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New design of Box Type solar Cooker

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Abstract: By concentrating sun rays with panel type reflectors into a compound parabolic trough kept in insulated box for cooking food with less and minimal intervention of people for tracking the sun and to cater the common man day to day cooking needs .Cooking needs are of boiling, baking and frying for temperatures up to 120 ºC with assured performance justifiable quantity of food and boiling time period.

Keywords: sun rays analysis, Tracking Reflector, parabolic trough, Overlapping of reflections , Solar thermal cooking

Sun Rays analysis: Sun rays travels East to West. East to noon the rising sun-shade length decreases/ reduces. Noon to west lowering sun-shade length increases. In spite of this shade rotates. Shade length & Rotation varies according to season and time through out the year.
In this way rays can be classified into inclined and vertical types and having rotation also. As distance from equator increases the peak verticality /inclination of rays changes. With reference to India, in winter & rainy seasons sun rays fall in the east in early hours as the sun raises rays rotates towards south side up to noon & at noon due change in direction of sun to west rays falls on west& South faces . In summer season rays fall on east& north up to noon and at noon rays vertical& at noon due change in direction of sun to west rays fall on west& south The rays peak inclined position E1 (Fig-1)occurring day(Uttarayanam-sun starts moving towards north-Makara Sankranti- this day occurs middle of January)& peak vertical position of ray E2 occurring day(Dakshinayanam –sun starts moving towards south- occurs in July 2 nd week)was identified by ancient Indian sages. It was described in Bhagavatham - 3rd Skandham written by sage Vedavysa.
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.

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There is a change in the position of direction East to E2& E1 as shown in the fig-1. The change of other directions are shown in the fig-1. Due to this there is a change in reception of sun light(insolation) at different locations of earth at different periods of time .Due to this different seasons forms in a period one year .

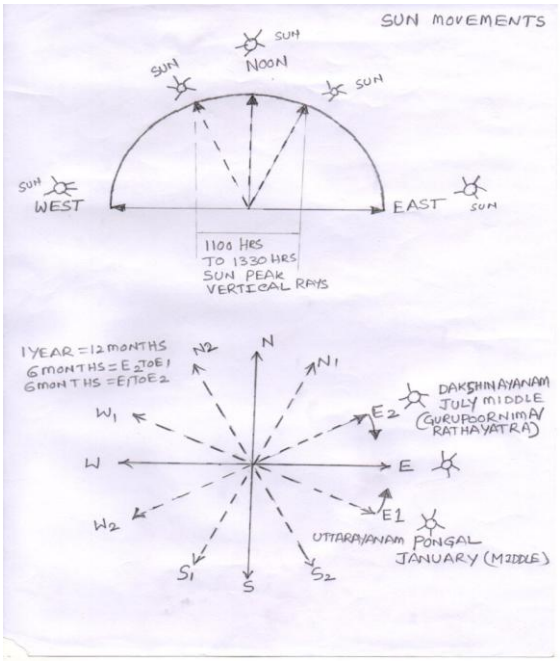

Fig. 1- Sun rays position horizontal plane(top fig), vertical (bottom fig) planes

