E-ISSN: 1115 - 8492 P-ISSN: 3027 - 0693
MPRI-JNSAR | INTERNATIONAL JOURNAL OF NATURE AND SCIENCE ADVANCE RES. VOL. 07 NO. 9 JANUARY. 2025

DEVELOPMENT OF A SOLAR KETTLE FOR MILITARY APPLICATION

ABDULRAUF A. IBRAHIM; ABUBAKAR N. MOHAMMED; AND LAWAL I. ATIKU

Department of Mechanical Engineering, College of Engineering, Kaduna Polytechnic, Kaduna.

Corresponding Author: abdulraufabdullahi@kadunapolytechnic.edu.ng

DOI: https://doi.org/10.70382/mejnsar.v7i9.031

Abstract

The need for auxiliary military hardware to sustain the wellbeing of the personnel's during combat and to boost local technological development in the face expanding and growing level sophistication of military operations and to cut down on cost of military expenditure due to high cut of imported military hardware and equipment. As such innovation in solar heating system are being sought to achieve higher level of adaptation, flexibility and reliability for efficient military operation. In overcoming this challenges, there is need to pursue the development of solar kettle as heating device for military application using indigenous technological content. This solar heating device enable the military personnel's to warm their food, cook noodles and warm up water for tea without releasing fumes into the air and thereby exposing their location to the enemy. The Emphasis on this work is to Design and fabricate a solar kettle

[redacted]

Keywords; Development, Military, Radiation, Solar kettle,Technology

thermal system which utilizes a solar conceptual system for different applications such as solar water heater, and evaluate the overall efficiency of the system. The experimental results has shown that there is an increase in the temperature which is proportional with time towards the maximum at summer season when the utmost solar radiation gets closer to perpendicular on earth. The useful energy increased steadily with the time until mid-noon. That is because that both temperature and solar radiation increased steadily up to the midday but decreased until sunset.

INTRODUCTION

Solar Energy is the resultant outcome of thermonuclear reactions of fusion from "hydrogen" into "helium" taking place in the sun. These thermonuclear reactions release huge energy and radiate the energy to space continuously. This kind of energy which is continuous and perennial is available as solar energy. The average intensity of solar radiation on the earth orbit is 1367kW/m2, and the earth's equatorial circumference is 40,000km, so it can be worked out that the energy the earth obtains is up to 173,000TW. The energy on earth, including wind energy, hydropower, ocean thermal energy, wave energy, bio-energy and some tidal energy all come from the sun. Even the fossil fuels on earth (such as coal, petroleum, natural gas, etc.) are at bottom the solar energy that has kept in storage since time immemorial, so the solar energy in a broad sense covers a vast scope, and the narrow-sensed solar energy is confined to the direct transformation of solar radiation from sunlight to heat, electricity and chemical energy. The solar energy is a primary energy source, and it is also renewable energy. It is rich in resources without transport, which is both free for use and non-contaminative to the environment [Balakrishnan, M., et al. (2012)].

A typical solar kettle is designed specifically for those off-grids in need of clean safe drinking water, hot coffee, tea or soup [Ibeh G.F, et (2012)]. It can be used to cook meals such as hot cereal, eggs, noodles, rice, potatoes or any other that can fit inside the tube. When finished cooking, just keep the cap closed to maintain content warm and ready to drink or eat for hours after the sun is out. No monitoring is required [I. E.A,. (2011).]. Depending on the season and intensity of the sun and altitude, a solar kettle can warm up content as quickly as 15-20 minutes and reach boiling point of 200 F (93.4 C) in less than 1 hour. It can be designed to work in all seasons as long as the sun is up and also function in cloudy days or with the snow around, capturing ultraviolet light and holding its heat. An example of a solar kettle structure is shown in figure 1.

Fig I: An example of a solar kettle structure [U.S. Energy (2011)]

Geometrical Principle of two Main Reflecting Surfaces

A mirrored surface reflects a ray of light at the same angle at which it strikes the surface. [U.S. Energy (2011)

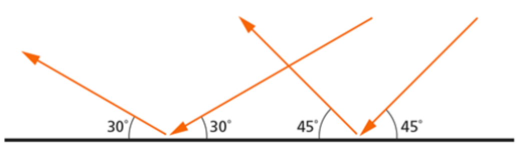

Figure 2: flat surface solar reflector

A parabola's unique shape has a slope that is proportional to the distance from the center. This means the further from the center a light ray strikes the parabola, the narrower its incident angle, and the broader its change in direction when it is reflected. In this way, all the light rays get reflected back to a single point. (Panwar, N.L, et al (2012).

