Fabrication of solar concentration and study its characterization

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Abstract

In this work we design and fabricate a of solar dish concentration with diameters (1.6) meters for application solar steam or Stirling engine, the dish fabrication by metal of galvanized steel and Its interior surface is covered with a reflecting layer with reflectivity up to(76%) and equipped with receiver in its focal position , The measurement for temperature and solar power were given .

Key word:-solar dish ,solar concentration ,solar steam concentration.

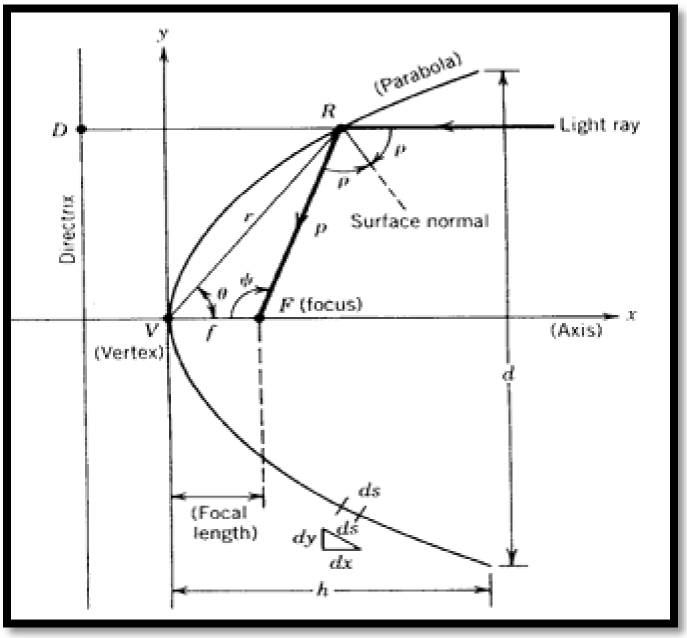
1- Introduction

The basic principle of solar thermal collection is that when solar radiation is incident on a surface (such as that of a black – body) part of this radiation is absorbed and causes to increase the [1]temperature of the surface**.** The typical solar flux concentration ratio typically obtained is at the level of 30 – 100, 100 – 1000, and 1000 – 10000 for trough, tower and dish systems, respectively [2]. -The Australian National University has re-engineered its Big Dish design for commercialization and mass production [3], building the 'SG4' 500m^2 Big Dish solar parabolic concentrator[4] for solar-thermal[5] to electric energy conversion using direct-steam generation.[6] The SG4 Dish implements two-axis tracking and may be incorporated into a dish-array for large-scale power production.[7].The parabolic dish system [8] uses a parabolic dish shaped mirror or a modular mirror system that approximates a parabola and incorporates two-axis tracking [9] to focus the sunlight onto receivers located at the focal point of the dish, which absorbs the energy and converts it into thermal energy. This can be used directly as heat for thermal application or for power generation. The thermal energy can either be transported to a central generator for conversion, or it can be converted directly into electricity at a local generator coupled to the receiver. The operation of any solar thermal energy collector can be described as an energy balance between the solar energy absorbed by the collector and the thermal energy removed or lost from the collector [10,11].

2-Theoretical part

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 on Figure (1), where the fixed line is called the directory and the fixed point F, the focus. Note that the length FR equals the length RD. The line perpendicular to the directory and passing through the focus F is called the axis of the parabola. The parabola intersects its axis at a point V called the vertex, which is exactly midway between the focus and the directrix



Figure(1) The parabola diagram.

Concentration Ratio

The "concentration ratio" is used to describe the amount of light energy concentration achieved by a given collector. Two different definitions of concentration ratio are in general use. They are defined briefly here so that the terms may be used. Optical Concentration Ratio (C R_o). The averaged irradiance (radiant flux) (I_r) integrated over the receiver area (A_r), divided by the insulation incident on the collector aperture. [4]

$$CR_0 = \frac{\frac{1}{A_y}\int L_y dA_y}{I_a} \text{ -------- (1)}$$

Geometric Concentration Ratio (CR_g). The area of the collector Aperture A_a divided by the surface area of the receiver A_r

$$CR_g = \frac{A_a}{A_y} \text{ ------- (2)}$$

Optical concentration ratio relates directly to lens or reflector quality; however, in many collectors the surface area of the receiver is larger than the concentrated solar image Directory. If the origin is taken at the vertex V and the x-axis along the axis of the parabola, the equation of the parabola is

