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STUDY THE EFFECT OF USING TRIANGULAR CYLINDER BESIDES V-CORRUGATED PLATE SOLAR COLLECTOR ON HEAT TRANSFER EXPERIMENTALLY

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1. Abstract

The experimental work in this paper compares, under the same environmental conditions and at four flow conditions (2,3,5,7) Lpm, the performance of a solar collector with triangular tubes placed next to grooves of a V-corrugated absorber plate and a solar collector with circular tubes placed on a flat plate. The outcomes were

1-Because the surface area of the corrugated plate V with grooves is greater than the surface area of the flat plate, and as a result, the amount of solar radiation falling on it is greater than the amount of solar radiation falling on the flat plate, so the solar collector with triangular tubes placed beside grooves of V-corrugated absorber plate is more efficient in thermal conductivity than the solar collector with circular tubes placed on the flat plate. Additionally, the triangle-shaped tubes have a larger surface area of contact with the V-corrugated absorber plate than the circular tubes do with the flat plate. This enhances the heat transfer from the V-corrugated plate to the triangle-shaped tubes, which increases the heating of the water used.

2- Increasing the flow water in the pipes of the both solar collectors, increases the volume of heat exchange between the pipes and the water inside it, because in cases of high-water flow, the number of times the water passes inside the solar collector is greater, which increases the water absorption of heat that is generated from sunlight falling on the solar collector. which increases the efficiency of the solar collector. As it was used in this research four water flows, (2,3,5,7) l/min respectively.

Keyword.: Solar Collector, V- corrugated absorber plate, triangular tubes, circular tubes, heat transfer, thermal conductivity, grooves.

2. Introduction

The FPSC is one of the simplest solar application designs and installations, and because of its high efficiency relative to its low initial cost and high flexibility for building and development, it has received a lot of study interest. Flat plate solar collectors are used for low temperature heating applications. The household solar water heater is one of its typical applications. These collectors require less maintenance, are more dependable, and are simpler to use. These collectors are frequently used all across the world. This collector can also be used to heat swimming pools, dry agricultural equipment, and heat rooms.

Muhammad, et al. [1]uses the energy of the solar collector by building a new V-shaped

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solar collector with triangular channels, various operational settings, and a mass flow rate and solar heat flow for the home's hot water supply. The solar efficiency was calculated analytically and compared to the test results by taking into account the effect of the water temperature. This study also includes theoretical and practical analyses of the thermal performance of the proposed absorber and the influence of heat exchange. Due to the simultaneous exposure of all three sides of the triangular channels employed in this work to solar radiation, more heat energy may be collected, leading to higher temperatures and better collector performance.

The researchers Mangesh Thakare * and M.V.Khot[2] The many tube shapes utilized in solar flat plate collectors include round, triangular, square, and oval tubes. The primary objective of this work was to enhance the performance of solar flat plate collectors. Use molded tubes of different forms to conduct experiments and make predictions in order to increase the effectiveness of flat panel solar collectors. The various figures were obtained by research employing tubes of various shapes, such as square, triangular, circular, and oval tubes. The triangular tube has the highest efficiency when compared to other tubes, according to the efficiency table. Additionally, it has been discovered that efficiency is strongly connected to flow rate and fluctuates with solar intensity.

Ganesh K. Badgujar, et al. [3] used a variety of absorber tube geometries, including square, circular, semicircular, triangular, oval, and rectangular tubes, to undertake a performance investigation on the flat plate collector. The effectiveness of the solar collector was directly proportional to the flow rate of the fluid utilized, and the triangle tube that was employed had the maximum heat transfer efficiency when compared to the other tubes used. Additionally, by modifying the absorption using a material, the efficiency of the solar collector could be improved. By minimizing the area of FPC while increasing tube diameter and raiser length, high conductivity further enhances collector performance. This research suggests that an increase in the contact surface area between the flow tube and the liquid boosts the flat plate solar collector's efficiency.

Researchers H.Ambarita, R.E.T. Siregar, AD Ronowikarto, E.Y. Setyawan [4] CFD was utilized to analyze how the flat plate solar collector's efficiency was impacted by the inclination angle. This investigation came to the conclusion that the tilt angle significantly affects the performance of the collector and that the average heat transfer coefficient increases as the tilt angle increases. This suggests that extreme solar panel inclination is not recommended.

Researchers conducted Doctor. Nilesh. P. Salunke and J.S. Khatik,[5] research on the most recent developments in flat plate collector performance improvement, Through this analysis, researchers have discovered that papers are being produced concerning the design of risers, including switching from a circular to a triangular shape to improve efficiency. Researchers have studied how flat panel displays and glass materials function as solar panel efficiency increases. Tracking techniques have been discussed in a number of articles as a means of improving the efficiency of flat plate collectors. With the development of absorbent plates that can change shape and produce dents, flat plate collector efficiency will rise. Overall, several researchers are attempting to modify particular flat plate collector designs to improve the functionality of these apparatuses.

Sunil V. Yeole et al [6] The influence of different riser tube forms on flat plate solar water heater efficiency was investigated by comparing square and triangular tubes to circular tubes to discover which of the tubes is more efficient in transferring heat. According to the findings, riser tubes that are square or triangular perform roughly 8% to 10% more efficiently than tubes that are circular.

Shuilian Li et, al.[7] compared the performance of a solar air collector with a base flat-plate collector, a sinusoidal corrugated plate, a protrusion plate, and a sinusoidal corrugated and protrusion plate. where the results were as follows, increasing the mass flow rate increases the efficiency of the solar collector. The roughness of the collector's absorbing surface increases the efficiency of the solar collector because it provides a larger surface area for heat exchange. Instead of leaving the absorbent plate flat, this involves changing its shape to increase the solar collector's efficiency.

