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Experimental investigation of solar water heater type helical coil vertical collector with concentrator

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ABSTRACT: In this study using compact solar water heater type helical coil vertical collector with concentrator as a new setup. With this idea, most of the problems can be overcome by using the solar energy, such as the cost, the angle and the material. This type of solar collector can be utilized in more engineering applications. The results showed the enhancement of the performance of the new design about 40% more than conventional flat plate. Also, the effect of shape change of the solar collector was very important in enhancement the absorbed intensity of radiation with all directions of the tube coil. Therefore, the new type of solar collector can be employed instead of the conventional solar collector.

KEYWORD: Solar radiation, Natural circulation system, Thermosiphon system, Helical coil collector

INTRODUCTION

Solar water heating is one of the principle applications of solar energy. The crucial point in designing any solar collector is to allow maximum possible amount of solar radiation to reach the absorber part of the collector, and concurrently, reducing the thermal losses from the absorber to the minimum. Other benefit of solar energy include solar drying, electricity generation using photovoltaic cells, solar cooling and refrigeration, solar still and solar cooking. The planning to using solar energy in India, will be reduced the energy 2000 MW in 2022. In the late 1800s, Roman invented glass enclosed boxes within copper tubes to get the temperature of warmed baths. Although the problem of consuming the solar energy, there is a very necessary need about how to use general laws of thermal (thermosiphon). Other tropical countries is blessed with abundant solar energy, which is beamed over the geographical entity and received freely on daily basis. One of good idea to absorption solar radiation is by device known as the compound named (collector) to raise the water temperature significantly. V. Rajive [1] studied about a new design for a solar water heater, this model was easy to be fabricated, cost effective and high thermal efficiency. The analysis of the model and finding a maximum solar concentration of the solar water heater is 1.8 solar, therefore get the thermal efficiency of 70.54% of the whole system. Samson [2] investigated a performance as solar heating water in Akure-Nigeria, using a flatness collector covered by double glazing layers in 20o angle of tilt to the horizontal.

Marco et al. [3] studied the performance analysis of flat plate solar field for processing heat with use of technology to get high temperature with wide areas on the ground. The performance of the assemblies was discussed and a comparison of three types of different complexes practical thermal applications (vacuum tube complex, the CPC vacuum tube compound, and the flat plate collector) by S. Brunold [4], and the results of the collector efficiency and incident angle rate was presented in addition to the calculated energy gains of three different collectors; the Using glass filaments as transparent insulation. a significance of solar energy technologies for improvement of Rural region in India was verified by Renuka et al. [5]. Their investigation was about the direct solar usage systems as water heating system, solar cooking, solar drying and solar distillation. Also, Lauren and Truc [6] discussed the reasonable solar thermal water heating solution for rural Dominican Republic. It was possible to use solar energy at inexpensive prices with geometric ideas by reducing the number and simple designs of the solar complex. Arunachala U. C.[7] investigated the thermosiphon flatness plate solar heating water experimentally and theoretically. Subhra Das [8] studied the model of optimal exergy effectiveness of solar flatness plate collector. Arvind Kuma [9] verify the thermodynamic study of factors affecting the performance of solar collector. Lacour et al. [10] examined a flat plate and heat Pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate weather. In the present work, the design of the cylindrical solar collector bar type will be investigated. Collector was designed and fabricated instead of the flat plate collector with less space on the surface of the building.

PERFORMANCE EVALUATION

Thermal efficiency of the solar water heater as a performance parameter was estimated [2]. The radiant flux (Rf) striking the bar cylinder collector is

$$Rf = \zeta cov * Ap * G \qquad (1)$$

Where, G = The irradiance on the collector

Ap = Exposed area of the bar cylinder type

ζcov = The transmittance of the transparent cover only a fraction

α= The flux is actually absorbed. Since the bar cylinder is hotter than the environment, it loses heat at a rate

$\frac{Tp-Ta}{Rl}$– Where, Rl = Resistance to heat loss from the bar cylinder collector

Tp= Temperature surface cylinder, Ta= temperature outside environment, and the net heat flow into the bar cylinder is:

$$Pu = \zeta cov * Ap * G * \alpha - \left[\frac{(Tp-Ta)}{Rl}\right] = \eta c * Ap * G \qquad (2)$$

Anywhere, ηc = Captured efficiency (<1) .