$$y^2 = 4fx\text{------- (3)}$$

where f, the focal length, is the distance VF from the vertex to the focus. When the origin is shifted to the focus F as is often done in optical studies, with the vertex to the left of the origin, the equation of a parabola becomes

$$y^2 = 4f(x + f)\text{----- (4)}$$

In polar coordinates, using the usual definition of r as the distance from the origin and θ the angle from the x-axis to r, we have for a parabola with its vertex at the origin and symmetrical about the x-axis

$$\frac{sin^2\theta}{cos\theta} = \frac{4f}{r}\text{------ (5)}$$

Often in solar studies, it is more useful to define the parabolic curve with the origin at F and in terms of the angle (ψ)in polar coordinates with the origin at F . The angle ψ is measured from the line VF and the parabolic radius p, is the distance from the focus F to the curve. Shifting the origin to the focus F, we have

$$p = \frac{2f}{1+\cos w} \text{ ------ (6)}$$

The parabolic shape is widely used as the reflecting surface for concentrating solar collectors because it has the property that, for any line parallel to the axis of the parabola, the angle p between it and the surface normal is equal to the angle between the normal and a line to the focal point. Since solar radiation arrives at the earth in essentially parallel rays and by Snell's law the angle of reflection equals the angle of incidence, all radiation parallel to the axis of the parabola will be reflected to a single point F, which is the focus. Careful inspection of the geometry described in Figure (3) will show that the following is true:

$$\varphi = 2.0\text{---------(7)}$$

The general expressions given so far for the parabola define a curve infinite in extent. Solar concentrators use a truncated portion of this curve. The extent of this truncation is usually defined in terms of the rim angle (ψ_{rim}) or the ratio of the focal length to aperture diameter f/d. The scale (size) of the curve is then specified in terms of a linear dimension such as the aperture diameter d or the focal length f. This is readily apparent in Figure (2) which shows various finite parabola having a common focus and the same aperture diameter.

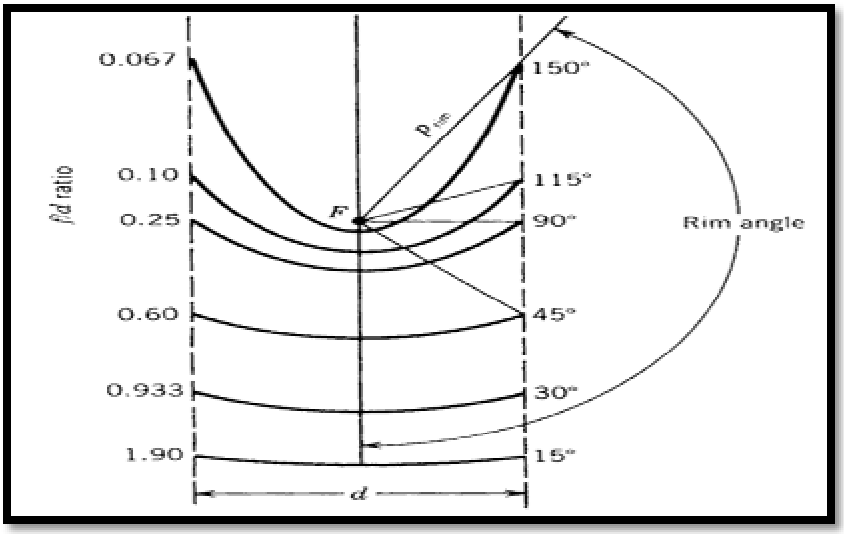


Figure (2) Segments of a parabola having a common focus F and the same aperture diameter

$$h = \frac{d^2}{16f}\text{-------------(8)}$$

In a like manner, the rim angle (ψ_{rim}) may be found in terms of the parabola dimensions:

$$\tan\varphi_{rim} = \frac{1}{(d/8h)(2h/d)}\text{-------(9)}$$

Another property of the parabola that may be of use in understanding solar concentrator design is the arc lengths. This may be found for a particular parabola from Equation (3) by integrating a differential segment of this curve and applying the limits x = h and y = d/2 as pictured in Figure (2). The result is

$$s = \left[\frac{d}{2}\sqrt{\left(\frac{4h}{d}\right)^2 + 1}\right] + 2f\ 1n\left[\frac{4h}{d}\sqrt{\left(\frac{4h}{d}\right)^2 + 1}\right] \text{-------} (10)$$