Researchers Basavanna S and K S Shashishekar [8] employed computational fluid dynamics (CFD) to simulate the solar collector and better understand the heat transfer properties of the triangular absorber tube of a solar flat plate collector. There is good agreement between the observed and calculated findings when the temperatures suggested by the CFD model are compared to the numerical values generated using the experimentally obtained temperatures. A triangular tube form raises the temperature at the exit due to improved contact between the tube and plate. The temperature at the end of the plate is higher due to the tube's larger surface area of contact with the plate in this configuration, which results in more heat absorption and hence improved performance of the collector.

Researcher Mojtaba Moravej[9] a standard for evaluating collectors under hot, dry conditions and selecting and presenting the best results was undertaken to test the functionality of a triangular-geometry solar flat plate collector. The study's results show that efficiency increases with flow rate and becomes more noticeable. Additionally, the amount of radiation and the collector's effectiveness rise from morning until noon. Late in the afternoon, however, the amount of radiation falls and the temperature difference between the incident and ambient temperatures increases, which lowers the collector's efficiency.

Ruchi Shukla et, al.[10] analysed several studies on this system (SWH) to increase solar water heating efficiency, the adjustments made by past research on the system's various components, such as the collector, storage tank, and heat exchanger, and performed research on contemporary advancements in solar water heating systems. Recently, it has been possible to use solar energy as a dependable heat source for applications requiring hot water delivery in sun-stressed areas using heat pump-based solar collector technology. The primary goal of the research was to increase the efficiency of different SWH system components. These advancements offer an additional way to increase market penetration while providing substantial economic and environmental advantages.

Yan Jiang et, al.[11] It was mathematically depicted to compare the performance of a triangle solar air collector (TSAC) and a flat plate solar air collector (FSAC). In this work, a unique triangular solar air collector with a tilting transparent cover plate was compared to its performance. In this study, a triangle solar air collector (TSAC) with a sloping transparent top plate and the same south wall coverage and a flat plate solar air collector (FSAC) with the same perforated corrugated absorber were both used (PCA). operating parameters. The results of various analyses were compared. The results suggest that: 60 The efficiency of the thermal TSAC is to increase solar radiation. The collected power per unit of the TSAC South Wall Cover Area (CPUWA) with transparent cover plate (TSAC60) is 100–130 W/m2 greater than the FSAC. Along with it, it stimulates its growth. This is due to the transparent cover plate's large surface area, which raises the TSAC60's solar heat fraction and heat absorption capacity during the heating season by 11.7% and 24.3%, respectively. As a result, TSAC can absorb more solar energy, which improves the effectiveness of heat collection.

Researchers Vishal G. Shelke, Chinmay V. Patil[12] For this experiment, a circular tube with a 12.7 mm diameter was used to examine the impact of different tube shapes for flat plate solar water heater. The ANSYS CFD FLUENT program was used to carry out the numerical analysis. When compared to circular geometries, the results of this study show that elliptical tubes offer the maximum water exit temperature for a given heat flow and entrance temperature.

Research Mr. Sunil V. Yeole et, al [13] has been carried out by academics. This study aims to investigate the performance of a flat plate collector in relation to various riser tube configurations. The effectiveness of flat plate solar water heaters is examined using CFD modelling to determine the impact of different riser tube shapes. According to CFD simulations, when the same operating conditions were used, square and triangular riser tubes had the highest water exit temperatures. When square and triangular riser tubes are utilized, there is a greater surface area that comes into contact with the plate, which may allow for greater heat absorption and improved collector performance.The numerical values produced from the experimentally recorded temperatures are compared to the temperatures indicated by the CFD study, and it is found that the calculated and observed findings are pretty similar. Triangular and square tube arrangements raise the exit temperature by around 20 C compared to a circular tube design because of the intense surface contact between the tubes and absorber plate. Square and triangular riser tube designs provide higher water outlet temperatures under the same working circumstances. Efficiency of an absorption tube with a square or triangular shape is 8–10% higher than that of a basic circular one.

The purpose of this study is to compare the efficiency of flat plate and V-corrugated plate solar collectors in heating used water.

3. Experimental apparatus

- **Flat plate Solar collector**

The FPSC stands out for its simple design and construction. The essential parts are the casing, insulator, clear cover, header and riser tubes, and energy absorber plate. In addition to providing stability, the enclosure protects the insulation and absorber from the impacts of the environment. The methods outlined below can be used to build an FPSC that matches the dimensions and details of the flat plate solar collector displayed in table 1 as well as the solar collector depicted in figure 1. The riser tubes, which are comprised of four circular copper tubes with an inner diameter of 11.5 mm, an outer diameter of 12.5 mm, and a length of 0.8 m, are assembled first. They are attached in a parallel configuration to the absorber flat plate, with a 100 mm space between the centre line and the other line. To reduce conductivity loss, the absorber panel was placed in an aluminium container with 5 cm of glass wool insulation between it and the bottom and sides. Copper tubes with 17.5 mm inner and 18.5 mm outer diameters serve as the lower and top headers, respectively. Insulating the collector's bottom and edges is essential for minimizing heat loss through conduction. So, a good insulator may aid in preventing any heat loss. Glass wool was chosen as the best material for this application due to its low heat conductivity of 0.04 W/m, resistance to weathering and condensation, and dimensional and chemical stability at high temperatures. Two layers, each approximately 2.5 cm thick, lined the bottom and sides of the casing box. The dimensions of the aluminium absorber plate were as follows: L=1 m, W=0.5 m, and a thickness of 0.5 mm. It had a matt black paint covering with absorption properties to increase the quantity of solar energy that the plate is able to collect and to decrease the loss of long wavelength light from the absorbing surface (0.92-0.98). In order to lower convection losses from the flat plate solar collector's top, two pieces of standard window glass, measuring 4 mm thick, were used to seal the container shut. The sheet has the excellent property of transmitting about 90% of short-wave radiation incidence and preventing long-wave radiation emitted from the heat absorber plate from escaping into the atmosphere. The distance between the plate and the glass1 is 4.5 cm, while the distance between the two glasses is 2 cm. The outside dimensions of the solar collector are 60 mm in width and 110 mm in length. Additionally, the solar collector's aluminium stand is 45 degrees inclined to face south. Figure1: Flat plate solar collector.

