A PROTOTYPE PARABOLIC TROUGH SOLAR CONCENTRATORS FOR STEAM PRODUCTION

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Abstract

In this work, the potential for a solar-thermal concentrator to produce steam has been studied. Three parabolic trough solar concentrators (PTSCs) of dimensions: - aperture width of 1.2 m, Collector length of 5.8 m and aperture area of 6.95 m^2 were investigated. The absorber pipe was a copper tube which carried water as the heat transfer fluid, were designed, fabricated, characterized and their efficiencies compared when closed and when open. The PTSCs´ were made of appropriate materials and were manually tracked. They were designed with principal focus at 0.4 m so that the receiver heat loss is minimized by covering the collectors with glass which was 0.0025 m in thickness. The concentration ratio of the solar concentrators was 128. The concentrator testing was carried out for each of the concentrators. The maximum temperature of steam obtained was 248.3^oC while average temperature of steam was produced was 150^oC. When closed their efficiencies were: Aluminium sheet reflector PTSC; 55.52 %, Car solar reflector PTSC; 54.65 % and Aluminium foil reflector PTSC; 51.29 %. The open solar concentrator efficiencies were 32.38 %, 34.45 % and 27.74 % respectively. The efficiency of car solar reflector when open was higher than for aluminium sheet since it was less prone to thermal degradation when exposed to weather elements. The results obtained show that production of power using the sun flux is a viable undertaking. The concentrators can be used to provide power to remote areas which are far away from the power transmission gridlines. This will make power readily available to the marginalized rural people. Improvement of the tracking system and optical efficiency can improve the efficiencies of the fabricated concentrator systems.

Keywords: Parabolic trough concentrator, solar-thermal, transmittance-absorptance product, thermal and optical efficiency

1.0 Introduction

Kenya is endowed with solar power intensity adequate for power electricity generation since the yearly average global irradiation in Nairobi, Lodwar and Mombasa are 5.25 kWh, 6.18 kWh and 5.48 kWh respectively among other areas (SWERA, 2012).

Solar energy is a renewable source of energy. Its use does not contribute to emissions of greenhouse gases and other pollutants to the environment. It is sustainable since it cannot be depleted in a time relevant to the human race. Kenya has an average solar irradiance 6.12 kWh in most of arid and semi- arid regions. Therefore her potential for use of solar collectors for thermal steam production is a viable commercial undertaking. However research efforts to that direction are still wanting. The aim of this study was to use appropriate materials in design, fabrication and characterization of local solar thermal steam producing systems for power generation. Solar collectors transform short wave radiation of the range 0.29 µm - 2.5 µm into long wave radiation and trap this energy in form of heat which is transferred into a heat storage vault by the heat transfer fluid.

Parabolic trough power plants are the only type of solar thermal power plant technology with existing commercial operating systems. A parabolic reflector reflects all the rays that are parallel to its principal axis to a point focus. When this parabola is extrapolated in three dimensions, a parabolic trough is generated, whose focus lies along the axis of the trough. In terms of power capacity solar genix has produced parabolic trough collector modules which are commercially viable and produce 176 Kw of peak energy for dual functions factory roof and for solar heating with an efficiency of 56 % (Cleaveland, 2005). In Africa, a solar thermal plant in Cairo, based on 1,900 m^2 of parabolic trough collector provides steam for pharmaceutical plant, el Nasr project (Ecoworld, 2009). Globally parabolic trough power plants technology with existing commercial operating systems include Nevada solar one which operates on a 250 acre site in Nevada desert and generates 134 MW of power per year. A larger solar based facility already exists in Mojave Desert in USA, generates 354 MW of solar energy power. In Spain Torresol and Arcosol have a 50 MW parabolic trough based plants located in Seville Cadiz. Other Spanish plants using this technology are Andasol 1, 2, 3 in Granada province (Ecoworld, 2009).