where d is the distance across the aperture (or opening) of the parabola as shown in Figure (2) and h is the distance from the vertex to the aperture. The cross sectional area of the space enclosed between a parabola and a line across its aperture and normal to the axis is given by

$$A_x = \frac{2}{3}d.h \text{----------}(11)$$

this area should not be confused with the reflecting surface area of a parabolic trough or dish or their aperture areas [10]

$$\tan\varphi_{rim} = \frac{(f/d)}{2(f/d)^2 - \frac{1}{8}} \text{ ----------}(12)$$

$$tan\left[\frac{\varphi_{rim}}{2}\right] = \frac{1}{4(f/d)} \text{ -------- }(13)$$

$$\frac{f}{d} = \frac{1+cox\varphi_{rim}}{4sin\varphi_{rim}} \text{ --------}(14)$$

$$\frac{f}{d} = \frac{1}{4tan(\varphi_{rim}/2)} \text{ -------- }(15)$$

Optical Energy Absorbed by the Receiver

To calculate the Optical Energy of receiver and heat transfer the following equation may be used .

equ$Q_{opt} = Aa\, p_{s.m}\, .\tau g.ar.S.Ia$ ---(16)

$p_{s.m}$ –specula reflectance of concentrating foil.

τ_g –transmittance of any glass envelope covering the receiver. A_a –aperture a of the collector .

S- receiver shading factor (fraction of collector aperture .Not shadow by the receiver).

I_a-insulation incident on the collector aperture.

a_r-absorbance of the of the receiver

S,a_r,$p_{s.m}$ and τ_g are constants dependent on the materials used and the structure accuracy of the collector. These constants are nominally lumped into single constant term.

n_{opt}:the optical efficiency of the collector

Thus, the quantity of thermal energy produced by the solar collector is described by

$Q_{out\ 1}(v_1)= Q_{opt} - Q_{Loss1}(v_1)$=w -------(17)

Collector Efficiency .

$\eta_{collector}(v_1)=\frac{Q_{out-1}(v_1)}{Aa.Ia}$.-----(18)

$T_{receiver}=T_{sun}[1 - \eta . \tau. \frac{a}{\varepsilon}\frac{CRgeometric}{CRidial}]^{1/4}$----(19)

3-**Expermantal work:-**

***A- Parabolic dish**:-*

we choose concave dish made of sheet galvanized steel and lined with an steel the sheet. Method of a given focus and directory was employed in the construction of the parabolic dish. The reflector plain mirror cut into shapes and fixed by screw, this structure or the sheet painted by steel paint and used miller paper stick with reflective (76%) and high reflectivity on the metal sheet reflecting surface of the parabolic Figure (3).

Figure (3) Show the design parabolic dish.

The dimensions of the designed dish were given in table (1)

Table 1: Characteristics of the solar concentrator

Diameter of opening of the parabola	1.6 m
Surface collecting of the parabola	2.0 m^2
Depth of the parabola	0.018 m
Focal distance f	0.84 m
Rim angle	45°
f/d	0.677

B. Receiver:-

The experimental receiver was made of stainless. Covered with a thin coat of black paint to decrease the reflection of the solar rays and it was located in the focal zone of the parabola dish of (1.6 m) diameter to study the radiation and temperature on a cavity of receiver .otherwise the geometrical concentration of this model is done by applying Equation (2) in order to get the optimum design of the receiver , heat losses of the receiver should be minimizes, since convection and radiation losses are normally significant compared to conduction loss, convection and radiation heat transfer from the receiver to the surrounding should be carefully investigated. On the other hand, it is difficult to find simple method for predicate surrounding. Since the major concern for most of the studies. is the convection and radiation are losses approximated by a simple equation if 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 wind can greatly affect the amount 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 of work. The cylindrical receiver was chosen because ,it has a small area facing the aperture window which lead to minimize the reflection losses .Thus ,this type of receiver design give more chance to absorb the internal reflected photons. The receiver consists of a set copper windings coil house within carbon steel conical cavity .All these parts were made locally .the dimensions of conical cavity are (200)mm depth and (170)mm a aperture diameter .the length of the coil (4m) consisting of (13) windings of reduced diameter serially, with tube diameter of (12.5) mm. Figure (4) shows the design and structure of conical receiver, respectively and the design calculations can be found.

Figure (4) 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 in inlet and outlet temperature of the heat transfer fluid (HTF).

