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To cite this article: Yaseen H. Mahmood and Rafa Y. J. Al-Salih 2018 *J. Phys.: Conf. Ser.* **1032** 012006

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Experimental Study of Two Different Types of Solar Dish Characteristics and its Efficiency Based on Tikrit, Iraq Weather Conditions

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Abstract. Two solar dish concentrators (SDC) with diameter of (2 m) have been designed for water heating purpose. This study applied on solar steam water heater (SSWH). Both of the dishes coated with thick layer of steel (galvanized), while its interior surface covered with a reflector layer. The first dish interior surface covered with a layer of reflectivity up to 80%, whereas the second one covered by a pieces of mirrors with a reflectivity of 95%. The receivers have been fixed in the focal position of both dishes. The measurement of temperature and solar power for both types have been documented and recorded. The optical energy for the 1st dish is 1909 W, the final energy is 1551 W, and the efficiency is 61 %, while the optical energy for the 2nd dish is 1607.68 W, the final energy is 1853 W, and the efficiency is 73 %. The obtained results affirmed that the materials used in this research are economic, with high quality to obtain solar concentrator, but the dish which is covered with pieces of mirrors is better, and it can be used for water heating.

Key words: Solar dish, Solar concentrator, Solar boiler, Solar thermal, Concentrator reflectance.

1-INTRODUCTION

In the last 50 years, a need of renewable energy have been appeared because of the contamination and the high cost of fuel . The solar thermal radiation is the main energy source in the world. many researchers worked on using the solar thermal energy to design a useful project; e.g. design and test solar trough with length 2.4 m and 1 m aperture for solar water heat, and it reached 82 °C without tracking [1]. To help soldier getting water in high places like Himalaya a solar dish with receiver has been used to reflect the solar radiation to this receiver an ice has been put in the receiver to melt it and get water and tank has been used to store the water, then the result analyzed for the system [2]." The Australian National University had been re-designed the big dish installation for mass production and commercialization [3]. The building had been designed and structured as an"SG4" big dish of (500 m²) solar parabolic concentrator using direct-steam generation [4,5].By using a solar trough a 228 °C had been obtained by using metal reflector to produce electricity [6] and an "SG4" solar dish array with dual tracing used for electrical power [7]". Design and fabricate a



primary sample for a concentrator that was used as a water heater and also a Cu boiler was used and with efficiency of about 65.9% in April and May [8], making of a solar cooker by using empty tubes and a storage system to store the heat, and the system was tested in different condition in Japan to focus the radiation on boiler which are located at the focus of the concentrator [9]. This boiler absorbs and transports into thermal energy. This heat can be used directly for power generation.

The operation of solar thermal energy collector can be demonstrated as an energy balance between the absorbed solar radiation by the collector and the removed or lost thermal energy from the collector [10, 11] . Therefore, the main goal of this paper is to analyze and evaluate the effect of the location of the designed solar dish, and to study the reflectivity of concentrators, and its feasibility in the work location (Middle of Iraq).

2- THEORETICAL DETAILS

1- Parabolic Geometry

"A parabola is the locus of a point that moves so that its distances from a fixed line and a fixed point are equal. This is shown in Fig.1, where the fixed line is called the *directrix* and the fixed point F , the focus. Note that the length FR equals the length RD . The line perpendicular to the directrix and passing through the focus F is called the axis of the parabola. The parabola intercepts its axis at a point V called "vertex", which is exactly midway between focus and directrix"[10].

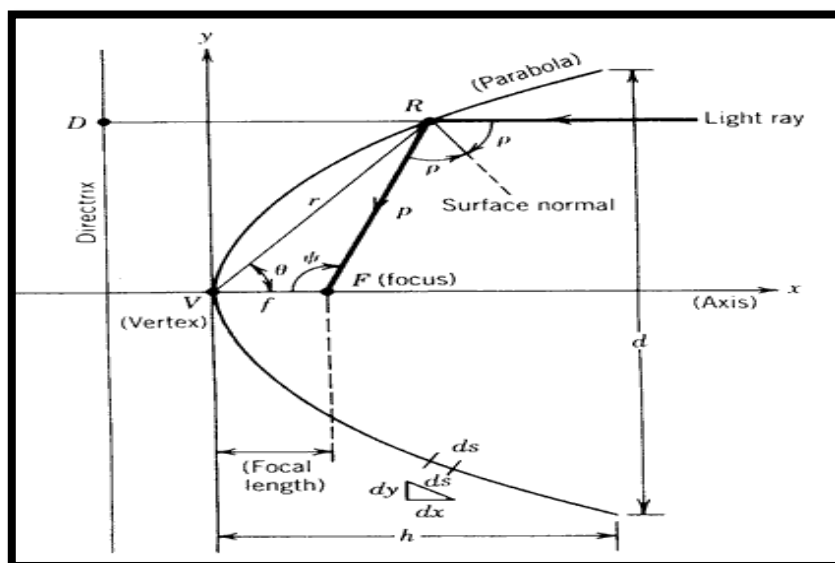


Fig.1: The parabola diagram.