2 Materials and methods

2.1 Fabrication of solar concetrator trough

Angle iron beams of aperture width 1.2 m were bent into parabola with a focus at 0.4 m using Equation 1. These beams have a tensile strength that is able to with stand wind loads of wind speed greater than 10 m/s. Wind loads that are not mitigated cause the collector to be misaligned to the solar beam when the wind blows hence low thermal energy collection. After fabrication the structure was painted to prevent rusting. Equation 1 was used curve the angle iron beams into parabola.

$$y^2 = \frac{x}{4p} \qquad (1)$$

Where y and x are Cartesian plane coordinates and *f* is the predetermined focal length.

Black sheets were folded and welded into angle iron beams on the outside and the ends closed. The black sheets and the angle iron beams were painted to prevent rusting. The edges of the sheets were folded to provide a rail which was lined with rubber sheets so that the glass covers slid smoothly. A rubber sheet was put between glass and metal to prevent the glass from cracking. The length of the collector was 5.8 m and an aperture width of 1.2 m. A manual tracker system was fabricated using a general gears of gear ratio 1:30 and a class B black pipe of external diameter 0.008 m and internal diameter 0.003 m. This pipe was fitted onto one of the bigger diameter slots of the gears while the other slot a winch of radius 0.04 m was fitted to effect minute turning of the collector on the North – South axis. The turning would be affected when a 0.005 m by 0.003 m pin that was placed at the plane of aperture width would cast a shadow. The collector was laminated with three appropriate materials each in its turn i.e. aluminium sheet, car solar reflector and aluminum foil each in its turn. The receiver was a cylindrical copper pipe painted black with appropriate black paint. The paint coat was kept as thin as possible so that there was minimum resistance of flow of heat through the coat to the pipe and to the heat transfer fluid. The collector was covered with a 0.0025 m thick glass cover.

The fabricated collector parameters were: Aperture area = 6.95 m^2, Collector area =15.75 m^2, Aperture width = 1.2 m, Focal length = 0.4 m, Collector length = 5.8 m, Outer diameter of absorber pipe = 0.025 m, Inner diameter of absorber pipe = 0.002 m, Concentration ratio = 128. Figure 1 shows the setup for the fabricated trough solar concentrator used for production of solar thermal steam.

Figure 1: Fabricated prototype parabolic trough solar concentrator for steam production

The parabolic trough was laminated with aluminium sheet, car solar reflector and aluminium foil appropriate materials each in its turn.

2.2 Collector test

Collector testing was done at Juja which is -1.18333 ^{o} in latitude and 37.1167 ^{o} in longitude. During the collector testing the wind speeds varied between 3.2 m/s and 7.0 m/s.

To perform steady state collector testing: a heat exchanger and a 6 kW heater were fabricated. The testing was done at 2.0 m surface above the ground since the collector was designed for rooftops. The inlet temperatures used were 90^o C, 140^o C, 190^o C and 240 ^{o}C. The test times were taken systematically about solar noon, to give a total of sixteen data points.

Testing was carried out for fifteen minutes with a selected fluid inlet temperature. This was followed by further testing with steady state conditions for more fifteen minutes.

The solar irradiance and intercept factor for testing period were found by calorimetric method.

The pressure gauges gave the values of pressure drop across the collector and the thermocouples at both ends of collector mixing joints were read to obtain the fluid inlet temperature, T_1 and the fluid outlet temperature, T_2.

Direct solar irradiance from the sun was computed from calorimetric method by placing a calorimeter with water and a thermocouple at the plane of collector aperture and continuously recording temperature changes.

2.3 Measurement of intercept factor

Four calorimeters with 50 g of water were placed at equidistant points along the receiver and the solar thermal heat they absorbed was determined. The ratio of area of absorbing surface in the direction of the sun to the area of receiver superimposed was also evaluated and Equation 2 and was used to find the irradiance at the collector plane.

$$\alpha\tau A I_b = mc\frac{\Delta\theta}{\Delta t} \quad \text{.......} (2)$$

Where:-

$\alpha\tau$ = beam transmittance-absorptance product, m = mass of water in kg and the density of water = 1000 kg/m^3, c = specific heat capacity of water J / kg ^{o}C, 4200 J/kg ^{o}C. $\frac{\Delta\theta}{\Delta t}$ = temperature change per unit time (^{o}C/s) and A = aperture area and I_b = 852.5 W/m^2 beam irradiance.