This is called Hottel-Whiller calculation (Twindell and Weir, 1986). Usually, only a fraction, ηpf, of Pnet is transferred to the fluid at the temperature Tf. For a elegant collector, the temperature difference amid a bar cylinder and fluid is small, then the transmission efficiency ηc is only somewhat fewer than One. Thus, the valuable output power after the bar cylinder collector is

$$Pu = \eta c * Pnet = \dot{m} * c * (T2 - T1) \qquad (3)$$

Where $\dot{m}$ is the mass that currents through a bar cylinder collector each hour, T1 = temperature of water incoming the bar cylinder, T2 = temperature of water departure the bar cylinder. A bar cylinder collector of area Ap bare to irradiance G slow in the plane of the collector gives a valuable output

$$Pu = Ap * qu = \eta c * Ap * G \qquad (4)$$

From equations (3) and (4), (ηc) becomes

$$\eta c * Ap * G = \dot{m} * c * (T2 - T1) \qquad (5)$$

Hence,

$$\eta c = \frac{\dot{m} * c * (T2 - T1)}{Ap * G} \qquad (6)$$

The efficiency can be estimated by the formula:

$$\eta c = \frac{\dot{m} * c * (\Delta t)}{Ap * G} \qquad (7)$$

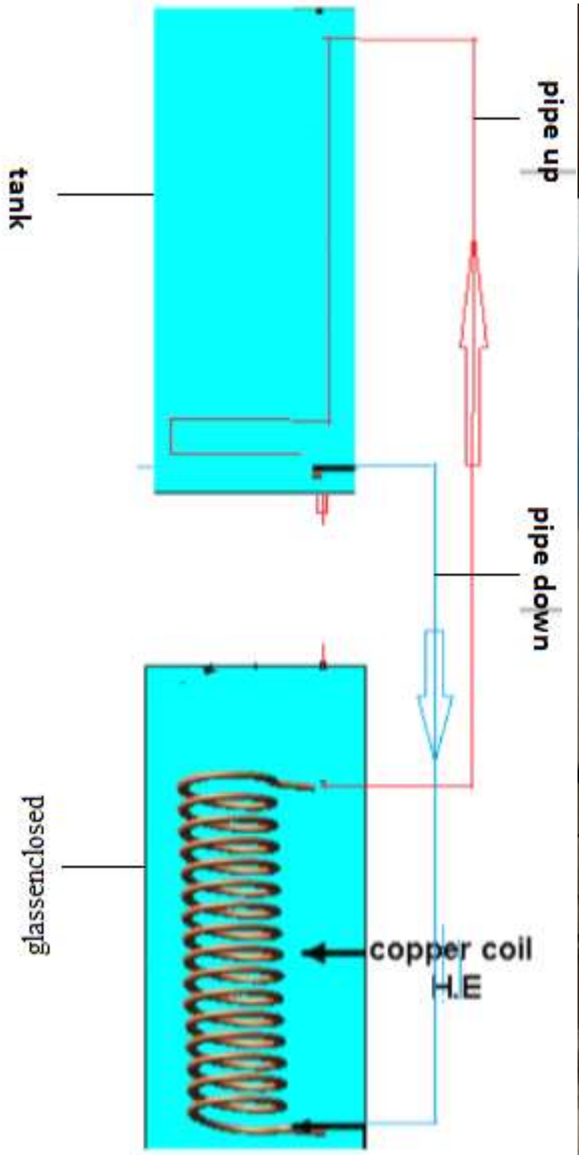
Where, $\Delta T = T_W - T_{air}$ is the temperature of water entering the collector, Tair is the ambient temperature and G= Radiation Intensity (W/m^2).