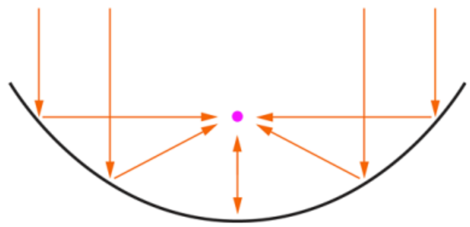

Figure 3: Parabolic shaped solar reflector

METHODOLOGY

After going through the literature review of previous research works, trends used and experimental standards for the design, construction and testing a solar heating and solar cookers, the design dimensions and materials used for the prototype were decided upon. In this project, considerations are made concerning the sun irradiation, the reflecting surface, the parabolic geometrical structure and the basic support components for the development of the solar kettle would be used. The solar kettle parts would be developed based on essential mathematical engineering equations and design data from heat and mass transfer manuals, texts books and published journals. This study was conducted in Kaduna State ,with a geographical location which lies between Latitude 10.31°N and Longitude 7.26°Eand altitude 900 m above sea level C. Laughton, (2010).

Materials

The materials used in the construction of the solar kettle included: stainless steel cylindrical vessel, aluminium metal sheets, glue and aluminium foils, metal hinges.These materials must have properties like corrosion resistance. The selection is based on factors such as; availability and cost.

Principle of Operation

Designed like a thermos consisted of a stainless steel cylindrical vessel and a glass like outer covering place at the centre of a folded out parabolic trough reflectors specifically designed to maximize capturing the energy of the sun, the outer tube allows light rays to pass through the minimum reflection, while the inner tube will absorb heat energy warming up the water/content inside. The reflectors will gather three times more energy of the sun than with only a plain tube.

It would be easy to heat water at zero cost! No electricity required! No more reliance on a gas, propane or charcoal stove. You will use this anywhere there is sunlight. Whether camping in a tent, motor home, mountaineering, hunting, fishing, and kayaking or on maneuvers with the army - our solar kettle is a reliable source of easily made safe hot beverages and food. (Fuller, R.J. (2022).

Design Considerations

The design considerations stated below have been adopted with regards to the preliminary drawing of the solar kettle to facilitate adherence to the required specification so that an effective and efficient solar heating system is developed to enhance fabrication process. The structure of the solar kettle in it open state is shown in Figure 3.1. This structure is taken from the structure shape figure 3.

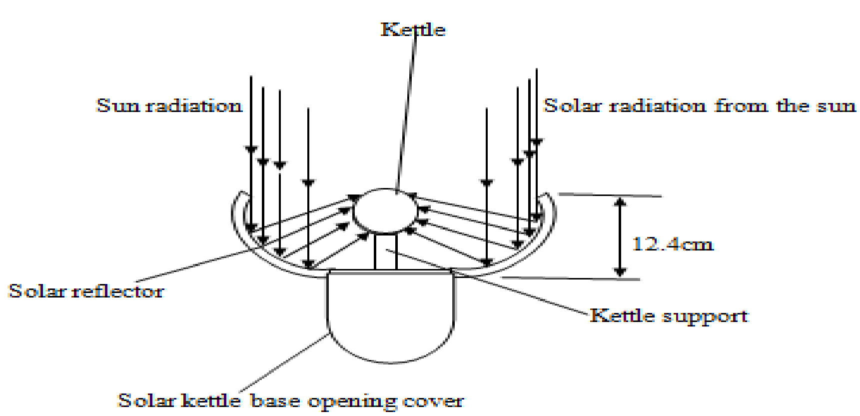

Figure 4: The solar kettle structure in open state

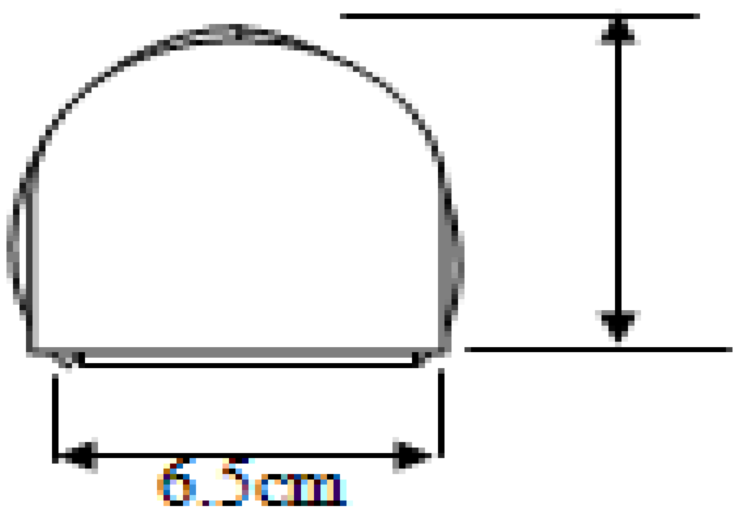

Figure 5: The solar kettle structure in folded state

The design consideration includes;

1. The solar kettle must be resistance to corrosion; therefore, it must be made from stainless steel material, Aluminium sheet.
2. The parabolic shaped reflector must be structured to house the kettle.
3. The vessel use as kettle is cylindrically shape
4. The kettle is coated black on the outer surface to facilitate absorption of thermal heat
5. The kettle support should be high enough to keep it at focal point of the parabolic reflector.
6. It should be portable and easy to carry around.
7. Considered heat transfer take place under steady state conditions.
8. The Heat flow is unidirectional.
9. The temperature gradient is constant and the temperature profile is linear.
10. There is no internal heat generation.
11. The material is homogeneous and isotropic.

