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# Experimental Investigation on Performance of Fresnel lens Concentrator in Iraqi Climate

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**Abstract.** This work an experimental study to use extremes sunrays temperature using a container tank receiver with a Fresnel lens concentrator. Cubical steel water tank (20 cm each side) which was manufactured with different metal finned cover, namely steel and aluminum, are used. The tank was placed in the focus of the lens to study the distribution of temperature in the tank. The Fresnel lens concentrator is controlled to track the sunlight and maintain the focal stationery. The experimental tests are performed with local weather conditions in Najaf city/Iraq. The results indicated that the highest focal temperature recorded was 258.6 ° C when the ambient temperature was 24.6 ° C and the solar radiation was 1251 W/m$^2$ of the steel finned cover of the container. The results showed that the Fresnel lens concentrator can be implemented for melting phase change material (PCM) or heating water applications.

**Keywords:** Solar Energy, Fresnel lens, Solar Tracking System

## 1. INTRODUCTION

Minimizing the reliance on fossil fuels and other nonrenewable and unsustainable energy sources. The most promising source of renewable energy is solar energy., which can be invested in several ways, one of which is the solar concentrators. Since a long time ago, solar concentrator systems have used sunlight to generate solar thermal energy. The use of Fresnel lenses for generating electricity and heating water is very powerful equipment for meeting this requirement. Thus, the use of renewable energy is the best choice for this reason and has been the subject of research around the world [1].

Several studies were conducted to examine the use of a different type of receiver with a solar concentrator. In the literature, however, only a limited number were listed which examined the effect of using a different type receiver with a Fresnel lens concentrator and similar concentrators. However, the parabolic trough has been proven as a successful solar starting device [2]. The performance of the parabolic trough was enhanced by modeling the system theoretically using optical formulas [3] or by geometry optimization [4]. A more advanced theoretical methodology using the Monte Carlo ray-tracing method was successfully presented by [5]. Mohammed S. E. Bellos, et al. [6] developed a secondary booster reflector and tested it on a parabolic trough collector. The proposed model enhanced the optical characteristics especially during winter and the results showed that the model provides higher intensity in higher operating temperatures.

Similar methodologies were conducted to produce more intense and smaller focal in industries, a thorough review about such methodologies and technique are discussed in [7].

On the other hand, Mogana Theebhan, et al. [8] designed and developed a parabolic dish with single axes solar tracking system. The parabolic dish collector was constructed using two units of identical dish solar thermal collectors. One was a stationary collector, while another collector was connected to a sun tracking system. The collector will be used to heat 1L of water at a container in the dish's focal point. The results showed that the operational efficiency of collector quipped with sun tracking system increased to 31 % comparing with a stationery collector.

Vinayak Sakhare and V.N.Kapatkar [9] investigated the idea found by Mogana Theebhan, et al. [8] by using a parabolic dish collector for water heating and cooking. The collector is fabricated with aluminum foil as a reflective material and using a receiver of a helical copper tube, it is mounted at the focus of the collector. The results showed that the temperature of the coil receiver is 190°C. Another device to manufacture solar concentrators was introduced by Sonneveld, P. J., et al. [10] used a giant Fresnel lens for solar stove heat. The lens was connected to a solar tracking system to controlling the Fresnel lens and maintain the focal stationery.

Moreover, Cheng, Tsung Chieh, et al. [11] used the Fresnel lens concentrator to produced NiAl by a self-propagating high-temperature synthesis (SHS). The lens has a surface of 0.8m2 is built into an aluminum installation designed, and the solar tracking from east to west was operated automatically and the other direction was hand positioned. The maximum density of power obtained in the focus is 260W/cm. Tsung Chieh, et al. [12] used a Fresnel lens with a sun tracking system and install two optical cells to supply electrical power to the tracking system. This device is used in thermal solar applications (such as the Stirling engine). The results showed that temperatures of more than 1000 ° C were obtained when focusing the sunlight on the Stirling engine's heating head. Pham et al. [13] presented a model for a curved Fresnel lens by implementing both Snell’s law and ray theorem. The proposed model could enhance the concentration ratio up to 900. K. Liang, et al. [14] designed and tested a new model of fresnel lens with a higher concentration ratio. Zou and Yang [15] developed a design method for a Fresnel lens concentrator and perform a numerical analysis for the optical performance. The concentration ability was increased by implementing two confocal parabolic reflectors.

Current work presents an experimental study about using Fresnel lens solar concentrator to utilize the extreme temperature at the focal of the concentrator in container tank receiver under Iraqi climate and this paper is organized as follows; section two illustrates the experimental rig setup, and section three contains the experimental results and discussion and finally, the concluding remarks are in section four.

