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Design, Construction and Testing of a Parabolic Solar Steam Generator

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Abstract

This paper reports the design, construction and testing of a parabolic dish solar steam generator. Using concentrating collector, heat from the sun is concentrated on a black absorber located at the focus point of the reflector in which water is heated to a very high temperature to form steam. It also describes the sun tracking system unit by manual tilting of the lever at the base of the parabolic dish to capture solar energy. The whole arrangement is mounted on a hinged frame supported with a slotted lever for tilting the parabolic dish reflector to different angles so that the sun is always directed to the collector at different period of the day. On the average sunny and cloud free days, the test results gave high temperature above 200°C.

Keywords

Solar Energy, Sun, Heat, Steam, Water, Radiation, Temperature

Introduction

The sun and its Energy

When solar energy is mentioned anytime, the sun readily comes to mind, so it is justifiable to discuss in brief the physical and chemical behaviours of the sun before its application to heating. The sun has structure and characteristics, which determine the nature of the energy it radiates into space. The sun is sphere of intensely hot gaseous matter with a diameter of 1.39×10^6km and is on the average 1.5×10^8km from the earth. The surface of the sun is at an effective temperature of about 5762K (5489°C). The temperature in the central interior regions is estimated at between 8×10^6K to 40×10^6K and the density about 80 to 100 times that of water. The fusion reactions which is suggested to supply the energy radiated by the sun is several, the one considered most important is a process in which hydrogen combines to form helium [1].

A schematic of the structure of the sun shows that 90% of the energy is generated in the region 0 to 0.23R (where R = radius of the sun) and contains 40% of the mass of the sun. At a distance of 0.7R from the center, the temperature drops to about 130,000K and density dropped to $0.07 g/cm^3$. Here convection processes begin to become important and from 0.7 to 1.0R is known as the convective zone. The upper layer of the convective zone is called the photosphere. The edge of the photosphere is sharply defined, even though it is of low density. It is essentially opaque as the gases it composed of are strongly ionized and able to absorb and emit a continuous spectrum of radiation. The photosphere is the source of most solar radiation [2].

Outside of the photosphere is a more or less transparent solar atmosphere, which is observable during total solar eclipse or by instrument that occult the solar disk. Above the photosphere is a layer of cooler gases several hundred miles deep called the reversing layer, outside of that is layer referred to as the chromospheres, with a depth of about 10,000 km. This is a gaseous layer with temperature higher than that of the photosphere and with lower density. Further out is the corona of very low density and high temperature.

The sun's energy which is nuclear energy released in fusion reaction reaches the earth as electromagnetic in the wavelength band of about 0.3μm with its peak spectral intensity near 0.5μm. The scale of the sun's thermometer reaction is such that, as far as the earth is concerned, the energy available is practically inexhaustible.

The intensity of solar radiation on a surface normal to the sun's rays beyond the earth's atmosphere at the mean earth-sun distance is defined as the solar constant I_{sc}. Although there are recurrent small variations in the sun's radiant output caused primarily by periodic changes in the ultraviolet portion of the solar spectrum, the currently accepted value of I_{sc} is $4353 w/m^2$. Because the earth orbit is slightly elliptical and the extraterrestrial radiation intensity Io varies inversely as the square of the earth-sun distance, Io ranges from a maximum of $1398 w/m^2$ on January 3, when the earth is closer to the sun, to a minimum of $1310 w/m^2$ on July 6, when the earth-sun distance reaches its maximum.

Despite the variations, solar energy can be used in three processes:

a. Heliothermal- this is the system in which the incident radiation is absorbed and turned into heat.

b. Heliochemical- in which radiation between 0.3 and 1.0µm can cause chemical reactions, sustain growth of plants and animals and through photosynthesis convert exhaled carbon dioxide to breakable oxygen.

c. Helioelectrical – in which part of the radiation in the band between 0.33 and 1.2 µm can be converted directly into electricity by photovoltaic cells.

The incoming solar radiation suffers depletion in the following ways:

1. Absorption by the ozone in the upper atmosphere.
2. Scattering by dry air.
3. Absorption, scattering and diffuse reflection by suspended solid particles.
4. Absorption and scattering by thin cloud layers.
5. Absorption and scattering by water vapour.