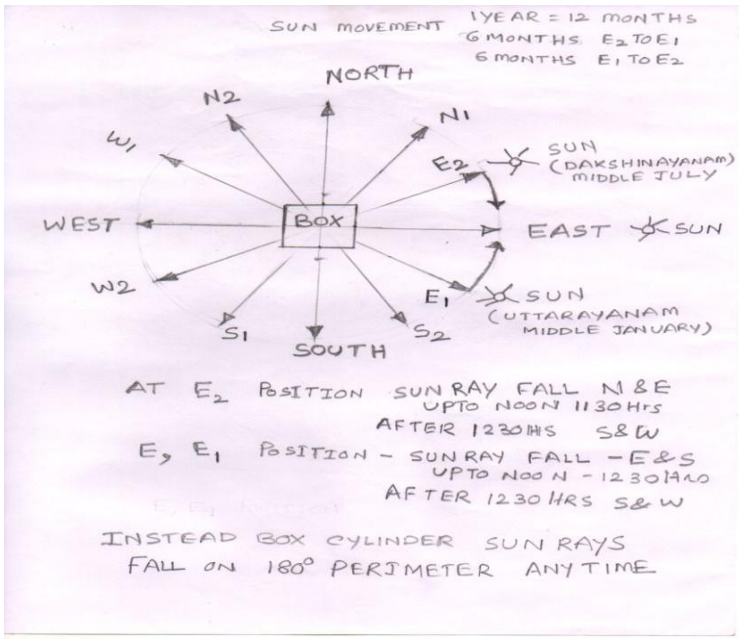

Fig. 1A- sun rays position at different seasons, time on box

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The sun rays when falls on a box (Fig-1A)), it can be observed that rays falls on two sides of the box& top side of box at any time. If the same rays falls on a cylindrical surface it can be seen that at any point of time 180 degrees of perimeter will be exposed to sun rays.

Keeping this observation into consideration reflector has been designed to cover 2 sides of box and or 180 degrees perimeter of box only. By increasing reflector coverage more than 2 sides or more than 180 degrees perimeter the cooker cannot receive/catch inclined zone rays. Both cooker box & reflector is to be aligned with respect to sun frequently**.**

Reflector Design: If rays falling on a inclined mirror depending upon the incident angle reflected rays position will be varying as shown in the Fig-2.At Q1 the rays reflected length will be up to X1 on the ground. For less than Q1 up to Q2 the reflected ray length is X2 on ground .If reflected ray angle decreases 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 fig-2 for different positions of sun.(Fig-2). In this present designed reflector the reflected ray part (X1, X2) will be transferred to black trough of solar cooker to generate heat.

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.).Present design the reflector will track the sun to some period of time without changing the mirrors position.

In the present system the reflector design take care of rotary part of sun rays in inclined portion to some extent without aids for aligning with respect to sun by arranging 5 mirrors in Fig-2A(cut curve) different angles& planes, position the reflections will overlap and high intensity beam will forms in inclined zone of sun rays .But as the sun raises at noon the rays inclination with respect to vertical axis will be less and reflector effectiveness is less. For better results the angles of mirrors is important. To keep the thermal regime of cooker, in this design black box has been replaced with parabolic trough(of cross section square).. At this period (noon) the profile of trough surface will play important role in maintaining the temperatures in side cooker

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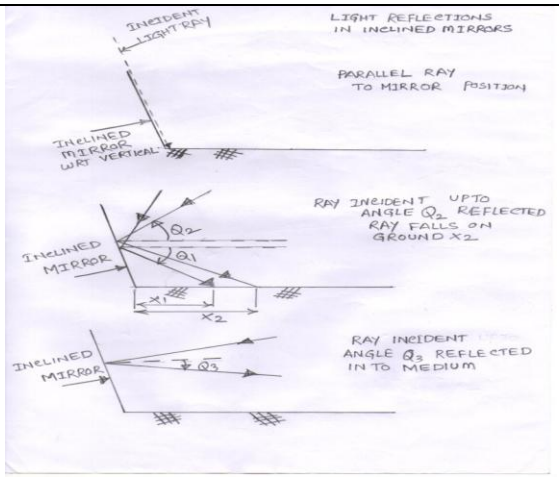

