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The Effect of Booster-Mirror Reflector on the Thermal Performance of a Truncated Pyramid Solar Thermal Cooker

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ABSTRACT
In this paper, the results and analysis of the performance of a truncated pyramid solar thermal cooker under two conditions are presented: booster-mirror reflector covered with black cloth, and booster-mirror reflector exposed to solar radiation. Results of the thermal performance tests show respective stagnation absorber plate temperatures of 145 ^{o}C and 137 ^{o}C. First/Second Figures of Merit are 0.120/0.346 and 0.125/0.400 respectively. The total heating times of 5.2 kg of water when reflector is covered with black cloth and when exposed to solar radiation are respectively 195 and 190 minutes. There is a nominal time reduction of 5 minutes in favour of the case when reflector is exposed to solar radiation, but in reality the time reduction could be as high as 30.5 minutes. In a similar vein, the difference in pot wall temperatures for corresponding water temperatures during sensible heating could be about 6 ^{o}C higher, and at boiling point this could be up to 11.6 ^{o}C. Thus, the overall thermal performance of the cooker when reflector is exposed to solar radiation is superior to its thermal performance when reflector is covered with black cloth. This superiority is manifested in improved values of the First and Second Figures of Merit, reduction in the overall heating and boiling times, and higher values of pot wall temperatures.
Keywords – Booster-mirror, reflector, performance, truncated, pyramid, solar, thermal, cooker

I. INTRODUCTION

Solar cooker is any device that converts radiant energy from the sun into heat energy for cooking, water purification, and other household uses. Solar cookers have a long history dating back to 18th century when Nicholas de Saussure (1740 – 1799) built first ever fabricated solar box cooker. He successfully cooked fruits at that time reaching a temperature of 88 ^{o}C [1]. In the course of time de Saussure and other researchers concentrated their cooker design works on variation on size, shape, glazings, sidings, mirror reflectors, insulators, and the composition and reflectance of the surfaces. Today there are over 60 major designs and more than hundreds of variations [2], [3].

In the last four decades, there have been significant contributions by many researchers to the design, development, and performance analysis of solar box cookers. El-sebaii et al [4] designed and constructed a solar box cooker with multi-step inner reflectors. The reflectors were arranged in a three-step fashion of different inclinations, and a mathematical model based on energy-balance considerations in the different components was developed to characterise the behaviour of the cooker. Ekechukwu [5] presented the design philosophy, construction, and measured performance of a plane-reflector augmented box-type solar cooker. The experimental solar cooker consisted of an aluminium plate absorber painted matt black and a double-glazed lid. The bottom and sides were lagged with fibreglass wool insulator. The reflector consisted of a wooden-framed specular plane mirror which was sized to form a cover for the box. Results of thermal performance tests showed stagnation absorber plate temperatures of 138 ^{o}C and 119 ^{o}C for the cooker with and without the plane reflector in place respectively. Boiling times of 60 minutes and 70 minutes for 1 kg of water were recorded for the cooker with and without the plane reflector in place, respectively. Abu-khader et al [6] reviewed and tested two designs of solar cookers. The first type had a black-painted base and the second one had internal reflecting mirrors. The designs were examined under two modes of operation: at fixed position and on tracking system. The cooker at a fixed position recorded thermal efficiencies ranging from 17% to a sharp peak of 41.2%; whereas cooker with internal reflecting mirrors installed on a sun-tracking system gave higher water and pot temperatures, and thermal efficiencies ranging from 25.3% to 53.1%. Kumar et al [7] designed, fabricated and tested a truncated pyramid solar thermal cooker. During testing, the highest plate stagnation temperature, under no-load condition, was approximately 138.5 ^{o}C at 1:40 pm. The ambient temperature and solar insolation at that time were 37.9 ^{o}C and 858.11 W/m^2 respectively. SPRERI [8] developed and evaluated three prototypes of truncated pyramid solar cooker cum oven with different geometries. Two prototypes were of rectangular shape with single and double glazing, and the third was of square shape with double glazing. No-load testing of the cookers was carried out during May and October 2009 to determine stagnation plate temperatures. During May, the highest stagnation plate temperature of 143.1 ^{o}C was achieved in square geometry truncated pyramid cooker followed by 140.6 ^{o}C and 136.2 ^{o}C for rectangular geometry truncated pyramid cookers with double and single glazing respectively. During October, the stagnation plate temperature in square type cooker reached up to 157.4 ^{o}C followed by 143.6 ^{o}C and 137.8 ^{o}C in rectangular cookers with double and single glazing, respectively. Mohammed et al [9] presented the results of performance testing of a truncated pyramid solar thermal cooker developed in Kaduna Polytechnic. During testing, the highest plate stagnation temperature achieved, under no-load condition and reflector covered with black cloth, was 145 ^{o}C. In full-load condition the temperature of 5.2 kg of water inside the cooker rose from 60 ^{o}C to 90 ^{o}C in 72 minutes. The highest plate temperature developed during testing demonstrated that the cooker could be used for all the four major methods of cooking, namely: boiling/steaming, baking, roasting/ grilling, and shallow frying. Mullick et al [10] developed method of evaluating the thermal performance of box-type solar cookers using two figures of merit. Therefore, a method of cross comparison of different cooker models became available; single cooker design could also be evaluated for their thermal capability and accuracy. Mullick et al [11] also conducted experiments to study the effect of the number of pots, and the load, on the Second Figure of Merit. Funk and Larson [12] and Funk [13] developed parametric models for testing box-type and paraboloidal-type cookers, and they tested several types of commercially available cookers.