Design Mathematical Model for the Solar Kettle System

The construction of the parabolic solar reflector

An aluminium metal sheet was converted to a parabolic trough solar reflector using the parabola equation. The focal point was determined using the following analysis.

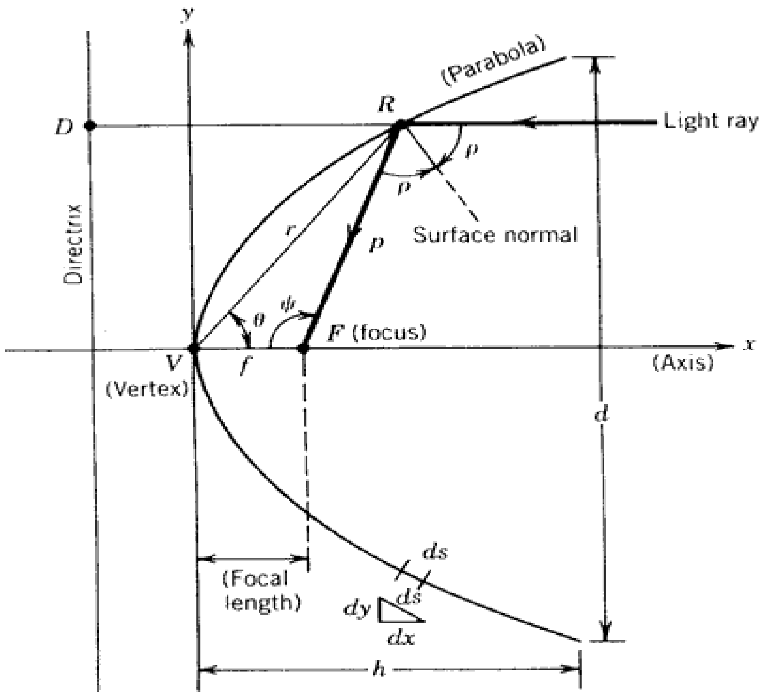

Figure 6: A typical Analysis geometrical orientation of a parabolic shaped trough

Important and useful definitions / terminology related to Parabolic Dish Solar Concentrator are as follows. (Toonen H. M. (2009).

a) Aperture area of dish concentrator (m^2): The total surface area of concentrator upon which solar energy is incident.
b) Diameter of dish aperture (d): The diameter of dish (denoted by d in the Fig. 3.3).
c) Focal length (f): The focal length is the distance VF from the vertex to the focus.

d) Dish rim angle (ψ): Solar concentrators use a truncated portion of the basic parabola curve.
e) The extent of this truncation is usually defined in terms of the rim angle or the ratio of the focal length to aperture diameter f/d.
f) Height of the curve (h): The maximum distance from the vertex to a line drawn across the aperture of the parabola.
g) Arc length (s): Found by integrating a differential segment of the basic parabola curve and applying the limits x = h and y = d/2.

RESULTS

Testing and Result

The experimental results for solar radiation with time in Kaduna for Latitude (10.52N) and longitude (7.43E) between 10- 20- April, and 10- May 2020, was observed in the middle of solar radiation. It was observed that there is an increase in the solar radiation with time between 9:00 AM to 2:00 PM and a decrease between 2:00AM to sun set. Though there was an observed decrease in the solar radiation (20/4/2020) at 10.14 o'clock, this is as a result of availability of the partial clouds

Table 1 DETAILS OF SOLAR CONCENTRATORS

Surface Collecting of the Parabola	2.0 m^2
Depth of Parabola	0.9 m
Focal Distance	0.2 m
Rim Angle	45^o
Efficiency of Parabola	50%

Observations and Performance parameters

Optical performance of solar collector shows the magnitude of energy that is received by the collector. Thus the aim here is to investigate the optical performance of the system or receiver.

$$\text{Angle of incidence: } \cos\theta = (\cos 2\theta z + \cos 2\delta * \sin 2w)1/2$$

$$Zenith\ angle: \ cos\theta z = cos\varphi * cos\delta * cosw + sin\varphi * sin\delta$$

$$Declination: \ \delta = 23.45 * sin(360 * (284 + n)/365$$

Table 2. Optical performance of solar collector

Hour angle	Angle of incidence	Zenith angle
-90	3.892	91.6158
-75	9.6077	77.8675
-60	15.0209	64.3875
-45	19.7795	51.4611
-30	23.528	39.6491
-15	25.9392	30.52386
0	26.7728	26.7728
15	25.9392	30.52386
30	23.528	39.6491
45	19.7795	51.4611
60	15.0209	64.3875
75	9.6077	77.8675
90	3.892	91.6158

