

## Construction and Operation of Solar Energy Dish for Water Heating

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### Abstract:

Construction and operation of (2 m) parabolic solar dish for hot water application were illustrated. The heater was designed to supply hot water up to 100 °C using the clean solar thermal energy. The system includes the design and construction of solar tracking unit in order to increase system performance. Experimental test results, which obtained from clear and sunny day, refer to highly energy-conversion efficiency and promising a well-performed water heating system.

**Keyword:** Solar Energy, Solar Radiation, Heat Transfer, Thermal Performance, Water Boiler, Water Heater.

### Introduction:

The solar dish is the main component in a solar thermal power plant. It is also important to study solar dish collectors in order to understand the characteristic of a concentrating solar thermal power system. The heat received from the sun is concentrating on a black absorber which is placed at the end of the focal length of the reflector, in which a high temperature can be obtained to produce steam [1][2]. The study is dealing with developments of the membrane concentrator [3][4]. The focal-diameter ratio for concentrator and number of facet rows can be optimized by utilizing a Monte Carlo ray-tracing method to specify the optical performance of the sun beam concentrator [5][6]. The heat losses of the receiver have been studied by many numerical models. A reflector consists of a lot of flat square shape mirrors which are arranged on the parabolic dish [7]; furthermore, using the McDonald and Stine models, heat loss from the receivers can be estimated [8][9].

### Theoretical Calculations:

The “optical concentration ratio” ( $\gamma$ ) can be defined as the ratio of incident solar energy on the receiver ( $I_r$ ), to flux density on aperture ( $I_a$ ). It's referred to flux concentration ratio as shown in fig(1).

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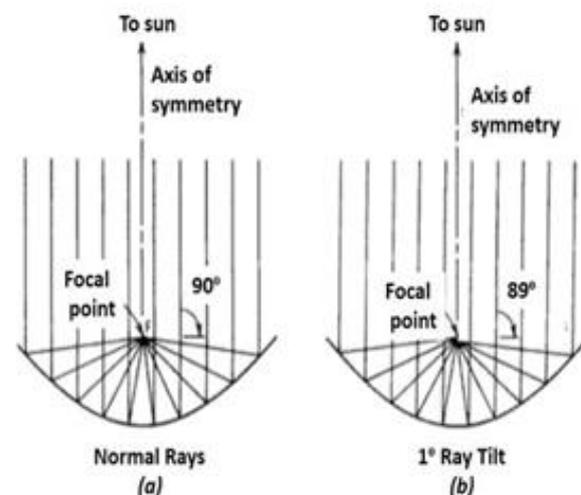


Figure 1. Solar dish concentration .[13]

$$\gamma = \frac{I_r}{I_a} \quad (1)$$

The concentration of solar radiation can be increased by refracting the incident flux on an aperture area ( $A_a$ ), into a smaller area of the receiver ( $A_r$ ) [10][11]

$$\gamma = \frac{A_a}{A_r} \quad (2)$$

The absorption of sun radiation is depending on several parameters such as the size of the concentrator, weather condition and angle of concentrator direction. The useful energy which can deliver by the collector is calculated by following energy balance relation ( $P_u$ )

$$P_u = \eta_o I_c A_a - U_c (T_c - T_a) A_r \quad (3)$$

where  $\eta_o$ : “optical efficiency”,  $U_c$ : the “collector heat-loss conductance”,  $T_c$ : temperature of the collector,  $T_a$ : temperature of the ambient air, and  $I_c$ :

insulation incident on the collector. Furthermore, "The instantaneous collector efficiency"  $\eta_c$  is then given by

$$\eta_c = \eta_o - \frac{U_c(T_c - T_a)}{I_c} \frac{1}{\gamma} \quad (4)$$

The "instantaneous efficiency"  $\eta_{inst}$  of the solar thermal collector can simplify by neglecting the optical efficiency