Fig-2 Incident ray,Reflected ray position

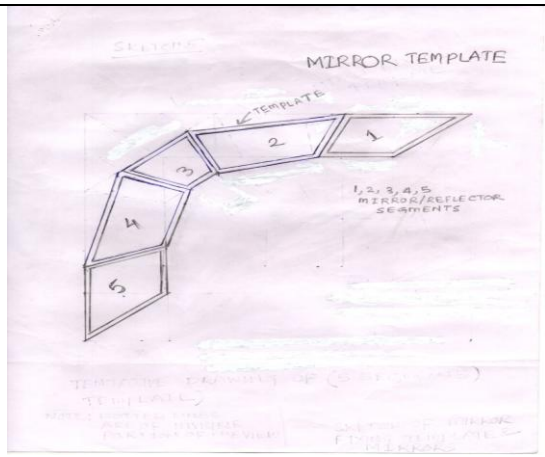

Fig-2A-Reflector assembly

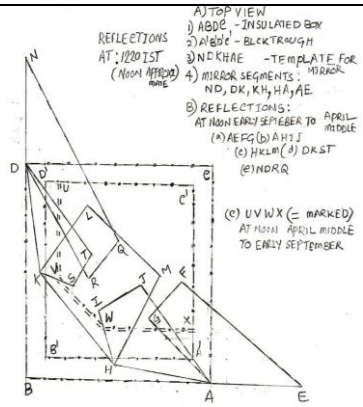

Fig-2B- Reflection patterns

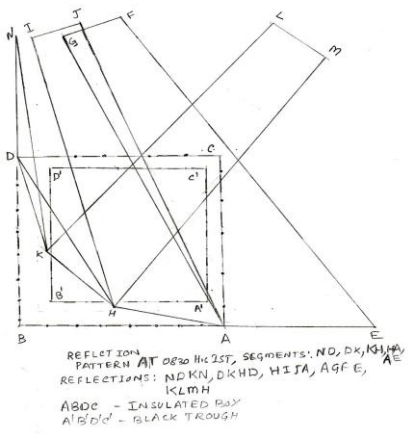

Fig-2C Reflection pattern

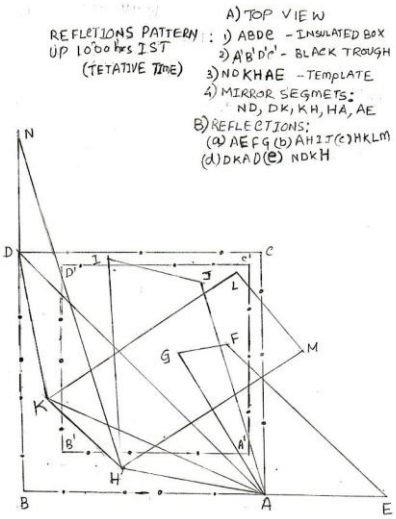

Fig-2D-Reflection patterns

All the reflection patterns at time intervals from 0600 hrs IST morning to evening 0600 hrs IST are observed keenly for different periods of year . The present design 5 number of segments were taken for observation. In the drawings 2B, 2C, 2D the reflection patterns at different times was shown. (In fig 2B, 2C, 2D the top view the cover glasses was not shown): 0600 hrs to 0700 hrs IST the reflection lengths are too lengthy , these reflections will not get overlapped ..At time 0700 to 0830 hrs IST) the reflection start overlapping for EA,AH,HK segments .After 0830 hrs (Fig-2C) segments EA,AH,HK reflections length are lengthier and coming beyond box. .If we closely observe these reflections rotation/diversion of light can be observed over passage of time .Variation of segment reflections length can be observed over passage of time. Also there is overlapping of reflections in side the trough is seen in this period .Segments KD, DN reflections fall in side the trough&on box(ABDC) but length of reflected ray is very less in comparison to segments,EA,AH,HK & slight overlapping can be observed.. This concentrated beam generates temperature inside box. (Fig-2D)After time 1000hrs to 1100hrs all segments EA,AH,HK, KD, DN reflections maximum inside trough & falling beyond the box(ABDC) bare minimum. At this period higher overlapping can be observed. After 1100 hrs further reduction of reflection length& all reflections fall in side trough. At time 113 0 to 1240 hrs (Fig-2B)the reflection lengths of segments EA,AH, starts lessening(period September to Middle April) remaining segments reflection increases and fall in side trough. In this way rotary motion & vertical motion of rays are adjusted automatically .After 1230 hrs the reflector is to be rotated to cater sun movement to west(tracking) .In April middle to September during this period (summer) the rays are vertical(reflections at noon shown double line = UVWX Fig-2B). To take care of this situation the parabolic trough was designed. At noon after rotating reflector the reflections behave in reverse order. .After 1240 hrs the reflection lengths of rays will increase up to 1400hrs, fall in trough. The reflections length is nearly up to insulated box(beyond black trough). Overlapping of reflections can be observed. .After 1400 hrs the reflected ray length will increases and crosses the box(ABDC) length .Up to 1500hrs overlapping of reflected rays can be observed .Beyond this divergence of reflections will be observed and slowly divergence increase and pattern will be like time 0730 to 0600hrs.(The reflections, time is approximately mentioned for making guide line for design of reflector. This time is with respect IST, location Visakhapatnam, State -Andhra Pradesh, India).