EXPERIMENTAL RIG AND TEST PROCEDURE

The natural circulation systems do not require adjustment and are only used in areas with a high solar irradiation. Natural solar systems are made from collector and a tank, mounted on the same frame. They are closed circuit systems, which operate with indirect exchange, meaning that the heat carrying fluid circuit is always separate from that of the water directed to the utility. Moreover, as they are natural circulation systems, mechanical or electrical parts are not required for their operation. The sun is the only energy source with which must be supplied.

It is for these reasons that this type of system is virtually maintenance-free. The heat carrying fluid is pushed due to the difference in the density between the hottest column of fluid leaving the collector, which tends to rise, and the coldest column of fluid leaving the storage tank, which tends to drop. The fluid transfers the heat to the water contained in the tank through a cavity. This water flows through the user's domestic hot water circuit.

Reducing the necessary maintenance makes it an interesting alternative to the forced cycle by means of a heat exchanger, which in turn converts the incident solar radiation into greenhouse-effect heat and thus assembles it into the box. Its remarkable efficiency is combined with the simplicity of construction, self-operation, and the absence of moving parts. systems. The collector consists of copper tube with dimension of 6000 mm length, 12 mm diameter and 1 mm thickness as shown in figure (1). The pipe of collector is made of the shape of helical coil - six lopes with the outer diameter 200 mm and the pitch 50 mm. The bar collector is then put in glasses box with dimension (250 mm * 250 mm *500 mm) with a thickness of 10 mm. The storage tank is made of stainless steel with dimension (300 mm *300 mm *500 mm). The distance between the part of the solar collector and the storage tank is (1500 mm), also a double coil bar type solar collector is used with the same dimension of one coil, as shown figure (2).



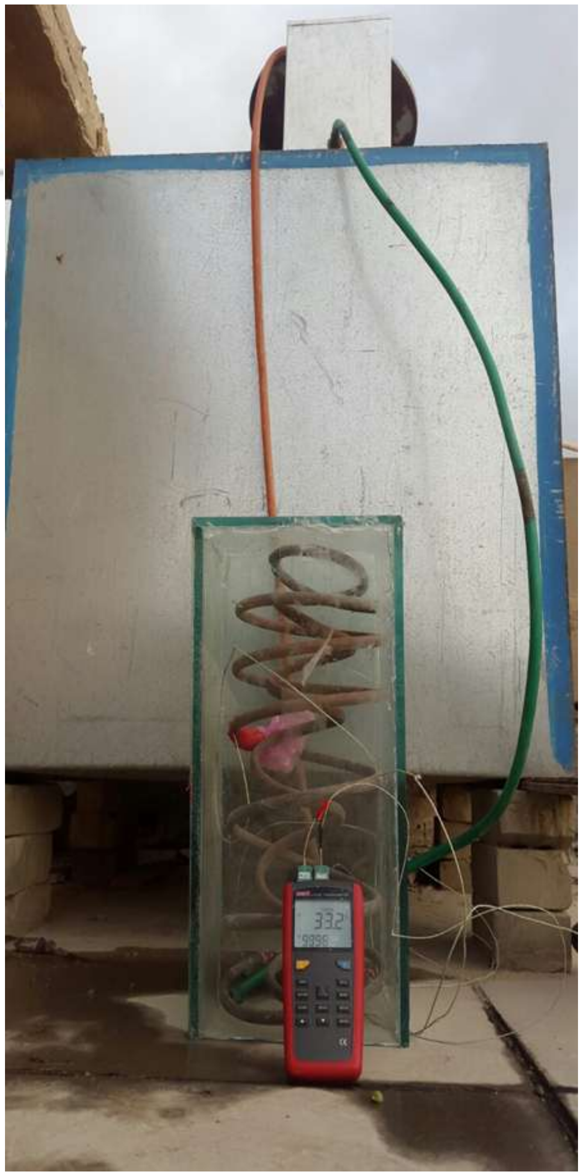


Figure 1. Schematic of one coil bar type solar collector

Figure 2. Double coil bar type solar collector

RESULTS AND DISCUSSION

Figure 3 shows the relationship of the various temperature readings. The temperature of bar-type collector reaches a peak at 1.00 pm because it has a vertical shape, and the sunlight surrounds the tube, therefore making the peak temperature premature with the movement of the sun. Figure 4 demonstrations the difference between the single and double lope, where the inlet temperature increases slightly during the day and follows a nearly straight line, and then the inlet temperature with double lope coil increases about 8% than single lope.