Availability of Solar Energy in Nigeria

To evaluate the economics and performance of system for the utilization of solar energy in a particular location, knowledge of the available solar radiation at that place is essential. Thus the utilization of solar energy, as with any other natural resource requires detailed information on availability.

The availability of solar radiation on the earth's surface is a function of geographical zone. The regions lying between 15° and 35°latitude north and south respectively seem to be most favourably located. They have relatively little rains and clouds so that over 90% of the incident sunshine is direct radiation and the yearly sunshine hour is usually over 3000. The next most favourable region is the equatorial belt from 15°S to 15°N which receives about 2300hours of sunshine per year with very little seasonal variation. The high humidity and frequent clouds in this belt generally result in a high proportion of the solar radiation taking the form of scattered radiation. Nigeria lying approximately between 4°N and 13°N latitude is a geographically favourable zone for harnessing solar energy. On average the yearly total solar energy incident on a horizontal surface in Nigeria is 2300kwh/m^2 [3].

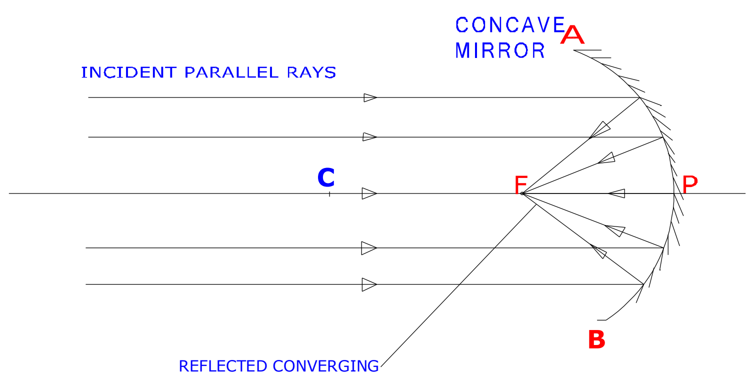
The earth is closest to the sun at a distance of about $1.45x10^{11}$m and farthest from the sun at a distance of about $1.54x10^{11}$m [4].

The objectives of this research work are:

- to design and fabricate a parabolic dish solar steam generating machine which uses solar energy as its fuel;
- to carryout performance analysis of a parabolic dish collector to heat the water located at the focal point of the concentrator;
- to minimize heat loses on the reflectors and thereby improving high temperature concentration at the focal point.

Theoretical Background

The basic principle adopted in the construction of the parabolic dish solar steam generator is that when parallel rays of light from the sun close to and parallel to the principal axis are incident on a concave or parabolic shaped mirror, they converge or come together after reflection to a point F on the principal axis called the principal focus as shown in figure.



where
F = Principal Focus
P = Pole
C = Centre Curvature
AB = Aperture is the width of the mirror

***Figure 1**. Parabolic Dish*

Material and Method

The parabolic dish solar steam generator considered in this paper is made up of the following parts as shown in figure 2.

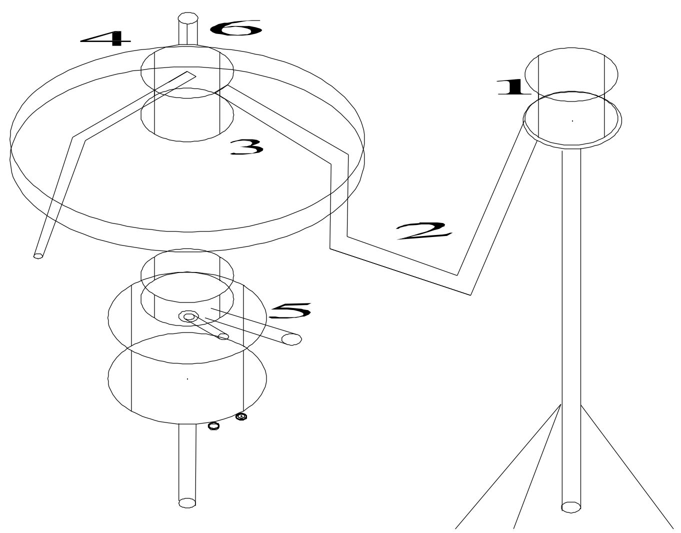


Figure 2. *Representation of the Parabolic Dish Solar Steam Generator*

where:
{1} - Cold Water Storage Tank;
{2} - Galvanized Pipe for Cold Water;
{3} - Absorber;
{4} - Parabolic Dish Reflector;
{5} - Adjustable Mechanism;
{6} - Outlet Pipe for Steam.