The angle of mirror segments, sizes/dimensions were judged by trial and error method to suit different sky conditions (Indian climatic conditions), by testing continuously over a

span of one year period (includes maximum & minimum allowed tilt of reflector, time of boiling, quantity of boiling)*.As the distance from equator goes on increasing towards poles the sun rays angles varies, the segment sizes are to be adjusted accordingly*.

In the present solar cooker reflector 5 nos segment mirrors are fixed on a template (Fig-2A). Instead of mirrors anodised aluminium sheet or other reflectors of glass equivalent area can be fixed on the template. Further study in this direction is in progress

Parabolic Trough design: 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 fall 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. This shape can be observed in Indian Temples-architecture.

This shape will take care of inclined sun rays which are reflected by mirror .It also take care of direct reception of sun rays (without reflector). In this case the radiation is absorbed by trough & IR emission from trough occurs. (Due absorption & emission process of sun rays). As the trough is kept in an insulated box the trough is further get heated up and further IR emission from trough occurs. As the rays hourly angle increases the reflector reflections overlapping occurs& beam intensity increases tends to emit more IR generation. By virtue of surface profile of trough deflect/reflect the IR rays to cooking pot. Due to increased radiation exchange in between trough & cooking pot in spite of direct reception of sun rays, leads to increase of temperature. In this way temperatures raises in the cooker and corner to corner temperature differential is less. This leads to increase in quantity of food boiling& reduction in boiling time.

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More over the depth/thickness of food layer will affect the cooking period. The compound parabolic surface can be designed suitably with respect to utensils (used for cooking) height, the food layer thickness can be optimised.

Description of Model: As shown in Fig-3 Black coated (non selective) utensils with food material are placed in compound parabolic trough. The compound parabolic trough coated in side with black paint (non selective coating).The whole assembly is placed in an insulated box. Over the box rubber sealing fixed. The bottom cover glass is positioned on this rubber seal and second cover glass placed on bottom cover glass at a gap 10 mm. The reflector assembly (Fig-2 A) is placed on the top cover glass and tied/locked to aluminium angle pieces which are (refer fig-3) fixed to box .