This paper presents the results of experimental investigation into the effect lid-cover booster-mirror reflector on thermal performance of a Truncated Pyramid Solar Thermal Cooker (TPSTC) using, in part, test procedures described by the Bureau of Indian Standards [14], [15].

II. DESCRIPTION OF THE SOLAR COOKER

The TPSTC used for the experimental investigation is the same as the one used in ref [9] and is shown pictorially in Fig 1. The TPSTC is made up of two main parts, namely:

1. The truncated pyramidal box collector mounted on wheels for easy handling and transportation.
2. The booster reflector/cover.

II.1 Basically, the truncated pyramidal box collector consists of the following elements:

***Absorber plate*:** This is the part that receives solar energy radiation and converts it to heat energy. It is made from mild steel sheet of dimensions 52 cm length (l) x 46 cm breadth (b) and thickness 2 mm. The upper surface of the absorber plate is painted black to form a black body for maximum absorption of solar energy.

***Glazing*:** This is the material that transmits the short wavelength solar radiation but blocks the long wavelength re-radiation from the absorber plate, thereby acting as a thermal trap for the solar collector. The glazing material is a single piece of transparent glass of dimensions 83 cm (l) x 78 cm (b) and thickness 2 mm. The glazing also prevents rain, wind, and cold air from reaching the absorber surface.

Figure 1: Photograph of the TPSTC

***Sidewall Reflectors*:** The sidewalls of the cooking chamber are made from silver-coated, highly reflective glass material of thickness 2 mm. Due to the geometry of the design, solar rays impinging on the inner sidewalls are reflected downward, creating a region of high temperature at the bottom, which results in higher absorber plate temperature. The sidewalls are separated from the outer casing by 27mm–thick insulation made of cotton.

***Insulation*:** The purpose of the insulation is to prevent heat loss from the solar collector's outer surfaces. The insulator must be heat resistant and be able to withstand stagnation temperatures. Insulating materials are usually fibreglass, mineral wool, poly-urethane boards, Styrofoam, and cotton. For this cooker design, cotton is used as an insulator because it is cheaper and readily available. It is used as insulator under the absorber plate, and between the gaps that separate the sidewalls and outer casing.

Casing**:** the entire solar collector box and insulation are kept inside the casing. The casing of the cooker is of mild steel sheet, which has better weatherproof ability and longer lifespan than cardboard or hardboard solar cookers. The overall outer dimensions of the box are 89 cm (*l*) ***x*** 84 cm (*b*) ***x*** 70 cm (*h*).

II.2 Booster-Mirror Reflector/Cover: Two plane glass mirrors of total length 86 cm and height 81 cm, fixed in metal frame of mild steel sheet, serve as a booster reflector as well as a cover for the single glazed top. The reflector, set on top of the back side of the cooker, captures stray solar radiations and reflects them through the aperture of the cooker to heat the shaded parts of front sidewall and absorber surface.

III. FIRST AND SECOND FIGURES OF MERIT

In order to evaluate the thermal performance of a solar cooker and to make comparison between various cookers, certain parameters that are more or less independent of climatic variables are needed. Two important parameters have been defined in this respect: The First and Second Figures of Merit [10], [15].

The First Figure of Merit, F_1, is defined as the ratio of optical efficiency, η_o, to the overall heat loss coefficient, U_L. It is mathematically defined as:

$$F_1 = \frac{\eta_o}{U_L} \quad (1)$$

Experimentally,

$$F_1 = \frac{T_{ps} - T_{as}}{H_s} \quad (2)$$

where T_{ps} is the plate stagnation temperature (°C), T_{as} is the ambient temperature at stagnation (°C), and H_s is the solar radiation intensity at stagnation (W/m^2).

The stagnation (steady state) condition is defined as the 10-minute period when

(i) variation in absorber plate temperature is less than ±1 °C.

(ii) variation in solar radiation is ± 20 W/m^2.

(iii) variation in ambient temperature is ± 0.2 °C.

The permissible solar radiation condition during testing should always be greater than 600 W/m^2.