The parts in the figure are as follows:

- *Tank:* The storage tank is made of iron sheet or plastic and mounted on a stand higher than the parabolic dish stand for storing cold water.
- *Flexible pipe:* This is a pipe made of galvanized steel. It carries cold water from the storage tank to the absorber.
- *Absorber:* It is a metal container that carries water, painted black and located at the focal point of the parabolic dish. When the sunlight rays are incident on the reflective surfaces of the parabolic dish, they are reflected and converged to the base of the absorber located at the focal point to heat up the water in it and generate steam.

- *Parabolic dish:* This is the concave dish made of wood and lined with an aluminium sheet. Method of a given focus and directrix was employed in the construction of the parabolic dish. The reflector plain mirror cut into shapes and fixed by glue to the aluminium sheet which is in turn riveted to the wooden skeleton structure serve as the reflecting surface of the parabolic dish that converges heat to the base of the absorber.
- *Adjustable mechanism:* Parabolic dish adjustable mechanism is made of metal to support the weight of parabolic dish and absorber. The main function is to allow the parabolic dish to align at various angles to capture the sunlight rays depending on the movement and position of the sun.
- *Outlet Hose:* This is a pipe made of galvanized steel and it is fixed at the top of the absorber. It serves as the outlet for the steam generated in the absorber to the generator.

Design Analysis

Design Specifications

The construction of the parabolic dish solar steam generator was made taking into account following design specifications:

- Diameter of the sun: 1.39×10^6km;
- Average distance of the sun from the earth: 1.5×10^8km;
- Radius of the earth (r_e): 6400km;
- Effective temperature of the surface of the sun 5762K;
- The sun's central interior region temperature (estimation): 8×10^6K to 40×10^6K;
- Density of the sun: 80 to 100 times that of water;
- Solar constant (Isc): 1353w/m^2;
- Extraterrestrial radiation (Io): 1398w/m^2 (maximum); 1310w/m^2 (minimum);
- Geographical location of Nigeria.
  - Latitude between 4°N and 13°N.
  - Longitude between 3°E and 15°W
- Nigeria land area (A) = 932768km^2 [5]
- On average yearly total solar energy incident on a horizontal surface in Nigeria: 2300kwh/m^2 [5]

Design Equation

Average distance of the sun from the earth = 1.5x10^{8}km

Consider a sphere of radius 1.5x10^{8}km with the sun at its centre.

Let Ss = surface area of this imaginary sphere

A_E = cross sectional area of the earth

r_s = radius of the sphere

r_e = radius of the earth

Therefore,

$$A_E = \pi r_e^2 = 3.142(6.4\text{x}10^6)^2 = 1.287\text{x}10^{14}\ \text{m}^2 \quad (1)$$

$$Ss = 4\pi r_s^2 = 4\text{x}3.142\ (1.5\cdot 10^{11})^2 = 2.828\cdot 10^{23}\text{m}^2 \quad (2)$$

Percentage sun's output= [(A_E/Ss) x100} (3)

= {[(1.287x10^{14})/ (2.828x10^{23})] x100}

= 0.0000000455%

This then means that the earth receives 0.0000000455% of sun's energy output.

The world's average annual energy consumption is 9.262x10^{23}kwh [6].

Hence, Nigeria would receive radiation at that rate:

Let R_c = extraterrestrial radiation

A = continental land area

I_{sc} = extraterrestrial solar constant

Therefore,

$$R_c=I_{sc}A \quad (4)$$

$$=1353\cdot 932768\text{x}10^6$$

$$=1.262\cdot 10^{15}\text{w/m}^2$$

Therefore, for a yearly average sunshine hour of 9hours/day

$$= 1.262\cdot 10^{15}\text{x}\ (366\text{x}9)$$

$$= 4.157\cdot 10^{18}\text{wh/year}$$

Assuming a clearness index of 50% since 47% of extraterrestrial radiation reaches the earth surface.