$$\eta_{inst} = \frac{Q}{A_a I_c} = \frac{\dot{q}}{I_c} \quad (5)$$

Where  $A_a$  is the aperture area, and a useful heat  $\dot{Q}$  is depending on specific heat at a constant pressure  $C_p$ , the inlet and outlet temperatures  $T_{in}$  and  $T_{out}$ , and water flow rate (m)[12]

$$\dot{Q} = m C_p (T_{out} - T_{in}) \quad (6)$$

Where  $C_p = \eta_{inst} A_a I_c \frac{1}{m \Delta T}$

### Experimental Work

The solar dish consists of a 200 cm in diameter. The bottom surface of the concentrator is completely covered with an efficient reflector material. A disc receiver is fixed in its focal position. A parabolic dish heat cooker was constructed with aperture diameter 180 cm, depth 35 cm and focal length 80 cm. The system is fabricated with highly reflective aluminum foil sheet of 0.8 reflectance factor. For effective performance, the design concentrator required to track the sun azimuth position frequently. A linear actuator was used for this purpose.

The performance of the concentrator was investigated by circulated water as heat transfer fluid. The tests were carried out in open space. The collector's efficiency was noticed. The receivers were designed to work on thermo-siphon principle. The heat energy requirement for each receiver is (650 kJ). The amount of required solar energy to provide the threshold power input in the collector's receiver is about (0.967 kJ/s). According to results of the analysis, each collector has a diameter of the receiver of 30 cm, the aperture diameter of 140 cm and the internal surface area is about 1.53 m<sup>2</sup>.

In order to enhance the thermal performance of the water heater, a development of an electronic tracking system with high accuracy control circuit was carried out.

#### A-Parabolic dish

A concave dish was made of galvanized steel and lined with a sheet steel. The construction of the parabolic dish is basically employing the method of a given focus and directory. The plain mirror of the reflector was cut into specific shapes and fixed by a screw, this structure or the sheet painted by steel paint, a miller paper sticker fixed on the internal surface of the concave dish. The reflectance of the

covered surface was about (76%). Table 1 describes the optimum dimensions of the solar concentrator

**Table 1. Optimum dimensions of the solar dish concentrator**

Diameter of open side of the parabola	200 cm
Length of the collecting surface of the parabola	3140 cm
Focal distance	80 cm
Deep	35 cm

**B- Receiver:** The receiver was made of stainless steel and coated with thin layer of black paint to reduce the reflection of the solar light and it was placed in the focal zone of the parabola dish. Heat losses of the receiver were minimized to keep water temperature almost constant. The heat loss increased in the case of wind direction parallel to the aperture plane than head-on wind direction. In this of work, a cylindrical receiver was chosen, the receiver was designed in a small area which facing the aperture window in order to minimize the reflection losses. Thus, this type of receiver design can provide higher absorption of the internally reflected photons. The receiver consists of a set of copper windings coil house paint by black color. All these parts were made locally the dimensions of the cavity was (15 cm) depth and (10 cm) thickness and (0.3 cm) of an aperture diameter, the coil consist of (15) windings of (500 cm) length of reduced diameter pipe. Two thermocouples of k-type were used for temperature measurements the of inlet/outlet fluid (HTF).

**C-Storage tank:** A 20 liters steel tanks was used to storage cooling refrigerant. The tank has two holes for water inlet and outlet. A k-type thermocouple was placed to measure water temperature.

**D-Tracking system:** A DC- motor with light sensor consist of two cds- photo resistor was used for the solar light tracking system.

**E- System Operation:** the system was assembled and operated in clear, sunny weather. The solar radiation was focused as water boiler for about (10) minutes, the boiler temperature rose to about 300°C (without water). A low power water pump was run for water circulation between the boiler and the tank. This process was repeated for 5 times. The temperature of inlet and outlet water was recorded.

