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Study the Effectiveness of the Parabolic Concentrating Solar Collector and Test the Efficiency of Its Performance

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Abstract

In this research, the design and manufacture of a parabolic concentrating solar collector mounted with a flat receiver can benefit from the solar radiation falling on it. Manufacturing was carried out according to the capabilities and materials available in the local Libyan market Verifying the performance of the solar collector under the climatic conditions of our country, Libya. During these experiments, three different water flow rates were used to demonstrate the effect of flow rate on the system's performance. The results showed The thermal efficiency in experiments is 30–40% lower than the thermal efficiency in theory. Based on the manufacturing cost of this complex and the simplicity of its installation, manufacturing such Collectors locally and using them in multiple applications of thermal conversion is Possible.

Keywords: parabolic collector, solar radiation, water flow rates,

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1- Introduction

A concentrating solar collector is designed to reduce the heat losses connected to solar collection. Many times, it is preferable to supply energy at higher temperatures than what flat plate solar collectors are capable of. In this instance, a parabolic "mirror" concentrates incident solar irradiation onto a significantly smaller receiver area, significantly reducing heat loss and maximising the solar energy that is available. Currently used concentrating solar collectors come in a wide variety. Concentrators come in a variety of shapes, including cylindrical, spherical, parabolic, reflecting, and segmented. Receiver shapes include cylindrical, flat, convex, covered, and uncovered. It is challenging to discover developed general evaluations of each distinct concentrator due to the intricacy and extremely broad breadth of concentrators and concentrator designs.

The development of engineering, design, and materials will be crucial to the success of concentrating solar collectors in the future. The optical systems of solar concentrators must be kept in good condition for extended periods of time. This involves, among other things, taking into consideration weather, grit,

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and corrosion (Eames, P. C., et al., "Modelling Line-Axis Solar Concentrators in the Medium Temperature Range").Renewable Elsevier, 1999, Energy16 (accessed November 12, 2012).Designing, creating, simulating, and testing a concentrated solar collector are the objectives of this project.

Heat is transported from the sun in solar systems to water or any other substance that absorbs heat as it moves through the receiver tube. In a tank, the hot water created in this manner is ultimately kept for home consumption [1]. Concentrated collectors are utilised to create high temperatures with great thermal efficiency using a small collection area while producing solar thermal energy [2]. Low temperature applications employed non-concentrating compounds. At high temperatures, a condenser is employed in place of a non-concentrating collector [3].

Human is surrounded by energy; nature works tirelessly to provide enormous amounts of limitless energy so that starting recently, but human can only use a little portion of it. The amount of energy present on Earth is enormous. For instance, wind energy provides a percentage of energy estimated at 167,000 terwatts. In addition, waterfalls can generate energy from hydroelectric breaking point at a value comparable to 80%. One-fifth of the energy consumed by people and a portion of the ocean's water streams can provide vast energy The sun continues to be the primary source of energy in the environment, with an estimate of 280 terawat, and disregarding the variety of energies employed during the ebb and flow period, With an estimated 444,000 TW of energy, the sun continues to be the primary source of energy for the environment [3].

That is why researchers made a good effort to think about this kind of elective energy in light of its immeasurable significance in terms of size and acceptability in contrast to other alternative and reasonable force sources on which humanity's well-being depends in all regions of the earth. There is no doubt that solar energy, which derives from the sun, is the primary source of usable power because it is the planet's primary energy source, even though it also serves as the rationale for the creation of biomass energy, which is found in a variety of plant species, and perhaps the most notable manifestation of this energy is the point at which plants can no longer absorb chlorophyll. By 1% of sunlight, sunlight is the source of energy for plants, giving them the option to convert it into artificial energy, which they use to make oxygen.

2- Design and Experimental Setup

A parabolic surface, such as mirrors, was first intended to be used to create a solar collector. However, the search revealed that the focal point (the focal point) of the centre of the mirrors is situated at a distance of an oval radius from the centre of the cut, and we tried for a while to try to find a way to direct the parts of this piece in a mechanical manner, but some challenges and a lack of capabilities imposed on us, as the concept goes First, use the parabola equation's derivation to get the proper slope at various locations along the inner surface of the segments, and then rotate those slopes around the

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December 2023
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origin or the segment's centre. Figure (1) shows the measurements of the parabola. The chosen parabolic trough satisfied the following equation:

$$Y = 0.041667\ X^2 \quad \ldots\ldots\ldots\ldots (1)$$

For ease of assembly, this equation was chosen to produce a focus point that is 6 cm above the top of the parabola. A mathematical model that takes into account the temperature of the water entering the upper basin and the amount of seepage absorbed by the receiver will help determine the temperature of the water inside the receiving basin [3].