## 2. PROCEDURE AND RIG

### 2.1. Procedure

The solar concentrator, used in this experiment, is a mechanism that allows two-axis free motion to track the sunray during daylight. A control system contains a two-stepper motor and an Arduino unit is implemented to monitor the sunlight. As shown in Figure (1) [16], a 520X520mm Fresnel lens was mounted to an aluminum frame that was connected to a one-direction moving joint (vertical direction) by four arms, which was controlled using a screw rod. As the screw rod moves to the top and bottom, the lens moves in the vertical direction. In order for the lens to be able to move in the second direction (horizontal direction), the moving joint is connected to a moving base. For the apparatuses to be stable, the two bases were placed on a stationary frame.

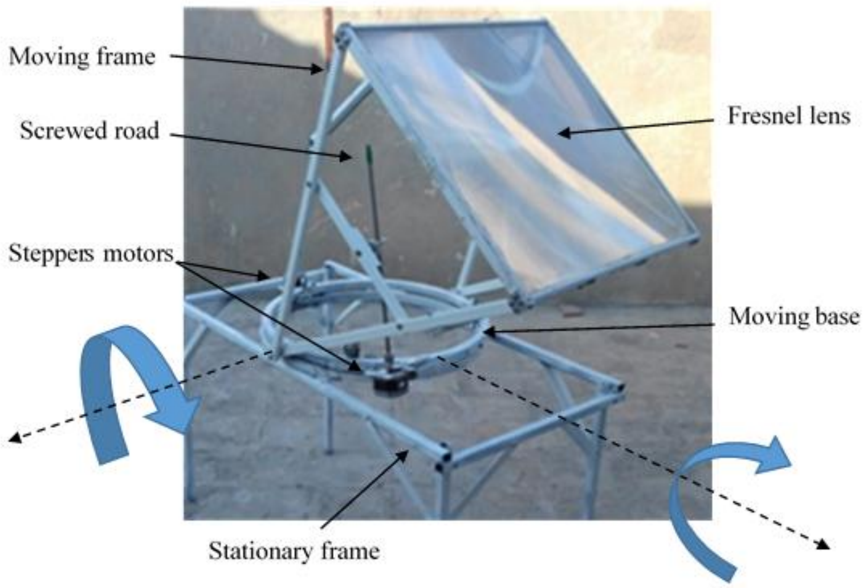


**Figure1. Fresnel lens Solar Concentrator**

2.2. RIG

A cubical steel water tank (20 cm on each side) which was manufactured with different metal finned cover is used to study the temperature distribution in the tank, as shown in Figure (2-a). Two different metal finned covers are used, namely steel and aluminum, as shown in Figure (2-b). The purpose of using fins is to evaluate the temperature distribution in the depth far away from the heat source (plate subjected to focal). This application can be implemented for melting phase change material (PCM) or heating water applications.

Thermocouples are installed on the upper surface and the fins to measure the heat distribution on the cover and inside the container depth. The data was collected using thermocouples type-K, which has a wide range of measuring temperatures from (-270 to 1260)°C. Thermocouples are joined with data logger temperature modal Applent 32 Channels Temperature Recorder for Heating Appliance (AT4532) with measurement range (-200 – 1300)°C and accuracy 0.2% + 1°C. The direct solar radiation reached on a Fresnel lens was measured using (Tenmars TM-207 Solar Power Meter) W/m$^2$. It has a range to measure solar intensity from (0 to 2000) W/m$^2$; the accuracy of solar irradiation is (± 0.5%).

