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# The impact of a double glassed flat plate solar water heater collector performance

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***ABSTRACT—*** *The present work proposes a design for solar thermal collectors and experimental setup procedure to evaluate the performance of double glazed solar flat plate water heater. Copper plate of 1.75 x 1m2 size was employed as absorber plates which is designed and fabricated with different geometries of absorber flat plates and v-grooved. Two glass plates of similar size are used to protect the absorber plate from heat loss to atmosphere. Performance of double glazed solar water heater for various geometries and mass flow rate (0.0041, 0.0083, 0.0125 kg/s) are performed under climatic of Kirkuk city along three months (April, May and June 2018). The heat gain of a flat plate solar collector is increased as increase in water flow rate with time along light day. Highest absorber plate temperature has been recorded with time along light day as compared to other two plate collectors. A best heat gain and thermal efficiency are observed for the double glazed flat absorber plate then the v-grooved plate and finally the square pulse plates.*
***KEYWORDS****— Double glazed solar water heater, flat plate, copper plate, v-grooved .*

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## I. INTRODUCTION

A special kind of heat exchanger is a flat plate solar collector that converts the solar energy to thermal energy by using the liquids inside tubes for many industrial and domestic applications. It is widely used for supplying thermal energy at moderate temperatures. The common application of the flat plate collectors are mostly found in domestic hot water and space heating, industrial processes, vapour absorption refrigeration and air conditioning system. Therefore, due to their various applications, there is continuing endeavor of a designer to determine thermal performance of flat plate solar collectors.

The solar collector optimal design and performance of flat plate parameters studied by Farahat and Sarhaddi [1]. The evaluating of optical and thermal performance by detailed of energy and exergy analysis has been conducted. The solar collector dimensions, absorber plate area, mass flow rate, pipe's diameter, overall loss coefficient, fluid temperature inlet and outlet were considered as variables. The solar water heating modeling installation for domestic is performed by Zehib and Chaker [2]. It was consists of a solar flat plate collector, a water storage tank, an auxiliary energy source and radiators. The accurately of thermo syphon flow rate and consequently the stratification degree of the tank on the water heater system performances. It was observed that the analysis of nodes can be used in the gain energy.

Number of researchers [3- 4] have concentrated on the development of effective design methods for solar collectors. For their analysis the cross sectional area of the absorber plate has been constant. However, the collector receives energy from the sun that is absorbed by the plate and is then transferred to the fluid. On this basis, energy transferred increases in the direction of flow energy in a plate. It is well known fact that for effective design, the profile shape of the absorber plate increases the collector performance.

Abdul Majeed and Sulaiman [5] were evaluated the increase of the output temperature of the water flowing inside an absorber of flat plate solar water heater, here concentrating material had been used. It was influenced the improvement in the flat plate solar water heater thermal efficiency by increasing the water temperature along the absorber pipe length. Kalogirou [6] studied an analysis of the environmental problems related to the use of conventional sources of energy and the benefits offered by renewable energy systems. The various types collectors including flat plate, compound parabolic, evacuated tube, Fresnel lens, parabolic trough, parabolic dish and heliostat field collectors were followed by an optical, thermal and thermodynamic analysis of the collectors and a description of the methods used to evaluate their performance. The thermal performance of the solar collector was determined by obtaining values of instantaneous efficiency for different combination of incident radiation ambient temperature and inlet fluid temperature. Kundu [7] have determined the performance and optimization of several profile shapes namely, rectangular, trapezoidal and rectangular profile with a step change in local thickness (RPSLT). The result indicates that there is optimum fin efficiency of trapezoidal profile for constant plate volume. Chong [8] performed study of solar water heater using stationary V -trough collector. The result shown was cost effective cum easy fabricated v-trough solar collector can improve the overall performance of the solar water heater.

Ihaddadene and Ihaddadene [9] performed the effect of distance between double glazings on the performance of a solar thermal collector. Experiments were carried out on an active solar energy demonstration system. The results show that the efficiency of double glazing solar collector decreases with increasing the distance separating the two glasses. Duffie and Beckman [10] performed annual simulation to monitor the thermal performance of a direct solar domestic water heating system operated under several controlled strategies. According to the authors higher flow rate leads to higher collector efficiency factor. However, it also leads to higher mixing tank and therefore, a reduction in the overall solar water heating system efficiency. Jaisankar and Radhakrishnan [11] have performed experimental investigation of heat transfer, friction factor and theoretical performance of thermosyphon solar water heater system with helical twisted tape of various twist ratios has been performed and presented. The overall thermal performance of twisted tape collector is found to increase with increase in solar intensity. Kajavali and Sivaraman [12] have performed an analysis of single tube and a newly designed modified absorber in a parabolic trough collector. The solar energy recovery efficiency of the modified absorber was found to be higher than the single tube in the form of increased water temperature. Sae-jung and Krittayanawach [13] have determined the mathematical model and the experimental study for prediction of the temperature of hot water produced from thermosyphon solar water heater. Results are presented of storage temperature, collector temperature and thermal efficiency of the solar water heater.