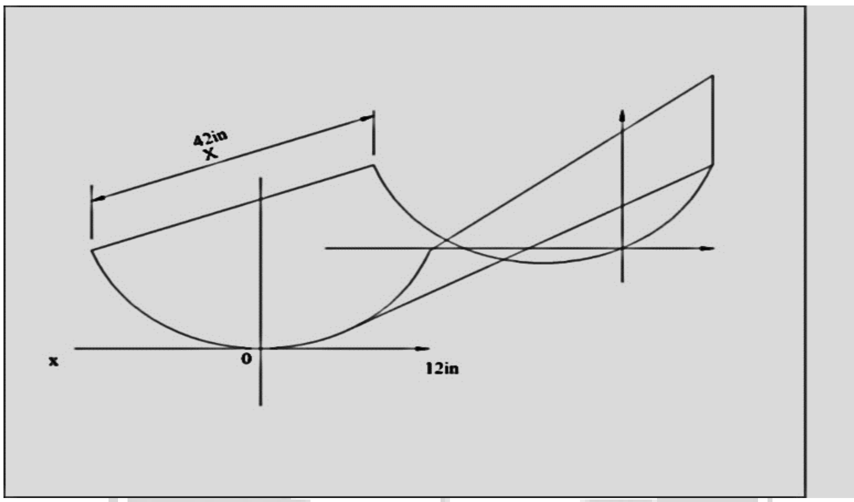

Figure (1) The measurements of the parabola

The parabolic trough could receive heat from a variety of orientations thanks to the parabola frame, which was made of plywood and would be coupled to a mobile base. The design could be flexibly adjusted either manually or automatically. Due to its high and excellent thermal conductivity in relation to both the workplace temperature and the location of the study (ACT, Tripoli, Abu Salim), silver-colored aluminum was used to make the conductor or receiver in order to accommodate the natural temperatures of the work environment. With regard to gravity and without using pumps to raise and lower them, they operate on the principle of gravity and with the flow of gravity auxiliary through the upper basin. Water was used as a test liquid, and the idea of this liquid was completely successful due to its ability to conduct heat well, its appropriate boiling point, and its speed in response to heat transfer by conduction and convection.

2-1 Solar collector construction:

The building supplies for the solar collector, including wood, nails, nuts, and pipes, were obtained from the neighbourhood market based on the preliminary designs and sketches. The largest obstacle in the installation and assembly activities was to create a profile that fits into the contour of the parabolic shape of the basin. And then place the receiving tube in the focus that was located, where manufacture and assembly took place at the ACT, Tripoli - Abu Salim.

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Volume 11 Issue 02
December 2023
ISSN 2958-6119

2-2 Production of the wooden frame for the solar collector.

Calculations and engineering drawings of the woodblocks make up this step. SOLIDWORKS, software, was used to create engineering drawings for the products in accordance with the necessary dimensions, as shown in Figure (2).

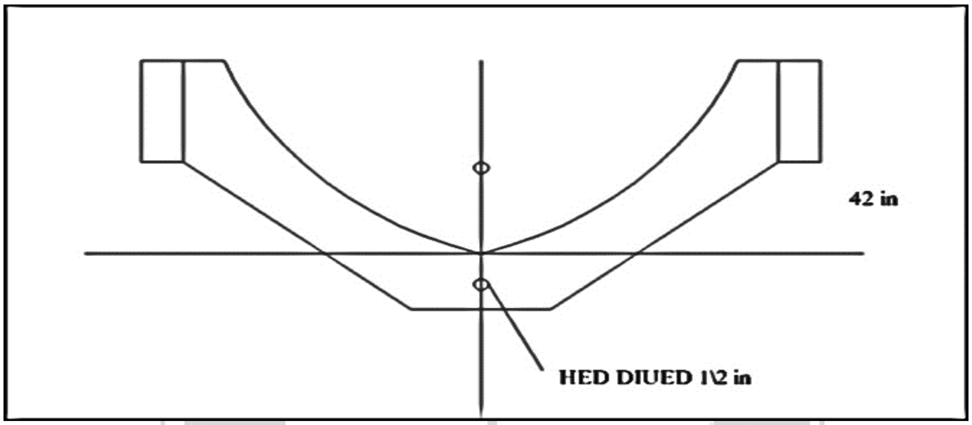

Figure (2) The wooden frame measurements.

The working drawings were used to determine the necessary proportions for the wooden blocks, which were then brought to the workshop for cutting and shaping. Figure (2-3) shows the creation and manufacturing of the wooden frame in the shape of a parabolic trough.