2- Concentrator Geometry

The concentration ratio is usually used to describe the quantity of light energy concentration realized by a given collector. "Geometric Concentration Ratio" (CR_g) is described as the area of the collector aperture (A_a) divided by the receiver surface area (A_r), and it can be directly calculated according to the following equation:

$$CR_g = \frac{A_a}{A_r} \quad (1)$$

The distance from the aperture to the vertex (h) can be calculated in terms of the focal length (f) and the aperture diameter (d), as the following expression[10,11]:

$$h = \frac{d^2}{16f} \quad (2)$$

$$\frac{f}{d} = \frac{1}{4 \tan(\psi_{rim}/2)} \quad (3)$$

In a same manner, the rim angle (ψ_{rim}) can be expressed: as:

$$\tan \psi_{rim} = \frac{1}{(d/8h) - (2h/d)} \quad (4)$$

3- Optical Energy Absorbed By The Reciever

"To calculate the heat transfer and optical energy (Q_{opt}) of the receiver; the following equation can be used [12,13]:

$$Q_{opt} = A_a p_{s.m} \cdot \tau_g \cdot ar \cdot S \cdot I_a \quad (5)$$

where:

$p_{s.m}$: "Specular reflectance of concentrating foil".

τ_g : "Transmittance of any glass envelope which covering the receiver".

A_a : "Aperture of the collector".

S : "receiver shading factor" ("fraction of collector aperture, not shadow by the receiver").

I_a : "Insolation incident on the collector aperture".

a_r : "Absorbance of the of the receiver".

S , a_r , $p_{s.m}$, and τ_g : "constants". They are depending on the material type used, and on the geometric accuracy of the collector. These constants are nominally agglomerated into single constant term.

n_{opt} : "The optical efficiency of the collector".

The quantity of thermal energy generated by the solar collector is characterized by [12,14]:

$$Q_{out1}(v_1) = Q_{opt} - Q_{Loss1}(v_1) \quad (6)$$

4- Collector Efficiency

The collector efficiency ($\eta_{collector}$) and the receiver temperature ($T_{receiver}$) can be calculated using equation (6) above with another parameters, and expressed by [11]:

$$\eta_{collector}(v_1) = \frac{Q_{out-1}(v_1)}{Aa.Ia} \quad (7)$$

3- EXPERIMENTAL WORK

1- Parabolic Dish

A concave dish "made of galvanized steel" and lined with a steel sheet have been chosen. The dimensions of the designed dish were given in table 1 below:

Table 1: Characteristics of the solar concentrator.

Diameter of opening of the parabola (d)	2 m
Surface collecting of the parabola	3.14 m ²
Depth of the parabola (h)	0.25 m
Focal distance (f)	1 m
Rim angle (ψ_{rim})	53°
f/d	0.5

Method of a given focus and directrix have been employed in the construction of the parabolic dish. The reflector plain mirror cut into small rectangular shapes and fixed by screws. This structures painted by steel paint and used as mirrors with reflectivity of (95%). In another dish, a miller paper have been covered the dish's metal as a reflective surface of (80% reflectivity). The reflective surfaces of the parabolic dishes used here are shown in Fig. 2.



Fig. 2: The designed parabolic dishes.

2- Reciever

The experimental receiver is made of stainless steel and coated by a thin layer of black paint; to decrease the reflection of the solar rays. It was located in the focal point of the parabola dish of (2 m) diameter; to study the radiation and temperature on a receiver's cavity. The geometry of the

concentrator of this model has been done by applying equation (1) mentioned above. To obtain the optimum design of the receiver; heat losses of the receiver should be minimized. Convection and radiation heat transfers from the receiver to the surrounding should be investigated carefully, because of the significant difference between them. On the other hand, it is difficult to find simple method for predicate surrounding. The major concern for most of studies is the convection and radiation losses approximated by a simple equation when the operating temperature is low, however, the convection losses are also relatively low to high temperature. It is found that the magnitude and the direction of the winding can greatly affecting on the amount of the heat loss. The heat loss became higher in the case of wind parallel to the aperture plane than that of the case of the head-on wind.

