve profile accuracy limit easily ascertained.

(The above is from" Role of parabolic surfaces & paraboloids for better utilization of solar Energy- Presented at 23rd Indian engineering congress held at Wrangal/India in December 2008 published by Institution of Engineers of India .the photo copy of acceptance of paper is enclosed for reference.)

Chapter-4

For solar cooking box type or concentrated type cookers are of mainly two types.

In this text exclusively deals with new generation of box type solar cookers deign/development based on the observation as mentioned below.

Sun rays analysis:

As earth rotates, Sun rays travels East to West, East to noon the rising sun-shade length decreases- reduces the reflected light length the intensity of sun rays increases from morning to noon and reaches peak value at noon. Noon to west lowering sun-shade length increases- increase the reflected light length. The intensity of sun rays reduces from peak value to minimum. In spite of this the shade rotates. The rotation of sun rays varies with respect to season wise.

In this way rays can be classified into inclined portion& vertical type. The sun rays usage in inclined zone will increase the operating period of solar cooker. This is done with the help of tracking system using one direction& two direction using electrical/mechanical aids manually automatically.

In the present design the tracking part is eliminated to maximum extent and incorporated in reflector design.

In general the direction sun raising position varies season wise. The sun raises in east. Due to variation in east the directions west, north and south positions varies. The change in the position of direction East was identified by ancient Indians and for time calculation it is one of base for Indians. E2& E1 as shown in the fig-3 As per Indian time calculation as mentioned in Srimad Bhagavatum written by Indian Sage Veda Vysa, year is divided in to two parts called Ayana. In Uttarayana, Sun starts moving towards north w.r.t. to East. In Dakshinayana, Sun starts moving towards South w.r.t. to East. The change of other directions, west /south/north are shown in the fig-5. Due to this there is a change in reception of sun light (insolation) at different locations of earth at different periods of time /seasons. Due to this different seasons forms in a period one year.

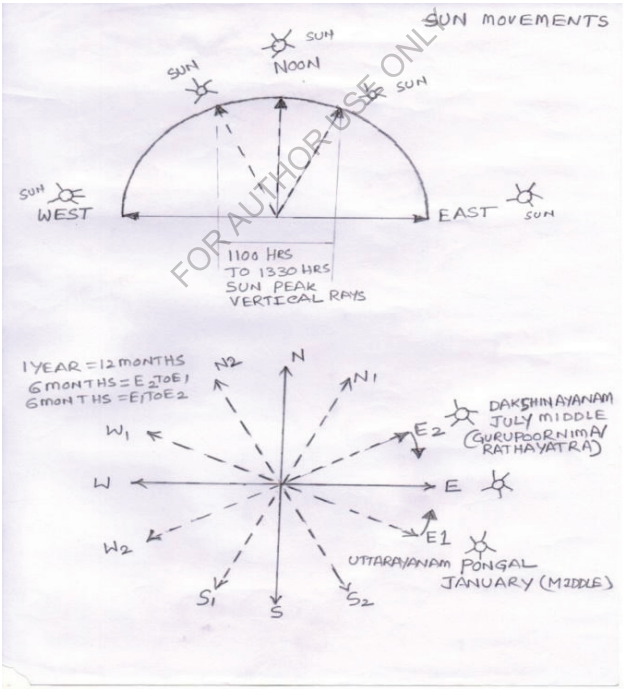


Fig-5

In the above figure top one indicates the sun position East to west. The time if we consider 0600 hrs east position, mid noon 1200hrs and west 1800 hrs of clock position (180 degrees of circle). The hourly angle is 15 degrees. The sun position is 90 degrees at 1200 hrs ideally. Plus minus 10 degrees of 90 degrees is almost vertical condition of Sun. With reference to clock the time 1120 hrs to 1220 hrs. But due to earth axis is inclined the time varies slightly. For general purpose it was considered after 1100 to 1330 (max) vertical portion of rays.

At position E2 with respect to India peak summer. At position E1it is peak winter in India. If we observe the above figure the sun crosses 2 times position E where the day and night timing are equal. With this figure we can understand differences summer, rainy and winter seasons in the geographical locations above And below equator .Below equator it is opposite to above equator conditions that means peak summer at E1 and peak winter at E2. Rainy season will be at March month and at E position where days & nights are equal.

The following fig-6 we can observe the sun rays falling on a box.

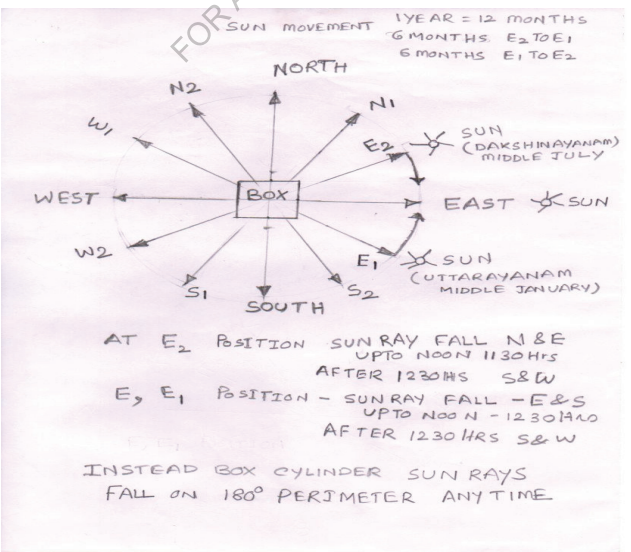


Figure-6

The sun rays when falls on a square box (Fig-6) it can be observed that rays falls on two sides of the block& top side /surface at any time. At position E1 the sun rays fall on East & south side of box. At noon rays falls on South side for some period (This is observed practically at Visakhapatnam in 4 week of December Month). Afternoon rays fall on South and West side of box. At position E2 sun rays fall on east and north of box. At noon the rays are vertical for some period. Afternoon rays fall on South & west side of box. At position E the rays falling is similar to E1.

If the same rays fall on a cylindrical surface it can be seen that at any point of time 180 degrees of perimeter will be exposed to sun rays and top surface of cylinder exposed to sun rays. But the change in the position of direction East is understandable causes due to rotation of shade.

Keeping this observation into consideration reflector has been designed to cover 2 sides of box and or 180 degrees perimeter of box only. It is mounted/positioned in sides (directions where radiation does not falls).