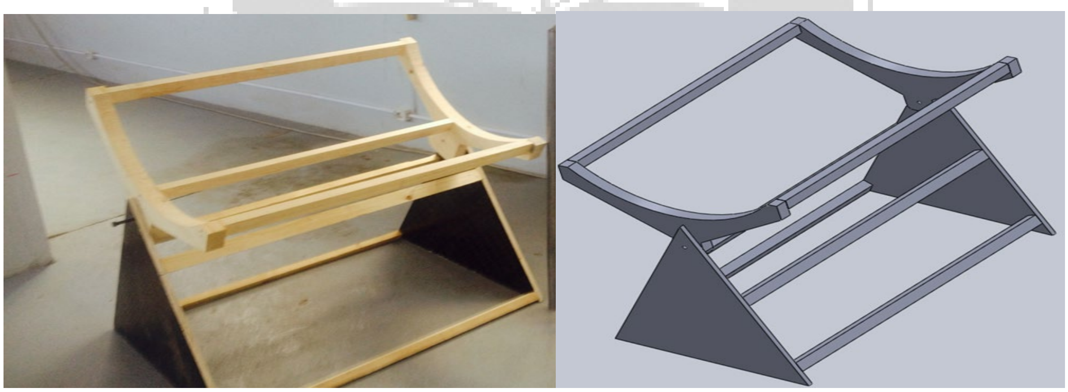

Figure (3) shows the wooden frame of the parabola

2-3 The wooden frame for the parabola:

A side plank is used to unite two identically sized and shaped pieces of plywood that have been carved to resemble parabolas and are spaced along the length of the reflective sheet. As illustrated in Figure (4), the base of the arch was constructed from the bottom up in a bigger size so that it could be perforated to be installed in a wooden basis in the shape of a triangle of compacted wood, with the fastening points on the two sides serving as the combined basin's rotational axis.

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Volume 11 Issue 02
December 2023
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The wooden foundation of the device also has the following features; it comprises of two triangle-shaped supports and arms that link the two triangles to each other for fixation. A sheet metal cutter was used to cut the reflective sheet into a sufficient size rectangle so that it could be fixed to the frame. In order to accommodate screws for attaching to the wood frame, holes were drilled along the edges at equal intervals and with a 3 mm diameter, as illustrated in Figure (5).

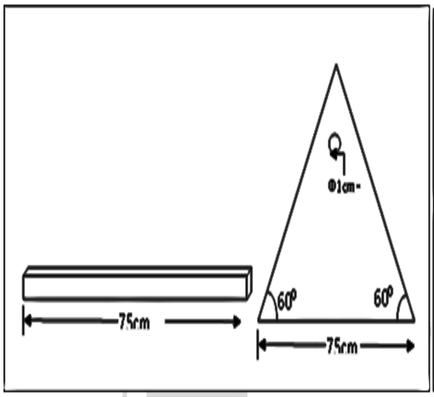

Figure: (4) wooden base

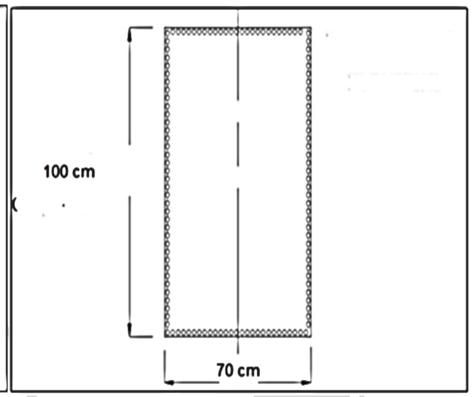

Figure (5) Reflective sheet

The parabolic frame's iron sheet was manually put there. Due to the sheet's inability to bend evenly between the two frames as indicated in drawings (6) I ran into several issues.

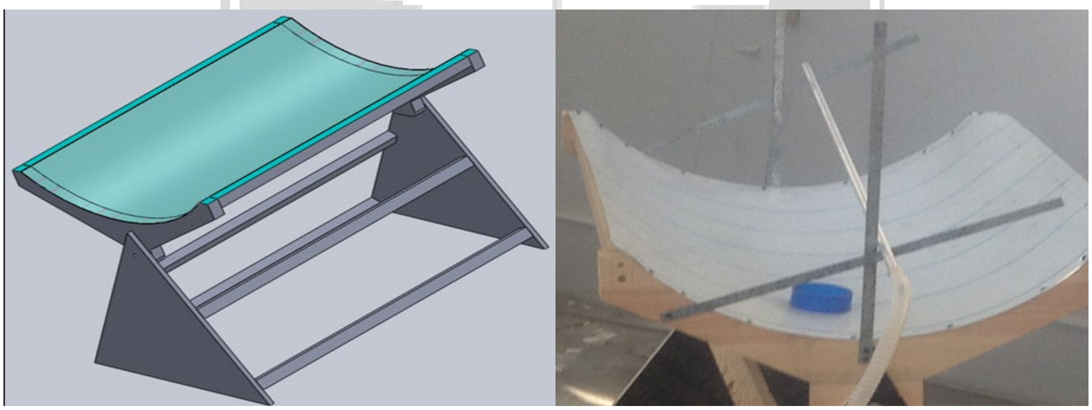

Figure (6) Fixing the sheet of iron sheet to the parabolic frame

In order to create chairs for the future tube, an arrangement in the shape of two intersecting rulers was installed. One ruler was fixed vertically in the centre of the combined basin, and the other was mobile so that he could move the tube up and down to get it in focus, as shown in Figure (2-6).