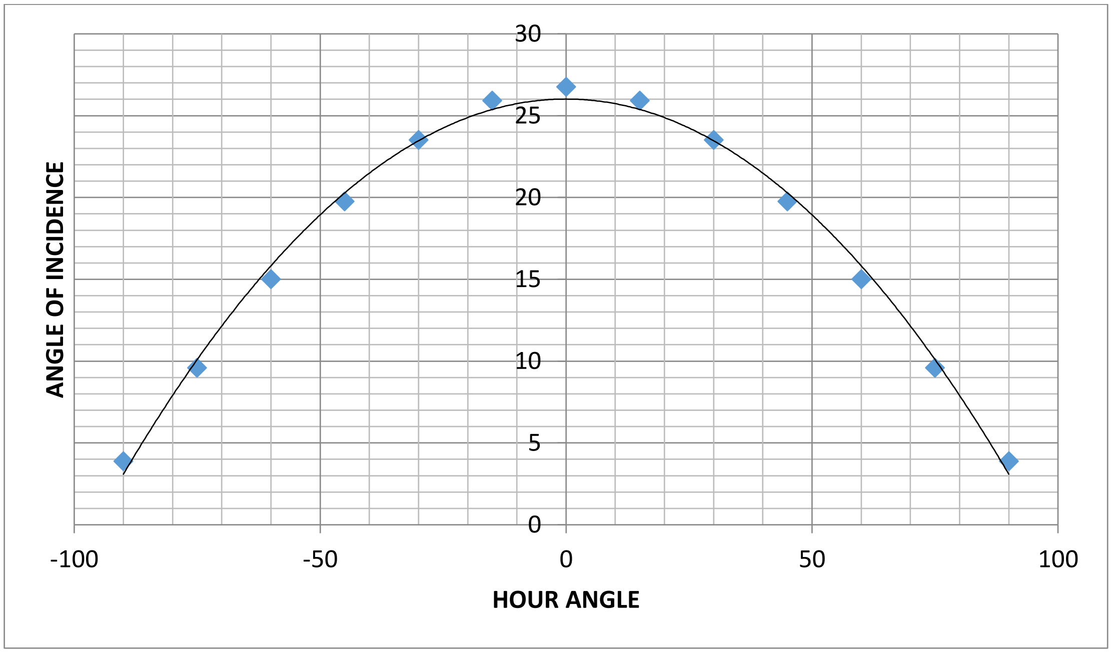

Fig. 7 Variation of angle of incidence with hour angle

Table 2 [2] Initial temperature of water 22 °C [Day 1 Observation]

Duration for temperature measurement 40 min

Time	Final Temp of Water
7	22
8	28
9	32
10	44
11	45
12	49
13	52
14	50
15	46
16	41

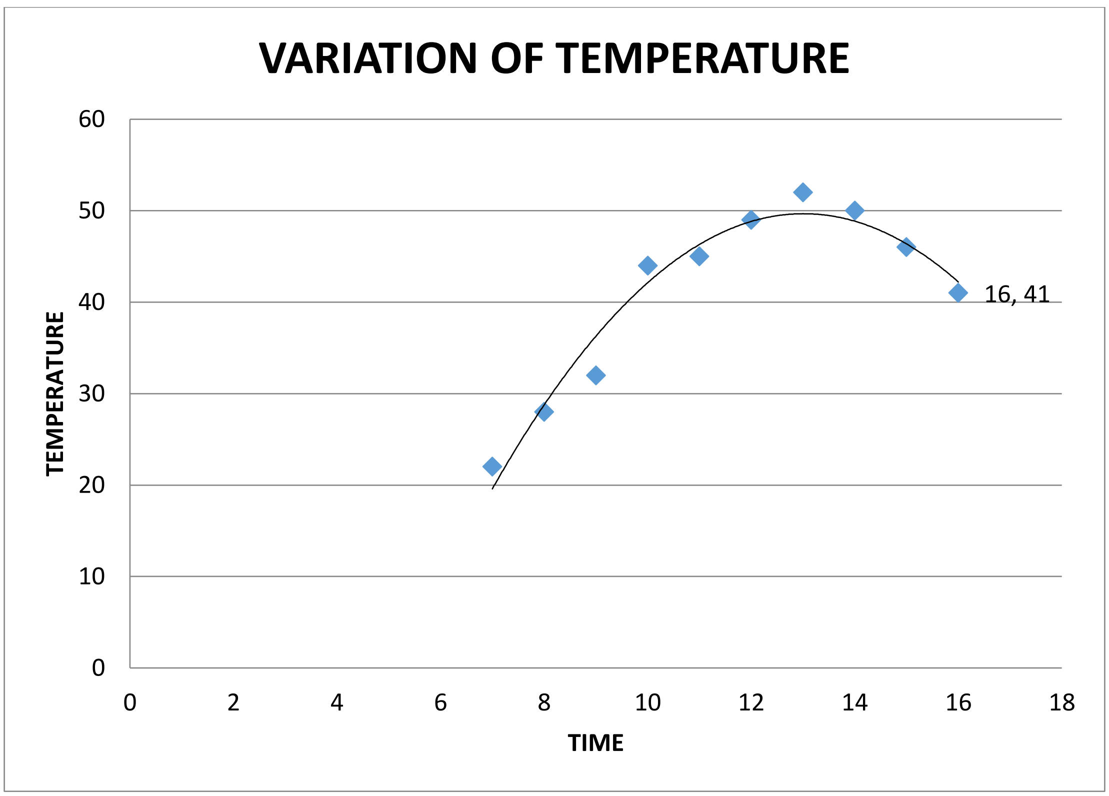

Fig 8 Variation of temperature with time for Day I

MEDITERRANEAN PUBLICATION
AND RESEARCH INTERNATIONAL
E-ISSN: 1115 – 8492 P-ISSN: 3027 - 0693

INTERNATIONAL JOURNAL – NSAR
VOL. 07 NO. 9 – JANUARY, 2025

Table 3. [2] Initial temperature of water 21 °C [Day 2 Observation]