Reflector, reflection patterns:

If rays falling on an inclined mirror depending upon the incident angle reflected rays position will be varying as shown in the sketch. At Q1 the rays reflected length will be up to X1 on the ground. For more than Q1 up to Q2 the reflected ray length is X2 on ground. If reflected ray angle increase further reflected ray will not fall on ground& falls in air. As the sun raises from early hours to noon the length of reflected ray on the ground will decreases. From noon to sun set the length of reflected ray on the ground will increases. If the ray is parallel to mirror (at noon) reflected length will be slit as shown in sketch- for different positions of sun. As the sun lowers from noon hours to West the length of reflected ray on the ground will increases. (Fig-2). In this present design the reflected ray part (X1, X2) will be transferred to black trough of solar cooker to generate heat

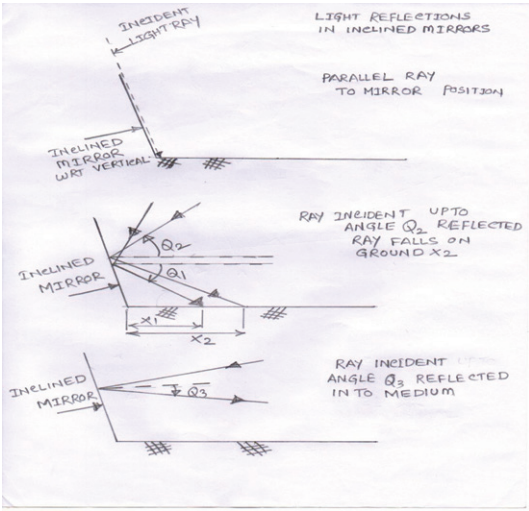


Fig-7

Reflector design is based on the reflection pattern and temperature raise is based on reflections intensity and retention time of reflections in parabolic trough. The reflections varies w.r.t. to sun position

Fig-8

In the above figure single mirror reflection when mirror is perpendicular to sun rays intensity of reflected rays is maximum. The reflected light is wider equal to mirror side. But length varies with respect to hourly angle.

Fig-8A

In the above figure 8A the mirror is rotated about vertical axis slightly. The reflection width is less and reflected rays are inclined w.r.t. mirror bottom edge. There is slight reduction in intensity

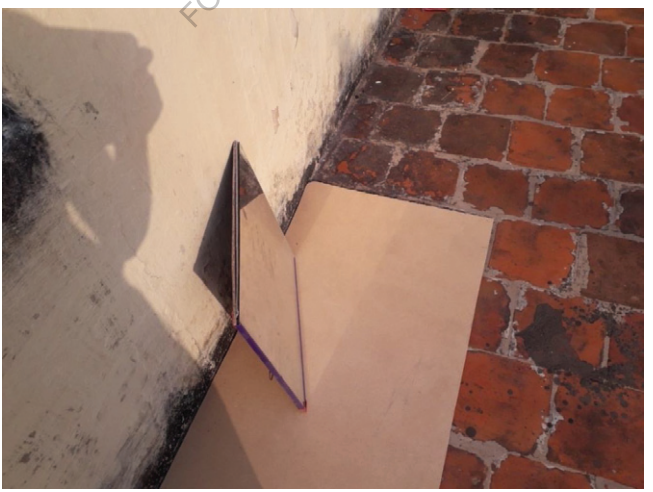


Fig-8B

The mirror is rotated about vertical axis is more (fig-8B).The reflection width is still reduced in comparison to fig-8A and reflected rays are more inclined w.r.t. mirror bottom edge.

When reflection is straight and falling on the ground as shown in the picture fig-8the intensity of reflected ray is maximum .As the mirrors are rotated about vertical axis the reflection width is reduced and reduction depends upon the angle of rotation .If mirrors are arranged in above mentioned positions different intensity reflected beams will form as the sun position changes .Reflections direction will change due to change in position of sun and reflection intensity and size reduces as per hourly angle.

It can be concluded that mirror segments are inclined and arranged in the nearer to curve form reflections overlaps and high intensity beams forms. The arrangement of mirrors is done after observing positions actually at site. Any change in mirror angles will lead to change the reflection pattern and effect the performance of temperature raise and cooking period. The reflections falls on black surface temperature raises quickly.

Fig-9

In the above picture there is 2 piece reflector (behind black trough right side author in sitting position). The author is explaining about solar cooking to colleagues in the picture. Its reflection pattern is over lapping reflections partly.

With 2 piece reflector there is some improvement in boiling quantity due to over lapping. But the time is more

Fig-10

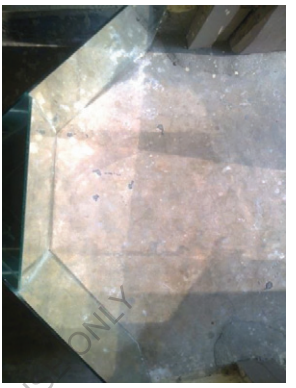


Fig-11

There is variation in reflection pattern of 3 segment reflector as shown in Fig-10 nearer to noon and fig-11 at 1045 hrs(the timing are tentative for noting variation of reflection pattern).If observed closely 3 different reflections and 3 different variations in intensity of overlapped reflections. Variation in intensity of reflections due to segment shape and sizes causes differential temperature in the black trough.

Fig-12

Fig-13

Fig-12&13 different reflection patterns of 5 segment reflector. There is difference of distribution as per hourly angle of Sun and different overlapping reflections cause intensity variations of reflected light leads to variations in temperatures.

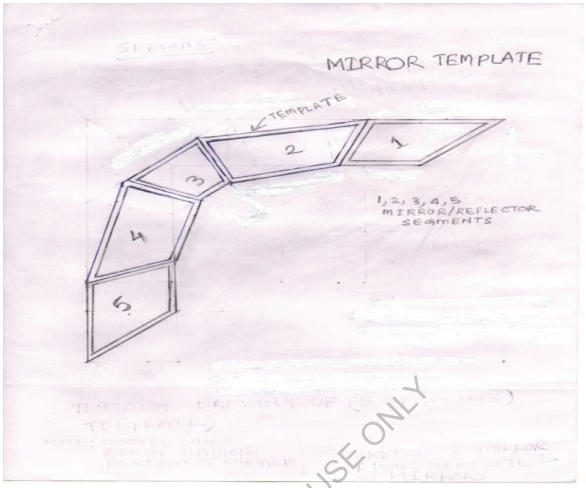


Fig-14(sketch reflector5 segments with template)

Fig-14 A: Reflector assembly-template fixed with mirrors

Presented for 6th SCI world conference in year 2017 held at Goraj/ Vadodara/ Gujarat/ India.

In above figures, five piece reflector there is 5 reflections at different timings of a day..There is improved spreading of reflections and increase in overlapping. Overlapping varies w.r.t. to time. The quantity and time of boiling has improved.

In this way by it is indicating that increasing segments number the temperature raise increases and boiling time reduces. There is optimum number of mirrors and sizes. The angles at different planes of reflector are more important. This is because the sun rays angle varies with respect to sun position at different season. The angles are decided after continuous recording of temperatures at different seasons. The angle varies with respect to distance from equator of the geographical location. The reflector is effective in inclined zone of sun rays and not at vertical sun rays. This is because the reflected ray length is bare minimum when sun is at noon position. To keep the thermal regime of cooker compound parabolic trough is used to take care of vertical rays.