A copper tube was supposed to represent the future, but owing to market circumstances, an aluminium tube with a diameter of 10 mm and a thickness of 1 mm has taken its place. A copper tube was supposed to represent the future, but owing to market circumstances, an aluminium tube with a diameter of 10

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mm and a thickness of 1 mm has taken its place. For the purposes of simulating reality and the subsequent actions, the tube was fitted without a coating.

3- The reflector design

Second: The reflector was designed based on equation (1) and the following equations to determine the focal point mathematically:

$$= \frac{1}{4(0.041667} \ldots\ldots\ldots\ldots (2) \frac{1}{4a}$$

The focus of the parabola was determined using the following equation:

Y=0.041667X2……………………………………………..(3)

$$\ldots\ldots\ldots\ldots (4) \frac{1}{4a} = \frac{1}{4(0.041667)} =$$

$$6\text{inc} = \gg 15.24 \text{ cm}$$

The length was calculated from x1 to x2 "S" according to the following equation:

$$q=\sqrt{t^2 + p^2} \ldots\ldots\ldots\ldots (5)$$

where is:

and t=2f and f=6

From the above, and after defining the plane Y and (x1) to (x2) and defining x as a point, we find "s" using its equation:

$$S = (\frac{pq}{t} + t\, l_n\, (\frac{p+q}{t})) \ldots\ldots\ldots\ldots (6)$$

Where

P=12

T=(2)(6)=12

$$q=\sqrt{(2^2)}*(12) =16.97$$

$$S=(\frac{12*16.97}{12}+12 l_n(\frac{12+16.97}{12}))$$

Where "S" represents the length of the reflective surface = 27.5in = 65cm

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The (s) was made in the design 70 cm to suit the working conditions as well as not to affect the model by modification as illustrated in figure (2-5)

Calculating the efficiency of the solar collector: The theoretical efficiency of the solar collector

$$\eta_{th} = \frac{Q_{u,th}}{I_b A_a} \quad \text{……………………..…………(7)}$$

Real solar collector efficiency

$$\eta_{exp} = \frac{Q_{u,,exp}}{I_b A_a} \quad \text{…………………….………..…………(8)}$$

The equation can express the theoretical amount of energy learned:

$$Q_{u,th} = A_{ap} F_R \left[H_{ab} - \frac{A_{r,ext}}{A_{ap}} U_l (T_{fi} - T_{amb}) \right] \text{……(9)}$$

where:

Hab The amount of energy incident solar radiation

$$Hab = Ib\ \alpha\rho$$

Aap is the net area of solar cumulative exposure to incident solar radiation

$$Aap = W - Dr,ext\ L$$

L is the length of the solar collector and the absorber tube

W is the width of the concentrating solar collector

FR is the thermal efficiency coefficient of the solar collector

The actual amount of energy benefited from the concentrator solar collector is expressed by the equation:

$$Q_{u,exp} = Mc_p (T_{f,o} - T_{fi}) \quad \text{………………(10)}$$

where

M is the flow rate of the fluid in the collector pipes.

Cp is the specific temperature of water.

Tfo is the temperature of the fluid at the outlet.

Tfi is the temperature of the fluid at entry.

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The parabolic trough was delivered to the test location after construction and assembly went according to plan. Before utilizing the tanks, the experiment was carried out using a garden hose and it was fixed with tape as indicated in Figure (3-1).

Figure (7) Collector test with a garden hose

Figure (3-2) illustrates the values obtained from the experiment using an IR device for measuring water temperature.

Figure (8) The IR gun for the readings resulting C° from the experiment

4- Results and discussion

4-1 The first case when the flow rate was as low and equal to $3.8 \times 10^{-6}\ \frac{m^3}{s}$

The experimental performance was carried out on summer days and the temperature indicators were when there were no clouds in the sky. Both the inlet and the outlet collector's temperatures were measured during the testing period and at regular intervals. Figure 4-1 displays the temperature graph

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for the collector and shows The relationship between the average water temperature at the inlet and outlet of the collector in the first case. The tank temperature was 25.31°C on average and the outlet temperature was 37.54°C on average. The experiment on the collector lasted a total of 30 minutes, with readings being collected. Figure 4-2 shows the temperature change rate (ΔT) between the inlet and outlet collector temperatures. It was discovered that the average rate of change in temperature was obtained at 12.3°C in the first case when the flow rate was as low.

Figure 4-3 describes the solar radiation changing with time. The average radiation intensity was 842 w/m2 during the first case.