In this work, the cylindrical receiver was chosen, because it has a small area facing the aperture window, which leads to minimize the reflection losses. Thus, this type of receiver design gives more chance to absorb the internal reflected photons. The receiver consists of a set of copper coil windings house within carbon steel conical cavity. All these parts were made locally. The dimensions of cylindrical cavity are (200 mm) depth and (170 mm) aperture diameter. The length of the coil of (4 m) consisting of (10 windings) of reduced diameter serially, with tube diameter of (12.5 mm). Fig. 3 shows the fabricated structure of the cylindrical receiver. The receiver design is explained in the next section.



Fig. 3: Experimental cylindrical receiver

The aperture diameter of the cylindrical receiver is chosen according to the diameter of the focus of the dish. Two thermocouples of k-type were used for measuring the inlet and the outlet temperature of the heat transfer fluid (HTF)[14].

4- EXPERIMENTAL CALCULATIONS OF THE RECIEVER

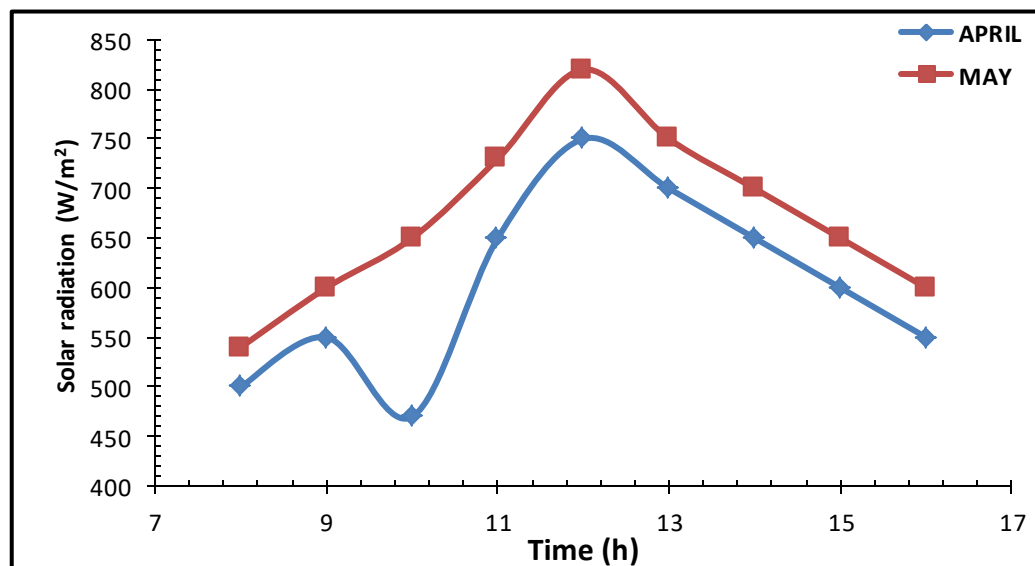
The parameters of the receiver have been calculated using equations (5, 6,7) by using experimental values and heat transfer for the inlet temperature and the outlet temperature [15], and illustrated in the table 2 below:

Table 2: Experimental calculations of the receiver concentration.

Sample	a_r	$p_{s.m}$	τ_g	A_a (m ²)	I_a (w/m ²)	Q_{Loss} (w)	Q_{opt} (w)	Q_{final} (w)	$\eta_{collector}$
1	0.15	0.8	1	3.14	800	48.3	1607.68	1551.6	0.617
2	0.15	0.95	1	3.14	800	56	1909	1853	0.73

5- RESULTS AND DISCUSSION

This study, demonstrated the relation between solar radiation and time in Tikrit, Iraq for latitude (34.616) and longitude (43.679) in one day at a middle of April and one day in the middle of May / 2016. Iraq is one of the 2nd favorable area solar application; due to the fact that it locates in the middle of solar radiation zone. Fig.4 illustrates the distribution of solar radiation according to local time. It can be seen that there is an increasing in the solar radiation from dawn to mid noon. After mid noon, it starts decreasing until sun set in May. Similarly, in April, with the important exception that decreasing in the solar radiation was dramatically observed at 10:10 AM; due to the passing of clouds at this period of time which causes this decreasing

**Fig. 4: Relation between solar radiation and time .**

It is important to mention that the receiver used without water; as presented in Fig. 5. It is clear that the temperature increasing as the time increasing, due to the absorption of solar radiation by the receiver; so the heat increases.