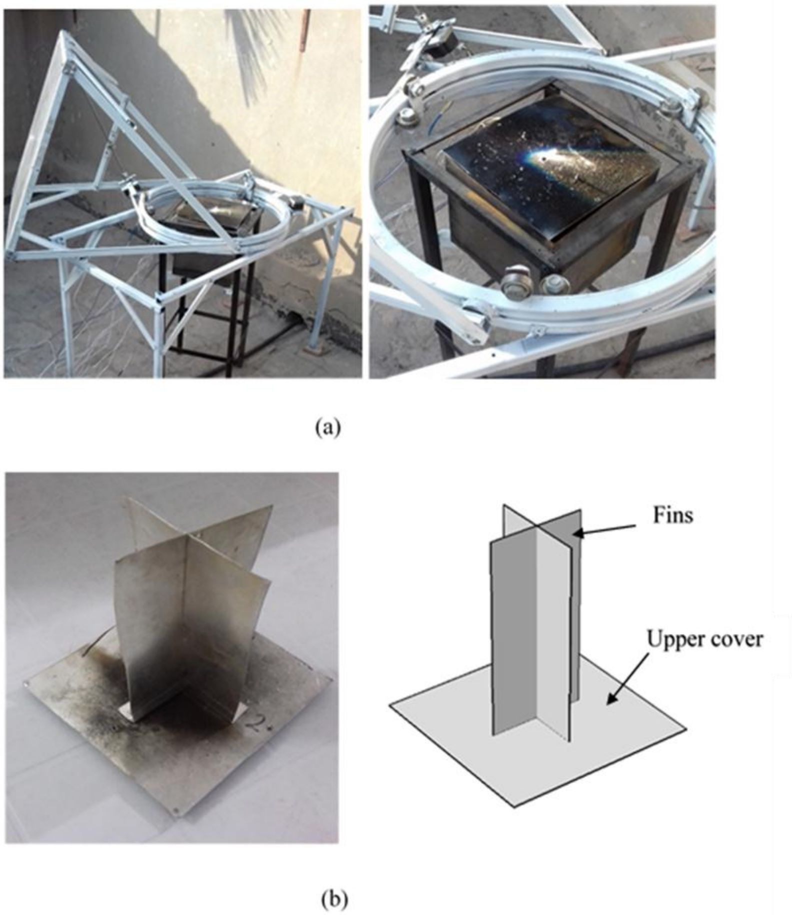


**Figure 2. Container Tank Receiver**
**(a) Cubical Steel Water Tank**
**(b) Finned Cover**

## 3. RESULTS AND DISCUSSION

### 3.1. RESULTS

The tests are carried out under local weather conditions in Najaf city/Iraq (44 ºE, 31 ºN) [17]. A cubical steel water container (20 cm on each side) was manufactured with vertical metal fins connected to the upper cover of the container. Two different metals were used to manufacture the finned covers, namely steel and aluminum (one experiment for each type). The temperature is measured using a digital data logger. Following is a detailed illustration of the two experiments.

The first experiment was performed using a steel finned cover on Nov-22-2019. The experiment started at 9:00 and was completed at 15:00. The ambient temperature ranged from 17°C to 26°C and the solar radiation in W/m$^2$ ranged from 1130 to 1251, as shown in Figures (3a and 3b). The results are illustrated in Figure (4a), where the highest recorded temperature is 258.6°C at the center of the cover and 98.05°C at the edge when the ambient temperature is 24.6°C and the solar radiation intensity is 1251 W/m$^2$. Figure (5a) shows the relationship between temperature distributions along with the steel fins versus time, the highest recorded temperature at 6 cm depth is 44.1°C, at 13 cm depth is 37.6°C, and at 19 cm depth is 34.1°C. Noting that at 15:00 the sky turned partially cloudy resulting in a reduction in the amount of solar radiation to 260 W/m$^2$, causing a decrease in temperature of the focus to 48.8°C.

The other experiment was performed using an aluminum finned cover of the container on Nov-27-2019. The experiment started at 9:00 and was completed at 15:00. The ambient temperature ranged from 19.6°C to 25.3°C and the solar radiation in W/m$^2$ ranged from 764 to 1008, as shown in Figures (3a and 3b). The findings are shown in Figure (4b), where the maximum measured temperature at the center of the cover is 81.3°C and at the edge is 68.18°C while the ambient temperature is 22.4°C and the solar radiation is 1008 W/ m$^2$. Figure (5b) shows the relationship between temperature distributions along with the aluminum fins versus time, the highest recorded temperature at 5 cm in depth is 36.8°C, at 10 cm in depth is 33.4°C, at 15 cm in depth is 30°C, and at 19 cm in depth is 29.5°C. It can be noticed that at 14:00 the sky turned partially cloudy resulting in a reduction in the amount of solar radiation to 182 W/m$^2$, causing a decrease in the temperature of the focus to 40.7°C. The results show that the steel finned cover a higher temperature than the aluminum finned cover of the container and that is due to the difference in the thermal conductivity coefficient, which allows for further dissipation of heat to the surrounding.