Terrestrial radiation in Nigeria's land area

$$= [(50/100)\cdot 4.157\text{x}10^{18}$$

$$= 2.079\cdot 10^{18}\text{wh/year.}$$

The part of solar radiation that reaches the surface of the earth without being scattered, absorbed or reflected is direct radiation and it is the most intense. The intensity of the direct radiation reaching the surface of the earth is a function of time of the day, latitude of location and declination angle (Awachie, 1982).

To calculate the direct radiation reaching the earth surface as a function of time of the day (t), for a location (γ) with the sun at declination (δ):

Let Z -Zenith Angle

γ -Latitude of location

δ -declination angle

t -hour angle of the sun

I_Z -Direct Normal Radiation

I_{SC}-Extraterrestrial solar radiation constant

I_h -Horizontal radiation.

S and C are climatographically determined constants. The Zenith angle is calculated thus:

$$\text{Cos } Z = \sin\gamma \sin\delta + \cos\gamma \cos\delta \cos t \quad (5)$$

$$= \sin 14° \sin 0° + \cos 14° \cos 0° \cos 0°$$

$$= 0.2192 \text{ x } 0 + 0.97029 \text{ x } 1 \text{ x } 1$$

$$= 0.97029.$$

$$Z = \cos^{-1}(0.97029) = 14°$$

The intensity of the solar radiation after passing through the atmosphere is calculated thus:

$$I_Z = I_{Sc}e^{-C(\sec Z)S} = 1353\ e^{-0.357\ (1/\cos 14)0.678} = 940 \text{w/m}^2 \quad (6)$$

This is the value of the direct radiation on a normal surface and it is the maximum value possible. In practice only systems using full tracking mechanisms can collect this radiation.

The value of radiation on a horizontal surface is calculated thus:

$$I_h = I_Z \cos Z = 940 \text{ x } 0.970295726 = 912 \text{w/m}^2 \quad (7)$$

Energy Balance of the collector

For a steady state situation, an energy balance on the absorber plate yields the following equations [7].

$$q_u = A_p I_{sc} - q_1 \quad (8)$$

A_p – Area of absorber plate (m^2)

Solar Radiation

The total solar radiation falling on a horizontal surface is given by:

$$I = I_{Sc}\left(a + b\frac{n}{N}\right) \quad (9)$$

where:

I - Average horizontal daily terrestrial radiation for the period (usually 1 month)

I_{Sc} - Extraterrestrial solar radiation

A, b- climatically constants for a particular location

Φ - Latitude, 0.33°N, a, b are 0.32 and 0.4 respectively

n - day of the year

N - Possible daily maximum number of insolation.

θ – Angle

τ – transmissivity of cover

$$N = \frac{2\cos^{-1}(-\tan\phi\tan\delta)}{1.5} \quad (10)$$

where δ – declination angle and is given by

$$\delta = 23.45\ \mathrm{Sin}\ \frac{[360(284 - n)]}{365} \quad (11)$$

Efficiency

Collector efficiency is given by

$$\eta_i = \frac{q_u}{A_C I_T} \quad (12)$$

where

I_T -the amount of solar radiation falling on the collector

A_C- area of the collector (m^2)

η_i - instantaneous collector efficiency (%)

q_U - rate of useful heat gain (w_i)

Heat Loss

In term of overall coefficient (U_i) the heat loss from the collector is given in [7].

$$q_i = U_i A_p (T_{pm} - T_a) \quad (13)$$

Hence, the loss from the collector is the sum of the heat loss from the top, the bottom and the side, thus,

$$q_T = q_t + q_b + q_s \quad (14)$$

Each of the losses are defined by the equations below

$$q_t = U_t A_p (T_{pm} - T_a) \quad (15)$$

$$q_b = U_b A_p (T_{pm} - T_a) \quad (16)$$

$$q_s = U_s A_p (T_{pm} - T_a) \quad (17)$$

So, $U_T = U_t + U_b + U_s$

U_T is measure of all the losses. Therefore, it is an important parameter; typical values range from 2 – 10w/m^{2}K [8].