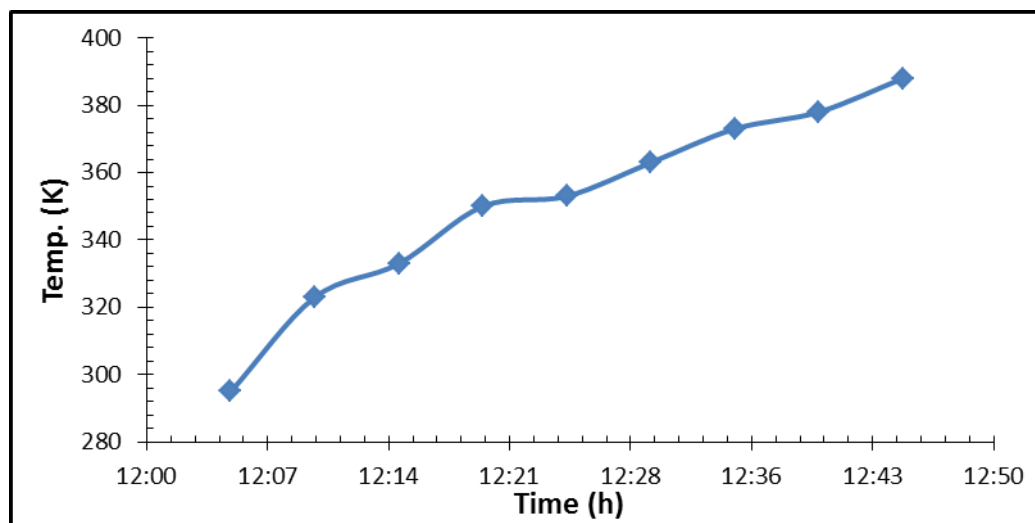


Fig. 5: Relation between temperature and time without water.

Fig. 6 shows the increasing of the temperature during the time for inlet, outlet, and ambient. In a clear day, where ambient temperature semi constant; the inlet, outlet temperature has been increased with time until the sun set. Practically a closed cycle between the storage tank and the boiler have been used. It is also noticed that the outlet temperature was greater than the inlet at 9:30 AM to 1:30 PM; because of the increasing in the solar radiation in this period of time [15].

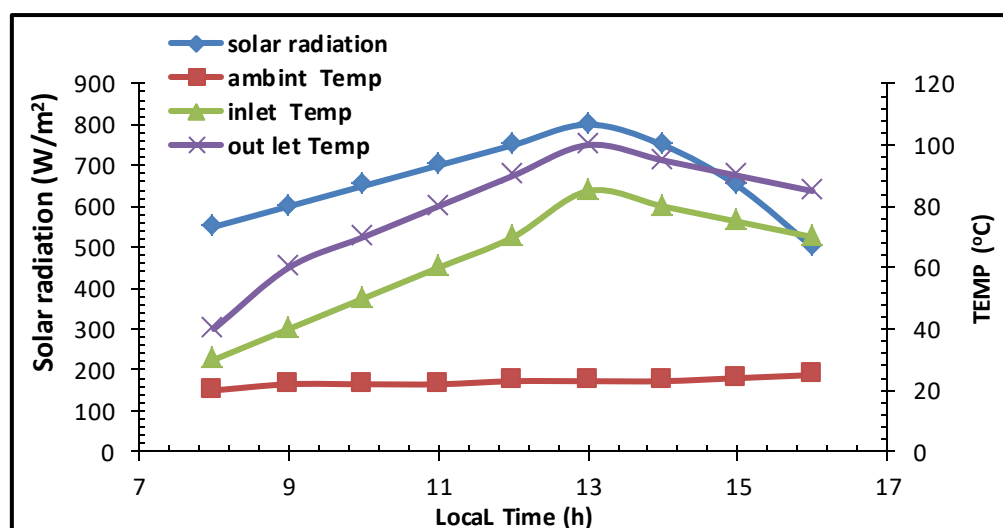


Fig. 6: Relation between temperature and time, with solar radiation

Moreover, in this work, the heat loss coefficient with time has been studied. When solar radiation increases, the stored heat increases also. So the heat radiation increases too, according to St-even- Boltzmann 4th power of source temperature. This fact is clearly appeared in Fig.7, where it is

clear that the curve of solar radiation of (800 W/m^2) is higher than that of (700 W/m^2). This figure shows increasing in heat loss coefficient with increasing of receiver heat. In addition, there is another factors which may be contribute in heat lose coefficient with mean temperature of receiver such as the wind speed, which is an important factor. The effect of ambient temperature is represented by the degradation in heat loss coefficient by radiation (h_r) of receiver at any specific temperature, when we left the winter months towards summer.