For a black body α = 1. The absorber was made of copper tube of diameter 0.0025 m whose thermal conductivity was taken as 3.9×10^{2} J/kg/K and absorptance = 0.9 (Hanssan, 1972).

2.4 Average heat absorbed by receiver

To determine the average heat that was absorbed by the receiver per unit time, it was partially filled with water and one end was closed using a control valve and the other end leading to a condenser was left open. The condenser was made of a plastic cylinder in which a coiled copper tube was fixed. The plastic cylinder was then filled with cold water to condense the steam. The collector is placed in the sun, far away from the shades until water in the receiver boiled continuously. The mass of steam condensed was measured using `and the time it took to obtain the steam was measured using a stop watch. The temperature at which steam was obtained was also recorded.

2.5 Measurement of solar irradiance

A copper calorimeter of radius 0.03 m was insulated on the outside using aluminium foil and on the inside it was painted black. 0.05 kg of water was poured inside and after waiting for five minutes the probe of thermocouple was used to read initial temperatures of water in the calorimeter and recorded. This calorimeter was left exposed at collector plane of the collector at noon and the time of exposure recorded. This was to done find the amount of solar irradiance incidence on the aperture of the concentrator i.e. at the glass cover. The final temperature reached by water in calorimeter was recorded and Equation 2 was used to determine solar irradiance.

The measurement of solar power intensity was measured throughout the day by recording the temperature changes of the water in the calorimeter every twenty minutes. The calorimeter was placed at the middle of collector plane and secured with a thin cotton thread.

2.6 Thermal efficiency

The efficiency of the concentrators was obtained from Equation 3,

$$Efficiency = \frac{heat - output}{heat - input} = \frac{Q_u}{A_c I_b} \quad \text{.........} \quad (3)$$

Where Q_u is the heat output, A_c is the collector area and I_b is the beam irradiance.

Hottel–Whillier–Bliss equation was also used to find efficiency of the fabricated concentrators as shown in Equation 4.

$$F_R \frac{Aa}{Ac}\left[I_b \rho\varphi < \alpha T >_b - U_L \frac{(T_1 - T_a)}{I_b}\right]$$

3 Results and discussion

3.1 Intercept factor

The intercept factor obtained in this work was 0.6. The intercept factors for the Euro trough, Luz collectors and the Sky fuel were 0.69, 0.68 and 0.71 respectively (Suhas, 1992). To find the intercept factor surface area of the calorimeter was obtained as 0.010995 m^2 and the superimposed absorber area was obtained as 5.498×10^4 m^2. The ratio of the two surfaces was found to be 1: 19. The calorimeter with water was exposed to the reflected sun rays at the focal axis and the absorbed solar thermal energy was 1.299×10^3 W/m^2. Intercept factor was found as a ratio of surface area of calorimeter to that of absorber with respect to thermal energy collected. Equation 10 was used to find the intercept factor for the fabricated PTSC

$$\frac{1.22 \times 10^3}{19} = 649.84 \quad (10)$$

The thermal energy that was obtained for four equidistant calorimeter positions of the absorber were: - 649.84 W/m^2, 591 W/m^2, 658.7 W/m^2 and 633.1 W/m^2 respectively. The intercept factor obtained as an average was 627.8 W/m^2. When integration of thermal energy absorbed along the absorber was evaluated, intercept factor was found to be 687.3 W/m^2.