For empirical relation:

$$\mathrm{Nu} = \frac{hl}{k} = \frac{h_p - ql}{k} \quad (18)$$

h –Heat transfer coefficient (w/m^{2}K)

$$\mathrm{Nu} = 0.54 (G_r p_r)^{\frac{1}{4}} \quad (19)$$

where hp-c = 0.54 $(G_r p_r)^{\frac{1}{4}} \frac{K}{L}$ (20)

where Gr – Grasshoff number and Pr – Prandtl number

For $10^5 < \mathrm{Gr} < 2 \cdot 10^7$ [9]:

$$\mathrm{Gr} = \frac{gL^3\beta(dT)\rho^3}{\mu^2} \text{ or } \frac{gL^3\beta(dT)}{\nu^2} \quad (21)$$

$$dT = T_{pm} - T_a \quad (22)$$

$$\beta = \frac{1}{T_m} \quad (23)$$

where: μ –Dynamic viscosity (Ns/m^2); ν – Kinetic viscosity (m/s); ρ – Density (kg/m^3); T_m – Mean temperature (K); L - characteristic length

$$h_{rp\text{-}c}=\frac{\sigma\left(T_p^{\ 2}+T_c^{\ 2}\right)\left(T_P+T_C\right)}{\frac{1}{\varepsilon_p}+\frac{1}{\varepsilon_c}} \tag{24}$$

where

ε_c – Emissivity of transparency cover

ε_p – Emissivity of absorber surface for long wave radiation

T_c – Temperature of transparency cover (K)

$h_{r,p\text{-}c}$ – Radiation heat transfer coefficient between absorber plate and surrounding. (w/m^{2}K).

$$h_{rc\text{-}s}=\frac{\varepsilon_c\sigma\left(T_c^{\ 4}-T_{sky}^4\right)}{\left(T_c-T_a\right)} \tag{25}$$

the top loss coefficient, U_t is given by

$$U_t=\frac{1}{R_1+R_2}=\left[\frac{1}{h_{p-c}+h_{ro-c}}+\frac{1}{h_{rc-s}+h_w}\right] \tag{26}$$

where

R_1– Thermal resistance between plate and cover (W/°C)

R_2 – Thermal resistance between cover and surrounding (W/°C)

h_w – Wind heat transfer coefficient (w/m^{2}K)

$h_{p\text{-}c}$- convective heat transfer coefficient between absorber and transparency (w/m^{2}K)

$h_{r,c-s}$ –Radiation heat transfer coefficient between absorber plate and surrounding (w/m^{2}K).

However, for a single transparent glass cover that is partially transparent to infrared radiation, the net radiant energy transfer directly between the collector plate and the sky is

$$q_p\text{–}sky=\varepsilon_p\sigma\left(T_P^{\ 4}-T_{sky}^{\ 4}\right) \tag{27}$$

where

T_p – Absorber plate temperature (K)

T_{sky} –Temperature of sky (K)

σ – Stefan-Boltzman constant (w/m^{2}K^4)

(Assuming transmittance is independent of source temperature) (John and Anthony, 1986).

Bottom loss coefficient

$$U_b = \frac{K_m}{\delta_b} \tag{28}$$

where

K_m –Thermal conductivity of casing material (W/mK)

δ_b – Thickness of absorber plate (m)

Side loss coefficient

$$U_s = \frac{(L_1 + L_2)L_3 K_m}{L_1 L_2 \delta_s} \tag{29}$$

Thus,

$$q_s = 2L^3 (L_1 + L_2) K_m \frac{(T_{pm} - T_a)}{2\delta s} \tag{30}$$

where $\frac{T_{pm} - T_\theta}{2}$ is assumed as average temperature drop for $L_1 - L_2$.