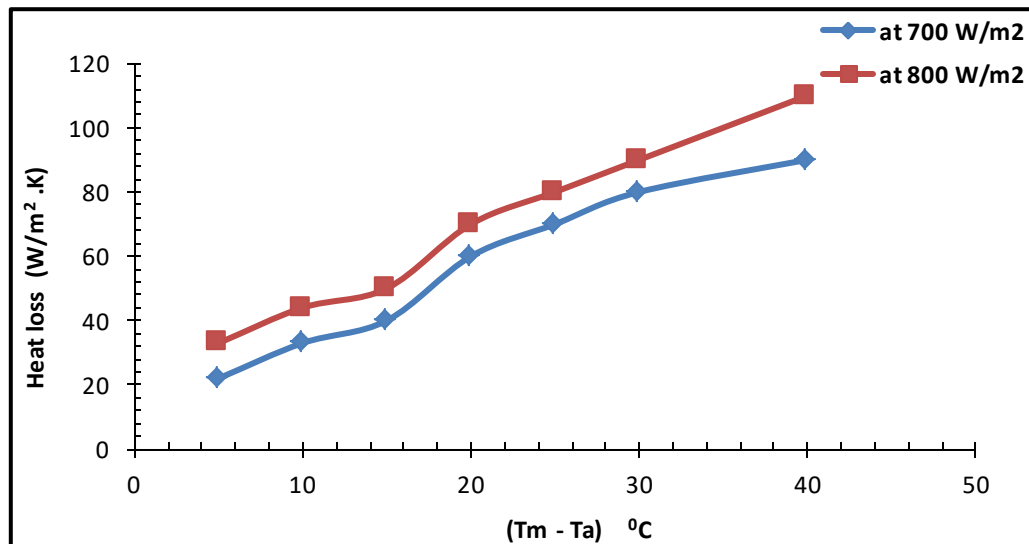


Fig. 7: Variation of heat loss coefficient of radiation with operating temperature of receiver.

Fig. 8 shows the variation of instantaneous efficiency with operating temperature ($T_m - T_a$) for receiver. Finally, the system efficiency is decreased with operating temperature.

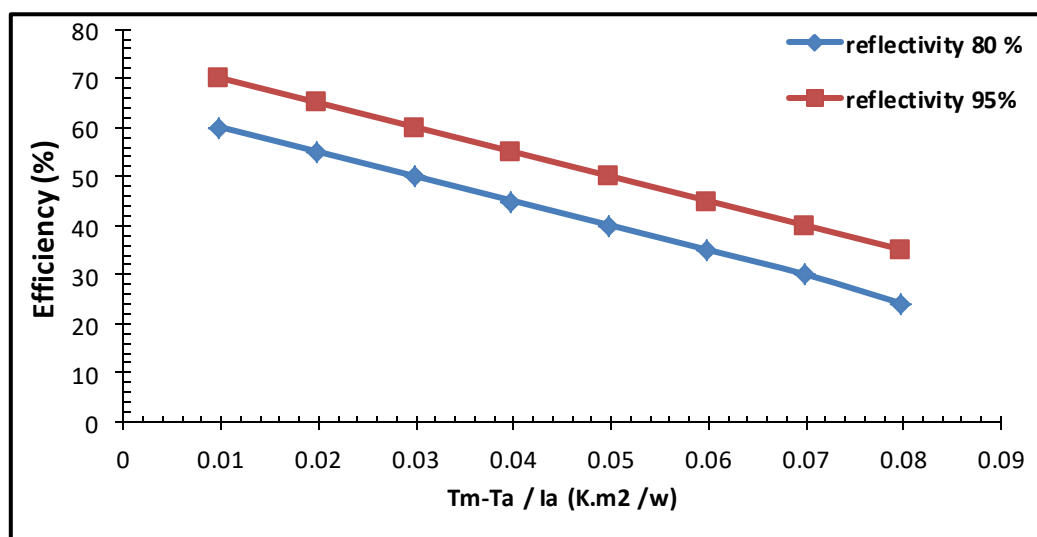


Fig. 8: Relation between efficiency of solar radiation with operating temperature.