3.2 Average heat absorbed by absorber

The absorber used was painted black with black board paint. The Luz, Euro trough and Sky troughs used absorbers coated with selective surface known as cermet surrounded by a vacuum jacket. To obtain the average heat absorbed, mass of steam used was 0.0778 kg at 150 ^oC collected in 198 s was used. The average power obtained was 886.9 W/m^2. Insolation was found to be 852.7 W/m^2 with the collector aperture area of 6.96 m^2. The power that was collected in one hour was 3.19×10^6 W/m^2. If the PTSC modules of an equivalent area to one acre, the power that would be collected in one hour would be 9.27×10^6 MW of steam at 150 ^oC. The PTSC tracked the sun on a N – S mode. This ensured that the solar image at the absorber was not very much enlarged in the morning and in the evening.

3.3 Determination of solar irradiance

The solar power intensity for Juja was obtained as 852.7 W/m^2. The heat gained by the mass of liquid passing a point in the absorber in time t was obtained using Equation 11.

$$Q = mc_p \frac{\Delta\theta}{\Delta t} \quad (11)$$

(Twidel, *et al,* 1986).

Where Q = quantity of heat gained, m = mass of heat transfer fluid, $\frac{\Delta\theta}{\Delta t}$ was the rate of change of temperature with time and c_p is the specific heat capacity at constant pressure. The rate of heat gain was found to be 2.4 J/s. The area of the calorimeter base was obtained as 2.8×10^{-3} m^{-2} and the solar irradiance for the site found as 852.7 W/m^2.

3.4 Thermal efficiency

The increase in the temperature across the collector during the collector testing was obtained from the thermocouple thermometers and the pressure drop was obtained from the pressure gauges. Hottel – Whillier – Bliss equation was used to represent collector efficiencies for the fabricated concentrators as shown in the Figures 2, 3 and 4.

The collector efficiency was plotted as a function of $(T_m - T_a)/ I_b$ $^oCm^2$ for both open and closed fabricated concentrators. Figure 2: Shows characterization of aluminium sheet PTSC when open and when closed.

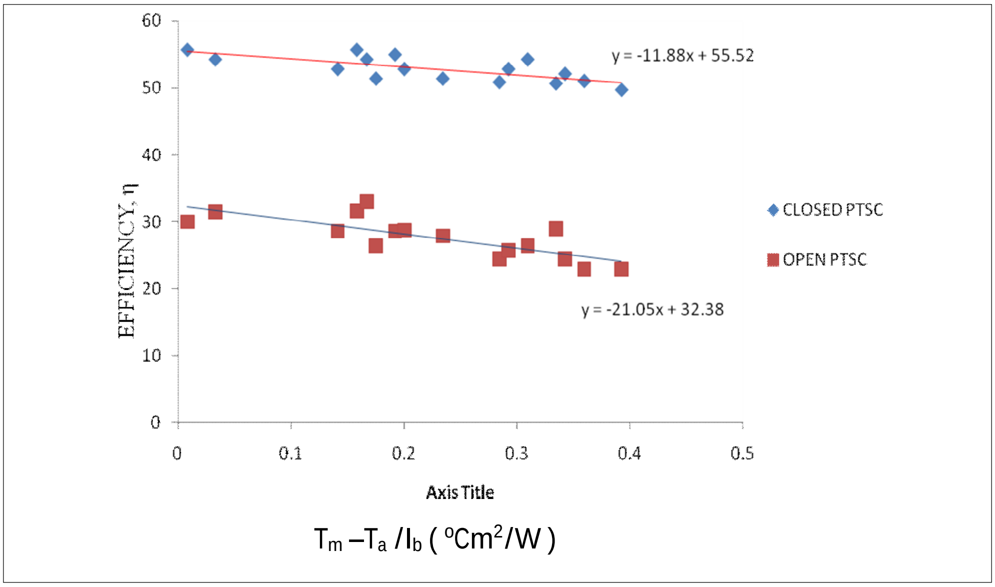

Figure 2: Characterization graph for aluminium sheet solar concentrator when closed and when open.

The following parameters were also used in characterization; - collector heat removal, F_R; intercept factor, γ; reflectance, ρ and the absorptance – transmittance product, $< \alpha\tau >$.