### Result and Discussion:

A parabolic solar concentrator prototype was built by using available cheap materials. Through a clear day, with temperatures over (350 °C), the evaluation of the operation of solar concentrator has been achieved. The data indicates to maximum incident solar radiation at mid noon

time and it decreases until sunset time, as shown in Fig.(2) [1][12].

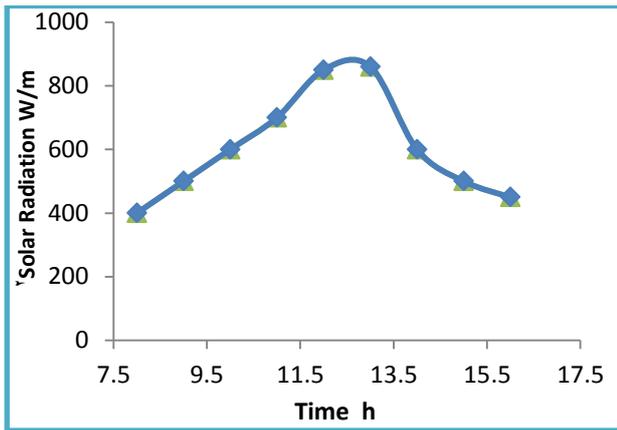


Figure 2. Relation between solar radiation and time.

Fig. (3) shows a preheating behavior for water boiler without water flow, the curve showed a fast increasing in temperature within a short time interval (about 30 min.). This behavior is preferable in domestic requirements for hot water supply.

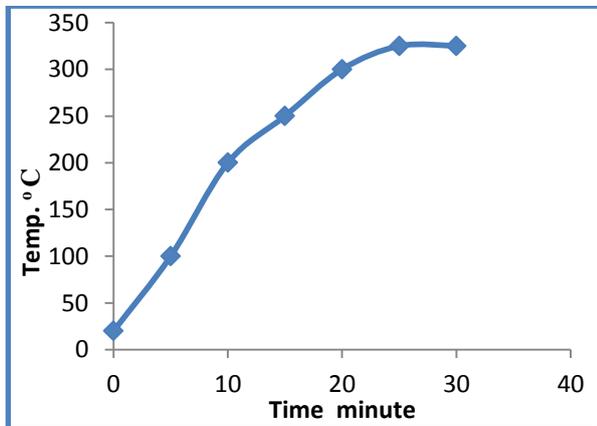


Figure 3. Show boiler temperature without water with time.

Fig.(4) shows a quickly increased temperature of the boiler which can be obtained during summer months because the solar radiation direction is perpendicular to earth surface [13].

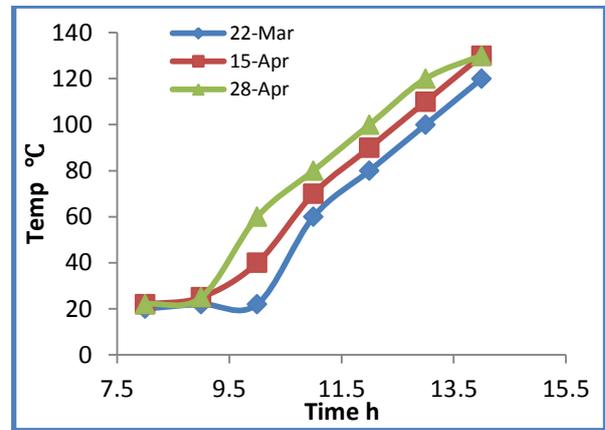


Figure 4. Relation between temperature and time within two months.

Fig. (5) and Fig. (6) describe the efficiency of the solar dish concentrator related to the time of operation. The efficiency has high value in initial time of operation and decreased along with time. This behavior belongs to losing energy by radiation process which is proportional to fourth power of receiver temperature. This value indicates a perfect performance of the cylindrical receiver [12].