The Second Figure of Merit, F_2, takes into account the heat exchange efficiency of cookers and is obtained through the sensible heating of specified load of water (8 kg/m^2 of aperture area). F_2 is evaluated through the following expression:

$$F_2 = \frac{F_1(M_w C_w)}{A\tau} \ln\left[\frac{1 - \frac{1}{F_1}\left(\frac{T_{w1} - T_a}{H}\right)}{1 - \frac{1}{F_1}\left(\frac{T_{w2} - T_a}{H}\right)}\right] \quad (3)$$

where F_1 is the First Figure of Merit, M_w is the mass of the water, C_w is the specific heat of water, T_{w1} is the initial temperature of water (≡ 60 °C), T_{w2} is the final temperature of water (≡ 90 °C), τ is the measured time difference in which the water temperature rises from T_{w1} to T_{w2}, T_a is the average ambient temperature over the time period τ, H is the average solar radiation intensity incident on the aperture of the cooker, and A is the aperture area of the solar cooker.

IV. STANDARD BOILING TIME

The time, τ_s , for sensible heating from initial ambient temperature T_{amb} to a temperature T_{w2} can be obtained from:

$$\tau_s = -\frac{F_1 M_w C_w}{F_2 A} \ln\left[1 - \frac{(T_{w2} - T_{amb})}{F_1 H}\right] \quad (4)$$

This is a simplification of Eq. (3) by assuming T_{w1}= T_a= T_{amb}. In minutes, the time for sensible heating is:

$$\tau_s = -\frac{F_1 M_w C_w}{60 F_2 A} \ln\left[1 - \frac{(T_{w2} - T_{amb})}{F_1 H}\right] \quad (5)$$

The time for sensible heating from the ambient temperature to boiling point, which is also known as the Standard Boiling Time τ_{boil}, is obtained by replacing T_{w2} with 100 °C and is calculated as:

$$\tau_{boil} = -\frac{F_1 M_w C_w}{60 F_2 A} \ln\left[1 - \frac{(100 - T_{amb})}{F_1 H}\right] \quad (6)$$

V. EXPERIMENTAL PROCEDURES

The stagnation test was conducted by placing the empty cooker on a levelled horizontal ground with the glass mirror reflector covered with black cloth. The orientation of the cooker towards the sun was adjusted using the four wheels so that maximum solar radiation intensity was received at the aperture. The temperature of centre of the absorber plate was measured continuously using a thermocouple probe with analogue temperature indicator (0 °C – 250 °C). The ambient temperature was measured using a mercury-in-glass thermometer while the solar radiation intensity was measured using a pyranometer/ solarimeter (LI-18 Radiation Indicator). All measurements were made at intervals of 5 minutes.

The orientation of the cooker was adjusted after every 40 minutes to keep track of the sun, until stagnation condition was achieved. The stagnation test was repeated on a different date with the glass mirror reflector exposed to the sun. The procedure is the same as described above except that the absorber plate temperature was measured using a K-type digital thermometer (0 ^{o}C – 400 ^{o}C).

For the full load test, 5.2 kg of water was equally divided and put in four identical, black-painted, aluminium pots each of mass 0.15 kg and wall thickness 0.5 mm. The four pots containing the water were placed inside the cooker and the glass mirror reflector was exposed to the sun. The temperature probes of two K-type thermometers were placed in two of the cooking pots with the measuring tips submerged in the water. Two other temperature probes were attached to the outer sides of the pots to measure the pots' wall temperature. The four temperature probe leads were sealed where they left the pots and the cooker. Then the entire solar cooker was placed in the sun and orientated to receive maximum solar radiation to heat the water contents of the pots. The ambient temperature, water temperature, and solar radiation intensity were measured at intervals of 5 minutes throughout the test. All temperature measurements were made using K-type digital thermometers of accuracy ±1^{o}C. The orientation was adjusted after every 40 minutes. The data recording was continued until the average water temperature exceeded 95 ^{o}C. Initial and final temperature/time data pairs were chosen as 60 ^{o}C and 90 ^{o}C respectively. The average ambient temperature and the average solar radiation intensity over the time corresponding to these two data points were then calculated. The full load test was repeated on a different date with the glass booster-mirror reflector covered with black cloth. The procedure is also just as described above.

VI. RESULTS AND DISCUSSION

VI.1 Stagnation Tests

The first stagnation test (with reflector covered with black cloth) was conducted at Kaduna Polytechnic Kaduna (latitude 10.5^{o}N) on 23rd January, 2013. The test started at 10.55 a.m. till the maximum absorber plate temperature was reached after 2 hours 15 minutes. The temperature profiles of the absorber plate and ambient condition leading up to stagnation point are shown in Fig. 2. The trend of the curve shows that as time of the day progresses, plate temperature also increases (with increasing solar radiation intensity). The maximum plate temperature attained is 145 ^{o}C. The stagnation plate temperature attained is 145 ^{o}C, which coincides with the maximum plate temperature. The corresponding stagnation ambient temperature and solar radiation are 36 ^{o}C and 910 W/m^2 respectively. F_1 is calculated as per Eq. (2) and is found to be 0.120. This figure qualifies the TPSTC as Grade-A cooker, in accord with the criteria set by BIS.