The overall heat loss coefficient, U_l was found to be a weak function of temperature and corresponds to collector heat removal factor. This finding is similar to the one obtained by John, et, al, 1991. The scatter observed in the data was caused by variations of relative proportions of beam proportion of solar radiation, temperature dependency, wind effects and variations in angle of incidence. In this work the value of efficiency was based on effective aperture area, A_a. Figure 2 shows efficiency of closed aluminium sheet PTSC as 55.52 %. When experimental variables were used the efficiency was 56.8 %. The heat loss coefficients for the open and closed PTSC were obtained as -11.88 W/m^2 and -21.05 % W/m^2 respectively. The closed fabricated PTSC lost less heat compared to the open PTSC because the closed PTSC had lower speed convectional currents around it due to the enclosure. Therefore the thermal efficiency of the open concentrator was low since it suffered heat losses by convection from the collector to the sky. The thermal efficiency of the closed collector was higher because the collector was covered by glass cover and heat losses by convection were minimum. The experimental efficiency of the collector was lower than one obtained from evaluation of variables. This was because the experimental values were obtained from interaction of environmental factors hence has a higher variability. An example of such an environment factor is wind. When the wind speeds increased between 2.2 m/s to 3.5 m/s the rate of collector heat loss increased. The absorptance transmittance product for aluminium sheet PTSC was found to be 0.8. This was due to the stagnant air mass which formed a blanket around the receiver since it was closed. This caused retention of heat inside the collector; hence the thermal efficiency for the closed collector was 56.8 %. The open collector had a thermal efficiency of 35.73 % due to losses of heat from the absorber. The collector heat removal factor was found to be 0.9, and in agreement with the value obtained by John, et, al, 2005. The collector heat removal factor for the open collector was 0.53. This is an indicator of how low thermal efficiency due to the factors mentioned above. The collector flow factor was obtained as 1.5 for the closed collector and 0.82 for the open collector as can be evaluated using equation 7. The collector efficiency factor of 0.64 was obtained from the closed collector. This was due to the reflectance of aluminium sheet being lowered by scratches and absorber losses. The open PTSC had a collector efficiency of 0.48 due to inaccuracies in position of absorber due to expansion of collector enclosure. Figure 3 shows characterization of car solar reflector PTSC in terms of efficiency when closed with glass of thickness 0.0025 m and when open.

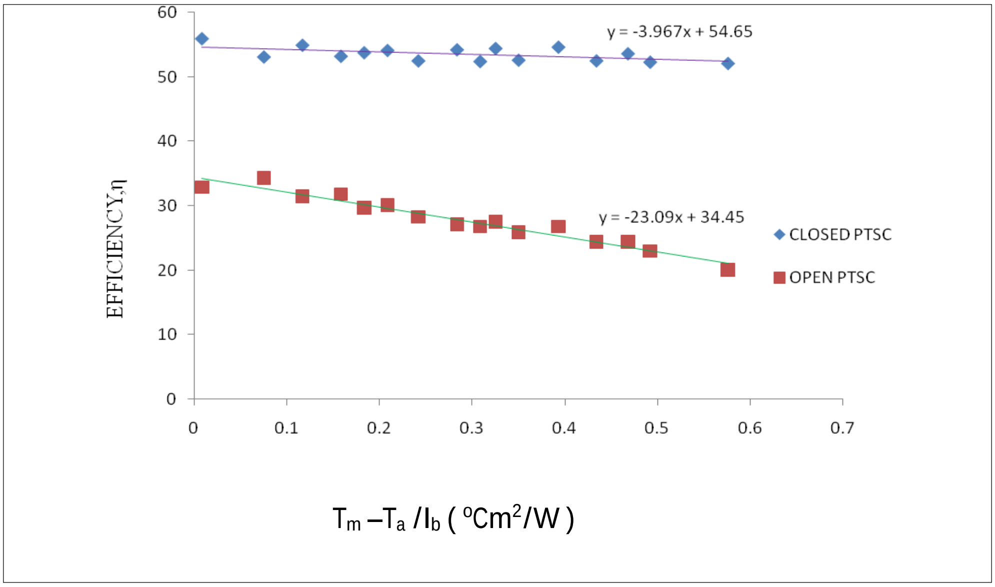

Figure 3: Characterization graph for car solar concentrator when covered with glass and when open