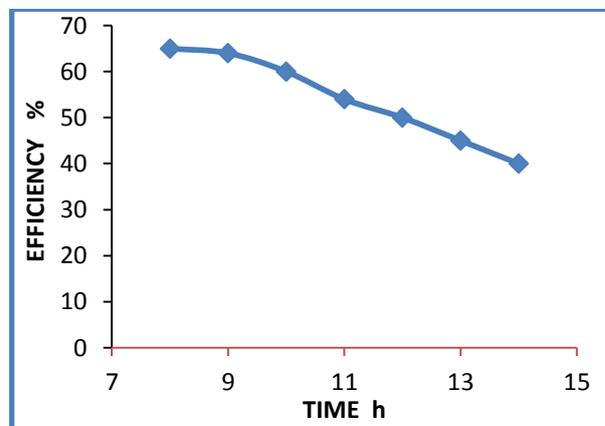


Figure 5. Relation between collector efficiency and time for the receiver.

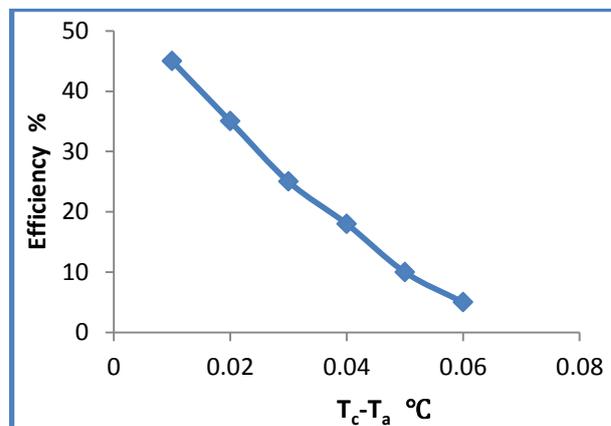


Figure 6. Relation between collector efficiency and operation temperature.

Finally, in order to conserve the hot water temperature, a thermally isolating layer has been wrapped and covered the hot tank.

Matteo M. et al. Showed that the conversion efficiency of the solar concentrator was close to 65% [13]. Ehsan G. reported that the maximum energy efficiency of the collector and total energy efficiency was 54% and 12.2%, respectively [14]. Flavia.V.Barbosa et al. Showed that the efficiency of solar dish concentrator increased from 0.8 to 0.96 due to using a solar tracking system; also, he found that the efficiency increased about 20% on "the collector with a higher reflectivity" [15].

## Conclusions

The results obtained from present study indicates that the parabolic solar concentrator can be used successfully for desalination of water to provide potable water for domestic usage. The parabolic solar concentrator operates with temperatures higher than different types of the solar radiation conversion systems. Water temperature increased with low flow rate and reply the water cycle between cold tank receiver and the hot tank. The amount of the potable water was much dependent on the accurate focusing of the system and increased when the preheating method was applied and increasing the time of water storage by insulated the hot tank and piping.

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## بناء وتشغيل الصحن الشمسي لغرض تسخين الماء

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### الخلاصة:

في هذا البحث جرى تصميم وبناء وتشغيل الصحن الشمسي ذو القطع المكافئ بقطر (2m) لأغراض تسخين الماء. وقد تم تصميم الصحن لتجهيز ماء بدرجة حرارة تصل الى (100 °C) باستخدام الطاقة الشمسية. وتتضمن المنظومة كذلك تصميم وبناء وتشغيل وحدة التتبع الشمسي لغرض زيادة كفاءة المنظومة. لقد اظهرت نتائج الفحوصات العملية والتي اجريت في الاجواء المشمسة والصحوه كفاءة عالية في تحويل الطاقة الشمسية الى طاقة حرارية، مما يفسح المجال للحصول على منظومة تسخين الماء بكفاءة عالية.

الكلمات المفتاحية: طاقة شمسية، أشعاع شمسي، انتقال حرارة، كفاءة حرارية، سخان ماء، مسخن ماء.