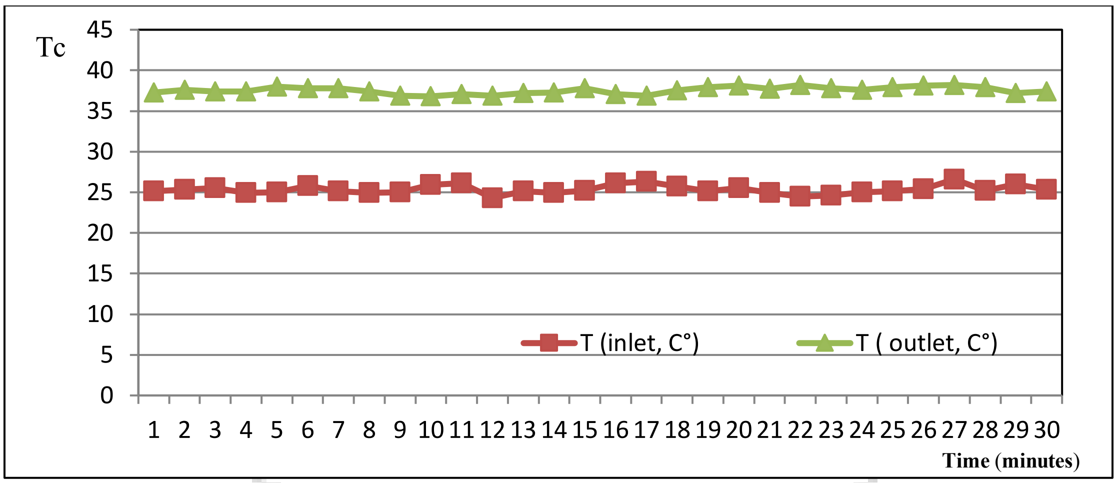

Figure (9) The relationship between the water temperature and time(minutes)

at the inlet and outlet of the collector in the first case

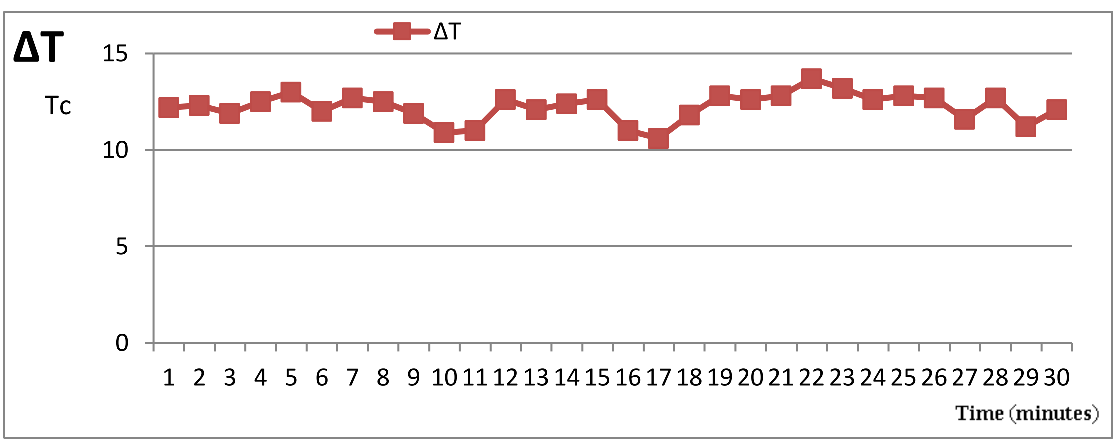

Figure (10) The temperature change between inlet and outlet from the collector

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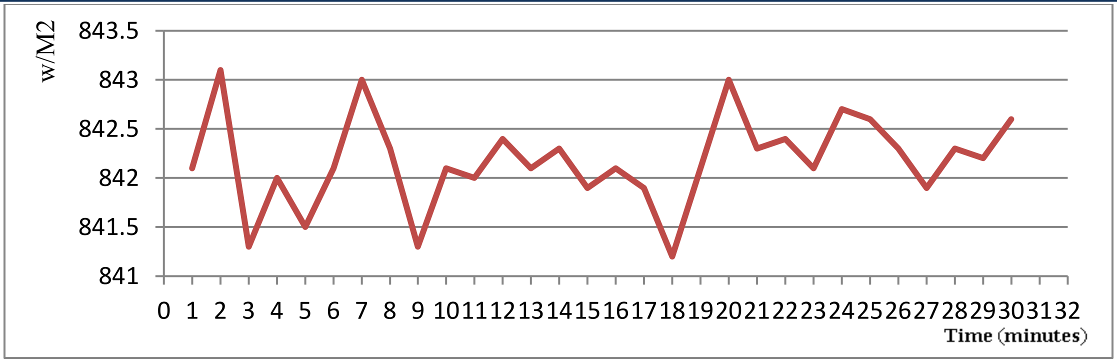

Figure (11) the intensity of solar radiation

4-2 The second case was when the flow rate was as low and equal to $7.7 \times 10^{-6}\ \frac{m^3}{s}$

The second case was carried out on the same conditions. Both the inlet and the outlet collector's temperatures were measured during the testing period and at regular intervals. The tank temperature was 25.86°C on average and the outlet temperature was 31.41°C on average. Figure 4-4 displays the temperature graph for the collector and shows The relationship between the average water temperature at the inlet and outlet of the collector in the first case. The experiment on the collector lasted a total of 30 minutes, with readings being collected. Figure 4-5 shows the temperature change rate (ΔT) between the inlet and outlet collector temperatures. It was discovered that the average rate of change in temperature was obtained at 5.55°C in the second case when the flow rate was 7.77778E-06.