When closed the efficiency was 54.65 %, this value is lower than the one that was obtained by Luz collectors, 68.78 %; Euro trough, 69 % and sky fuel 71 %. This difference is caused by higher reflectivity of Luz collectors of 0.94, absorber surface absorptivity of 0.97 and glass transmittance of 0.965. The efficiency of car solar reflector was higher when open since it was able to resist thermal degradation as compared to both aluminium sheet and aluminium foil PTSC.

When the concentrator was open heat losses due convectional currents caused heat loss on the absorber hence a lower efficiency of utilization of the solar flux. The collector characterization was carried out under the following conditions: - $\dot{m}$ = 8.0 kg/s, I_b = 752.1 W/m^2 and Δ P = 870000 Pa for the closed collector and $\dot{m}$ = 4.78 kg/s, I_b = 803.5 W/m^2 and ΔP = 463000 Pa for the open collector. The temperatures that were obtained were: - T_m = 210 ^oC and T_a = 22.7 ^oC. When test variables were used to find the efficiency it was obtained as 54.9 %. This was as a result of variability of solar intensity.

The transmittance absorptance product was obtained as 0.78. The air enclosed in the collector enhanced the thermal efficiency of the collector. The heat removal factor was obtained as 0.87 for the closed PTSC and 0.88 for the open PTSC. Over cast sky caused the heat removal factor for the open collector to be higher than for the closed PTSC. The collector efficiency factor that was obtained for the closed PTSC was 0.64 while that for the open one was obtained as 0.42. The heat losses by convection around the open collector contributed to the lower efficiency factor for the open collector. The collector flow factor for the closed PTSC was obtained as 1.5 since the heat retention in the collector enabled continuous supply of thermal heat to the absorber. The sky trough absorbance was 0.96, emittance of 0.19 and reflectance of 0.95. These factors ensured that the efficiency of the sky trough was 71 %.

The heat loss for the closed PTSC was found to be -3.967 W/m^2 due to the insulation of the backside of the collector and the glass covers. The heat loss for the open PTSC was found to be -23.09 W/m^2. This was because of the heat losses by convectional currents. Optical efficiency was obtained was obtained as 0.56 for this PTSC due to scratches and degradation of the aluminium sheet by the elements of the weather. Figure 4 shows characterization of aluminium foil PTSC when closed and when open.