Figure 5 illustrates that the outlet temperature rises significantly until it peaks at 1.00 pm. The outlet temperature with double lope coil increases about 1.25% than single lope because the exit temperature depends on the efficiency of the collector and the difference in the density between the hottest column of fluid leaving the collector, which tends to rise. The increased heat absorption from sunlight is due to an increase in the surface area of the double-coil complex.

Figure 6 displays that the peak of average hot water temperature of 70ºC wis registered. The collector efficiency increase slightly until 1.00 pm and thereafter it increases sharply and peaks at 95% at 4.00 pm. This may be due to the fact that the temperature of water approaching the inlet of the bar-type collector has increased slightly due to convection heat transfer in a storage tank compared through the level of the solar complex, which has an efficiency of 0.604 and an area of 0.721 m^2 [4], which is close to the size of our complex, but the impact of the new design has an efficiency of 0.841. Thus, its efficiency is 40% more than a conventional flat plate collector, based on the absorber area, which encourages the use of this type.

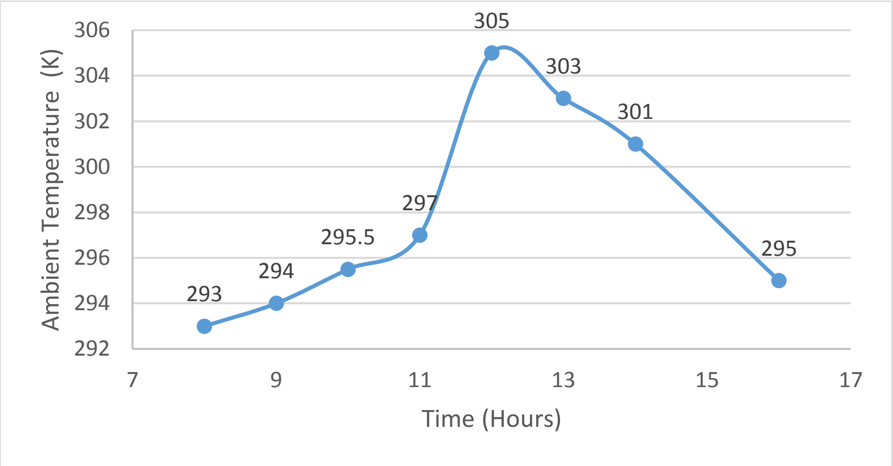


Figure 3. Change of the ambient temperature with time for the single and double lope coil