Equation (29) becomes,

$$U_s = \frac{2L_3 K_m}{L_1 \delta s} \tag{31}$$

And

$$q_s = \frac{2L_3 L_1 K_m}{\delta s} (T_{pm} - T_a) \tag{32}$$

where

L –Collector characteristic length (m)

L_1–Length of absorber plate (m)

L_2 –Width of absorber plate (m)

L_3 –Height of collector (m)

T_{pm}–Mean absorber surface temperature (K)

δ_s – Thickness of side plate

Incident Angle Modifier

The effective transmittance product $(\tau\alpha)_e$ of a solar collector can be described by

$$(\tau\alpha)_e = K\alpha\tau(\tau\alpha)_{en} \tag{33}$$

The incident angle modifier, $K\alpha\tau$, is a correction factor which is a function of the incident angle between the direct solar beams and outward drawn normal to the plane of the collector aperture.

Concentration Ratio

Two definitions of concentration ratio (CR) are natural and have been in use. To avoid confusion a subscript should be added whenever the context does not clearly specify which definition is meant. The first definition is strictly geometrical the ratio of aperture area, A_a to receiver area, A_r,

$$CR = \frac{A_a}{Ar} \tag{34}$$

For ratio of intensity at aperture to that of receiver

$$CR_{flux} = \frac{I_a}{I_r} \tag{35}$$

Since the angular radius of the sun is $\Delta s \approx \frac{1}{4}^{\circ}$, the thermodynamic limit of tracking solar concentrator is about 2000 in two dimensional line (focus) geometry, and about 40,000 in three dimensional line (point focus) geometry that is $y = (1/4f)x^2$ (Kreider and Kreith, 1980).

Calculation for reflector Area

The area of the reflector is obtained from all the quantity of heat to boil water to steam in relation to the design insulation.

Heat required boiling 1kg of water Q_1

$$Q_1 = M \text{ x } C \text{ x } \Delta T \tag{36}$$

$$= 1.0 \text{ x } 4200 \text{ x } (100 - 32)$$

$$= 285{,}600\text{J}$$

C –Specific heat capacity of water ($Jkg^{-1}K^{-1}$)

Heat required vaporizing (½) the water context of the pot

$$Q_2 = M \text{ x } L \tag{37}$$

$$= 0.5 \text{ x } 2.26 \text{ x } 10^6$$

$$=1130000\text{J}$$

Heat loss due to free convection across the surface of the absorber:

From the top of the absorber is given by

$$P_{top} = a_T \frac{KN_u \Delta T}{h_p} \tag{38}$$

Where a_T is base area of the absorber, h_p is the height of the absorber and ΔT is the change in temperature.

$$\Delta T = T_S - T_a$$

where

T_s –temperature of generating steam (K)

T_a –ambient temperature (K)

For turbulence at the hot bottom of the absorber

$$Nu = 0.14\, \xi^{0.33} \tag{39}$$

Where ξ is obtain from the equation

$$\frac{\xi}{d^3 \Delta T} = 5.8x10^7 \tag{40}$$

Absorber diameter da = 0.2m, h_p = 0.25m to be used for boiling for this design

Rayleigh number ξ for the top is

$$\xi_{top} = 5.8 \text{ x } 10^7 \text{ x } d^3 \Delta T \tag{41}$$

$$= 5.8 \text{ x } 10^7 \text{ x } (0.2)^3 \text{ x } (100 - 32)$$

$$= 3.1552 \text{ x } 10^7$$

From equation (39)

$$N_u = 0.14(3.1552x10^7)^{0.33}$$

$$= 41.764$$

N_U –Nusset Number (w)

From equation (38), heat loss at the absorber top is

$$P_{top} = \frac{\pi r^2 KN_u (T_S - T_a)}{h_p}$$

where $K = 0.027m^{-1}$

$$= \frac{0.03142x0.027x41.764x68}{0.25}$$

$$= 9.64w$$

Convective heat loss from the side of the pot:

The applied N_u for the vertical side of the pot due to laminar condition is

$$N_u = 0.56\,\xi_{size}^{0.25} \tag{42}$$

The dimension of the side (r/d)

$$\therefore \xi = \xi_{top} x \left(\frac{r}{d}\right)^3 \tag{43}$$

$$= 3.1552x10^7 x \left(\frac{0.1}{0.2}\right)^3 = 3944000$$

equation (42) becomes

$$N_u = 0.56(3944000)^{0.25}$$

$$= 0.56(44.564) = 24.96$$

heat loss from the side of the absorber

$$P_{side} = \frac{\pi d h_p K N_U (T_s - T_a)}{h_p} = \frac{3.142x0.2x0.25x0.027x24.96x68}{0.25} = 28.80w \tag{44}$$