Duration for temperature measurement 40 min

TIME	FINAL TEMPERATURE OF WATER
7	**21**
8	**25**
9	**30**
10	**44**
11	**42**
12	**49**
13	**50**
14	**52**
15	**41**
16	**39**

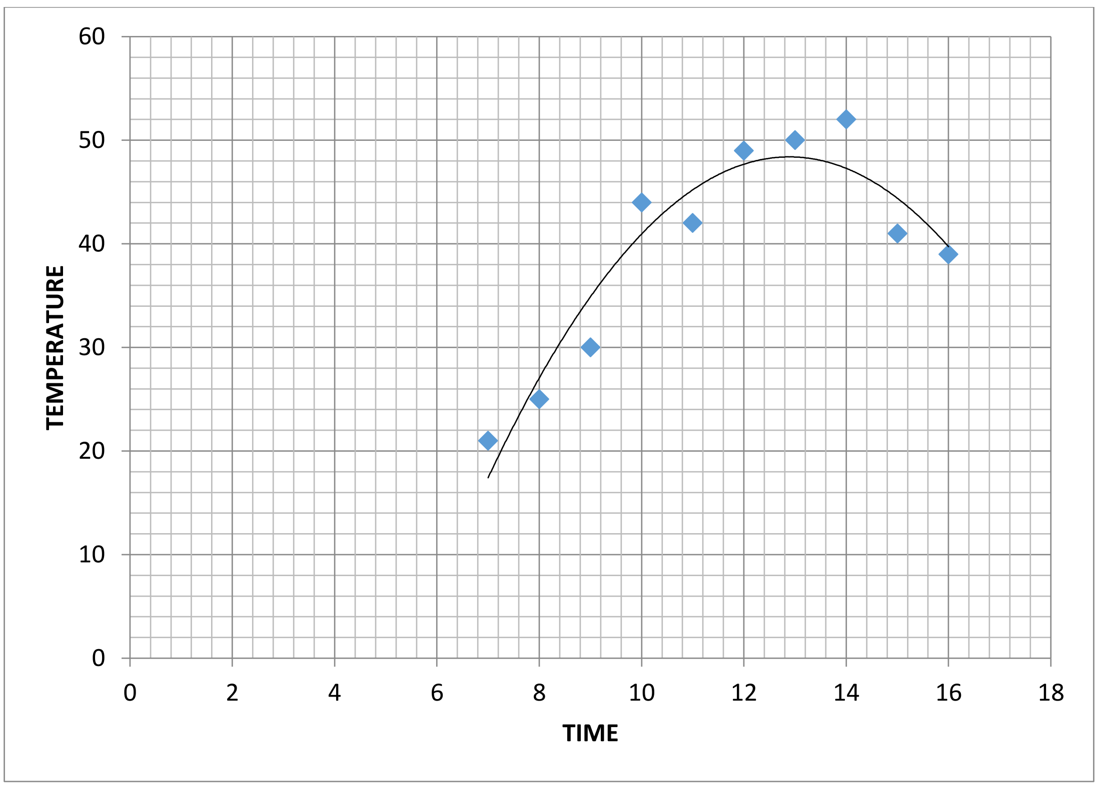

Fig 9 Variation of temperature with time for Day II

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

4.7.3 Table 4. [3] Initial temperature of water 19 °C [Day 3 Observation]