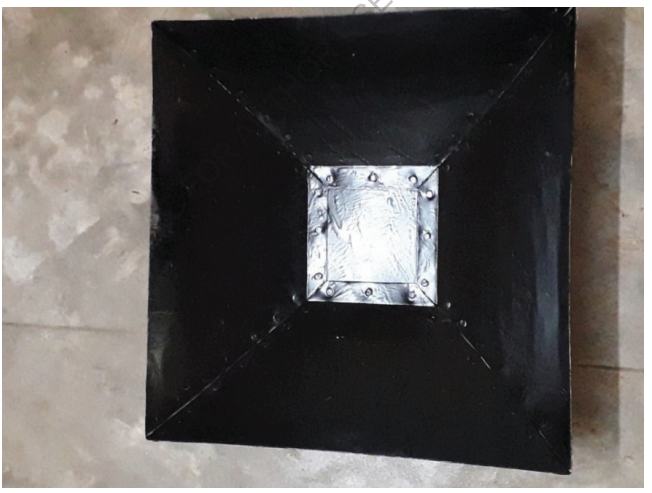


Fig-4A

Parabolic Trough design:

(Refer fig-4a aluminum make) Since parabolic profile will deflect/reflect the incident rays to focal point. The parabolic surface (parabola : Square $Y=4aX$-where a is focal point) incident light rays falling on parabolic surface below focal point rays will be

deflected/reflected to upwards& incident rays above focal point rays will be reflected/deflected to downwards.

Paraboloid cross section is circle in shape. If the circles are replaced with squares then compound paraboloid forms& the shape formed is two parabolas focal axes of which perpendicular to each other In this way the compound parabolic surface type absorber is designed to take care of vertical rays. At noon the reflector reflections are nil and only compound parabolic surface take care of heating of the food and food utensil. This shape can be observed in Indian Temples-architecture.

The Sun rays falling on parabolic trough as mentioned above from reflector through double cover glasses it is seen clearly with necked eye. This shape will take care of inclined sun rays which are reflected by mirror. As the experiment is carried out at residence due to lack of sophisticated cameras the photos could not be taken. Though shade is formed in the trough due to rays of different directions the effect of shade in reduced to large extent and improved performance observed in the form of sustenance of higher temperature for higher periods. Due to sustenance of higher temperatures increasing the number of times boiling increases.

More over the depth/thickness of food layer will affect the cooking period. By selecting parabolic surface suitably with respect to utensils used the height of utensil can be reduced in turn lessen the food layer thickness.

Fig-15

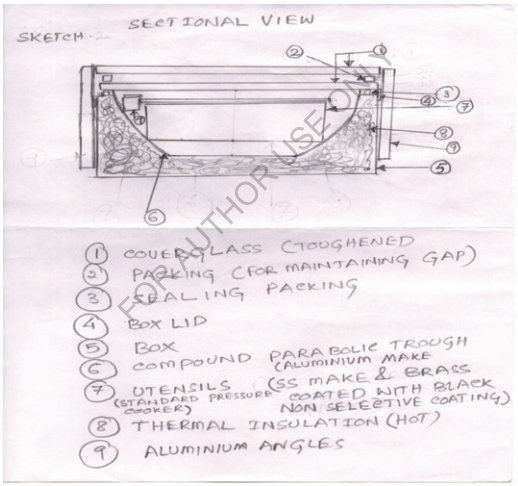


Fig-15 A(sketch insulated box assembly)

The above figure 15 is actual insulated box with compound parabolic trough. Fig 15A indicates the cross sectional view of insulated box fixed with rubber sealing and cover glasses. In the insulated box food containers black coated outside and lids coated with black outside with food material are placed in black coated compound parabolic trough as mentioned above. The insulation mineral wool to withstand more than 200 deg celcius. Sealing rubber is fixed on the insulated box. The sealing should

be of rubber material to withstand more than 200 degrees Celsius. Cover glasses are of toughened glasses .One toughened glass is directly placed on rubber packing. The toughened glasses are placed at 10 mm apart. The total load on the ceiling is weight of toughened glass and reflector material weight plus reflector template weight and in turn transferred on to insulated box..

Fig-16

The model of solar cooker presented in ABN TV (Indian TV channel) telecasted on February 8th year 2014 & in 6th SCI world conference held in January2017 at Munisevashram, /Goraj VAdodara, Gujarat/India. The same model was tested by Govt of India Minisrty of New & Renewable Energy Laboratory in Savitribai Phule Pune University in 2016 January. Satisfactory performance certificate was issued by Director, School of energy studies Savitribai Phule Pune University in year 2016.

In the above shown solar cooker (fig-16) reflector material is of mirror. It is fixed to template. The area of mirrors is 0.58 square meters. The reflector assembly is designed to mount on the top cover glass. It is fixed to box-by tying with plastic twine. The mirrors are fixed on the template. The assembly occupies space is 750mm

x750mm x 750mm. All parts are easily assembled and dismantled. The mirrors can be replaced with other material of equivalent reflection area of mirror.

Tracking of cooker:

With respect to Visakhapatnam geographical location the following is the sun rays position tentatively. To track the sun the reflector is to be rotated once in a day at noon when Sun moves towards west at noon, the amount of rotation 90 degrees w.r.t. vertical circle from early September to Middle April. In this period sun rays falls on East & rotates to south of box up to noon. After noon sun rays falls on south& west sides of box.

In the remaining period mid April to early September early hours to noon rays fall East & North and after noon South & West. In this period sun rays falls east& North during morning to noon1130 hrs & at noon sun rays are vertical. After noon beyond 1230 hrs the rays falls on South & West faces of box. The reflector is to be rotated 180 degrees at noon with respect vertical circle.

To cater the winter rays inclination (during December& January months) a semi permanent lever attachment is provided with reflector template to adjust tilt of reflector for better usage of cooker in this period.

The temperature generated is 110 to 120 degrees Celsius which suitable for normal household cooking needs..More over in this design more than one time boiling& frying was done in clear sunny days even in winter months also. In this cooker time of operation from 0900 hrs to 1500hrs IST. The utensil used is of stainless steel make standard pressure cooker 12 lts smaller one coated with non selective black coating outside. Lid is black coated outside like utensil.

Effective heat utilised:

Total area of light: Area of reflector (RA) + Direct incident rays received by black trough area (Tr A)

Due to variation in Sun, hourly angle the reflector reflections will be varying and varying heat inputs will be given to boil the food.

Effective heat generated (ideal situation where total light falls in to box)=incident light of the total area. The maximum heat = (RA +Tr A)

Quantity of food boiled = Q (heat used for boiling water& food material-for boiling .For frying quantity kept in the utensil for frying).

Considering solar constant 1000W/Square meter/Hour 860Kcals/hour/Square meter. Effective heat input=860(RA+ TrA) Kilo calories

Ideal Efficiency=output/input=Q/860(RA + TrA).The corresponding time period of boiling /frying is also to be noted to decide the performance of the cooker.