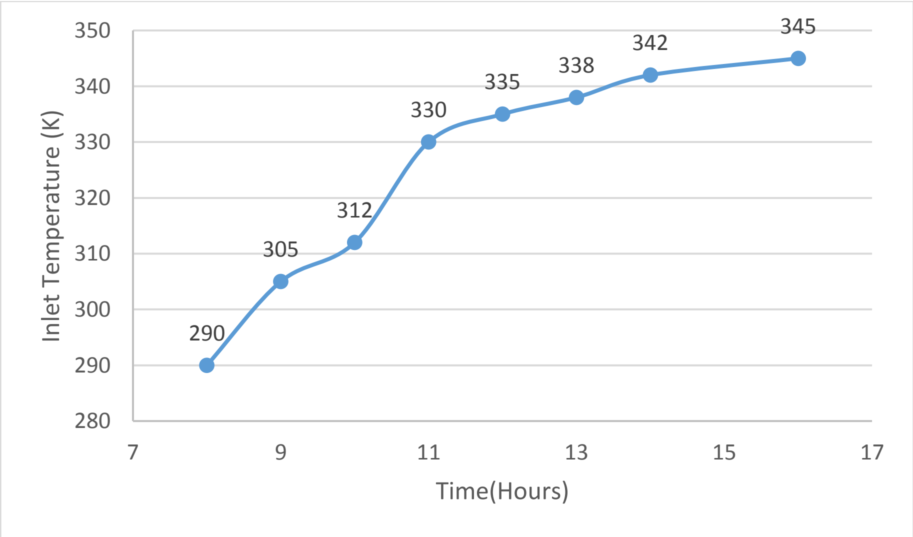
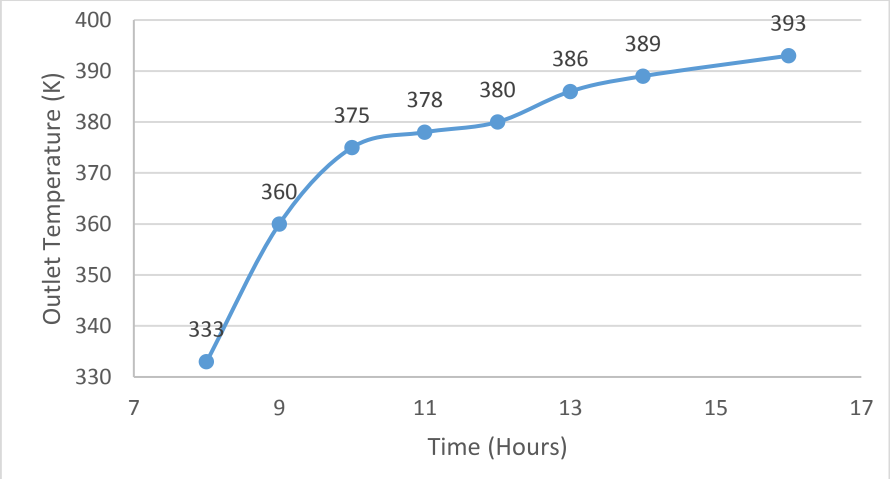
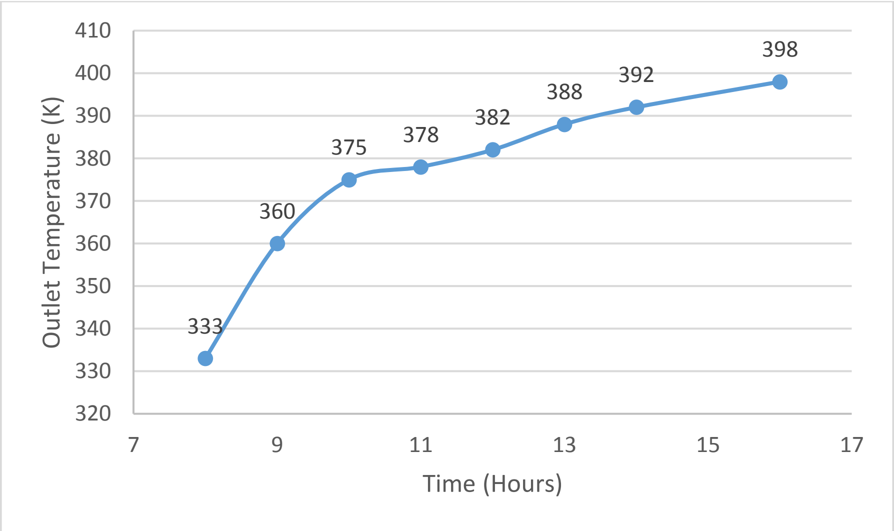


Figure 4. Change the inlet temperature with time for single lope coil and double lope coil