(a). Glass wool insulation (b). Circular copper tubes

(c). Absorber flat plate in container (d). Flat plate solar collector

Figure1: Flat plate solar collector.

Table-1: The specification of flat plate solar collector

Component	Dimension	Remark
Collector	1.10m*0.60m*0.15m	
Absorber plate	1.00m*0.50m*0.0005m	Material: black painted Aluminium
Riser tubes	The inner diameter is 0.0115m, The outer diameter is 0.0125m, The length is 0.8m The tube centre to centre distance 10cm	Material: copper Number of tubes: four Type of tubes: circular riser tubes
Header pipes	Inner diameter 17.5 mm, outer diameter 18.5 mm, length 0.5m	Material: copper Number of tubes: two
Bottom insulation	0.050 m thick	Material: glass wool

Edges insulation	0.050 m thick	Material: glass wool
Cover window Glass	1.00m*0.50m*0.004m	Material: clear window glass Number of covers: two
Tilt angle	45°	

- **V-corrugated plate Solar collector**

In order to maintain the accuracy of the comparison between the triangular riser tubes and the circular riser tubes, they must be equal in dimensions with different shapes, so the following calculation was performed:

perimeter of a circle= π*d = 3.14 * 0.0125m=0.03925m

perimeter of the triangle is equilateral = X + X + X = 0.03925m

3X = 0.03925m

X = 0.01308m

X = 13.08mm

where X is length of the side of an equilateral triangle

The V-corrugated PSC is distinctive for its straightforward design and construction. The casing, insulator, clear cover, header and riser tubes, and energy absorber plate are the components that are absolutely necessary. The enclosure offers stability in addition to shielding the insulation and absorber from environmental effects. The V-corrugated PSC seen in Figure 2 can be made using the procedures described below, and Table 2 lists the parts' measurements and specifications for the V-corrugated plate Solar collector. Making the triangular riser tubes, which consist of four copper tubes with equal sides that are placed beside the grooves of a V-corrugated plate and each measuring 0.8 meters in length, is the first phase. of the absorber plate in a parallel arrangement, where the distance between the centre line and the other is 100 mm. To reduce conductive loss, the absorber plate was placed in an aluminium box with 5 cm of glass wool insulation between the bottom and sides. Two layers, each measuring 2.5 cm, lined the casing box's bottom and sides. The lower and upper headers are copper tubes with lengths of 0.5m and inner and outer diameters of 17.5 mm and 18.5 mm, respectively. The bottom and edges of the collector must be well-insulated in order to minimize heat loss by conduction. Because of its low heat conductivity of 0.04 W/m, resistance to weathering and condensation, and dimensional and chemical stability at high temperatures, glass wool was chosen as the best material for this application. This will help to prevent any heat loss. thick. The dimensions of the aluminium absorber plate were as follows: L=1 m, W=0.5 m, and a thickness of 0.5 mm. It had a matt black paint covering with absorption properties to increase the quantity of solar energy that the plate is able to collect and to decrease the loss of long wavelength light from the absorbing surface (0.92-0.98). Two pieces of common window glass, each 4 mm thick, were utilized to seal the container, reducing convection losses from the flat plate solar collector's top. In addition to blocking long-wave radiation emitted by the heat absorber plate from escaping into the atmosphere, the sheet has the excellent property of transferring around 90% of short-wave radiation incident. The first glass is placed 4.5 cm from the plate, while the second glass is placed 2 cm apart. On the outside, the solar collector is 60 cm in width, 110 cm in length, and 15 cm in height. The solar collector's aluminium support structure is also 45° inclined southward.

(a). Glass wool insulation (b). Triangular copper tubes

(c). V-corrugated plate in container (d). V-corrugated plate solar collector

Figure 2: V-corrugated plat solar collector

Table- 2: The specification of V-corrugated plate solar collector

Component	Dimension	Remark
Collector	1.10m*0.60m*0.15m	
V-corrugated Absorber plate	1.00m*0.50m*0.0005m	Material: black painted Aluminium
Riser tubes	Triangular tubes of equal sides The length of the side of triangular tube is 13.08 mm The length of triangular tube is 0.8m	Material: copper Number of tubes: four Type of tubes: triangular riser tubes

	The triangular tube centre to triangular tube centre distance 10cm	
Header pipes	Inner diameter 17.5 mm, Outer diameter 18.5 mm, length 0.5m	Material: copper Number of tubes: two
Bottom insulation	0.050 m thick	Material: glass wool
Edges insulation	0.050 m thick	Material: glass wool
Cover window Glass	1.00m*0.50m*0.004m	Material: clear window glass Number of covers: two
Tilt angle	45˚	

4. Experimental measurements and test procedure

This study includes two solar collector systems (Flat plate Solar collector that contain the circular riser tubes placed on the absorber flat plate; V-corrugated plate Solar collector that contain triangular tubes placed beside the grooves of the V-corrugated absorber plate). In order to examine the effectiveness of the utilized solar collectors in terms of thermal conductivity and, subsequently, water heating inside the used tubes, four consecutive examples of flow (2,3,5,7) LPM over the course of four days were used. There are 19 temperature sensors spread throughout two solar collector systems, which use thermocouples wire of type K with a semi-spherical head to connect to detect the temperature distribution on various sections. The system parts where the sensors are located are as follows: There are two sensors installed at the water inlet and outlet points for the solar collector, three sensors on the absorber plate surface, two sensors on each of the two glass covers, one sensor in the water storage tank for the first solar collector, distribution of sensors to the second solar collector, and one sensor to measure the ambient temperature. these sensors are connected from the other side to the data logger device model (AT4532x) as show in figure (3) with an accuracy = ± 0.4%, accuracy = 0.1 degrees, the volumetric water flow meter is used for both collectors, as indicated in Figure 4. A type of solar energy meter model (TENMARS TM-207) with a variable range from (0 to 2000 W/m2), an accuracy of 0.1 W/m2, and an accuracy of 10 W/m2 is used to measure the energy radiation falling on the collectors (5). In Nasr City, Dhi Qar Governorate, Nasr, experimental testing of the efficiency of solar energy collectors was conducted at that site of with (31.54° N latitude and 46.12° longitude), where the angle of inclination of the two sun collectors was 45°. As illustrated in Figure (6) and for two collectors, the connection between the water tank and the solar collector was made using plastic tubes (1/2 inch in diameter) that were wrapped in glass wool for thermal insulation. The parameters of the two identical water pumps that were employed in the two solar collector systems are listed in Table 3.