6- CONCLUSIONS

Two solar concentrator designs have been built and investigated. These designs were based on a reflector dish and a close receiver. Experimental measurements of solar flux, heat transfer, and temperature distribution on the receiver have been carried out. The obtained results described the awaited physical phenomenon correctly. The temperature in the receiver have been reached a value up to 350 °C. To improve the results a bigger solar concentrator and smaller receiver as possible should be done to get rid of the heat loss and to get the best useful energy by using best reflective mirrors to eliminate defects; such as spherical aberration and astigmatism. The optical energy, the final energy, and the efficiency for both types have been calculated. The optical energy for the 1st dish is 1909 W, the final energy is 1551 W, and the efficiency is 61 %, while the optical energy for the 2nd dish is 1607.68 W, the final energy is 1853 W, and the efficiency is 73 %. The obtained results affirms that the materials used in this research are economic and they having a high quality to obtain solar concentrator. The dish which is used mirrors in it; is better, and it can be used for water heating in the metals melting. From the outcome of this work, it can be concluded that the two dishes used are good for the solar thermal application, but the dish which is covered with mirrors is more efficient; because of its high reflectivity, and this method can be used as a solar water heat.

ACKNOWLEDGMENT

We would like to express our sincere appreciation and gratitude to the Physics Department in the College of Sciences in Tikrit University for their kind support during the period of the research.

Our deeply grateful also to the Physics Department in the College of Sciences in Karbala University and to the supervisor committee of the 6th Karbala conference for sciences for their efforts in preparation of this conference.

REFERENCES

- [1] Eltahir Ahmed Mohamed 2013 Design and testing of a solar parabolic concentrating collector (*International Conference on Renewable Energies and Power Quality (ICREPQ'13 Bilbao Spain)* 20th to 22th ISSN 2172-038 X, No.11, March,
- [2] Kailash Karunakaran 2014 Thermal Modeling of Snow to Water Conversion Device Using Solar Energy (International Journal of Mechanical And Production Engineering) ISSN: 2320-2092, Volume- 2, Issue- 2, Feb
- [3] Lovegrove K., Burgess G, Pye J., *Solar Energy*, 85, (2011) pp.(620 – 626).
- [4] Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), "Radiation Protection Standard: Occupational exposure to ultraviolet radiation". *Radiation reaction Series* No. 12, December (2006).
- [5] Burgess G., Shortis M., Kearton A 2009 Photogram try for dish concentrator construction Solar (09, 46th ANZSES Conference, Townsville) 29 Sept. – 02 Oct
- [6] Parashar V., "Solar energy for domestic and small industries with help of parabolic trough solar concentrator" , International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 10 IJERT ISSN: 2278-0181, October - 2013.

- [7] Vinayak Sakhare V. N. Kapatkar, Experimental Analysis of Parabolic Solar Dish with Copper Helical coil Receiver" , International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163, Volume 1, Issue 8 (September
- [8] Nilkanth Shinde 2012 Performance evaluation of parabolic dish type solar collector for industrial heating application (J. Energy Technology and Policy, Vol. 8) No. 1
- [9] S. D. Sharma, T. Iwata, H. Kitano, and K. Sagara 2005 Thermal performance of a solar cooker based on an evacuated tube solar collector with a PCM storage unit (Solar Energy, Vol. 78) , pp. 416-426
- [10] William, B. S., and Michael G. 2001 Power from the Sun
<http://www.powerfromthesun.net/book.html>.
- [11] Newton, C. C. 2007 A Concentration Solar Thermal System M.Sc. Thesis, (Florida State University)
- [12] Duffie J. A. and Beckman W. A 2013 Solar Engineering of Thermal Processes 4th Edition, (Wiley, New York).
- [13] Karima Ghazouani, Safa Skouri 2017 Thermal study of solar parabolic concentrator (IOSR Journal of Mechanical and Civil Engineering) (IOSR-JMCE), -ISSN:2320–334X, pp. 118-123, www.iosrjournals.org (International Conference on Recent Innovations in Civil & Mechanical Engineering 118)
- [14] Mahmood, Y. H. 2017 Design and fabrication of Solar dish array and study its characterization (Tikrit Journal of Pure Science, 22) (11), ISSN: 1813– 1662 (Print), E-ISSN: 2415– 1726 (On Line) 78.
- [15] Mahmood, Y. H. 2017 "Design and installation of (flower sun) a concentration dish and study its parameters (Tikrit Journal of Pure Science, 22) (11) (2017) ISSN: 1813 – 1662 (Print), E-ISSN: 2415 – 1726 (On Line).