In general some loss of light occurs. It is -light not falling in trough.

To judge the performance the cooker is to be tested in different sky conditions& at different seasons of a year period and for time of boiling with respect to quantity.
In normal box type cooker, with single reflector, in the place where sun rays does not fall temperature is less in comparison to place sun rays fall. Even in this design temperature gradient from one corner to other corner& top to bottom were observed. The temperature gradient is very less in comparison to single reflector box type cooker.

In solar cooker cooking starts from top to bottom along with sides to central portion.

In the present model reflector area (mirror area) = 0.585 Square Meter. Trough incident area = 0.1764 Square meter

For boiling 450 grams rice water used is 1000to 1100 grams depending upon the rice.

In normal sky conditions in 2 hours period 450 grams of rice is boiled in the model. All types of vegetables green leafy & roots are tested for boiling. Chick pea (gram dals-chana, mung etc), peas, peanuts were tested for boiling. All gram dals including peanuts/groundnuts were tested for frying. Suji & Chick pea powder was also tested for frying.

The cooker was tested for last 5 years continuously at different seasons and different sky conditions of Visakhapatnam Area (at geographical location Visakhapatnam) State Andhra Pradesh, India.

The same design was selected by SCI, (Solar Cookers International) Scremento -California USA for demonstration at 6th SCI world conference The cooker was demonstrated for performance at 6th SCI world conference held at Munisevashram, -Goraj, Vododara, India during January 16 to22 year 2017.(The copy of letter is in back up)

At 6th SCI world conference peanuts (ground nuts) were fried and chick pea/ Gram dal (Chana) was also tested for boiling. The food material was distributed for cooking performance during conference days.

The model was tested at winter season January 16 to 22 year 2017 to know the performance..

It was noticed due high insolation at Vadodara, Gujarat the time of boiling/frying time reduced by 20 minutes (approximately) in comparison to Visakhapatnam for same period.

Experimental set up of Box type solar cooker:

Fig-17(pilot model)

Fig-17A (pilot model)

In pilot model fig- 17 Rice 370 grams& leafy vegetable with dal 75 grams boiled.The reflector is taken out and cover glasses are taken out in the fig-17A thermometers 3 nos are placed to monitor the temperature.They are used to measure temperature at different time periods.19 months temperatures were monitored continuously to rectify the problems arised during this experimentation This has led to ensuring guranteed performance in normal sky conditions at different seasons.

Fig-17B (pilot model)

If we closely observe fig -17B we can find moisture accumulation. Due to moisture accumulation in winter slight cloudy sky there is increase in cooking period. In pilot model sealing material used is papers

The black trough in which leafy vegetable boiled in brass utensil& rice boiled in stainless steel utensil of standard pressure cooker 12 lts (smaller one). The lids are in open condition. Utensils outside black coated and lids outside black coated. In Fig-17B slight increased load with 2nd cup. Moisture accumulation is observed.

The temperature readings at different seasons are shown in next pages.

Fig-18 pilot Model 1 kg boiling

In bigger size model fig -18 boils 1 kg rice. (The reflector used is 5 segments model used for ½ kg boiling). Reflector is mounted on box.

In this position in normal sky in 3 hours one kg of rice boiled.

This indicates if reflector is mounted on box there is increased boiling quantity and reflection losses reduction (falling out side box) reduced.

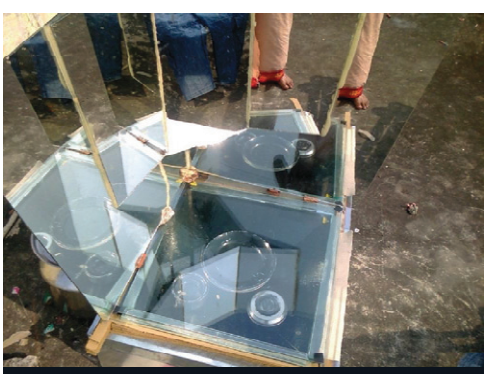


Fig-18A

In the fig18A to adjust the tilt in winter stones are placed underneath reflector. In working model permanent arrangement made (liver arranged)

***** Temperature readings:

Conclusions of Temperature Readings:

1. The place where light is not falling temperature is less and place where light falls temperature is more by 20 Deg Celsius. This indicates temperature differential in black trough is to be reduced.
2. Thermal leaks are to be arrested with better sealing. This reduces condensation.
3. Uniform distribution of light and overlapping are increasing temperature and reduces boiling time.
4. Reduction in loss of light and light unexposed area during operation of cooker.
5. There is difference of temperatures of 3 corners observed. This corners temperature difference to be reduced for reducing boiling period.

The above observations are to be eliminated to promote solar cooking.

When the presentable model (fig-16) when tested at 6th SCI international conference it was found time of boiling/frying reduced by 30 minutes.

To increase the uniform distribution of reflections of reflector in compound parabolic trough and to reduce the boiling time the reflector design was changed.

Chapter-7 Advanced Reflector Design:

5 segment reflector function well in clear sky in inclined and rotary portion of sun rays. Boiling is also ensured without fail. But slight cloudy sky in winter boiling time increasing and sometimes boiling is incomplete due to intermittent sun. To increase the uniform distribution of reflections of reflector in compound parabolic trough and to reduce the boiling time further reflector design was changed. The aim of change in reflector is to equalize the boiling time of vadaodara/Gujarat and to complete boiling in slight cloudy sky of winter at Visakhapatnam.

A reflector of seven segments was fabricated. The same was tested and it was found that marginal improvement in performance. But moisture accumulation in winter part cloudy sky is remaining.

Therefore 9 segment reflector was fabricated. As shown in figure 19.

Fig-19 (9 segment reflector assembly)

- Fig-19A(9 segment reflector reflection pattren.)

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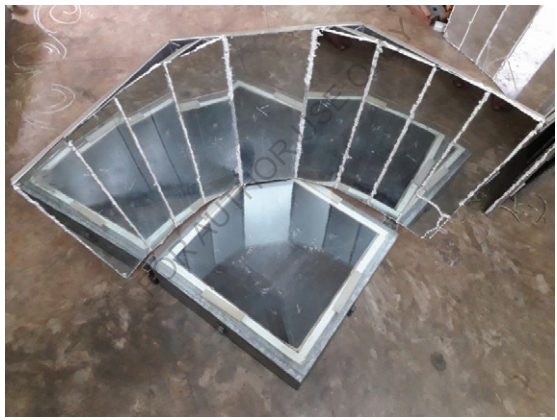


Fig- 19B(9 segment cooker assembly)

To compete the with boiling time at (6th SCI confernce held in January 2017 location Goraj/ Vadodara/Gujarat/India) new model 9 segment reflector assembly was made to improve the performance in winter slight whitish cloudy sky. In the above figures the distribution of reflected light is diffeering with 7 segments&5 segments. The overlappings are more and temperature gradients at corners lessened incomparison to5 & 7segments In this sky slight cloudy condition boiling ensured but time is 2hrs 30 mts. But there is less wastage of food material due to non boiling of food in comparision to 5segments & 7 segments reflectors.Still moisture formation on

botton cover insde suface and drop lets are prevailing in lesser quantity. The insulated box , trough, utensils etc, are of same size of previous models 5 &7 segments one.This is of new template. In this also at normal sky performing well. A permanent flexible fixture is used to template back side to adjust the inclination(tilt) of the reflector assembly to match or advance the sun position winter sky (the sun rays minimum insolation is available continuously). This is tested for different sky conditions of a year. The wastage of light reduced.The size of insulated box used is of same as 5 segmet one .