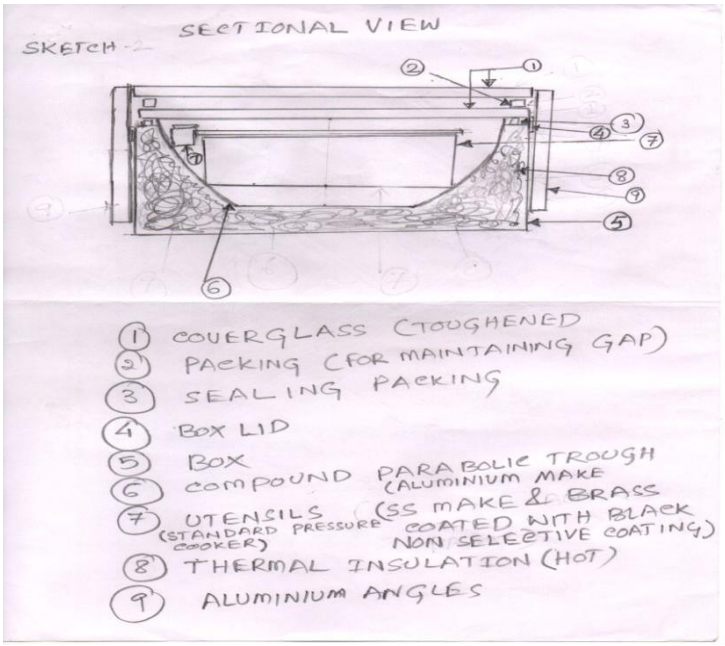

Fig-3- Model sectional view

Tracking of cooker: The reflector is to be rotated once in a day at noon when sun move towards from noon to west. From early September to mid April sun rays falls on East in morning hours & rotates to south of box up to noon. After noon sun rays falls on south & west sides of box. The reflector is to be rotated to 90 degrees at noon to cater sun movement to west. In the remaining period mid April to early September period early hours up to 1130 hrs IST sun rays falls East & North during morning to noon 1130 hrs IST & at noon sun rays are vertical. After noon beyond 1230 IST hrs the rays falls on south & West faces of box. The

reflector is to be rotated 180 degrees at noon with respect vertical circle. In present model the entire unit can be rotated as reflector is attached to box.

The design angles of mirrors are to be optimised for better performance and less human intervention (peak summer -Minimum inclination& Peak winter maximum inclination wrt vertical axis). To make additional provision the winter rays inclination (during December& January months) a semi permanent or temporary attachment was provided in the reflector template(to adjust tilt of reflector for better usage of cooker in this period).

The temperature generated is 110 to 120 degrees celcius 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 0900hrs to 1500hrs IST. The utensil used is of stainless steel make standard pressure cooker 12 lts with non selective black coating.

Calculation of Effective heat utilised& Efficiency:

1) Total area of light: Area of reflector (RA) + Direct incident rays received by black trough area (Tr A)
2) Due to variation in sun hourly angle the reflector reflections will be varying inclination and varying heat inputs will be given to boil the food.
3) Effective heat generated (ideal situation where total light falls in to box) = incident light of the total area. The maximum heat=(RA +Tr A)
4) Q heat quantity of food boiled=Q(heat used for boiling water& food material-for boiling .For frying quantity kept in the utensil for frying).
5) Considering solar constant 1000W/Square meter/Hour 860Kcals/hour/Square meter. Effective heat input=860(RA+ TrA) Kilo calories
6) 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.
7) In general losses - Top losses from cover glasses & loss of light occurs (not falling inside the trough).

To judge the performance the cooker is to be tested at different sky conditions at different seasons of a year period and for time of boiling with respect to quantity of food.

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 ml depending upon the rice.
In normal sky conditions in 2 hours period 450 grams of rice is boiled in this 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 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 operation of the model was telecast by ABN TV in Telugu(Indian Language in 8th February 2014).This was transferred by ABN TV to google under title –Special Story on Solar Cooking in the year 2014 .
The model was tested by Govt. Of India Ministry of New & Renewable energy authorised test centre located at Savitri Bai Phule Pune University, Pune in Year 2016.The director energy studies of the test centre has approved for satisfactory performance .

The same design was selected by SCI, (Solar Cookers International) Scremento -Caliofornia USA, for design 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.

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.

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

Conclusion: The reflector designed will take care of sun rays inclined portion as well as rotary portion of rays and increases operating period of cooker. This reflector design reduces

tracking with respect to sun. Black trough is parabolic in nature which reduces the temperature gradient and boiling time reduces. The model ensures boiling/frying in winter sunny days. More over in this model justifiable quantity of food can be boiled/fried for people of different parts of world.