Duration for temperature measurement 40 min

TIME	FINAL TEMPERATURE
7	19
8	23
9	29
10	32
11	38
12	46
13	49
14	46
15	41
16	38

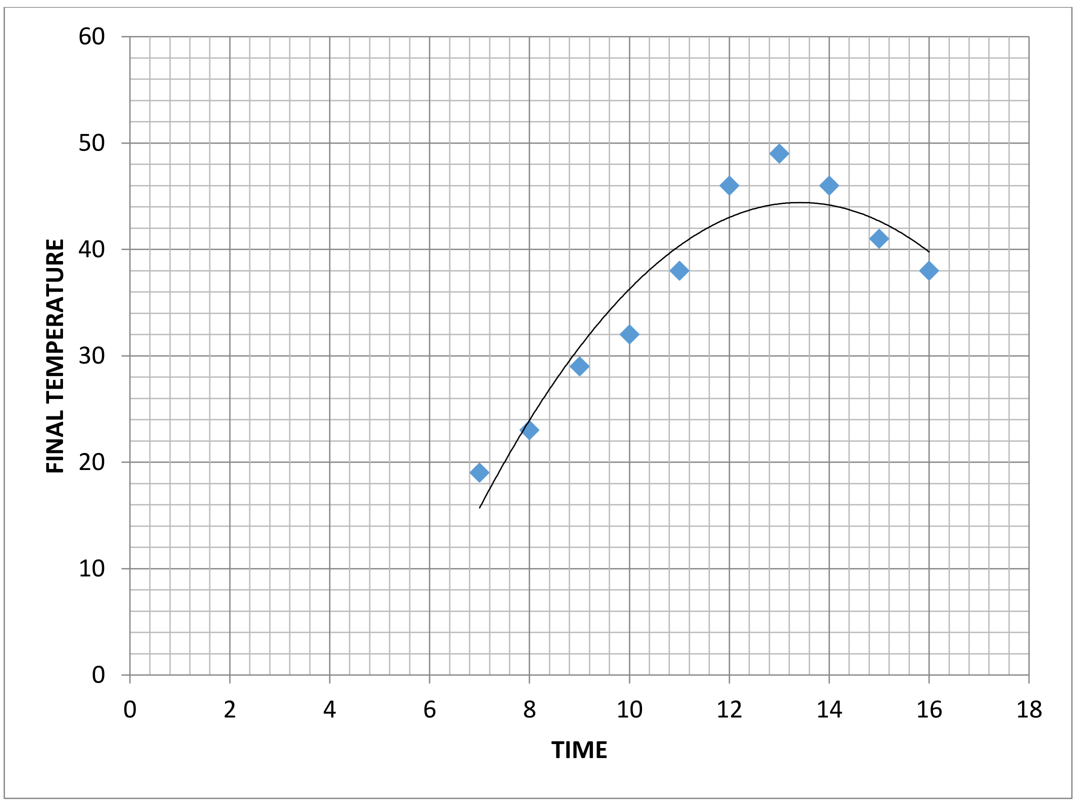

Fig 10 Variation of temperature with time for Day III

4.7.4 Table 5. [3] Temperature of water in time duration at 1 p.m. by tilting parabolic trough at hour angle

TIME DURATION	TEMPERATURE
30	49
40	50
50	52