Each working day involves the implementation of the subsequent process phases.

1- Every working day, 20 litres of distilled water are added to the tank.
2- Setting up the measurement equipment for this operation so that it can take the needed readings each working day.
3- Start the data logger to read and record temperatures for each temperature range (30 minutes)
4- Turn on the water pumps, open the bypass valve, and use a ball valve to adjust the water flow meter.
5- Running the solar power meter and setting it to the W/m² unit
6- This experimental activity was carried out daily for 10 hours, from 7:00 to 17:00.
7- Repeated this action for four days, and each day the water flow is different (2,3,5,7) LPM respectively.

Thermo-physical properties of the base fluid (water) [14]

The properties of water can be calculated from following equations and these equations can apply in the range0˚C ≤ 〖T〗_w ≤100˚C

Thermal conductivity

$K_w = 0{\cdot}56112 + 0{\cdot}00193T_w - 2{\cdot}60152749e^{-6T_w{}^2} - 6{\cdot}08803e^{-8T_w{}^3}$

Density

$\rho_w = 1000 \times [1 - \frac{(Tw-4)^2}{119000+1365\times T_w - 4\times T_w{}^2}]$

The Specific heat

$C_{pw} = 4217.629 - 3.20888T_w + 0.09503T_w{}^2 - 0.00132T_w{}^3 + 9.415e^{-6T_w{}^2} - 2.5479e^{-8Tw^5}$

The internal convection heat transfer coefficient of water flow (hi)in riser tube[15]

$Q_u = m\cdot C_p (T_o - T_i)$

$Q_u = hi\ A\ (T_o - T_i)$

The following equation, evaluates the Nusselt number from the common correlation of the convective heat transfer coefficient (h_i), (K_w) and, the internal riser tube diameter (d_i)

$Nu = \frac{h_i d_i}{K_w}$

Viscosity

$\mu_w = 0.00169 - 4.25263e^{-5T_w} + 4.9255e^{-7T_w{}^2} - 2.0993504e^{-9T_w{}^3}$

The area of the circular tube

$A = \pi r^2$

Water flow velocity

$U = Q/A$

Where Q thermal energy and A surface area

The area of the triangular tube

$$A = \frac{1}{2}\, X\, h$$

When X the length of the side of the triangle, h the height of the triangle

Hydronic diameter

D_h = A/P

Where A surface area and P perimeter of triangle

Reynold Number

$$Re = \frac{\rho\, U\, Dh}{\mu}$$

Where ρ Density of water, U Water flow velocity D_h Hydronic diameter and μ Viscosity

Table- 3: The specifications of centrifugal pumps

AKAD Water pump					
Q	Power	R. P. M	Electrical data		
10 – 30 L/min	0.370 kW	2850	A	V	Hz
			1.8	220	50

Fig.3 Data Logger

Fig. 4 solar power meter

Fig. 5 Volumetric water flow meter

Fig. 6 Plastic pipes (1/2 inch) covered by insulators

5. Results and discussion

5.1 Experimental results

The experimental work compares the efficiency of the solar collector with circular riser tubes placed on a flat plate with the efficiency of the solar collector that contains V-corrugated absorber plate, in terms of heat transfer (Nusselt number), and which contains four triangular riser tubes beside the grooves. The circular and triangular riser tubes are used under the same climatic conditions and have the same dimensions but different shapes.

5.2 The results of solar radiation

Using a solar power meter model (TENMARS TM-207) as shown in Figure (4), In order to compare the performance of flat plate solar collector and V-corrugated absorber plate solar collector that contain triangular riser tubes beside the grooves, the solar radiation data from the atmosphere was measured in September for ten hours each day from 7:00 to 17:00 hour, as shown in Figure (7), and for a period of four days. where it was observed that the peak of sun radiation occurred around midday, the radiation from the sun begins to rise at about 7:00 am and then gradually rises until it reaches it peak in the middle of the day at about 12:00 pm, after which it gradually begins to drop. When it reaches 4:00 pm, the solar radiation has begun to descend less sharply since the sun's disk has virtually horizontalized with respect to the solar collector. This descent began about an hour earlier. Where the greatest solar radiation is, roughly between the hours of 11:00am and 1:00pm, the solar collectors have more effective thermal conductivity. This is due to the difference in efficiency between the solar collectors used, as well as the different shapes of the absorber plates and rising tubes used in the solar collectors.

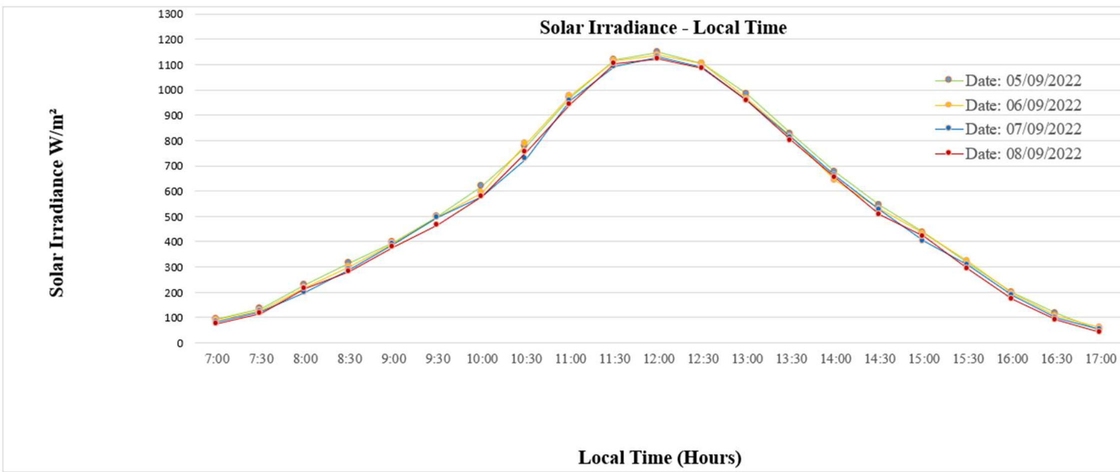

Fig.7: solar radiation for (5,6,7,8)/9/2022.