4-Calclation:-Experimental calculation of the receiver

by using equation (16,17 ,18,19)

ar =0.8 , P_{s-m} = 0.76 , τ_g = 1 , Aa =2 m^2

Ia =700$\frac{w}{m^2}$

Q_{opt} =Aa.P_{s-m}. τ_g.ar.S.Ia

Q_{opt}=831.4 watt

$Q_{LOSS1=73\ WATT}$

T_{receiver}=761k

Q_{opt} -Q_{loss} Q_{final}=

Q_{final}= 758.4 watt

$\eta_{\text{collector}-1}$= 0.54

5 -Result s and discussion:-

In this work study solar radiation with time in Iraq Tikrit for altitude (34.59) and longitude (43.68) 24-April , 10- May /2011 Figure (5) , because Iraq in the medal of solar radiation see increasing the solar radiation with time between 9:00 AM to 1:00 PM and decreasing between 1:00AM to sun set and see decrease the solar radiation (24-4 at 10,14 o'clock this result duo to pass partial cloudy.

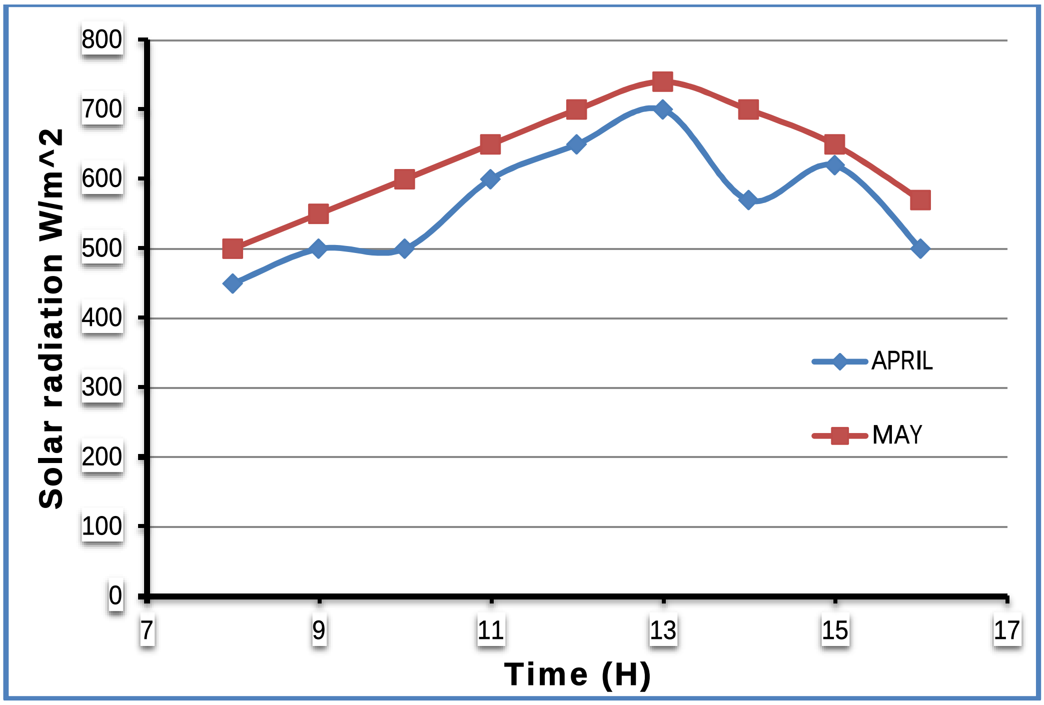


Figure (5) Relation between solar radiation and time

Otherwise study the temperature with time for receiver inlet and outlet and ambient, in clear day where ambient temperature semi constant Figure (6) and inlet ,outlet temperature increasing with the time until the sun set .but outlet temperature great than inlets with time between 9:30 to 1:30 because increasing the solar radiation and flow rate.