The second stagnation test (with reflector exposed to solar radiation) was conducted on 4th March, 2013. The test started at 11.00 a.m. and was concluded after 2 hours 40 minutes when stagnation condition was achieved. The temperature profile of the absorber plate and ambient condition are shown in Fig.3. The trend of the curve shows that plate temperature increases as time of day progresses, and as solar radiation increases. Stagnation is achieved between 13:30 and 13:40 hours local time at solar radiation value of 810 W/m^2 corresponding to a plate temperature of 137 ^{o}C and ambient temperature of 36 ^{o}C. The stagnation condition comes immediately after a maximum absorber plate temperature of 138 ^{o}C is attained, with a corresponding solar radiation level of 850 W/m^2 and ambient temperature of 35 ^{o}C. At stagnation condition F_1 is found to be 0.125, which is 0.005 (4.17%) higher than the figure when the reflector is covered with black cloth. Despite the fact that stagnation occurs at a lower temperature of 137 ^{o}C (compared to 145 ^{o}C when reflector is covered with black cloth), the higher figure of F_1 = 0.125 demonstrates the superiority of the heating capability of the cooker when reflector if exposed to solar radiation compared to when reflector is covered with black cloth (F_1 = 0.120). With reflector exposed to solar radiation, it takes 40 minutes for the plate temperature to rise from ambient condition of 31 ^{o}C to 104 ^{o}C (above 100 ^{o}C) at an average solar radiation of 737.8 W/m^2, while it takes 50 minutes (when reflector is covered with black cloth) for the plate temperature to rise from the same ambient condition of 31 ^{o}C to 101 ^{o}C (above 100 ^{o}C) at an average solar radiation of 786.4 W/m^2. There is a time difference of 10 minutes which, once more, shows the superiority of heating capability of the cooker when reflector if exposed to solar radiation compared to when reflector is covered with black cloth. The two stagnation test results are only representative of series of tests undertaken from January through April, 2013.

VI.2 Full-Load Tests

The full-load test (reflector covered with black cloth) was conducted on 15th March, 2013. The test started at 10:50 a.m. and was completed after 3 hours 15 minutes, when the temperature of water exceeded 95 ^{o}C. The result of the test is given in Table 1. The result shows that it took 88 minutes to raise the temperature of the water from 60 ^{o}C to 90 ^{o}C. The average ambient temperature T_a and the average solar radiation for the 88-minute period were found to be 34.1 ^{o}C and 900.00 W/m^2 respectively. F_2 was calculated as per Eq. (3) and was found to be 0.346, a figure below the minimum value of 0.4 set by BIS.

The second full-load test (reflector exposed to solar radiation) was conducted on 11th March, 2013. The test started at 10:55 a.m. and was concluded in 3 hours 10 minutes, after the temperature of the water exceeded 95 °C. The result of the test, given in Table 2, shows that it took 83 minutes to raise the temperature of the water from 60 °C to 90 °C, at an average ambient temperature and average solar radiation of 32.5 °C and 853.33 W/m^2 respectively. F_2 was calculated and was found to be 0.400, a figure which meets the minimum value set by BIS for box-type solar thermal cookers. The higher value of F_2 and the nominal difference of 5 minutes show the superiority of thermal performance of the cooker with reflector exposed to solar radiation over the case when reflector is covered with black cloth. The two tests are, also, representative of series of full-load tests undertaken in 2013 (from January through April).

The temperature profiles of the water and ambient conditions during the two full-load tests are shown in Figs. 4 and 5. The trends of the water-temperature curves show that as time of day progresses water temperature also increases (with increasing solar radiation intensity), up to 13:05 p.m. when water temperatures rise with downward trends in solar radiation.