Figure 4-6 describes the solar radiation changing with time. The average radiation intensity was 835 w/m2 during this case.

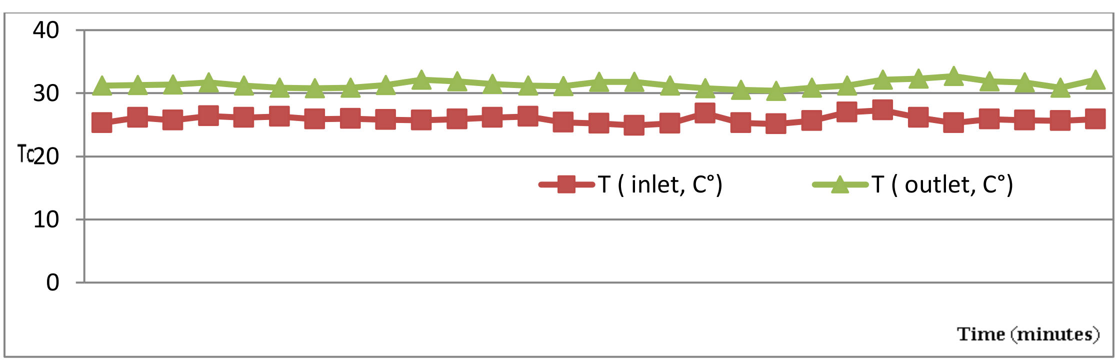

Figure (12) The relationship between the water temperature and time (mnt) at the inlet and outlet of the collector in the second case

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Volume 11 Issue 02
December 2023
ISSN 2958-6119

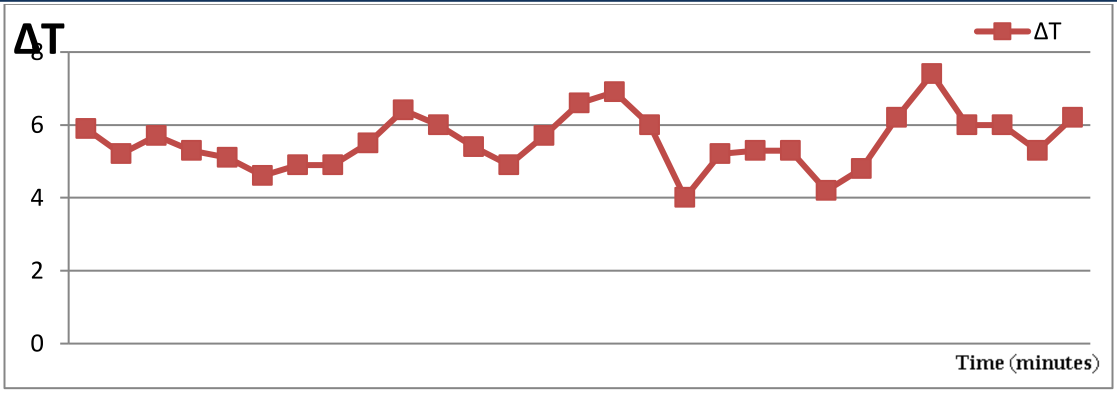

Figure (13) the temperature change between the inlet and outlet in the second case

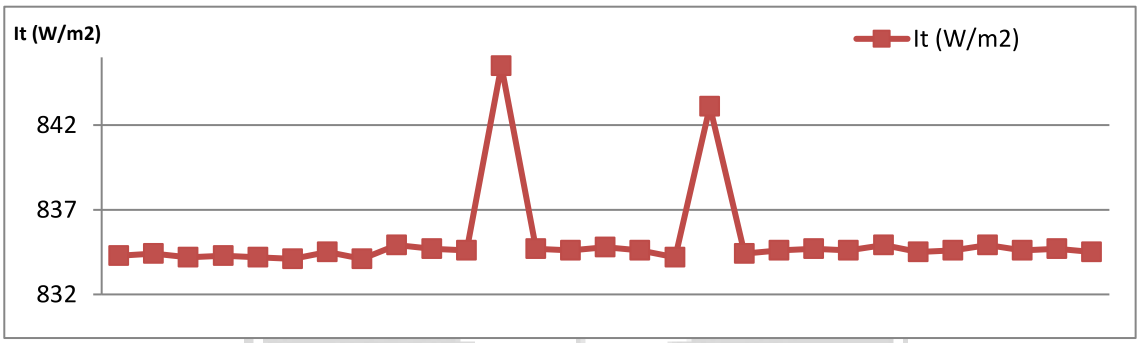

Figure (14) the intensity of solar radiation in the second case

4-3 third case when the flow rate was as low and equal to $9.72 \times 10^{-6} \frac{m^3}{s}$

The third case was carried out on the same conditions. Both the inlet and the outlet collector's temperatures were measured during the testing period and at regular intervals. The tank temperature was 25°C on average and the outlet temperature was 29.33°C on average. Figure 4-4 displays the temperature graph for the collector and shows The relationship between the average water temperature at the inlet and outlet of the collector in the first case. The experiment on the collector lasted a total of 30 minutes, with readings being collected. Figure 4-7 shows the temperature change rate (ΔT) between the inlet and outlet collector temperatures. As shown in figure 4-8 It was discovered that the average rate of change in temperature is obtained at 3.37°C in the third case when the flow rate was 9.72222E-06.