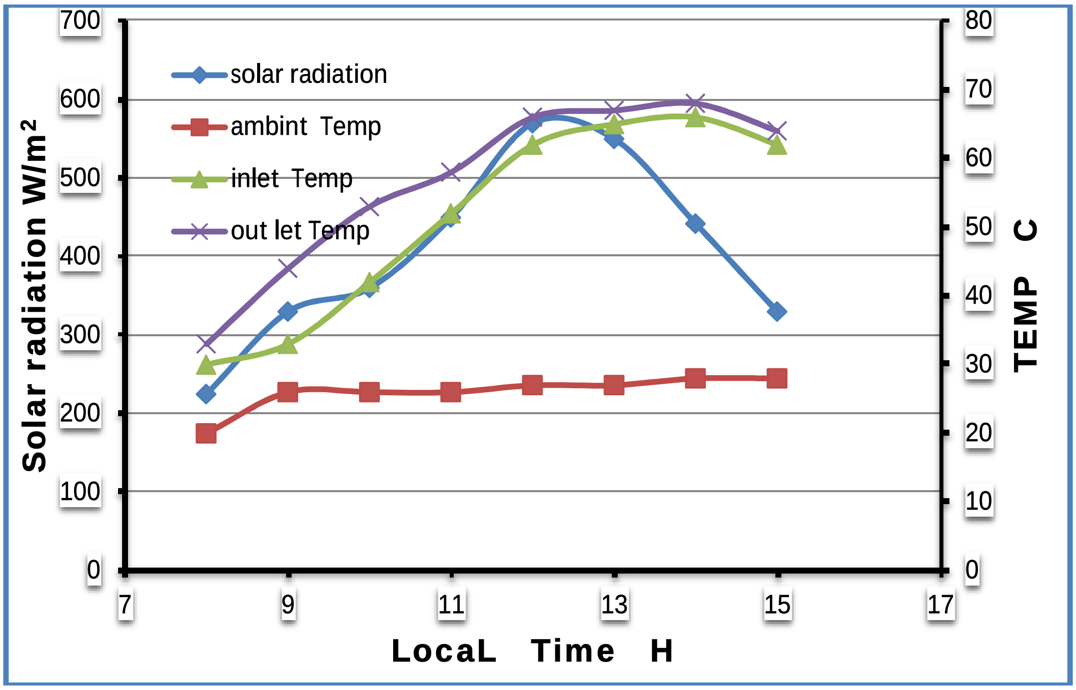


Figure (6) Relation between temperature and time, with solar radiation .

The ambient temperature contributes in quantity of heat loss of the receiver. This experimental fact is demonstrated in Figures (7), This Figure shows an increasing in heat loss coefficient by convection with increasing of receiver temperature.

This is justified by Steven- Boltzmann law in which the radiation emission from a hot source is proportional with the 4th power of source temperature Figures (7).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 toward Summer.