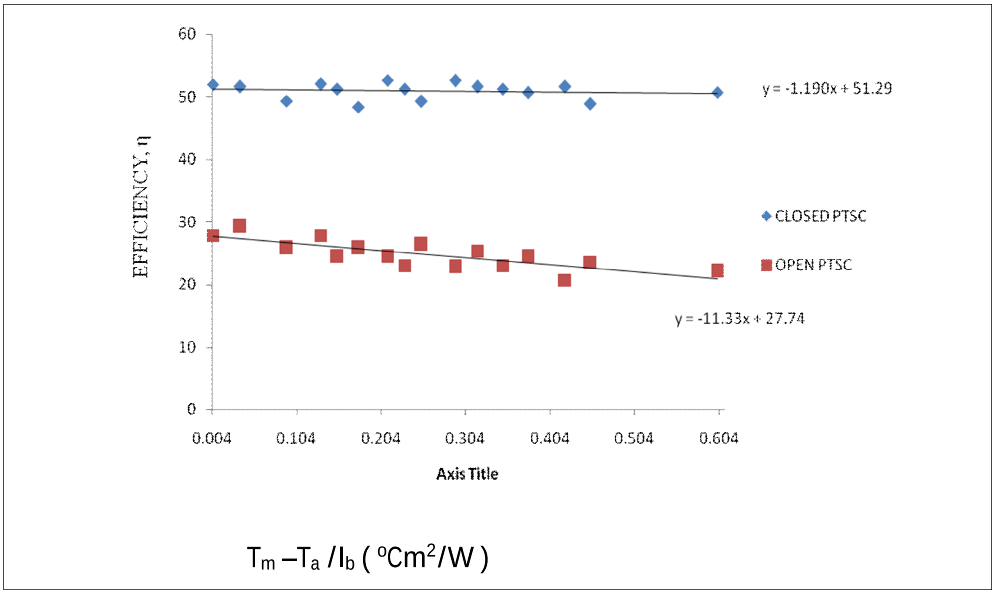

Figure 4: Characterization graph for aluminium foil solar concentrator when covered with glass and when open

The efficiency of aluminium foil PTSC was found to be 53.5 % when closed and 28.7 % when open. This efficiency is lower compared to the efficiency of the Euro trough that was found to be 69.0 %. This is attributed to the evacuated envelop into which the absorber in Euro trough is placed, ensuring minimum heat losses.

During characterization the following conditions were used: - $\dot{m}$ = 7.8 kg/s, I_b = 837.4 W/m^2 and ΔP = 745000 Pa when closed and when open the conditions under which the collector operated were: - $\dot{m}$ = 4.08 kg/s, I_b = 850 W/m^2 and ΔP = 411000 Pa. the temperatures achieved for the closed collector were:- T_m = 198 °C, T_a = 22.5 °C. When the wind speed increased from an average of 2.2 m/s to 3.5 m/s the heat losses by convectional currents from the glass cover of the collector increased by 9.8 W/m^2. The heat losses contributed to reduced thermal efficiency of the collector. The overall heat loss coefficient for the closed aluminium foil PTSC was -1.19 W/m^2 while the one for the open aluminium foil PTSC was found to be -11.33 W/m^2. The wind speeds increased from averages of 2.2 m/s in the morning to 7.0 m/s in the afternoon. These changes in the wind speeds caused reduced thermal efficiency of the collector. The transmittance absorptance product was obtained as 0.78 due to the heat that was trapped in the collector by the glass cover.

The collector heat removal factor was obtained from Equation 5 as 0.85 for the closed collector and 0.57 for the open collector. This was because the open PTSC lost more thermal heat compared to the closed PTSC.

The collector efficiency factor was obtained as 0.56 from Equation 6. This performance is as a result of overcast sky and increased folding on the reflector.

The collector flow factor was obtained as 1.52 for the closed concentrator and 0.73 for the open concentrator. This was as result of lower thermal absorption performance of the aluminium foil PTSC. The aluminium foil PTSC reflector was more prone to creasing than the other two reflectors. The optical efficiency for aluminium foil PTSC was obtained as 0.47. This is as a result of the diffusion of incident beam radiation by the creases and the folds.

The characterization graphs for the appropriate materials PTSC when closed with glass cover were as follows: - aluminium sheet PTSC, 55.52 %; car solar reflector PTSC, 54.65 %; and aluminium foil PTSC, 51.296 % and when open 32.38 %, 34.45 % and 27.74 % respectively. The Luz collector achieved an efficiency of 68 %, Euro trough PTSC 65.2 % and Sky fuel PTSC 73 %. This difference arises from more advanced absorber surface treatment, evacuation of absorber and use of absorbers with higher reflectance among other factors. It was observed that when operating temperatures of the collector increase the heat losses also increased. The comparison of efficiencies of the open and closed collectors shows that a closed PTSC minimized heat losses by convection. It was also observed that some radiation absorbed by the glass cover slightly raised the temperature of the cover by 3 ^{o}C hence reducing the rate of upward heat loss from the receiver. The reduction in the heat losses has an effect in producing some increase in transmittance absorptance product. Reduction of heat losses by introducing covers increased efficiency of each of the collector. The characteristics of the fabricated prototype parabolic trough solar concentrators were as shown in the tables 3, 4 and 5 which played a role in the design of the collector.