Visa and Duta [14] investigated a new flat plate solar thermal collector with isosceles trapeze shape was developed and stepwise optimised focussing on the insulation the bonding between the tubes and the absorber plate. The results show that the improved contact between the tubes and the absorber plate has a significant effect on the experimental conversion efficiency, as also the tubes with larger diameters have. A self-cleaning coating applied on the outer side of the glazing and multi-coloured absorber plate is formulated and tested. Eight types of solar thermal collectors were tested and optimized. Beikircher and Möckl [15] investigated advanced insulation methods for flat plate collectors. The collector front losses have been reduced by transparent insulation materials, the rear losses by an integrated vacuum super insulation (VSI). Four front side insulations have been developed and investigated. Facão [16] determined the thermal performance of flat-plate solar collectors with riser and header arrangements. A more uniform flow distribution leads to a homogenous temperature distribution which gives higher collector efficiency. The Z distribution usually has better performance when compared to Π distribution. The design of the manifold influences the observed flow distribution. To optimize the manifold design, a correlation model was developed, based on correlations for minor pressure losses. Furthermore, the flow in this optimized geometry was simulated in 3D using the computational fluid dynamics (CFD) software code in order to confirm the results of the correlation based model. A new experimental low-intrusive technique was used to measure the flow distribution in an existing solar collector, validating the simulation results. The flow inside the absorber tubes is laminar; the major pressure loss inside riser tubes was measured using a high accuracy differential pressure transmitter, which then permits the indirect estimation of the mean velocity inside the tubes. It was the first time that this experimental methodology has been applied to analyze the flow distribution in solar collectors. The influence of the total water flow rate was analyzed. For a good flow distribution it was concluded that the outlet header manifold should have a higher diameter compared to the inlet header diameter. Usually commercialized solar collectors have the headers with same diameter.

The aim of this study is to investigate the performance of double glazed flat plate solar water heater subjected to various absorber plate geometries (flat type and v-grooved) at different mass flow rate.

## II. EXPERIMENTAL SETUP

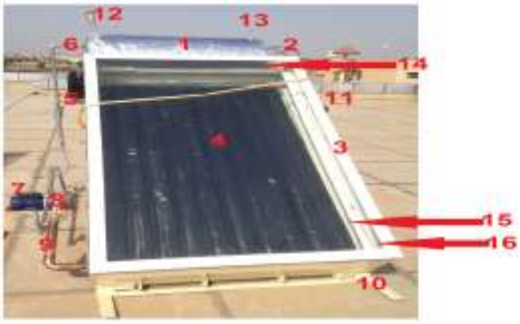
In order to study the performance of the solar collector , the design and manufacture of the collector is inclined to the horizontal at an angle (32.5 °) and dimensions of (1.75 x1)m . It consists of three main parts: the aluminum absorbing plate, copper pipes and glass cover. The small pipes shall be welded on the main distributor pipe from top to bottom to ensure an exemplary flow of water to plate (flat , v-corrugated)

The plate has been painted by dark black to coat that area is not shiny absorbent black and not to get lost in the thermal power and also to prevent the reflection of solar radiation. Two layers of glass cover are placed at the top of the solar collector with a thickness of 4 mm to prevent or reduce thermal loss]8]. The distance between the outer and inner glass is 5 cm. used heat sensors were used to measure the temperature of the solar collector The tests were conducted on the solar collector using three different values of the volumetric flow of water (0.25, 0, 5, 1.0) L / min

As an initial preparation, the Arduino drive readings are recorded at a uniform from 9.00 am to 3.00 pm. Experiments were conducted on( flat plate, v-corrugated) and using three different values of the volumetric flow of water (0.25, 0. 5, 1.0) L / min and the data's were collected in the Arduino drive. The thermal performance of double glazed solar water heater was evaluated. The specification of device illustrated in table (1) and photograph of the experimental setup has been shown in Figure (1).