5.3 The results of outlet temperature

- **Outlet temperature comparison of the circular and triangular riser Tube**

The V-corrugated plate solar collector was found to be more efficient at heating water than the flat plate solar collector. The sunlight strikes aluminum plates inside the solar collectors, converting it into heat energy that is transmitted from the plates to the riser tubes used. The contact area between the triangular tubes and the V-corrugated absorber plates was also found to be greater. According to the results, the triangle riser tube sun collector is more efficient than the circular riser tube solar collector, which raises the temperature at which the water is heated in the triangular riser tubes. This raises the V-corrugated absorber plate solar collector's efficiency because, as shown in Figure (8) the maximum outlet temperature of the triangular riser tubes is (75C°) more than that of the circular riser tubes. As soon as the solar collectors are turned on at 7:00am, the temperature of the outflow starts to rise (with variations depending on the type of collectors employed), and it keeps rising until it reaches a stable condition between 12:30 and 15:00 hours later. The most solar radiation fell on the two solar collectors at around 12:00 pm, as indicated in figure (7), which is why the outflow water was in a steady state, The heat exchanger reached its most steady state between the hours of 13:00 and 15:00.

After reaching steady state, the solar collectors' outlet temperature begins to fall until the end of the workday at 17:00. This is because the amount of heat exchange for the water used between the solar collectors and the storage tanks takes an hour or more to reach a steady state. This is due to a progressive decrease in the amount of solar energy hitting the collectors. Additionally, the usage of highly insulated water storage tanks and pipes results in higher outlet temperatures for the water storage tanks.

- **The outlet temperature comparison for the Tt beside the grooves at flow meter (2,3,5,7 LPM)**

By contrasting the solar collector's output temperature between its triangle tubes, its V-shaped grooves, and its four varied flow rates (2, 3, 5, and 7, respectively). Figure (8) shows the results, which show that a rise in flow enhances the efficiency of the solar collector in four scenarios of flow (2,3,5,7 LPM), respectively. This is because greater flows cause more water to travel through the solar collector than other flows do, extending the time that water may absorb heat as it passes through the rising tubes and increasing the effectiveness of the solar collector. In order to absorb the most heat from the employed ascending tubes, the outlet temperature rises as soon as the solar collectors are turned on at 7:00am and stays elevated until it reaches a steady level. And as indicated in figure (7), after noon and around 12:00, when the sun's rays start to fade, the temperature starts to drop till the conclusion of the workday at 17:00. The heat energy produced by the sun's rays when it strikes the aluminum plates inside the solar collectors is transferred from the plates to the riser tubes, where it heats the water. Figure (8) demonstrates that during the two hours following midday, when the solar collectors gathered the most solar energy, the water's output temperature remained constant (13:00 -15:00). This led to the outlet water being in a constant state. How much heat is exchanged between solar collectors and storage tanks for each unit of water used, given that steady state is not reached until an hour or more after the solar collectors' maximum incident solar energy Due to the high insulation level of the utilized water storage tanks and pipes and the gradually decreasing solar radiation, the water storage tanks' outlet temperatures are greater. After reaching steady state, the outlet temperatures of the solar collectors start to drop, and they keep doing so until the end of the workday at 17:00.

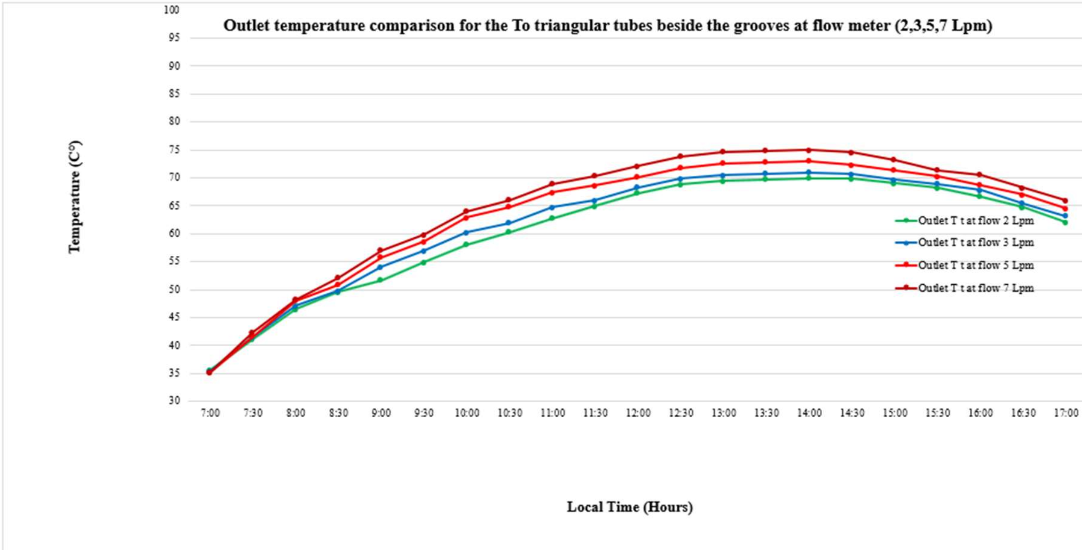

Fig.8: The outlet temperature comparison for the Tt beside the grooves at flow meter (2,3,5,7 LPM)