Figure 4-9 describes the solar radiation changing with time. The average radiation intensity was 829 w/m2 during this case.

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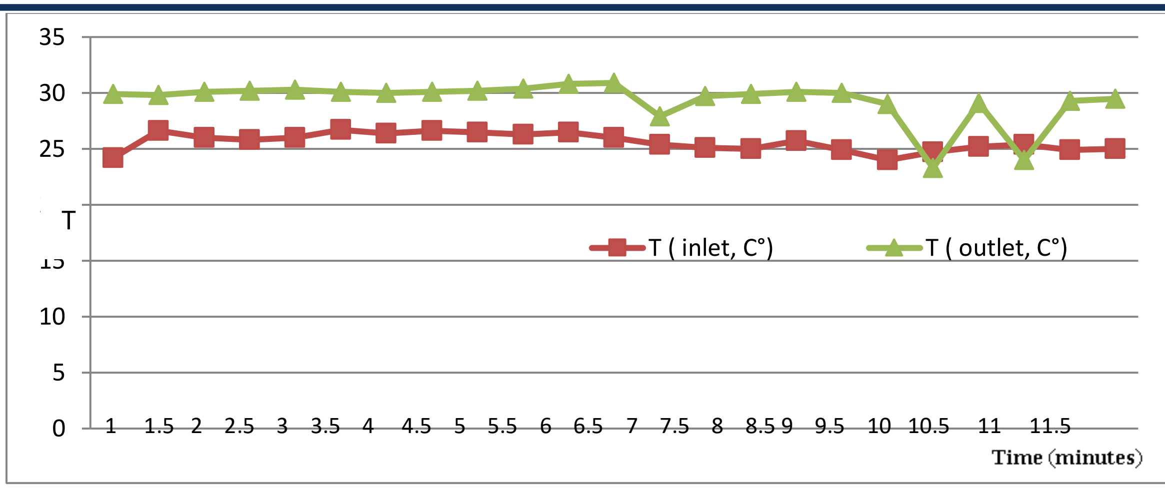

Figure (15) The relationship between the water temperature and time (minutes) at the inlet and outlet of the collector in the third case

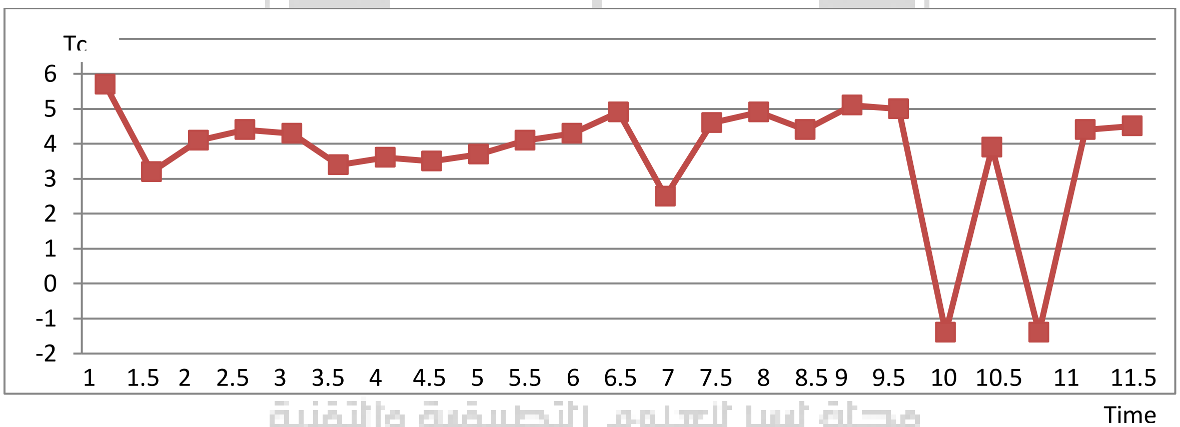

Figure (16) shows the temperature change between entering and leaving the solar collector