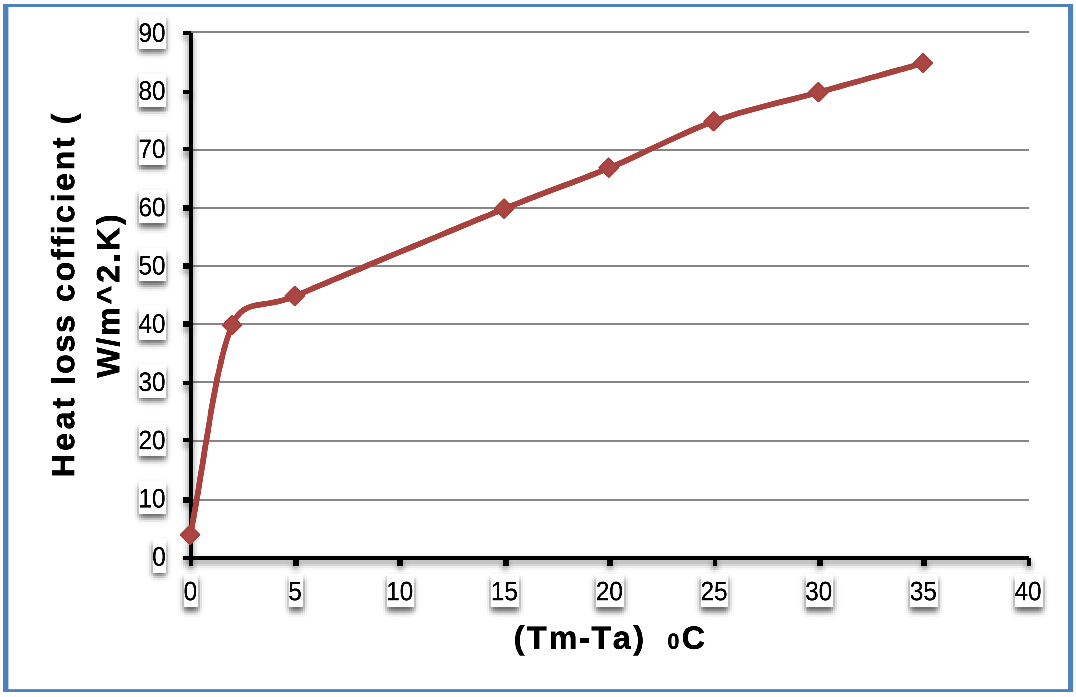
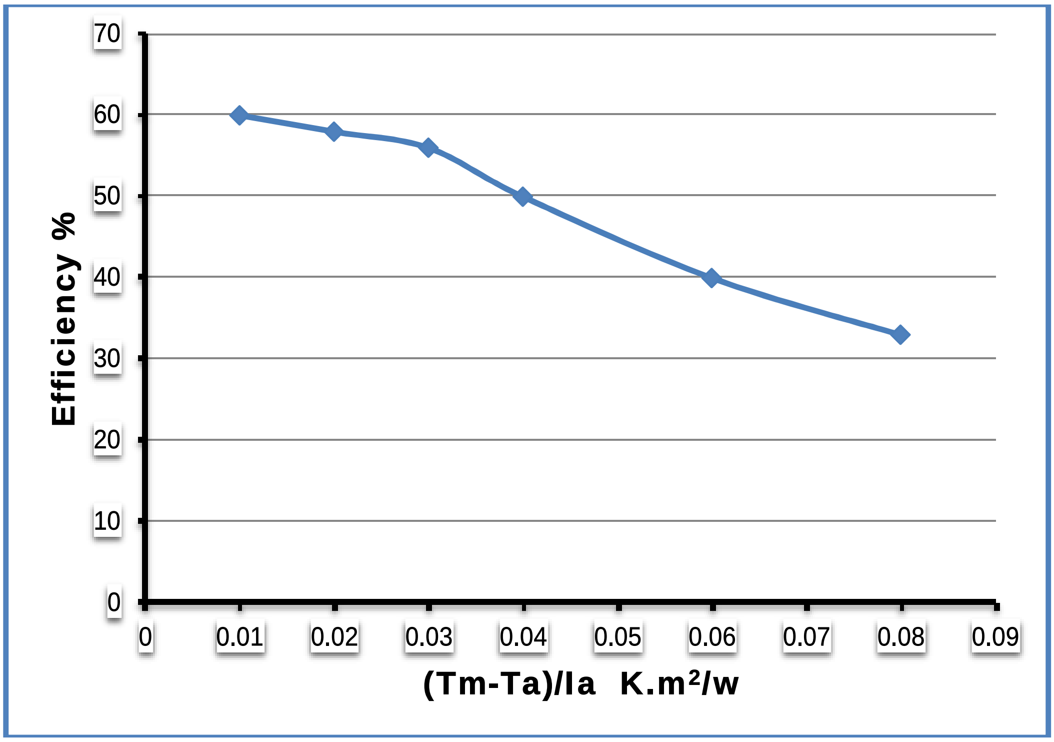


Figure (7) variation of heat loss coefficient by radiation with operating temperature of receiver

The Figures (8) show the variation of instantaneous efficiency with operating temperature(T_m-T_a) for receiver. It was clear that the system efficiency is decreased with receiver temperature because that the radiated losing energy is proportional to 4th Power of receiver temperature as mentioned before. Also , the results indicate the efficient of conical receiver decrees.

The amount of optical and thermal looses energy is part of the total solar energy that incident on the concentrator. The others are called Q $_{useful}$ energy. It is absorbed by employed fluid and stored in storage tank. The temperature of the stored fluid limits the type of thermal application .While the amount of this stored energy with respect to the total incident energy limits the efficiency of the thermal solar system equation (18).



Figure(8) Represent the relation between efficiency of solar radiation with operating temperature

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تصميم منظومة تركيز الإشعاع الشمسي ودراسة خصائصها

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الملخص:

في هذا العمل تم تصميم وتصنيع الصحن الشمسي المركز للإشعاع بقطر (1.6) متر لاستخدامه مع محرك سترلنك أو المحرك البخاري ،الصحن مصنع من مادة الحديد الكلفنايز وقد غلف المعدن بورق عاكس ذو انعكاسية أعلى من (76%) ،كما تم تثبيت المستقبل البخاري (البويلر) في بؤرة الصحن لإجراء القياسات الخاصة بانتقال الحرارة والإشعاع الشمسي للصحن.