- **The outlet temperature comparison of the circular tubes in different flows (2,3,5,7) LPM**

By comparing the outlet temperature of a solar collector that contain circular riser tubes and four different flow rates (2, 3, 5, and 7, respectively). Figure (9) displays the findings, which demonstrate that in four scenarios of flow (2,3,5,7 LPM), respectively, a rise in flow increases the efficiency of the solar collector. This is due to the fact that higher flows result in more water passing through the solar collector than other flows do, which lengthens the time that water is able to absorb heat as it goes through the rising tubes and raises the solar collector's efficiency. As soon as the solar collectors are turned on at 7:00am, the outlet temperature rises and continues to rise until it reaches a constant level in order to absorb the most heat from the ascending tubes used, And after midday and around the 12:00 the temperature begins to go down because of the decrease in the sun's rays ,until the end of the workday at 17:00 as shown in figure (7), The sun's rays fall on the aluminum plates inside the solar collectors, where they are converted into heat energy that is then transmitted from the plates to the riser tubes, where the water is heated. Figure (9) shows that the water's output temperature was steady for two hours after midday, when the solar collectors collected the highest solar radiation (13:00 - 15:00). This resulted in the outlet water's continuous state. Due to the fact that steady state is not attained until an hour or more after the solar collectors' maximum incident solar energy, how much heat is exchanged between solar collectors and storage tanks for each unit of water utilized, Because the water storage tanks' outlet temperatures are higher due to the high insulation level of the used water storage tanks and pipes as well as because of the gradually declining solar radiation, the outlet temperatures of the solar collectors begin to decrease after steady state and continue to do so until the end of the workday at 17:00.

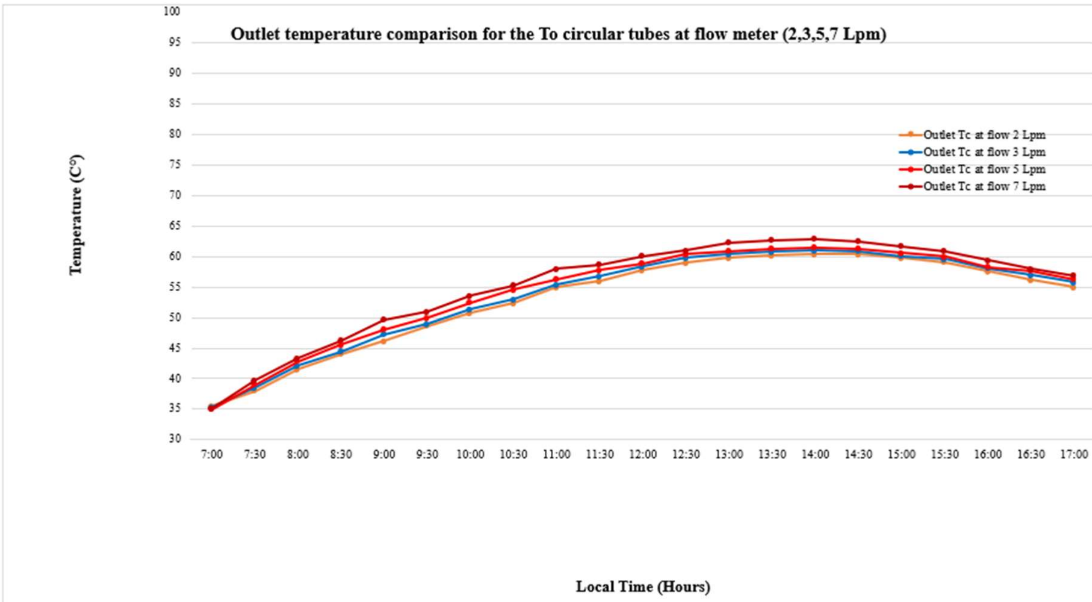

Fig.9: The outlet temperature comparison for the To circular tubes at flow meter (2,3,5,7 LPM)

- **Comparison (To t beside the grooves dividing on To c on the flat plate in different flows (2,3,5,7) LPM**

By dividing the outlet temperature of the V-corrugated absorber plate solar collector that has triangular tubes beside the grooves by the outlet temperature of the flat plate solar collector with circular tubes on a flat plate, ($Tot_{\text{beside grooves}}$ / $Toc_{\text{circular tubes}}$) and in four cases of flow (2,3,5,7) LPM, respectively. Figure (10) illustrates the findings, which demonstrate that an increase in flow boosts the solar collector's efficiency in four situations of flow (2,3,5,7 LPM, respectively). This is due to the fact that higher flows result in more water passing through the solar collector than other flows do, which lengthens the time that water is able to absorb heat as it goes through the rising tubes and raises the solar collector's efficiency. As soon as the solar collectors are turned on at 7:00am, the outlet temperature rises and continues to rise until it reaches a constant level in order to absorb the most heat from the ascending tubes used. The sun's rays fall on the aluminum plates inside the solar collectors, where they are converted into heat energy that is then transmitted from the plates to the riser tubes, where the water is heated. Figure 7 shows that the water's output temperature was steady for two hours after midday, when the solar collectors collected the highest solar radiation (13:00 -15:00). This led to the constant state of the outlet water. How much heat is transmitted for each unit of water utilized between solar collectors and storage tanks, given that steady state is not attained until an hour or more after the solar collectors' maximum incident solar radiation, Because the water storage tanks' outlet temperatures are higher due to the high insulation level of the used water storage tanks and pipes as well as because of the gradually declining solar radiation, the outlet temperatures of the solar collectors begin to decrease after steady state and continue to do so until the end of the workday at 17:00.