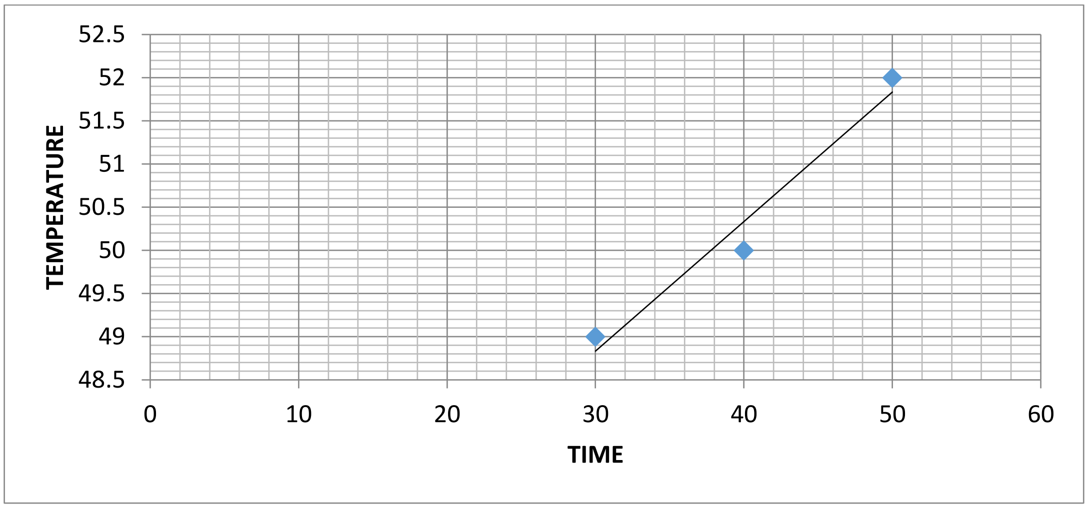

Fig 11 : Variation of temperature with time at hour angle

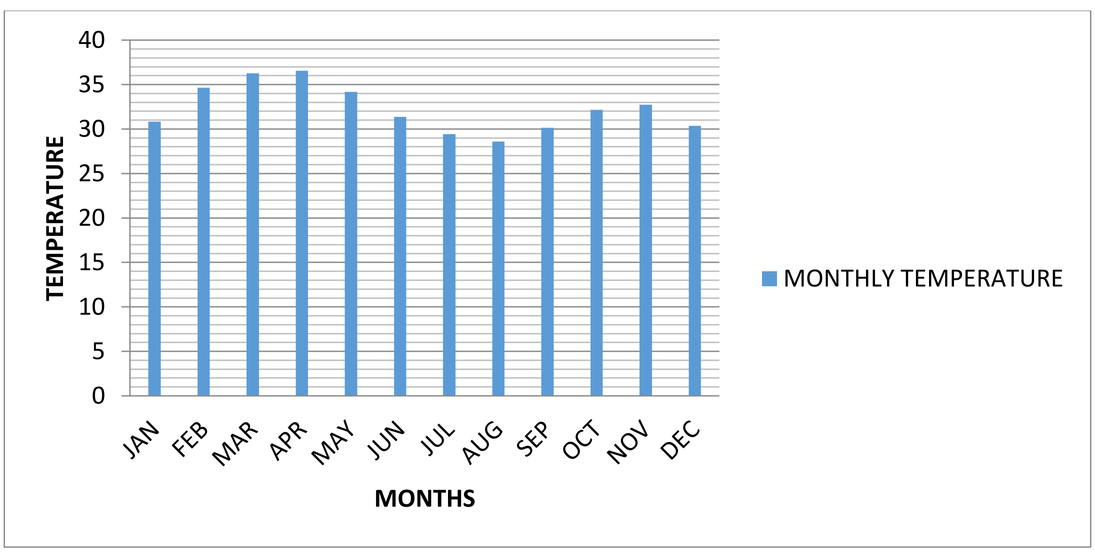

Fig 12: Solar radiation Variation with Months

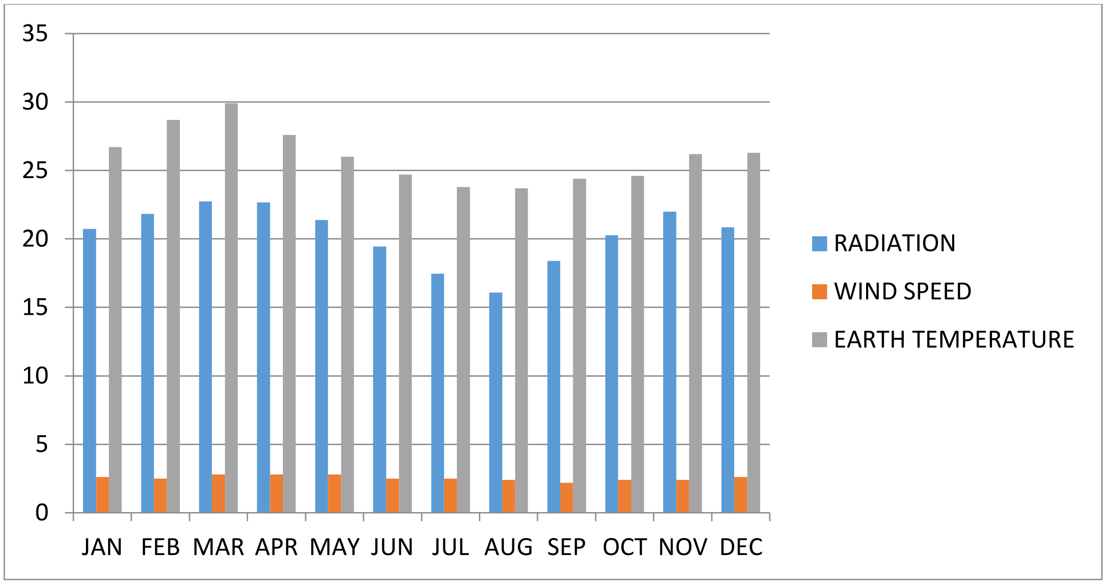

Fig 13: Variation of Radiation, Wind Speed and Temperature with Months

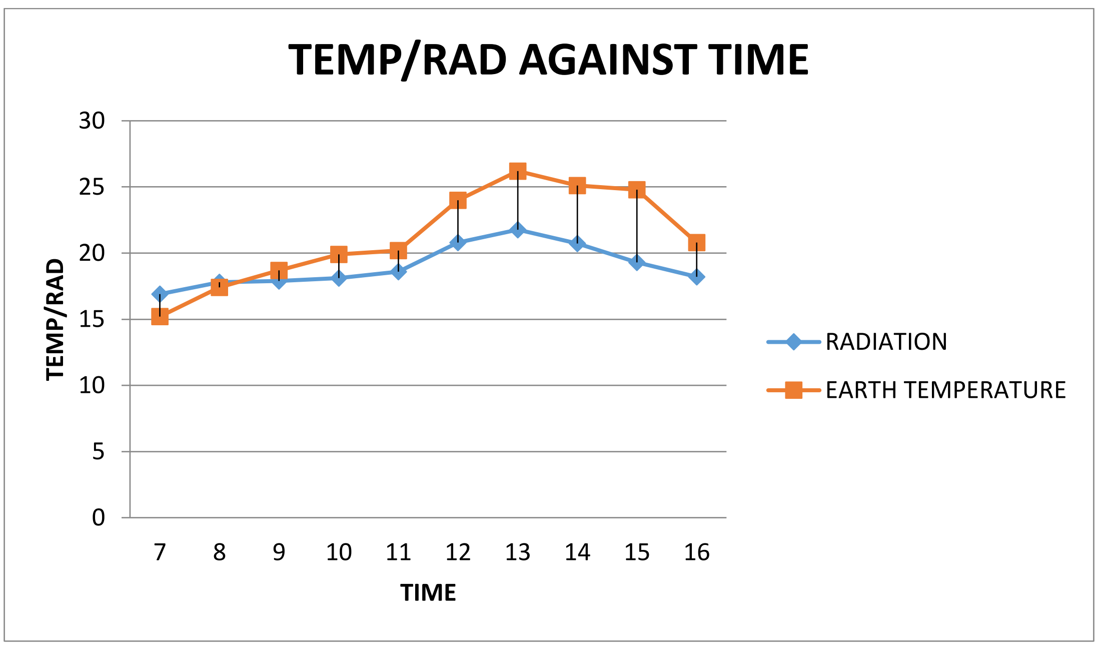

Fig 14: Relation between Radiation and Temperature.