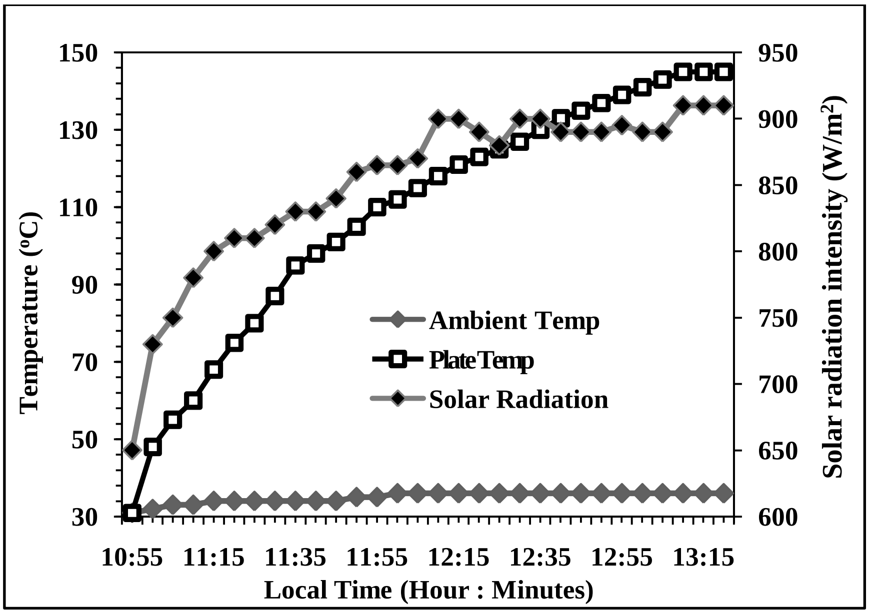

Figure 2: Stagnation test result (reflector covered with black cloth)

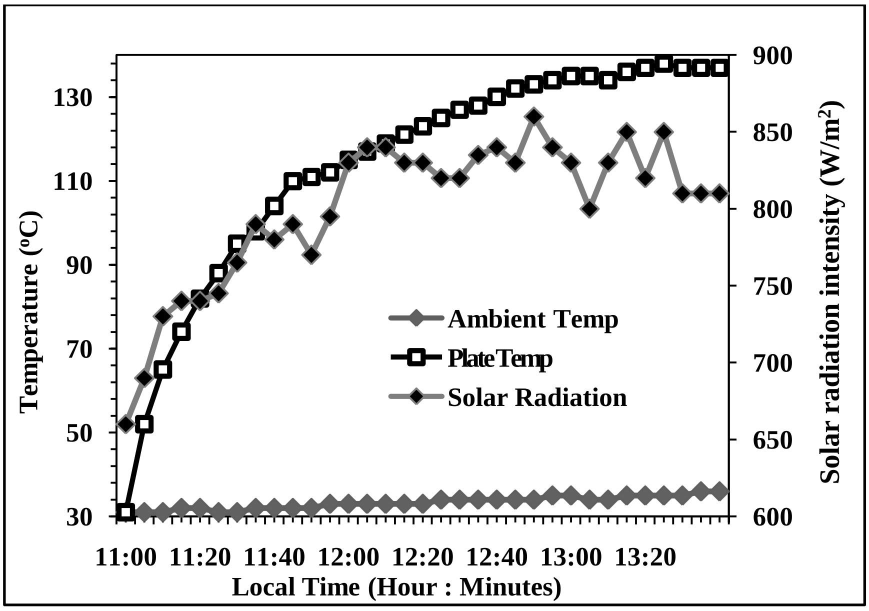

Figure 3: Stagnation test result (reflector exposed to solar radiation)

Table 1: Full load test result (reflector covered with black cloth)

Local Time (Hr:min)	Ambient Temp. (°C)	Pot wall Temp. (°C)	Water Temp. (°C)	Solar Radiation (W/m^2)
10:50	29	29	29	760
10:55	29	40	30	760
11:00	30	41	32	750
11:05	30	43	35	780
11:10	30	45	36	780
11:15	30	49	40	790
11:20	31	51	41	810
11:25	31	53	43	800
11:30	31	55	45	800
11:35	31	57	48	820
11:40	31	58	50	800
11:45	32	60	52	830
11:50	32	62	53	850
11:55	32	62	55	850
12:00	32	64	56	860
12:05	32	67	60	850
12:10	33	70	62	870
12:15	33	72	64	890
12:20	33	74	66	890
12:25	33	76	69	930
12:30	34	78	70	940
12:35	34	78	72	890
12:40	34	80	73	910
12:45	34	81	74	900
12:50	34	82	75	900
12:55	34	83	77	930
13:00	35	86	80	950
13:05	35	87	81	940
13:10	35	87	83	940
13:15	35	88	84	910
13:20	35	89	86	880
13:25	35	91	87	870
13:30	35	92	89	870
13:33	35	93	90	840
13:35	35	94	90	850
13:40	35	94	91	840
13:45	35	95	92	830
13:50	35	96	93	820
13:55	35	98	95	820
14:00	34	99	96	810
14:05	34	100	97	800

Table 2: Full load test result (reflector exposed to solar radiation)