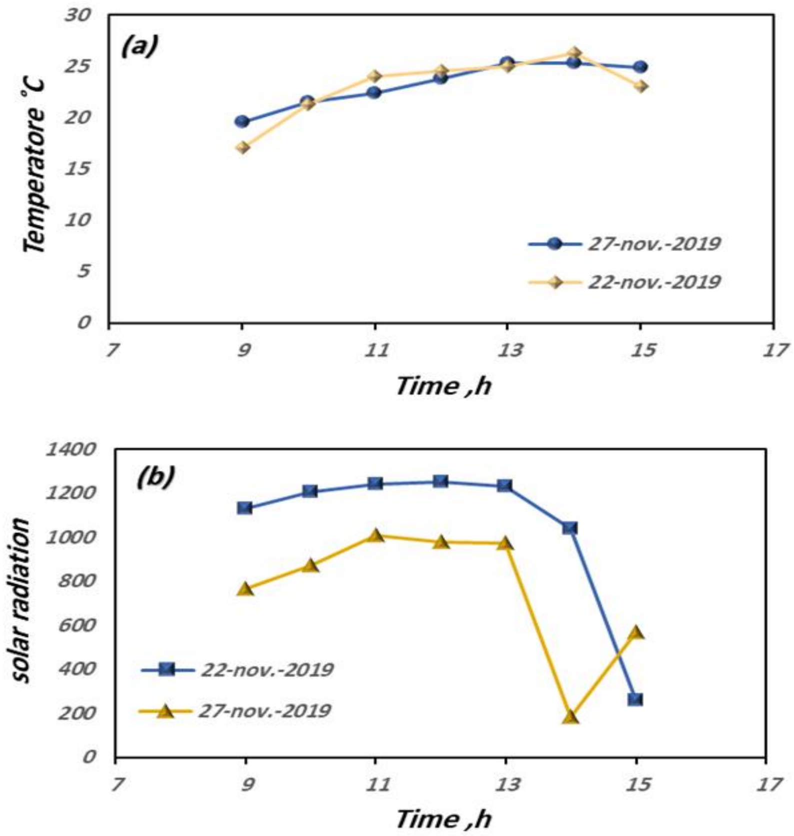


**Figure 3. Ambient Temperature and Solar Radiation Versus Time**

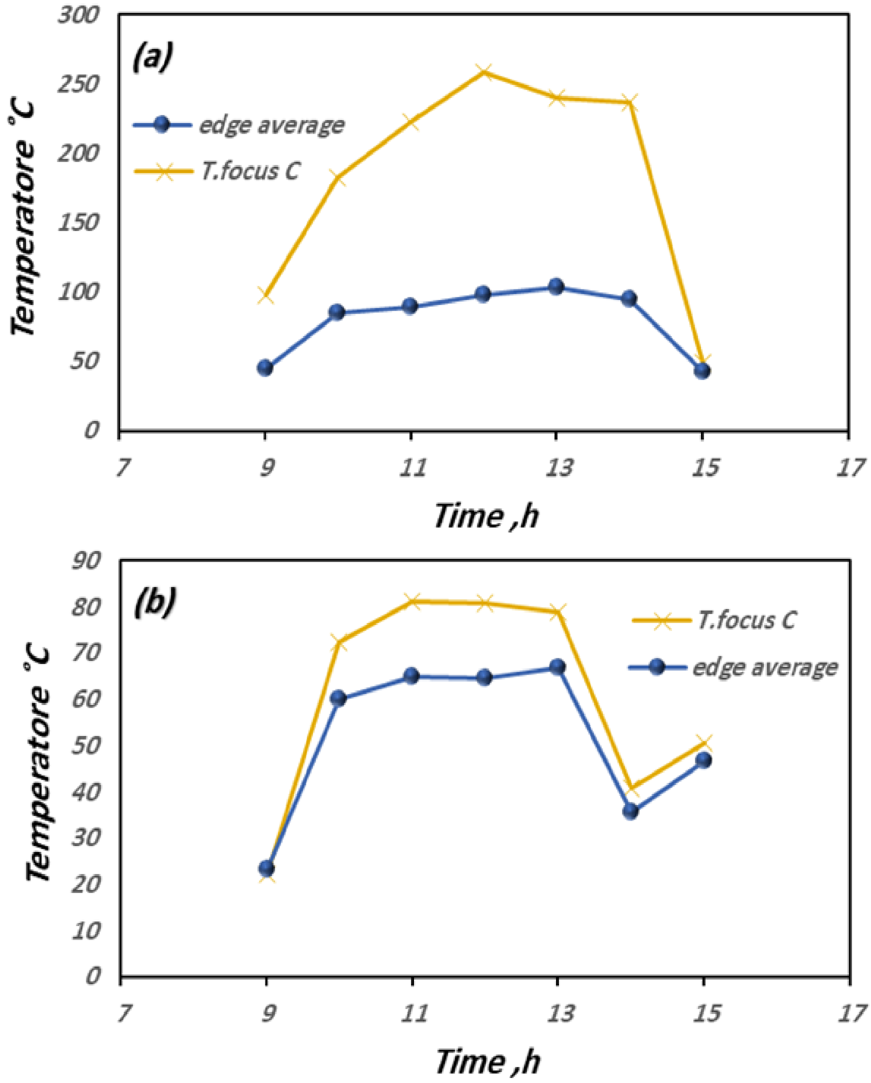


**Figure 4. Temperature Distribution of Upper Cover Versus Time of Container**
**(a) Steel Cover**
**(b) Aluminum Cover**