**Table (1):** Specification of solar collector

| | |
|---|---|
| 1 | water tank |
| 2 | The flexible pipe to exit the water |
| 3 | Plastic frame |
| 4 | Flat plat |
| 5 | The water withdrawal tube from the tank |
| 6 | The tube returns excess water to the tank |
| 7 | Water Recycling Pump |
| 8 | Water flow meter |
| 9 | The entry point of the pipe distributes water to the pipes |
| 10 | The iron base bearing the device |
| 11 | Electric motor |
| 12 | Valve safety valve |
| 13 | Water supply point for tank |
| 14 | Aluminum interior wall |
| 15 | Inner glass edge |
| 16 | Outer glass edge |




*A.* Collectors Dimension

Dimensions of collector is set by using the perfect parameters for flat plate collector refers to other investigation and manual, Ilustrated in table (2).

**Table (2):** Dimensions of used collector

| | |
|---|---|
| Area collector | (1.75x1) $m^2$ |
| Angle of collector | 32.5° |
| Number of tube | 8 tube |
| Length of Header | 1.50 m |
| Reflectivity of collector | 0.85 |
| Absorptivity of plat (α) | 1 |
| Tube material | Copper |
| Diameter of tube | 12.75 mm |
| Diameter of Header | 38.1 mm |

*B.* Equations

Total radiation can be estimated form the eq
ution (1)[9]

$$ID_{total} = I\,diffuse + ID \qquad (1)$$

- heat Removal Factors (FR)

Heat removal factor can be considered as the ratio of the heat actually delivered to that delivered if the collector plate were at uniform temperature equal to that of the entering fluid. [10]

$$F_R = \frac{m^{\circ}CP}{A_c U_L}\left[1 - exp\left(\frac{-AcF'U_L}{m^{\circ}cp}\right)\right] \text{ ------------(2)}$$

- Heat Loss coefficient (UL)

UL is the overall heat transfer coefficient from the absorber plate to the ambient air. It is a complicated function of the collector construction and its operating conditions[11]

$$U_t = \left\{\frac{N}{\frac{C}{T_{pm}}\left[\frac{T_{pm}-T_a}{N+O}\right]^{e}} + \frac{1}{h_w}\right\}^{-1} + \frac{\sigma(T_{pm}+T_a)(T_{pm}{}^2+T_{pm}{}^2)}{(\varepsilon_p+0.00591 N h_w)^{-1} + \frac{2N+f-1+0.133\varepsilon_p}{\varepsilon_g} - N}$$

(3)

Where

C=365.9(1- 0.00883β+0.0001298× $\beta^2$ )

f = (1+0.04ha – 0.0005ha$^2$)*(1+0.091N)

$h_w$ =5.7+3.8$v_w$

- Thermal Efficiency of the Collector (η)

$$\eta_{(th)} = F_R\left(\frac{\tau\alpha}{I_t}\right) - F_R U_L\left(\frac{T_i - T_a}{I_t}\right) ----(4)$$

Useful heat collected for an air-type solar collector Useful heat collected for an water-type solar collector can be expressed as[11]:

$$Q_{U(exp)} = m^{\circ}\,cp\,(T_o - T_i) ------(5)$$

- Thermal Efficiency of the Collector (η)

It is the ratio of the Useful heat gain to the Total input energy[12].

$$\eta_{(exp)} = \frac{QU}{It\,Ac} \text{-----------------(6)}$$

*C.* Asumption of Mathematical validation:

- The collector is in a steady state .
- The headers cover only a small area of the collector and can be neglected.
- Flow through the back insulation is one dimensional.
- Temperature gradients around tubes are neglected.
- Properties of materials are independent of temperature.
- Heat flow through the cover is one dimensional”.
- No energy is absorbed by the cover.
- Temperature drop through the cover is negligible.
- Same ambient temperature exists at the front and back of the collector.”.


**Figure 2** shows the comparison between the thermal efficiency of flat plat (0.0165kg/sec)

## III. RESULTS AND DISCUSSION

Figure 2 shows the comparison between theoretical and experimental flat plate solar collector. the coefficient of thermal efficiency starts increasing with sunrise hours until it reaches the highest value at midday due to increase of intensity of the radiation falling on the solar collector at flow rate 0.0165kg/sec.

Figure 3 shows the comparison between theoretical and experimental v-corrugated plate. The coefficient of thermal efficiency starts increasing with sunrise hours until it reaches the highest value at midday due to the increasing intensity of the radiation falling on the solar collector. The reason for the surface area of v-corrugated plate is the the ability of absorbed as much solar radiation as possible on both ends and thus increase the thermal energy acquisition at flow rate 0.0165kg/sec.