Local Time (Hr:min)	Ambient Temp. (°C)	Pot wall Temp. (°C)	Water Temp. (°C)	Solar Radiation (W/m^2)
10:55	27	27	27	720
11:00	27	40	31	750
11:05	28	42	34	790
11:10	28	42	37	800
11:15	29	46	39	830
11:20	29	51	40	840
11:25	29	53	41	850
11:30	29	54	42	800
11:35	30	59	44	800
11:40	30	62	48	830
11:45	30	63	50	750
11:50	30	63	51	730
11:55	30	66	53	760
12:00	30	69	55	830
12:05	30	73	58	900
12:10	31	74	60	760
12:15	31	76	61	880
12:20	31	79	63	920
12:25	32	80	65	890
12:30	32	82	69	740
12:35	32	84	70	790
12:40	32	86	71	750
12:45	32	88	72	840
12:50	32	91	74	910
12:55	32	92	76	900
13:00	33	94	78	900
13:05	33	96	80	880
13:10	33	98	82	880
13:15	33	98	85	870
13:20	34	98	86	880
13:25	34	99	88	870
13:30	34	100	89	850
13:33	34	102	90	850
13:35	34	103	90	850
13:40	34	103	92	840
13:45	34	104	93	820
13:50	34	104	94	810
13:55	34	105	95	810
14:00	34	106	96	800
14:05	34	106	97	790

In both cases, it takes 75 minutes for the water temperature to rise from initial ambient temperature to 60 ^oC. The main reasons for this are: 1 – the initial temperature of water in the cooker with reflector covered with black cloth is 29 ^oC which is 2 ^oC higher than temperature of water in the cooker when reflector is exposed to solar radiation; 2 – during this period the average ambient temperature and average solar radiation are 30.7 ^oC and 802.67 W/m^2 in the first case while these are 29.1 ^oC and 798.67 W/m^2 in the second case. Hence, the lower heating load, lower heating capability, but higher solar radiation intensity of cooker when reflector is covered with black cloth balances the higher heating load, higher heating capability but lower solar radiation intensity of cooker when reflector is exposed to solar radiation. Therefore, it takes the same time in both cases for water temperature to reach 60 ^oC. For practical purposes, these factors continue to balance each other and it takes, in both cases, 100 and 130 minutes for the water temperature to reach 70 and 80 ^oC respectively. After these periods the superiority of the cooker with reflector exposed to solar radiation emerges as it takes 158 minutes to raise the water temperature to 90 ^oC while it takes 163 minutes when the reflector is covered with black cloth. Thereafter it takes the cooker, in both cases, extra 35 minutes to raise the temperature from 90 to 97 ^oC, the final temperature of the water. Thus, the total heating times of the cooker when reflector is covered with black cloth and when exposed to solar radiation are respectively 195 and 190 minutes. Apparently, the time reduction (time saved) is just 5 minutes in favour of the case when reflector is exposed to solar radiation. But the real time reduction emerges by calculating the difference in heating times (of both cases) using the ambient conditions and solar radiation when the reflector is covered with black cloth. Applying Eq. (5) and using T_{amb}=29 ^oC, T_{w2}=97 ^oC and H=900.00 W/m^2, the respective heating times are 192.3 and 161.8 minutes. The time difference is 30.5 minutes, and this is the real time that is saved by the cooker when reflector is exposed to solar radiation over the case when reflector is covered with black cloth.
By extrapolation using Eq. (6), the Standard Boiling Times for both cases are respectively 207.4 and 201.1 minutes. There is a nominal time reduction of 6.3 minutes, but the real time reduction is obtained from the difference in boiling times when the cooker operates (for both cases) on the ambient conditions and radiation when reflector is covered with black cloth i.e. T_{amb}=29 ^oC and H=900.00 W/m^2.The boiling times are respecyively207.4 and 173.9 minutes. The time saved is, thus, 33.5 minutes in favour of the case when reflector is exposed to solar radiation.

VI.3 Water Temperature Versus Pot Wall Temperature

Figure 6 shows the variation of water temperature, T_w, with pot wall temperature, T_{pw}, during the full-load test with reflector covered with black cloth. The trend of the curve shows that as pot wall temperature increases water temperature also increases. Correlation analysis shows that the correlation coefficient for linear relationship, r, is 0.9985. This indicates strong linear relationship between the two temperatures. The equation of the *line of best fit* is:

$$T_w = 1.122\,T_{pw} - 15.47 \tag{7}$$

At final temperature of heated water (T_w= 97 ^oC), T_{pw} is calculated and is found to be 100.2 ^oC. This strongly agrees with the experimental value of 100.0 ^oC. At boiling point T_w=100 ^oC and T_{pw} is found, by extrapolation, to be 102.9 ^oC.
For the case when the reflector of the cooker is exposed to solar radiation the variation of water temperature with pot wall temperature is shown in Fig. 7. The curve shows that as pot wall temperature increases water temperature also increases, suggesting a linear relationship. The correlation coefficient for linear relationship, r, is 0.9978. The equation of the *line of best fit* is:

$$T_w = 0.9462\,T_{pw} - 8.347 \tag{8}$$

At T_w=97 ^oC, T_{pw} is found to be 111.3 ^oC. There is significant difference of about 5.3 ^oC compared to the experimental value of 106 ^oC. The reason for this may be due to wider fluctuations of solar radiation intensities throughout the testing period, and pot wall temperature stagnates at some points during the test (especially towards the end). At boiling point T_w=100 ^oC and T_{pw} is found to be 114.5 ^oC
At T_w=97 ^oC the experimental pot wall temperature difference is 6 ^oC while the calculated difference is 11.1 ^oC, all in favour of the case when reflector of the cooker is exposed to solar radiation. At T_w=100 ^oC the calculated difference (by extrapolations) is 11.6 ^oC. these temperature differences are only nominal, but the real difference will only emerge if the cooker is to operate, in both cases, at the average ambient temperature and average solar radiation intensity when reflector is covered with black cloth. However, these nominal differences demonstrate, once more, the superiority of the thermal performance of the cooker with reflector exposed to solar radiation over the case when reflector is covered with black cloth.

VII. CONCLUSION

a truncated pyramid solar thermal cooker is presented in this paper together with its thermal performances, when booster reflector is covered with black cloth and when booster reflector is exposed to solar radiation. The cooker has proved, in both cases, that it is capable of cooking domestic food items as it met the standard requirement set by BIS in terms of the First Figure of Merit (minimum of 0.120). The results and their analysis have shown that when the reflector of the cooker is exposed to solar radiation F_1 could be improved by 4.17%. Nominal time reduction of 5 and 6.3 minutes in heating and boiling times could be achieved, although in reality, these could be as high as 30.5 and 33.5 minutes respectively. Pot wall temperature could be increased by about 6 ^oC during sensible heating and at boiling point this could be up to 11.6 ^oC.

Thus, it is clear that the overall thermal performance of the cooker with reflector exposed to solar radiation is superior to its thermal performance with reflector covered with black cloth. This superiority is manifested in improved values of the First and Second Figures of Merit, reduction in the overall heating and boiling times, and higher values of pot wall temperature.

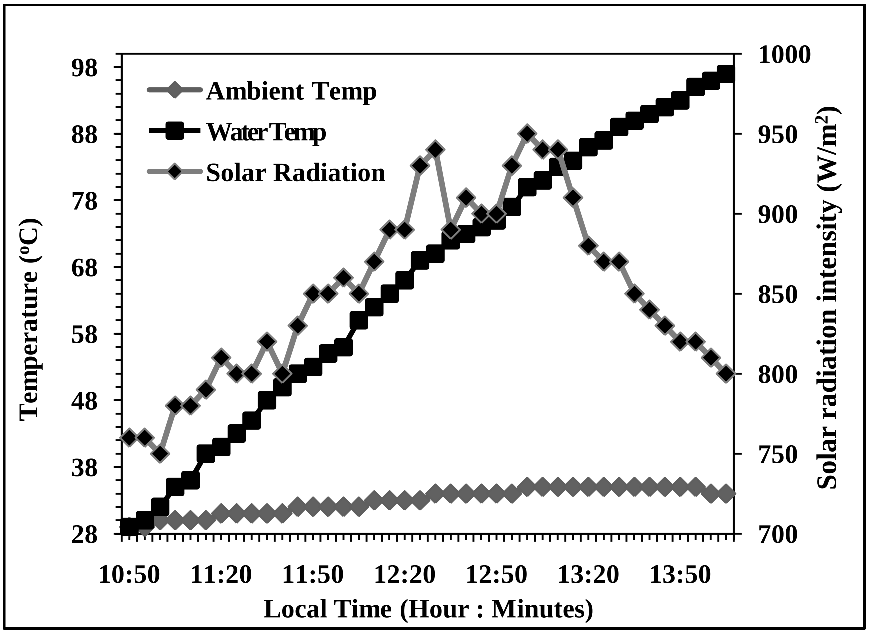

Figure 4: Full load test (reflector covered with black cloth)