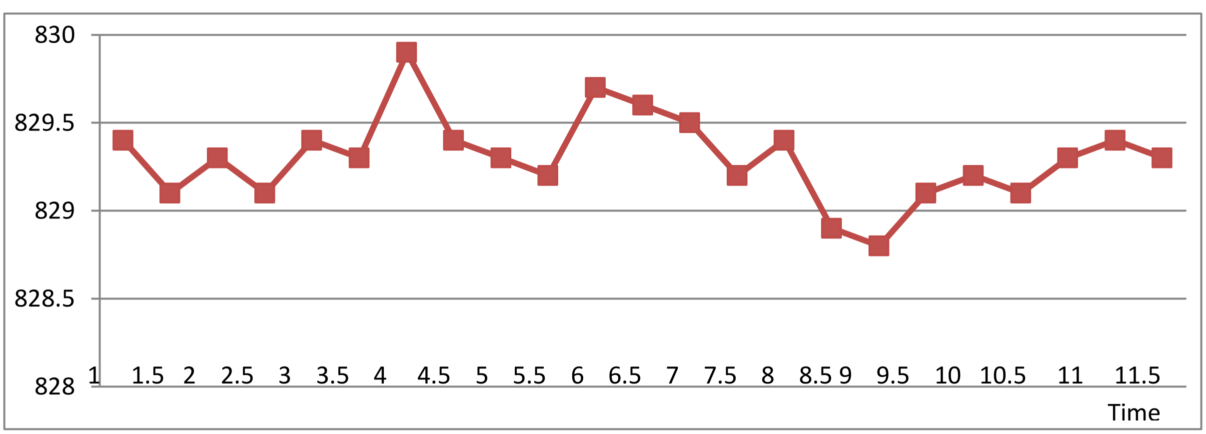

Figure (17) shows the intensity of solar radiation

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4-4 Real and theoretical efficiency of the three flow states:

The computed thermal efficiency is shown in table (4-1) with an example. The link between theoretical thermal efficiency and practical thermal efficiency is shown in Figures (4–1). The efficiency of the collector was shown to decrease with increasing flow rate. The thermal efficiency in experiments is 30–40% lower than the thermal efficiency in theory.

Table (4-4) Real and theoretical efficiency ratios

case	1	2	3
Actual Eff_ %	34%	31%	27%
Thr_Eff%	72%	66%	58.47%

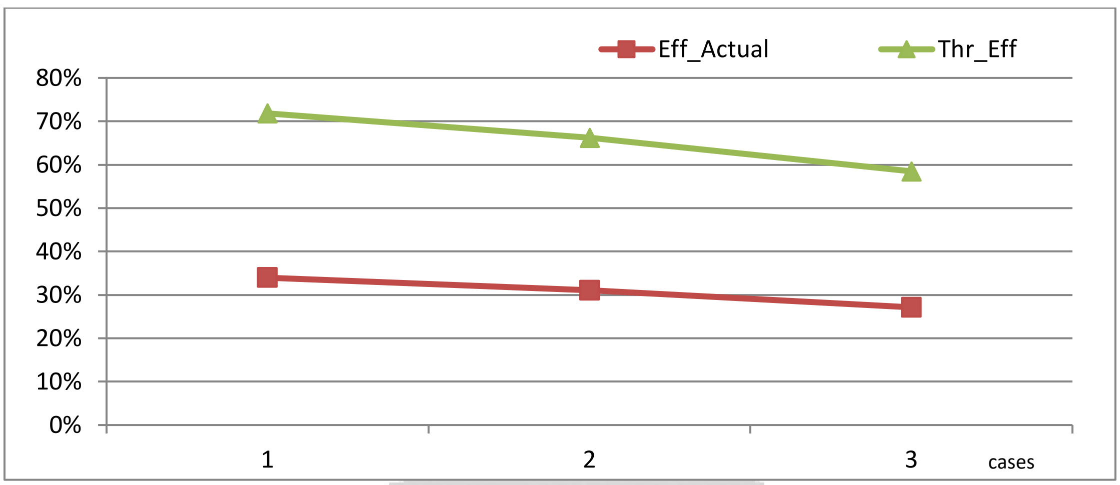

Figure (18). The relationship between real and theoretical efficiency

5- Conclusion

1. Exploiting solar energy by solar collectors is the simplest and most economical way.

2. The low efficiency of the solar collector results from the unavailability of materials with thermal properties that are suitable for this application.

3. The solar collector can be used for several purposes if the financial and scientific capabilities and capabilities exist for the development of these complexes.

4. The created compound is of test sizes but has been modified to make practical use of it to obtain hot water.

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5. Whenever the flow decreases, we get a quantity of the recovered heat, so that through the test the productive amount was equivalent to 6 kilowatts compared to the second test.

6. The temperature difference between entering and leaving the water increased and it was equivalent to an average of 12 degrees over the time of the first test with the increase in the efficiency obtained for the system, where the average efficiency was equivalent to 34%, compared to the other two tests 31% - 27%.

7. A decrease in efficiency occurred due to the increase in the flow rate, which greatly affected the ability of the device and tubes to absorb heat easily and transfer it to the fluid.

8. The comparison between the test results shows a wide difference in the amount of energy obtained practically and mathematically as a result of some winds blowing which is important in increasing the loss, as the theoretical efficiency reached 71% from the first test to 66% and 58% from the other two tests.

9. It has been observed that the loss resulting from the load and the connection affects the reduction in efficiency, noting that this effect of "delivery" is not very large compared to pregnancy.

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