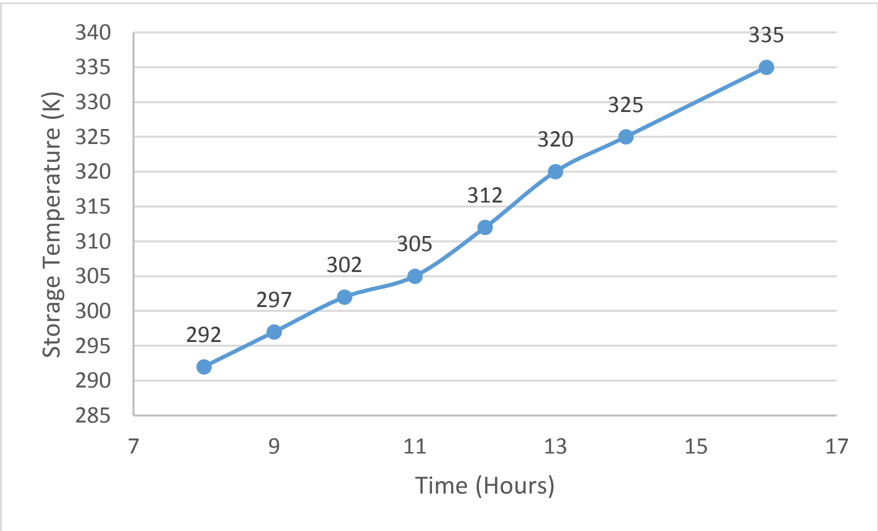


a- Single lope coil

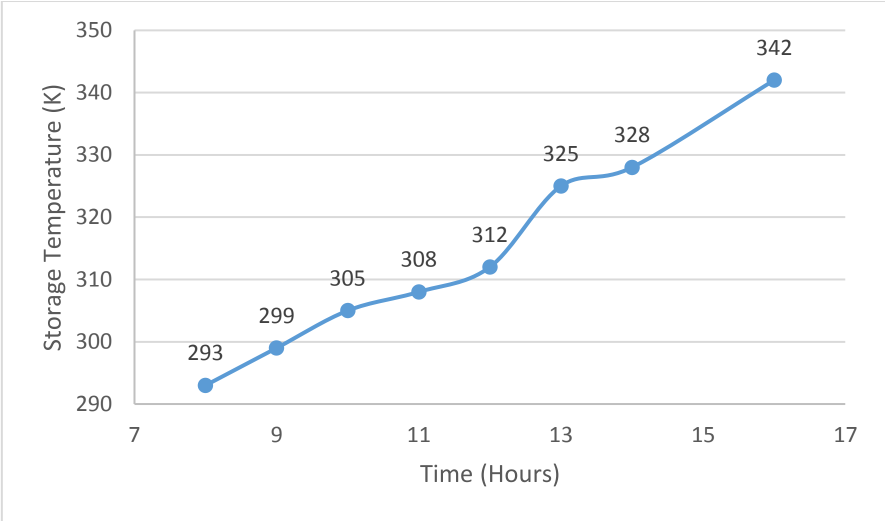


b- Double lope coil

Figure 5. Change of the outlet temperature with time



a- Single lope coil



b- Double lope coil

Figure 6. Change of the storage temperature with time

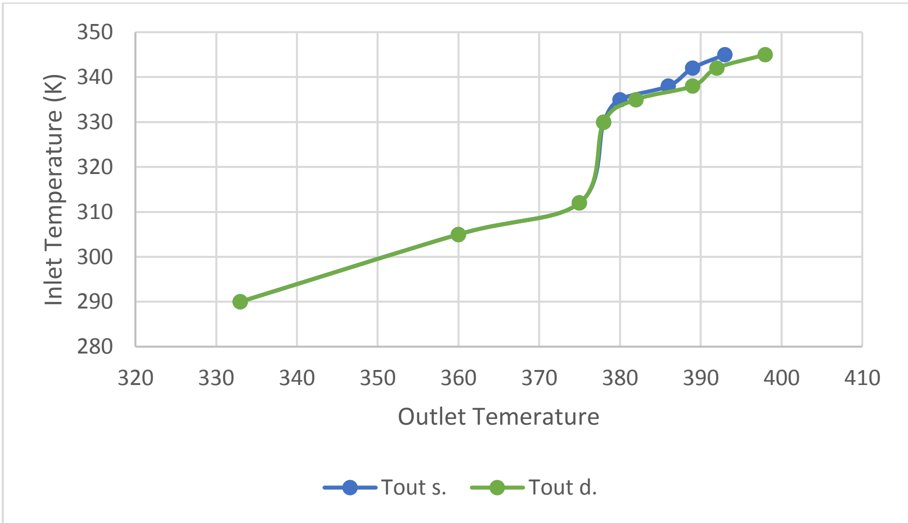


Figure 7. Change of the outlet temperature from Single and Double loop of Solar Collector