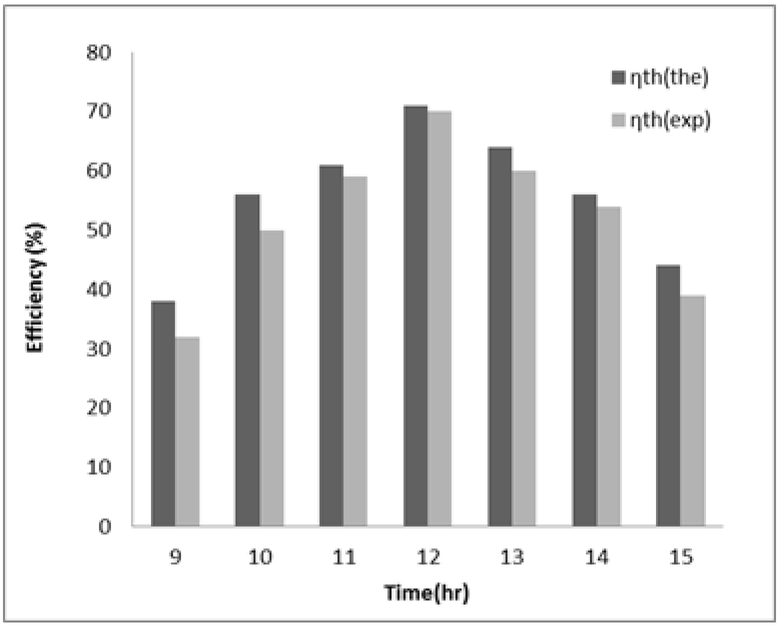



**Figure 3** shows the comparison between the thermal efficiency of v-corrugated plat (0.0165kg/sec)

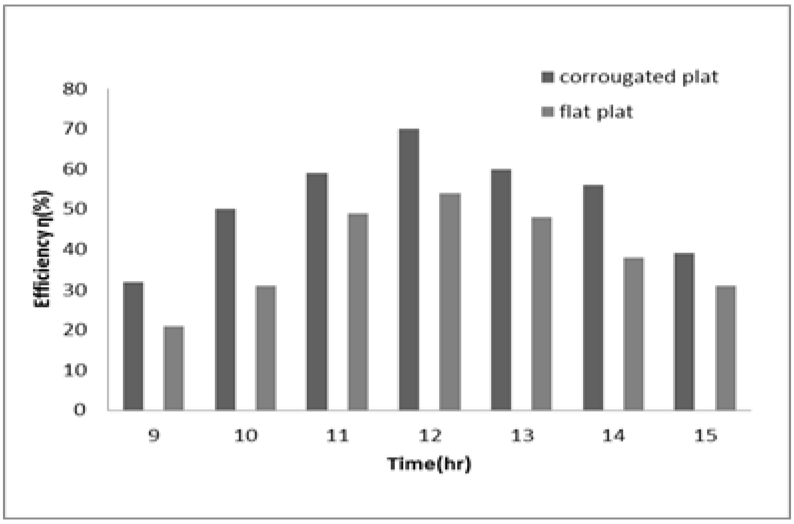



**Figure 4** shows the comparison between the thermal efficiency Experimental v- corrugated flat plat(0.0165kg/sec)

Figure 4 shows the comparison between experimental thermal efficiency flat plate and v-corrugated plate is higher efficiency from flat plat. The reason for the surface area of v-corrugated plate is the ability of absorption as much solar radiation as possible on both ends and thus increase the thermal energy acquisition at flow rate 0.0165kg/sec

Figure 5 shows the comparison between experimental thermal efficiency flat plate and solar radiation with time. The starts increasing with sunrise hours until it reaches its highest value at midday due to the increasing intensity of the radiation falling on the solar collector with increasing solar at 0.0165kg/sec.

Figure 6 shows the comparison between heat removal coefficient flat plat and v-corrugated plat is higher efficiency from flat plat, The starts increasing with sunrise hours until it reaches its highest value at midday due to the increasing intensity of the radiation falling on the solar collector with increasing solar at 0.0165kg/sec.