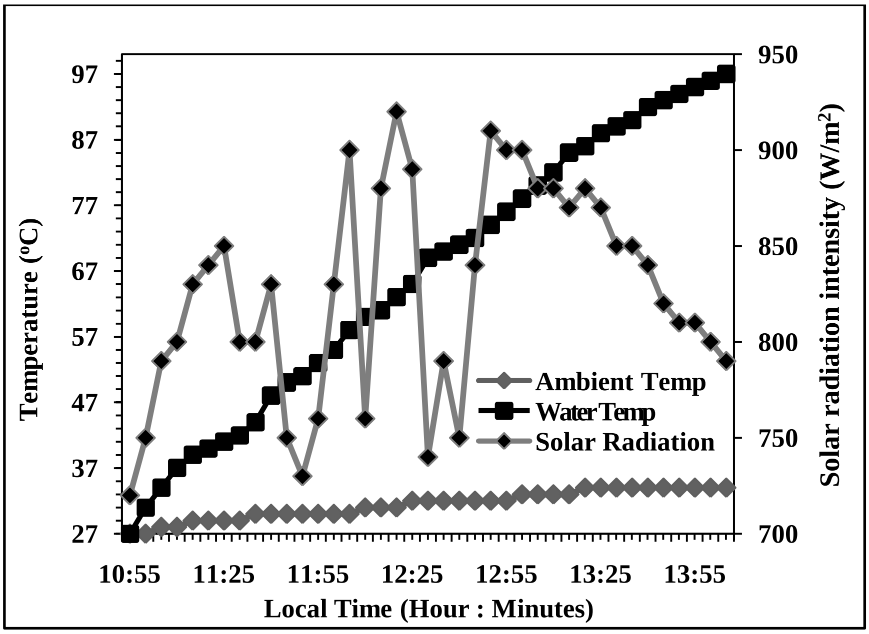

Figure 5: Full load test (reflector exposed to solar radiation)

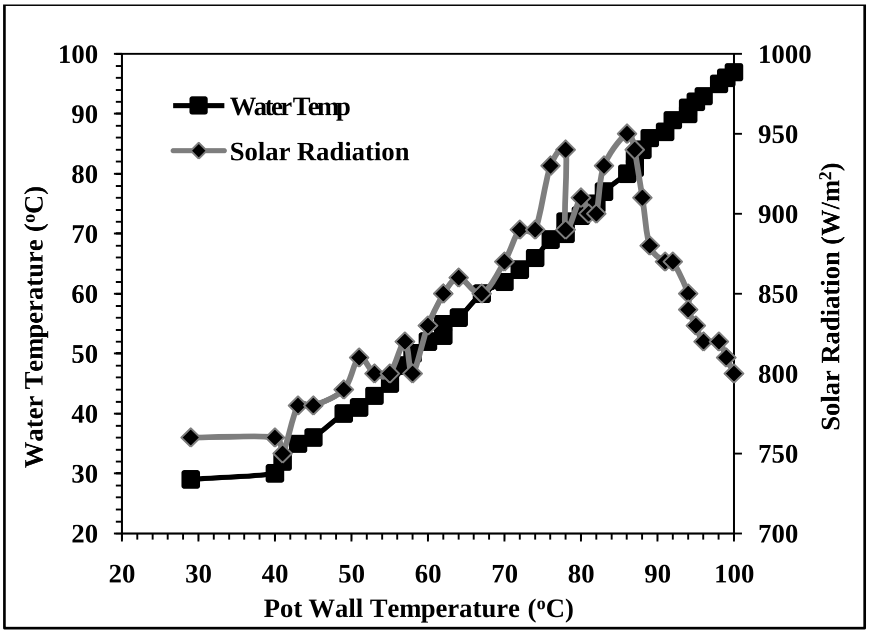

Figure 6: Water temperature versus pot wall temperature (reflector covered with black cloth)

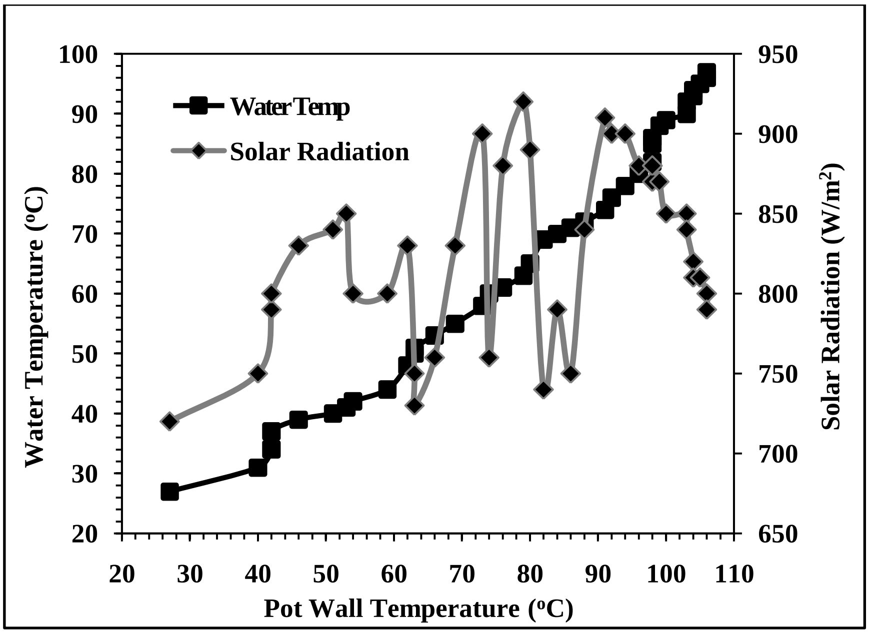

Figure 7: Water temperature versus pot wall temperature (reflector exposed to solar radiation)

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