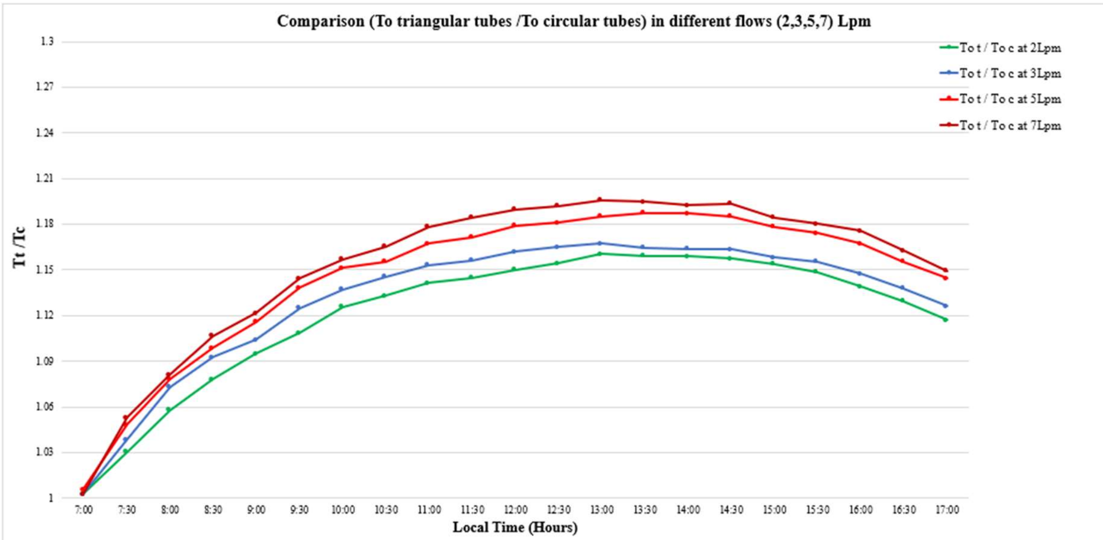

Fig.10: Comparison (To $_{circular\ tubes}$ on To $_{triangular\ tubes}$) in different flows (2,3,5,7) LPM

5.4 The heat transfer variation

The figures (11) to (14) show the variation of Nusselt number in two types of tubes with local time, the maximum heat transfer rates in the triangular riser tube that placed beside the grooves, and the variation of Nusselt number with Reynolds number. These variations are shown in this section to reveal the effect of two types of tubes (circular tubes, triangular tubes beside the grooves) on heat transfer in term Nusselt Number (2,3,5 and 7LPM). The figures (11) to (14) also demonstrate that the rate of heat transfer in triangular tubes is higher than the rate of heat transfer in circular tubes. This is because triangular tubes have a larger surface area in contact with the V-corrugated absorber plate than circular tubes do with a flat plate, and the V-corrugated absorber plate has a larger surface area exposed to the sun's rays. The figure (15) shows that the Nusselt (Nu) obtained from the triangular tubes beside the grooves tends to be higher than the one obtained from the circular tubes on flat plate with respect to circular tubes laminar flow for Reynolds Number Re ranges from 500 to 1900 respectively.

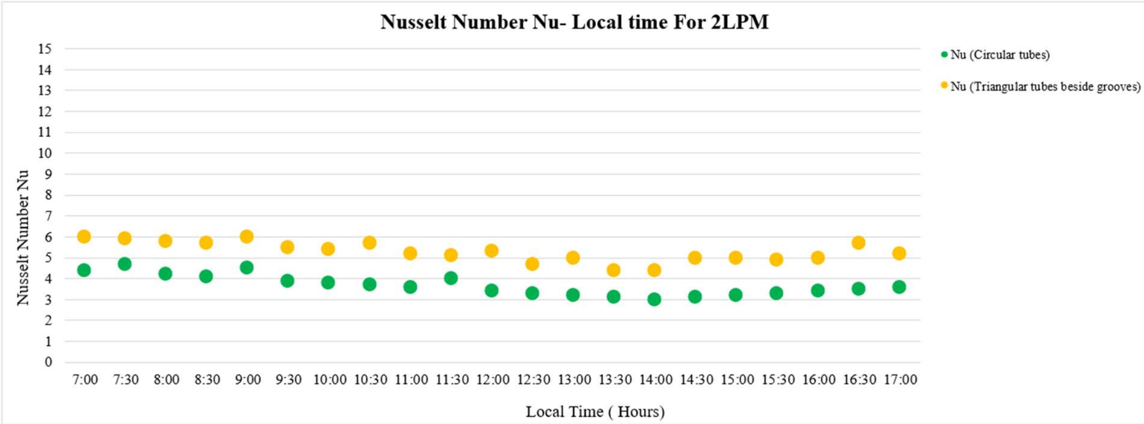

Fig.11:The variation of Nusselt Number with local Time For 2L/min.