References: [1] The Bhagavatha Puranam written by Sage Veda Vysa - Ancient Indian
[2] Indian Temples & their designs

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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 : hodenergy@unipune.ernet.in

School of Energy Studies
Department of Physics
Pune 411 007
Tel. : 91 020 25695201, 25601415
Fax : 91020-25695065

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,

02/02/2016

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

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TEST RESULTS:

Sr. No.	Parameter	Obtained Value
1	Stagnation Temperature (^{O}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)

School of Energy Studies * Savitribai Phule Pune University *

02/02/2016

Prof. S.R.Jadkar
(Authorized Signatory)

Director
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పారాబొలిక్ సోలార్ కుక్కర్

This is the latest reflector design of the box type cooker assembly was telecasted in Etv Andhra Pradesh news solt on June 3rd this year time 2000hrs to 2100 for 3 .5 minutes.In this the total height weight are same but to improve the reflection pattren the mirror segments sizes was changed, .The basic size of reflector dimensions were not changed,

The Photo is from Enadu Telugu Daily date 3rd June 2019.

Link of Enadu Telugu news& daily:

https://www.eenadu.net/ap/stories/2019/06/03/126461/

This is the latest reflector design with same dimensions same as 5 segment reflector.

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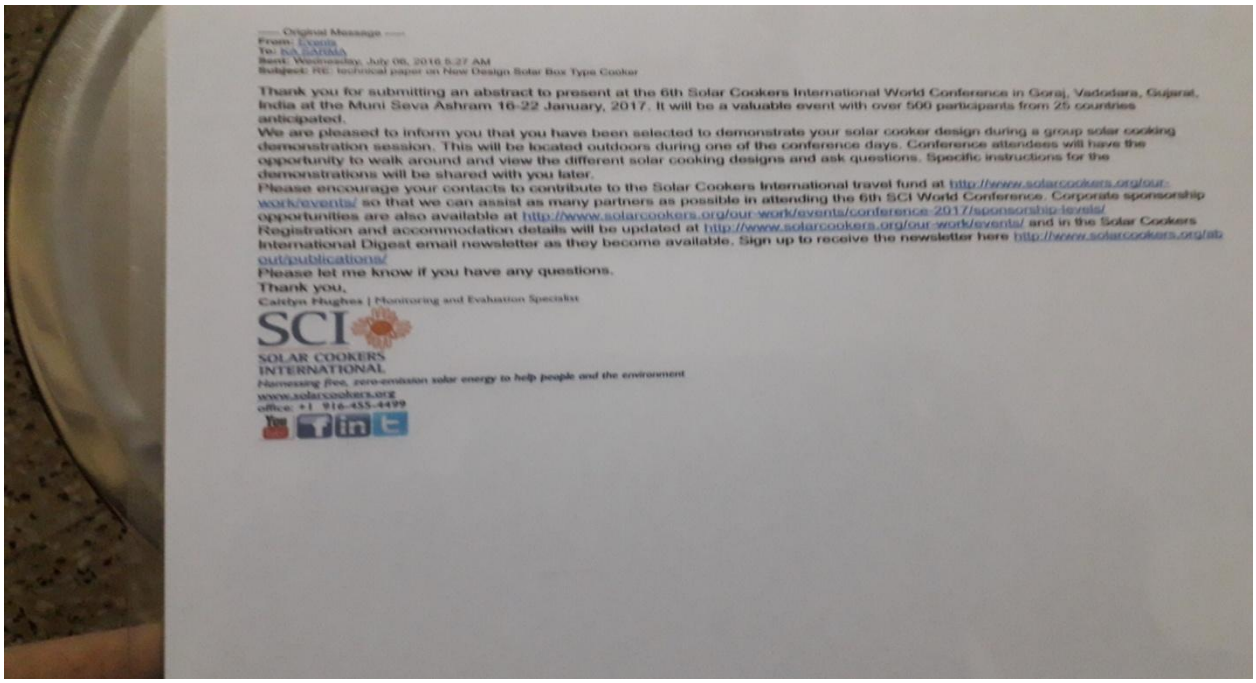

----- Original Message -----
From: Events
To: KA SARMA
Sent: Wednesday, July 06, 2016 5:27 AM
Subject: RE: technical paper on New Design Solar Box Type Cooker

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
Address; 122/C; Sector-1; Ukkunagaram, Visakhapatnam; Andhra Pradesh-530032, India
Mobile:+91-9949647167;email: sarma_ka@vizagsteel.com, kkrishnamurthy9515@gmail.com

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