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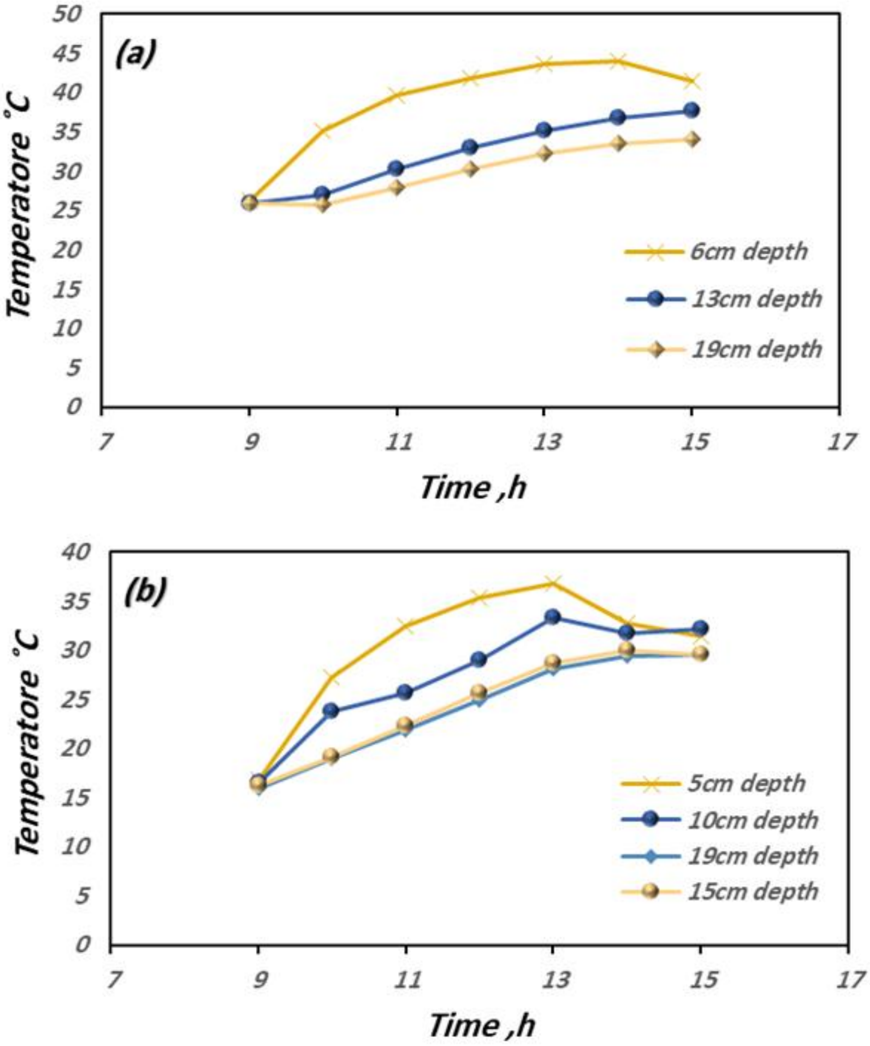


**Figure 5. Temperature Distribution Along the Fins of the Container**
**(a) Steel Fins**
**(b) Aluminum Fins**

## 4. CONCLUSIONS

The intensive solar radiation is used in Najaf city/Iraq to utilize extreme sun rays temperature using a container tank receiver utilizing a Fresnel lens concentrator, which consists of a solar tracking and Fresnel lens concentrator as the frame moves freely in two axes to track the sunlight and focus the solar radiation on a container tank. Two different metals finned covers are used, namely (steel and aluminum). The test was carried out during two days of November 2019, the results showed that for steel finned cover the maximum temperature is 258.6°C at the focus when the ambient temperature is 24.6°C and the solar radiation is 1251W/m$^2$. Whereas, the results of using an aluminum finned cover showed that the maximum temperature recorded at the focus is 81.3°C when the ambient temperature is 22.4°C and the solar radiation is 1008 W/m$^2$. It is promising results that are suitable for melting some types of the (PCM) or heating water applications.

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