.

Fig- 20 - 11 segment reflector

This 11 segment reflector was tested in year 2018. The reflector area is slightly less than 9 segment reflector. In comparison to 9 segment reflector the template design is if slight complicated. The specific advantage is the spreading of overlap reflections over the black trough area is more in comparison to 9 segments is more. There is a reduction of time 15 minutes in ½ kg food boiling occurred in comparison to reflector 5 segment, 7 segments, 9 segments. For frying or drying, 15 minutes reduction observed. The experiment was carried out at residence, Visakhapatnam, Andhra Pradesh, India. The size of black trough and insulated box are of same size of 5 segment reflector. But it could not match 6 SCI conference days cooking period

goraj/Vadodara/Gujarat/India. The cooking period 105 minutes. Moisture formation in part cloudy slightly reduced in comparison to 9 segment reflector.

Fig-21

Fig-21A

The photo is of reflector assembly, 13 segment reflector which was tested in this year. The area is same as 11 segments. In this clear focus is observed in comparison to 11 segment reflector. In comparison to11 segment reflector the template design is if slight complicated. The specific advantage is the spreading of overlap reflections over the black trough area after assembly is more in comparison to11 segments is more. There is a reduction of time 30 minutes in ½ kg food boiling occurred in comparison

to reflectors 5 segment, 7 segments , 9 segments and 11 segments.. Boiling 450 grams rice is completed by 90 minutes and reduction 15 minutes in comparison to 11 segment reflector. For frying or drying 30 mts reduction observed. There is no change in insulation box sizes and food quantities. The experiment was carried out at residence, Visakhapatnam, Andhra Pradesh, India. Only reflector geometry was changed. It matched 6th SCI conference days cooking period as mentioned in previous pages. Boiling period 90 mts as observed in clear sky. It is undergoing trials for different seasonal climates of a year.

Fig-22B(Moisture formation)

13 segment reflector when used for boiling the water droplet formation is less and lessened moisture drop formation. It ensures complete boiling in 2 hours winter slight cloudy sky.

The basic advantages in this design:

All the green leafy vegetables, all dals rice all roots were tested for boiling. In slight cloudy sky in 2 hours boiling is completed. Number of time boiling increased in winter. Though solar energy is available intermittently the energy for tropical and sub

tropical areas usage can be easily increased. Though it is not like LPG or electricity it can meet part needs of cooking.

Date	Time	Temp-1	Temp-2	Temp-3
03/20/2010	0845	45		
	0915	66		
	1045	82		
	1115	88		
	1215	93		
	1245	92		
	1315	93		
	1330	98		
	1415	91		
04/11/2010	0800	50		
	0915	70		
	1025	86		
	1150	96		
04/18/2010	0740	50		
	0810	60		
	0905	78		
	1300	102		
04/25/2010	0845	48		
	0915	58		
	0945	62		
	1015	74		
05/28/2010	1045	40		
	1115	100		
	1145	104		
	1215	108		
	1315	108		
	1400	108		
	1500	96		

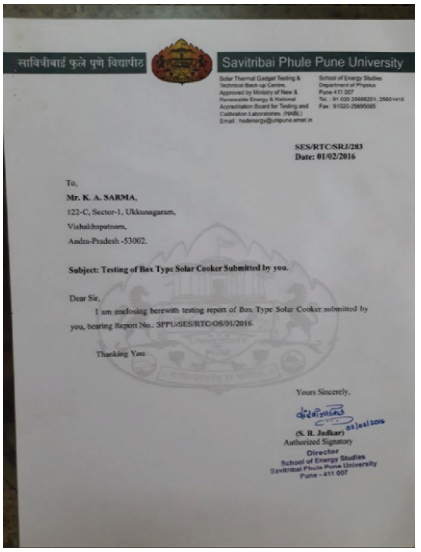
Date	Time	Temp-1	Temp-2	Temp-3
06/06/2010	0830	64		
	0935	88		
	1105	104		
	1310	110		
06/28/2010	1515	60/80	Sun exposed	80
	1515	60	Not exposed	60
	1545	60		
08/01/2010	0720	34		
	0830	52		
	0850	76		
	0930	90		
	1000	96	cloud	moving
	1020	96		
	1050	96		
	1105	92		
	1130	102		
	1145	96		
	1200	102		
	1210	100		
	1107	84		
08/22/2010	0740	32		
	0825	60		
	0930	88		
	1115	110		
09/11/2010	1430	85	2piece	reflector
	1500	110		
	1530	102		

Date	Time	Temp-1/2	Temp-2	Temp-3
09/12/2010	1105	42		
	1145	80		
	1200	70		
	1250	102		
	1300	80		
	1330	98		
10/03/2010	0815	52		
	0925	102		
	1005	106		
	1015	78		
	1055	85		
01/21/2011	0830	42/44/44		
	0920	75/70/64		
	1015	110/95/82		
	1200	94		
10/18/2010	1415	44		
	1455	76		
	1515	84		
	1535	74		
10/21/2010	1255	110		
	1300	92		
	132	100		
	1330	110		

Date	Time	Temp-1/2	Temp-2	Temp-3
11/10/2010	0840	start		
	1200	78		
	1220	100		
	1245	106		
11/14/2010	0924	90		
	0935	cloud	start	
	1010	90		
	1015	84		
	1028	84	sky	clear
	1040	110		
	1048	102	cloud	start
	1052	94		
	1103	96		
	1107	84		
	1117	76		
	1119	82	sun	appear
	1124	79	Sun dis	appear
	1140	sun	appear	
	1143	80		
	1147	90		
	1155	98		
	1207	102	Part white	cloud
	1209	104		
	1215	104		

Date	Time	Temp-1/2	Temp-2	Temp-3
11/21/2010	0750	36		
01/02/2010	0805	44		
	0840	54		
	0925	68		
	1005	80		
	1035	86		
	1045	cloud	start	
	1150	80	intermitent	cloud
	1200		Sun mild	visible
	1215	94		
	1230	110		
	1305	92		
	1335	100		
11/28/2010	1050	70		
	1110	78		
	1130	92	cloud	startmove
	1210	84		
	1245	94		
	1315	100		
11/28/2010	1050	70		
	1110	78		
	1130	92	Cloud start	movement
	1210	84		
	1245	94		
	1315	100		