Total convective heat loss in (w)

$$P_c = P_{top} + P_{side} \tag{45}$$

$$= 9.64w + 28.80w$$

$$= 38.44w$$

Converting heat from equations (36) and (37) to power over a period of 1 hour

$$P_h = \frac{285600 + 1130000}{3600} = 393.2w$$

Power needed for boiling outside

$$P = P_c + P_h = 38.43 + 393.2 = 431.63w$$

applying the solar insolation and reflectance of the mirror for the design, the effective solar beam I_t that is reflected to a focal plane is

$$I_t = PxI$$

$$= 0.9x750 = 675w/m^2$$

Using a design factor of 1.5 to calculate area of the reflector needed

$$A = \frac{P}{I_t} \text{ (Duffie, 1990)}$$

$$= \frac{431.63}{675.0} x1.50 = 0.96m^2$$

Calculation for the concentration ratio from equation (34)

$$C_R = \frac{A_a}{A_r} = \frac{\pi\left(b^2 - r^2\right)}{\pi r^2 + 2\pi rx}$$

Where b is the reflector aperture radius

$$= \frac{\pi\left(0.75^2 - 0.25^2\right)}{\pi(0.25)^2 + 2\pi x 0.25 x 0.25}$$

$$= \frac{3.142(0.5625 - 0.0625)}{0.196375 + 0.39275} = \frac{1.571}{0.589125} = 2.67$$

Testing

The testing of the parabolic dish solar steam generator was done in the month of January 2009 for three days. The whole set was placed in an open space in the sun from 9:00am in the morning to 5:00 pm in the evening each day for three days. Resistance thermometer placed at the focal point was used to obtain its maximum obtainable temperature. The results obtained for hourly reading of 8hours everyday are tabulated in tables 1-3.

Results

Result on 27th January, 2009

Table 1. Variation of Temperature at Focus Point with Time on the First Day

Time	Ambient Temperature (°C)	Focal Point Temperature (°C)
9am	29	89
10am	29	138
11am	30	172
12pm	30	208
1pm	30	224
2pm	33	228
3pm	32	200
4pm	31	183
5pm	30	140

Result on 28th January, 2009

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Table 2. Variation of Temperature at Focal Point with Time on the Second Day

Time	Ambient Temperature (°C)	Focal Point Temperature (°C)
9am	29	94
10am	29	120
11am	30	155
12pm	30	193
1pm	30	217
2pm	33	220
3pm	32	198
4pm	31	169
5pm	30	125

Result on 29th January, 2009

Table 3: Variation of Temperature at Focal Point with Time on the Third Day

Time	Ambient Temperature (°C)	Focal Point Temperature (°C)
9am	30	98
10am	30	102
11am	30	132
12pm	31	178
1pm	31	210
2pm	31	196
3pm	32	180
4pm	31	141
5pm	30	102

Discussion of Results

Based on the results obtained during the test of the parabolic dish solar steam generator, temperature above 200°C was recorded against the ambient temperature. The temperature at the focal point varied with time but however, a peak value was always reached. Variation of temperature with time was due to movement and position of the sun, the angle of inclination of the parabolic dish and the atmospheric condition. When 1kg of water was poured inside absorber boiling took place in less than 10 minutes.

Conclusions

In conclusions, the need for the construction of a parabolic dish solar steam generator arose as an alternative to solve the thermal energy needs of the populace. This will also reduce the total dependency on fossil fuels and other non-renewable and exhaustible energy source which have be known to be depleted with ages to come as they are being used up. As such, deforestation and other environmental populations are reduced to a minimum.

The need to utilize the free abundant natural resource of energy which is freely in abundance requires no recurrent expenses as other source of energy. Thus, it is regarded as the cheapest source of fuel for man.

Based on the result obtained in tables 1-3 during the test, temperature above 200°C was obtained at base of the absorber. Water boiled faster using the generator than when using ordinary charcoal or kerosene stove. The parabolic dish solar steam generator is very efficient heating equipment.

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