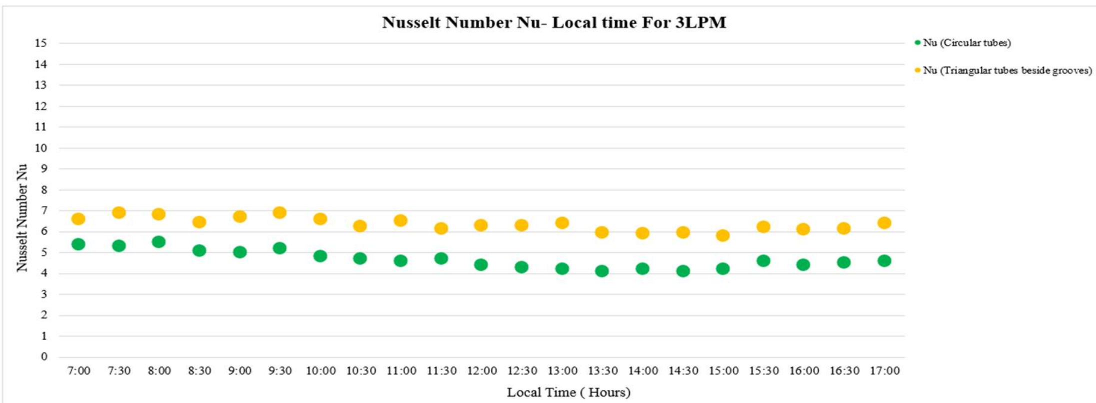

Fig.12:The variation of Nusselt Number with local Time For 3L/min

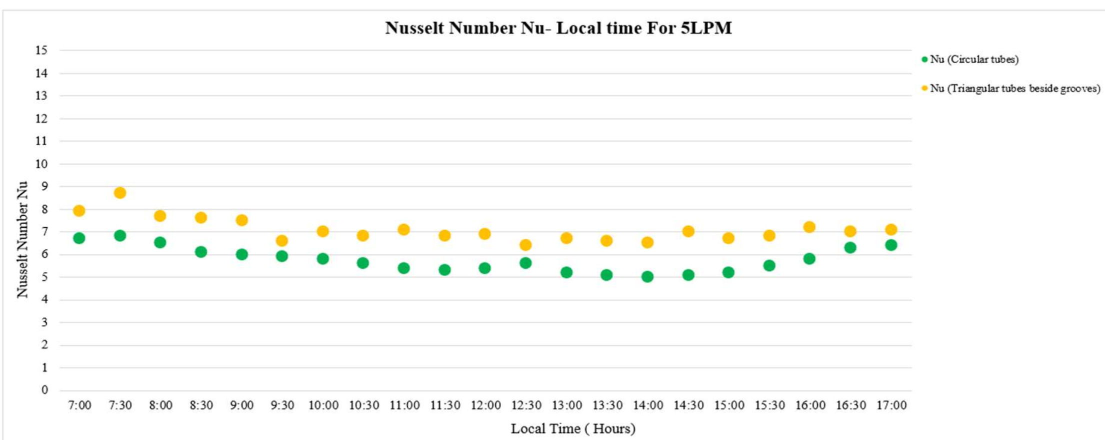

Fig.13: The variation of Nusselt Number with local Time For 5L/min.

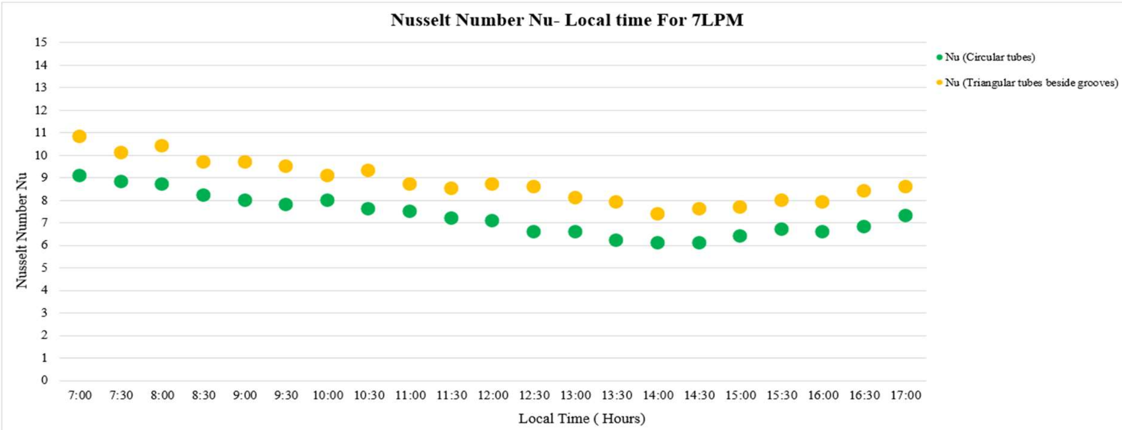

Fig.14: The variation of Nusselt Number with local Time For 7L/min.

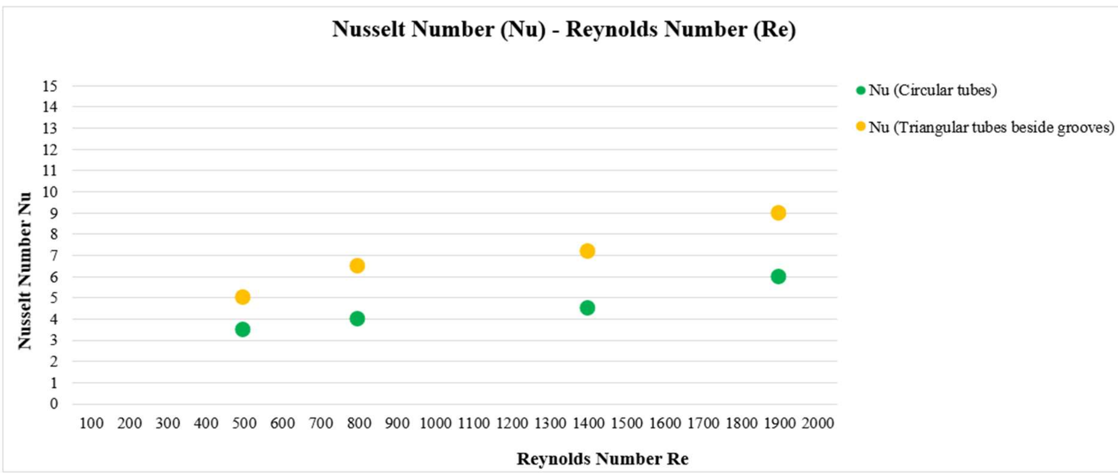

Fig. 15: Nusselt number (Nu) variation with Reynolds Number (Re) for (circular tubes, triangular tubes beside the grooves)

6 Conclusion

According to the study and from the experimental work,, for four flow conditions (2,3,5,7) LPM, solar collectors with triangular tubes placed beside grooves of V-corrugated absorber plates perform better in terms of thermal conductivity than those with circular tubes placed on flat plates. Water flow in the pipes of both solar collectors is being increased. improves the temperature of the water utilized, which boosts the solar collector's effectiveness.

7 References

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