Date	Time	Temp-1/2	Temp-2	Temp-3
	1215	104		
01/02/2010	0845			
	0920	84/70		
	1000	94/82		
	1100	110/96		
	1200	120/98		
01/09/2011	0845	62/48		
	0945	100/65		
	1030	124/75		
	1130	138/90		
	1222	122/98		
01/21/2011	0830	42/44/44		
	0920	75/70/64		
	1015	110/95/82		
	1050			
	1220			
	1335			



सावित्रीबाई फुले पुणे विद्यापीठ

Savitribai Phule Pune University

Solar Thermal Gadget Testing & Technical Back-up Centre, Approved by Ministry of New & Renewable Energy & National Accreditation Board for Testing and Calibration Laboratories. (NABL) Email : hsdenergy@unipune.ernet.in

School of Energy Studies Department of Physics Pune-411 007 Tel. : 91 020 25695201, 25601416 Fax: 91020-25691065

SES/RTC/SRJ/283
Date: 01/02/2016

To,
Mr. K. A. SARMA,
122-C, Sector-1, Ukkunagaram,
Vishakhapatnam,
Andra-Pradesh -53002.

Subject: Testing of Box Type Solar Cooker Submitted by you.

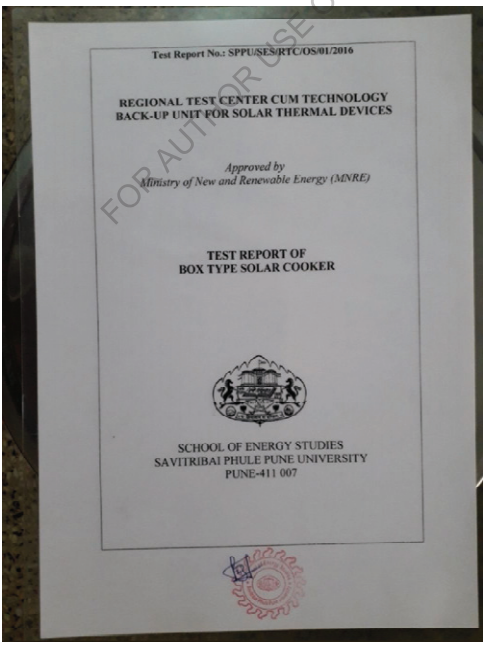
Dear Sir,

I am enclosing herewith testing report of Box Type Solar Cooker submitted by you, bearing Report No.: SPPU/SES/RTC/OS/01/2016.

Thanking You.

Yours Sincerely,

(S. R. Jadkar)
Authorized Signatory
Director
School of Energy Studies
Savitribai Phule Pune University
Pune - 411 007



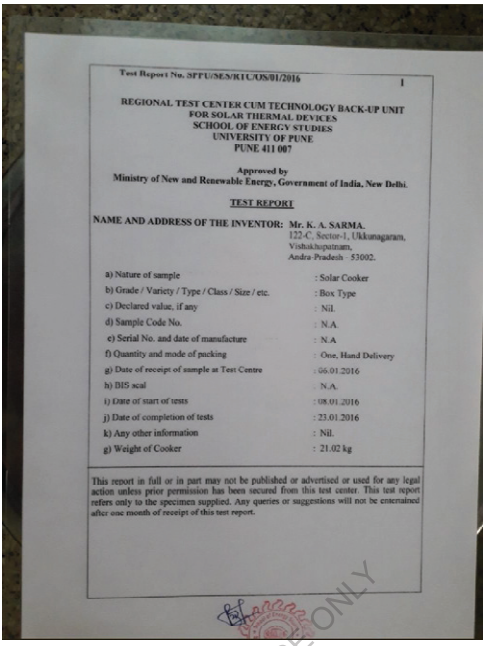
Test Report No.: SPPU/SES/RTC/OS/01/2016

REGIONAL TEST CENTER CUM TECHNOLOGY BACK-UP UNIT FOR SOLAR THERMAL DEVICES

Approved by
Ministry of New and Renewable Energy (MNRE)

TEST REPORT OF
BOX TYPE SOLAR COOKER

SCHOOL OF ENERGY STUDIES
SAVITRIBAI PHULE PUNE UNIVERSITY
PUNE-411 007



Test Report No. SPPU/SES/RTC/OS/01/2016 1

REGIONAL TEST CENTER CUM TECHNOLOGY BACK-UP UNIT
FOR SOLAR THERMAL DEVICES
SCHOOL OF ENERGY STUDIES
UNIVERSITY OF PUNE
PUNE 411 007

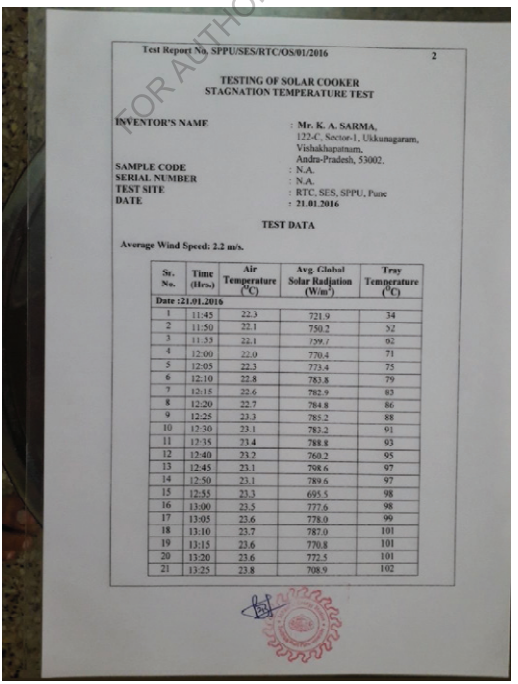
Approved by
Ministry of New and Renewable Energy, Government of India, New Delhi.

TEST REPORT

NAME AND ADDRESS OF THE INVENTOR: Mr. K. A. SARMA,
122-C, Sector-1, Ukkunagaram,
Vishakhapatnam,
Andra-Pradesh - 53002.

a) Nature of sample	: Solar Cooker
b) Grade / Variety / Type / Class / Size / etc.	: Box Type
c) Declared value, if any	: Nil.
d) Sample Code No.	: N.A.
e) Serial No. and date of manufacture	: N.A
f) Quantity and mode of packing	: One, Hand Delivery
g) Date of receipt of sample at Test Centre	: 06.01.2016
h) BIS seal	: N.A.
i) Date of start of tests	: 08.01.2016
j) Date of completion of tests	: 23.01.2016
k) Any other information	: Nil.
g) Weight of Cooker	: 21.02 kg

This report in full or in part may not be published or advertised or used for any legal action unless prior permission has been secured from this test center. This test report refers only to the specimen supplied. Any queries or suggestions will not be entertained after one month of receipt of this test report.