In this figure (13 and 14) we notice increasing in the water temperature with time comparing with the increasing of solar radiation, This is because Kaduna is in a suitable place for solar thermal application.

Discussions

The experimental results has shown that there is an increase in the temperature which is proportional with time towards the maximum at summer season when the utmost solar radiation gets closer to perpendicular on earth (Fig. 9). The useful energy increased steadily with the time until mid-noon. That is because that both temperature and solar radiation increased steadily up to the midday but decreased until sunset.

Apart from reflective film the present work involved building a parabolic solar concentrator prototype with locally available materials which was assessed to be of reasonable cost. On a clear day, a temperature above 100 °C makes it possible to achieve with the parabolic-shaped surface of the solar concentrator prototype. The results had confirmed the possibility of the direct increase in the solar radiation proportionally with time which could reach the maximum at mid-noon followed by gradual decrease towards the sunset. It has also been confirmed that the Kaduna climate would be a suitable place for solar thermal application (Fig. 10). It has also been found that an increase in the temperature is proportional with time towards the maximum at summer season when the utmost solar radiation gets closer to perpendicular on earth (Fig. 11). The useful energy increased steadily with the time until mid-noon. That is because that both temperature and solar radiation increased steadily up to the midday but decreased until sunset (Figs. 12 and 13) The efficiency has been the utmost at the beginning of the operation. However, it gradually decreased with the time. The temperature of the operation system was dropped to 104 to receiver's temperature of the cylindrical boiler as the radiation losing energy operates proportional. The latter confirms its suitability for operation (Figs. 13,and 14).

CONCLUSION AND RECOMMENDATIONS

Conclusion

The main objective of the current work is to Design and fabricate a solar kettle thermal system which utilizes a solar conceptual system for different applications such as solar water heater, and evaluate the overall efficiency of the system.

1. A solar water heating kettle has been designed
2. A solar water heating kettle has been developed using locally sourced materials and the performance evaluation of the system has been achieved after experimenting through testing.

The results analysis has shown that a parabolic trough solar thermal is a good example for solar thermal and there are many applications for this trough .one of this application, This project is design and fabrication of low cost of solar kettle with trough concentration and study parameter in home also studied is the solar radiation in this location. It was observed that the solar radiation is enough for all application of solar thermal and designing of simple solar kettle water heater, I found this kettle very suitable to heat water in places where is no electricity. This is possible because there is an increasing temperature with increasing solar radiation.

RECOMMENDATIONS

1. The Government should fund and encourage the production of solar kettle using locally source materials that can be used by the Military during the warfare.
2. A solar tracking system should be incorporated in the system for better sun tracking. This will increase the active area for solar trough and when used many stage the temperature will be increasing faster due to increase in solar radiation.

REFERENCES

Balakrishnan, M., Claude, A. and Arun Kumar D. R. (2012) Engineering, Design and Fabrication of A Solar Cooker With Parabolic Concentrator for Heating, Drying and Cooking Purposes. Archives of Applied Science Research, 2012, 4 (4):1636-1649. *Available online at* http://scholarsresearchlibrary.com/archive.html, retrieved on 10th June 2019.

C. Laughton, *Solar Domestic Water Heating: The Earthscan Expert Handbook for Planning, Design and Installation*. London (UK): Eathscan, 2010.

Fuller, R.J. Solar industrial process heating in Australia – Past and current status. *Renewable Energy*. 36:216-221.

Ibeh G.F, Agbo G.A, Anyigor S, and Isikwue B.C, *Archives of Applied Science Research*, 2012, 4 (3): 1223-1226 [3] International Energy Agency. 2011. Co-generation and Renewable:Solution for a Low Carbon Future. International Energy Agency. http://www.iea.org/papers/2011/CHP_Renewables.pdf (accessed on 7th June 2019).

International Energy Agency, Solar Heating and Cooling Program. 2011. Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2009. International Energy Agency. http://www.iea-shc.org/publications/downloads/Solar_Heat_Worldwide-2011.pdf (accessed December 1, 2011).

Panwar, N.L, Kaushik, S.C. and Surendra Kothari (2012). State of the art solar cooking: an overview. Renewable and Sustainable Energy Reviews16; 3776-3785 www. Eisevier.com/locate/rser.

Toonen H. M. (2009). Adopting to an innovation: Solar cooking in the Urban Housing holds of Ouagadougou (Burkina Faso). Physics and Chemistry of the Earth: 65-71.

U.S. Energy Information Administration. 2011. Table 2.1a Energy Consumption Estimates by Sector, 1949-2010. October 19, 2011. U.S. Department of Energy, U.S. Energy Information Administration. http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0201a (accessed December 1, 2011)