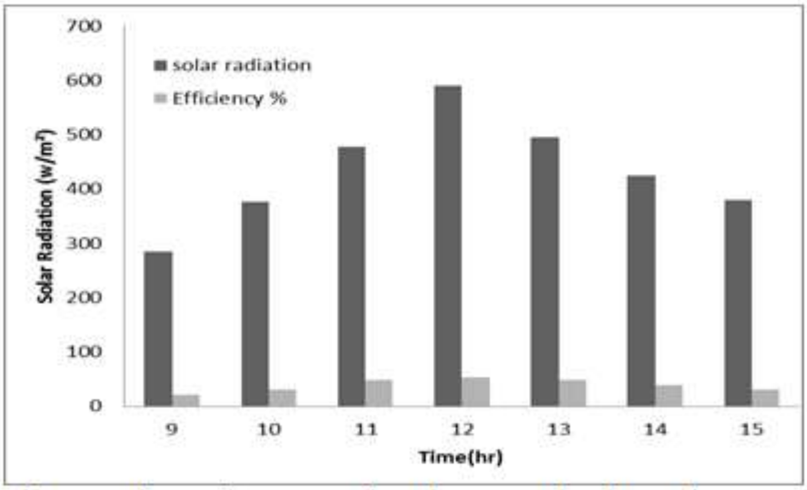



**Figure 3** shows the comparison between the thermal efficiency of flat plat (0.0165kg/sec)

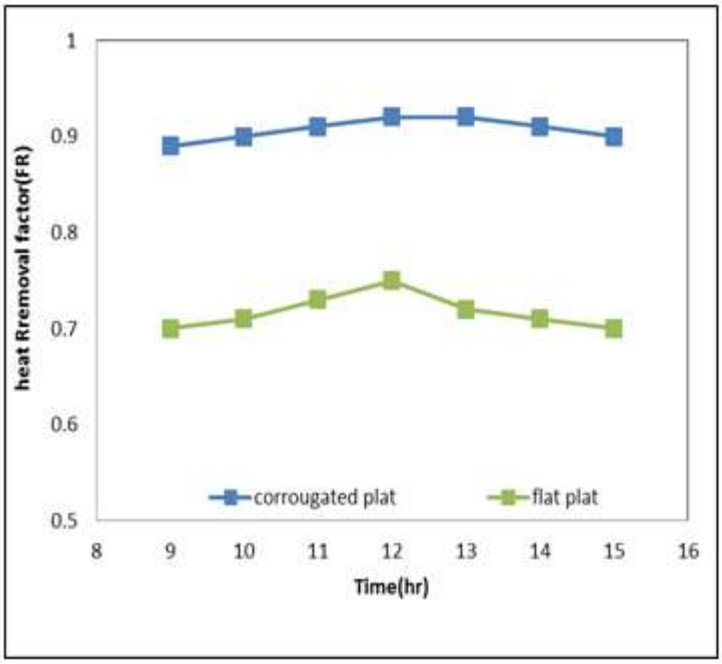



**Figure 6** shows comparison between heat removal coefficient v- corrugated and flat plate (0.0041 kg /sec).

Figure 7 shows the comparison between experimental thermal efficiency flat plat and v-corrugated plat with time , the starts increasing with sunrise hours until it reaches its highest value at midday due to the increasing intensity of the radiation falling on the solar complex with increasing solar at 0.0041 kg /sec.

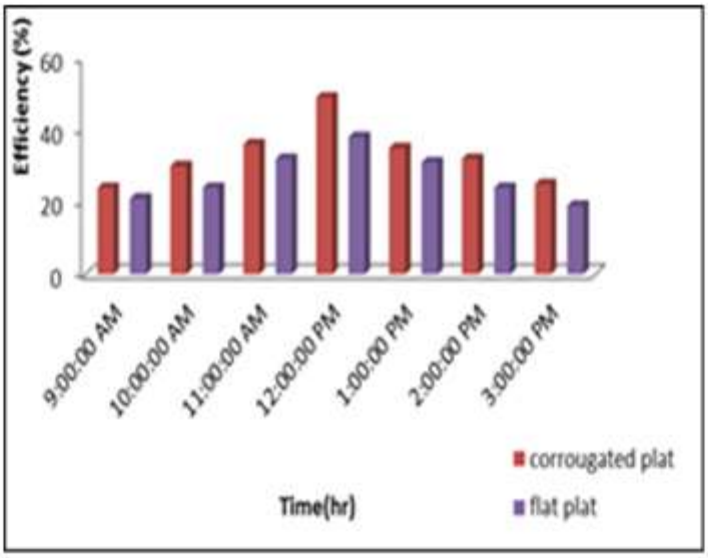



**Figure** 7 shows the comparison between the thermal efficiency v- corrugate and flat plate ( 0.0041 kg /sec).

## IV. CONCLUSION

Experiments were performed with double glazed solar water heater for the different geometric absorber plates subjected to uniform mass flow rate to find the performance of the set-up. The following conclusions were obtained from this study:

- The v-corrugate absorber geometry temperature is higher than the flat geometries during experimentation.
- Thermal efficiency is higher for v-corrgate absorber geometries is 70% and flat plat is 54% at flow rate 0.001658 kg /sec .
- Heat gained by the water in v-groove absorber geometry is comparatively higher than flat geometries.
- Thermal efficiency and heat gained by the water increases with increase in mass flow rate.

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