Test Report No. SPPU/SES/RTC/OS/01/2016 2

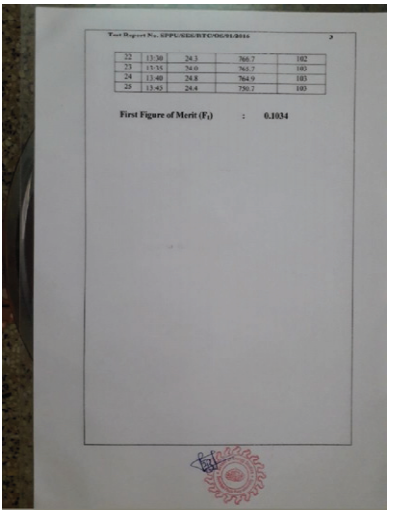
TESTING OF SOLAR COOKER
STAGNATION TEMPERATURE TEST

INVENTOR'S NAME	: Mr. K. A. SARMA, 122-C, Sector-1, Ukkunagaram, Vishakhapatnam, Andra-Pradesh, 53002.
SAMPLE CODE	: N.A.
SERIAL NUMBER	: N.A.
TEST SITE	: RTC, SES, SPPU, Pune
DATE	: 21.01.2016

TEST DATA

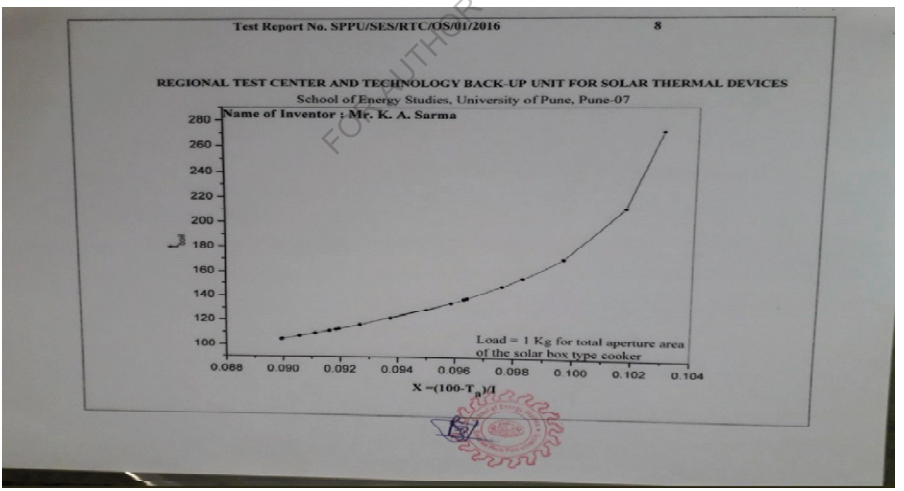
Average Wind Speed: 2.2 m/s.

Sr. No.	Time (Hrs.)	Air Temperature (^{0}C)	Avg. Global Solar Radiation (W/m^2)	Tray Temperature (^{0}C)
Date :21.01.2016				
1	11:45	22.3	721.9	34
2	11:50	22.1	750.2	32
3	11:55	22.1	739.1	92
4	12:00	22.0	770.4	71
5	12:05	22.3	773.4	75
6	12:10	22.8	783.8	79
7	12:15	22.6	782.9	83
8	12:20	22.7	784.8	86
9	12:25	23.3	785.2	88
10	12:30	23.1	782.2	91
11	12:35	23.4	788.8	93
12	12:40	23.2	760.2	95
13	12:45	23.1	708.6	97
14	12:50	23.1	789.6	97
15	12:55	23.3	695.5	98
16	13:00	23.5	777.6	98
17	13:05	23.6	778.0	99
18	13:10	23.7	787.0	101
19	13:15	23.6	770.8	101
20	13:20	23.6	772.5	101
21	13:25	23.8	708.9	102



22	13:30	24.3	766.7	102
23	13:35	24.0	765.7	103
24	13:40	24.8	764.9	103
25	13:45	24.4	750.7	103

First Figure of Merit (F_1) : 0.1034



REGIONAL TEST CENTER AND TECHNOLOGY BACK-UP UNIT FOR SOLAR THERMAL DEVICES

School of Energy Studies, University of Pune, Pune-07

Name of Inventor : Mr. K. A. Sarma

TESTING OF SOLAR COOKER
LOAD TEST: SENSIBLE HEATING OF WATER

INVENTOR'S NAME : **Mr. K. A. SARMA,** 122-C, Sector-1, Ukkunagaram, Vishakhapatnam, Andra Pradesh 53002.

SAMPLE CODE : N.A.
SERIAL NUMBER : N.A.
TEST SITE : RTC, SES, SPPU, PUNE – 411 007
DATE : **23.01.2016**

TEST DATA

Average Wind Speed: 2.4 m/s.

Sr. No.	Time (Hrs.)	Air Temperature (^{0}C)	Avg. Global Solar Radiation (W/m^2)	Water Temperature (^{0}C)
Date:23.01.2016				
1	10:00	22.2	218.7	20
2	10:05	22.3	506.9	24
3	10:10	22.6	527.2	24
4	10:15	22.7	545.7	25
5	10:20	22.6	548.3	27
6	10:25	22.7	553.3	28
7	10:30	23.4	584.0	30
8	10:35	23.4	600.4	31
9	10:40	23.2	609.6	33
10	10:45	23.7	627.5	35
11	10:50	23.7	641.9	37
12	10:55	24.7	645.7	39
13	11:00	24.4	662.7	42
14	11:05	24.2	657.7	44
15	11:10	24.6	679.6	46
16	11:15	24.5	659.8	48
17	11:20	24.4	664.3	51
18	11:25	25.3	698.7	53
19	11:30	24.9	717.5	56
20	11:35	25.0	729.0	58
21	11:40	25.3	734.3	60

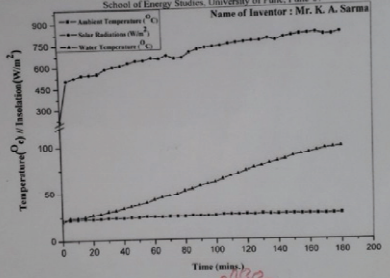
22	11:45	26.1	741.3	63
23	11:50	26.1	751.7	66
24	11:55	25.9	759.1	69
25	12:00	26.4	763.4	72
26	12:05	25.9	760.5	75
27	12:10	26.9	769.6	77
28	12:15	26.5	784.2	80
29	12:20	26.3	768.9	82
30	12:25	26.8	790.0	84
31	12:30	26.8	799.1	87
32	12:35	26.6	805.6	89
33	12:40	26.8	808.1	91
34	12:45	26.8	813.7	93
35	12:50	26.6	798.4	95
36	12:55	26.7	798.2	96
37	13:00	27.1	810.7	97