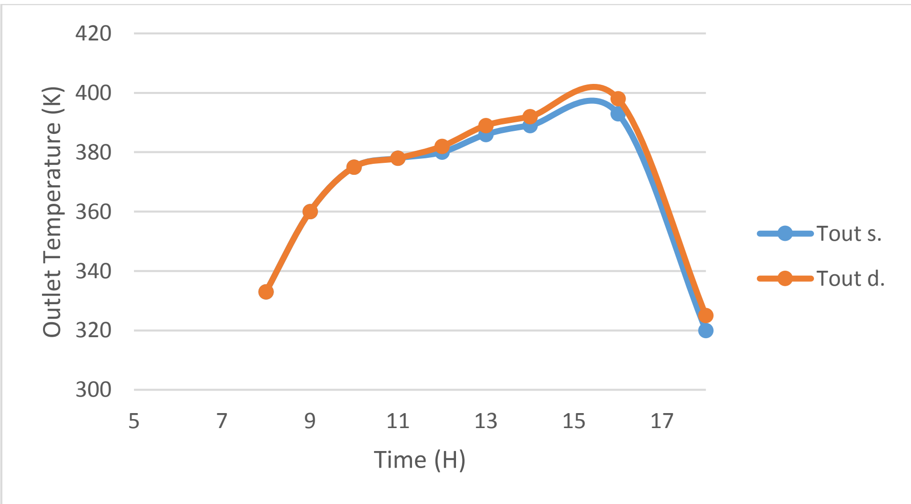


Figure 8. Change of the outlet temperature with time from Single and Double loop of Solar Collector

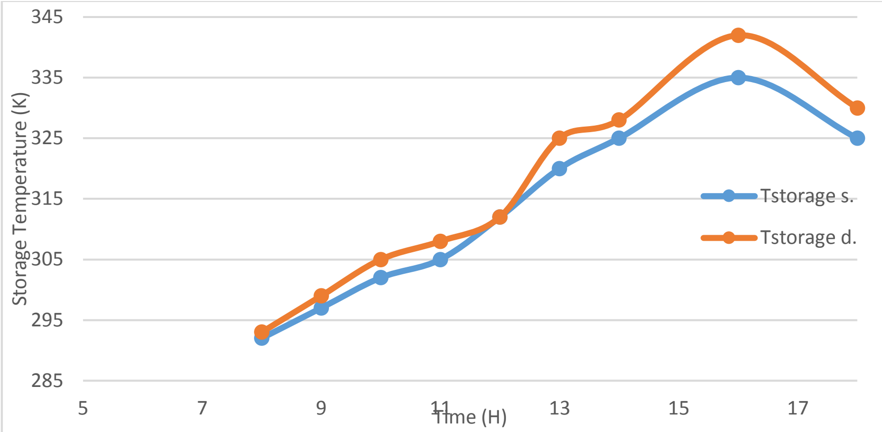


Figure 9. Change of the storage temperature with time from Single and Double loop of Solar Collector

CONCLUSION

The plan of this work was based on improving the thermal efficiency of solar collectors by means of the new proposal in terms of ease of manufacture and their cost-effectiveness and high thermal efficiency, which increase the use of solar energy, as a solution to the energy crisis. To help collector -. An uncommonly fixed double collector solar heating water has been proposed with a maximum solar concentration rate of 1.9 suns, the advantages are the data collected showed that the prototype achieved a thermal efficiency of 75.14%. The results manifested the enhancement of the performance of the new design about 40% more than conventional one. Therefore, the new type of solar bar - type collector can be used instead of the typical solar collector.

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