4.0 Conclusions and recommendations

In this paper a study was made to enhance Kenyan research in solar thermal steam generation for steam production by use of appropriate materials. The efficiencies for the closed PTSC were as follows: Aluminium sheet PTSC, 55.52 %, Car solar reflector 54.65 % Aluminium foil, 51.29 % which is lower than the efficiencies of Luz collector, 68 %, Euro trough, 65.2 % and Sky fuel parabolic trough, 73 %. This is due to evacuation of absorber tube surroundings and automatic tracking systems that they use. The reflectance of the fabricated PTSC was as follows: aluminum sheet PTSC 0.83; car solar reflector PTSC 0.81; Aluminium foil PTSC 0.78; Aluminium for the Luz collector, 0.94 and Euro trough, 0.96. The difference is as a result of the surface treatment of the optical systems, which improves their performance. The glass cover transmitivity of the 0.0025 m glass that was used in fabricated PTSC was 0.8 while the Luz collector has 0.965 and the Euro trough has 0.95. This is because they use selective coatings. The efficiencies observed for closed prototype parabolic trough solar concentrators demonstrates that this technology with appropriate reflector systems can produce solar steam that is hot enough for solar thermal conversion power systems. This can be achieved by use automatic tracking system and smoother reflecting surfaces. In this case higher temperatures and higher efficiencies would be realized. On the other hand use of open parabolic trough systems, where the absorber is exposed, led to high energy losses resulting to low operating efficiencies of the concentrating collectors made from various materials. Enclosing the receiver inside a transparent medium and evacuating it and also surface treatment of receiver as evident with the Euro trough, sky fuel trough, Luz collectors' e.t.c. would significantly improve the efficiencies of the fabricated solar concentrators.

The tables 1, 2, 3, 4 and 5 show a summary of the fabricated concentrator characteristics, which are:- comparison of the pressure difference ΔP, mass flow rate $\dot{m}$ and the average solar power intensity I_{bav} for the materials that were considered for closed solar concentrators, comparison of the pressure difference, Mass flow rate $\dot{m}$, and the average solar power intensity I_{bav} for the materials that were considered for open solar concentrators, collector flow factor, collector heat removal factor and collector efficiency factor.

Table 1: Comparison of pressure difference P, mass flow rate and the average solar power intensity Ibav for the materials experimented for closed solar concentrator

Reflector	ΔP(Pa)	$\dot{m}$ kg/s	I_{bav}(W/m^2)
Aluminium sheet	921000	8.8	752
Car solar reflector	870000	8.0	752.1
Aluminium foil	745000	7.8	837.4

Table 2: Comparison of pressure difference P, mass flow rate and the average solar power intensity Ibav for the materials experimented for open solar concentrator.

Reflector	ΔP (Pa)	$\dot{m}$ kg/s	I_{bav} (W/m^2)
Aluminium sheet	372000	3.98	749.3
Car solar reflector	463000	4.78	803.5
Aluminium foil	411000	4.08	850

Table 3: Collector flow factor for the fabricated concentrators

PTSC	CLOSED CONCENTRATOR	OPEN CONCENTRATOR
Aluminium sheet	1.50	1.12
Car solar reflector	1.42	0.84
Aluminium foil	1.52	0.73

Table 4: Collector heat removal factor for the fabricated concentrators

PTSC	CLOSED CONCENTRATOR	OPEN CONCENTRATOR
Aluminium sheet	0.90	0.88
Car solar reflector	0.53	0.86
Aluminium foil	0.56	0.81

Table 5: Collector efficiency factor for the fabricated concentrator

PTSC	CLOSED CONCENTRATOR	OPEN CONCENTRATOR
Aluminium sheet	0.64	0.48
Car solar reflector	0.60	0.40
Aluminium foil	0.56	0.34

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