Second Figure of Merit (F_2): 0.5886

REGIONAL TEST CENTER AND TECHNOLOGY BACK-UP UNIT FOR SOLAR THERMAL DEVICES

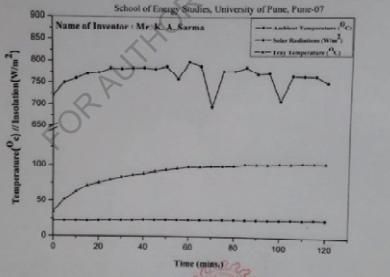
School of Energy Studies, University of Pune, Pune-07

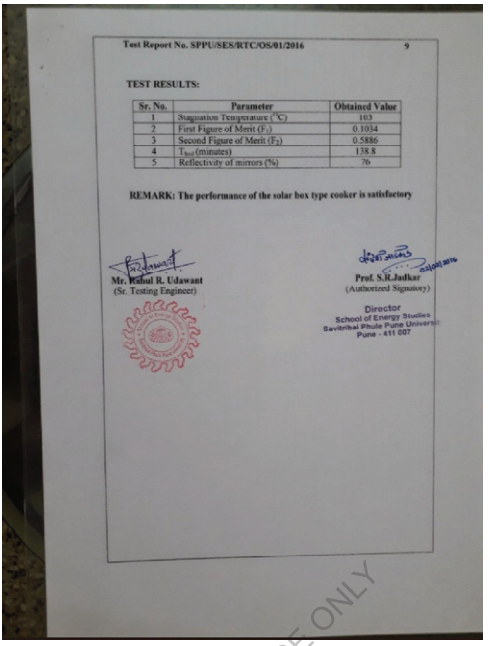
Name of Inventor : Mr. K. A. Sarma



REGIONAL TEST CENTER AND TECHNOLOGY BACK-UP UNIT FOR SOLAR THERMAL DEVICES

School of Energy Studies, University of Pune, Pune-07





Test Report No. SPPU/SES/RTC/OS/01/2016 9

TEST RESULTS:

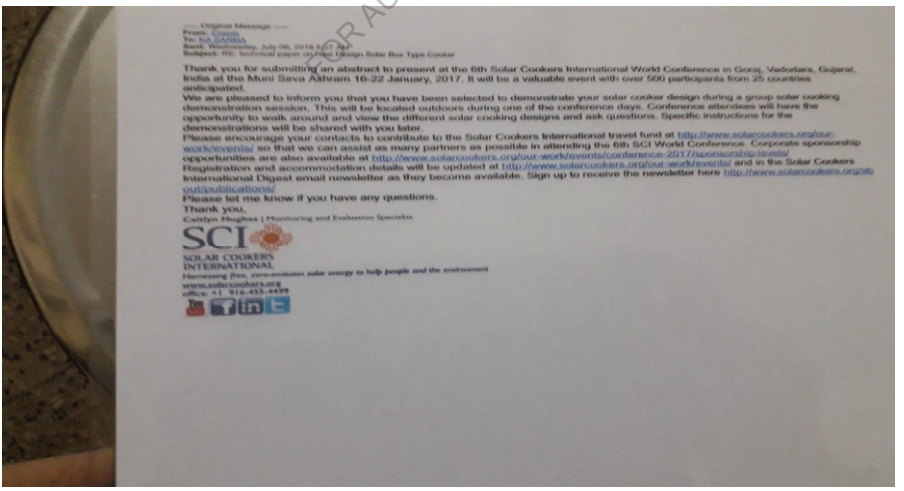
Sr. No.	Parameter	Obtained Value
1	Stagnation Temperature (°C)	103
2	First Figure of Merit (F_1)	0.1034
3	Second Figure of Merit (F_2)	0.5886
4	T_{boil} (minutes)	138.8
5	Reflectivity of mirrors (%)	76

REMARK: The performance of the solar box type cooker is satisfactory

Mr. Rahul R. Udawant
(Sr. Testing Engineer)

Prof. S.R.Jadkar
(Authorized Signatory)

Director
School of Energy Studies
Savitribai Phule Pune University
Pune - 411 007



Original Message
From: Caitlin
To: SCI BARMA
Sent: Wednesday, July 06, 2016 8:07 AM
Subject: RE: technical paper on New Design Solar Box Type Cooker

Thank you for submitting an abstract to present at the 6th Solar Cookers International World Conference in Goraj, Vadodara, Gujarat, India at the Muni Seva Ashram 16-22 January, 2017. It will be a valuable event with over 500 participants from 25 countries anticipated.
We are pleased to inform you that you have been selected to demonstrate your solar cooker design during a group solar cooking demonstration session. This will be located outdoors during one of the conference days. Conference attendees will have the opportunity to walk around and view the different solar cooking designs and ask questions. Specific instructions for the demonstrations will be shared with you later.
Please encourage your contacts to contribute to the Solar Cookers International travel fund at http://www.solarcookers.org/our-work/events/ so that we can assist as many partners as possible in attending the 6th SCI World Conference. Corporate sponsorship opportunities are also available at http://www.solarcookers.org/our-work/events/conference-2017/sponsorship-levels/.
Registration and accommodation details will be updated at http://www.solarcookers.org/our-work/events/ and in the Solar Cookers International Digest email newsletter as they become available. Sign up to receive the newsletter here http://www.solarcookers.org/about/publications/.
Please let me know if you have any questions.
Thank you,
Caitlyn Hughes | Monitoring and Evaluation Specialist

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CONSOLFOOD 2018, 22nd, 23rd and 24th January, 2018, Instituto Superior de Engenharia, Universidade do Algarve, Campus da Penha, 8005-139 Faro-Portugal.

To: Kota Anjaneyasarma
Assistant .General Manager(Mechanical)/ Visakhapatnam Steel Plant
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Dear Sir Kota Anjaneyasarma

Sunny Greetings from Faro, Portugal

January 2018 next year we will be conducting Consolarfood conference in Faro Portugal and it would be second such conference. In the first Consolfood we had very large Indian contingent and participation and would no wonder as India has been leading country with major solar projects and programs.

I herewith invite you to come to participate in the Consolfood 2018 Conference we are holding and of which I am chairman and share your work and experience with Solar Cooking and also get to know best practices from participants of the conference.

I am glad to inform you that your submitted paper with title New design of Box Type solar Cooker was accepted to be presented at CONSOLFOOD2018.

Looking forward to receiving you in Faro Portugal next year for ConSolFood 2018.

With Solar Greetings

Prof. Celestino Rodrigues Ruivo (PhD)
ISE-University of Algarve, Portugal
CONSOLFOOD 2018 (Chairman)

Group photo of Consolfood2016