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Develop of Local Flat Plate Solar Heater

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ABSTRACT

A new system of local flat plate solar water heater "LPSH" recommended to be used for heating water as step for maximizing renewable source of energy instead of traditional power.The local flat plate solar water heater is used to heat water from the atmospheric temperature. Evacuated, double and single glasses flat plate solar water heater were fabricate with the same dimensions and installed at a latitude angle of 31 degree facing towards N-S direction.The experiment has been carried out at 24th March 2021 between 8.00 AM to 5.00 PM.The solar collector efficiency depends with many parameters such as type of glass cover, wind velocity and overall top loss heat transfer coefficient.Top loss heat transfer coefficient (U_t) plays an important role for design of solar collector.Taking this point under consideration the present work is to reduce the overall top loss heat transfer coefficient and improve the collector efficiency.The result shows that the efficiency of (LVDG) is higher compared to (LDG) and (LSG).The higher instantaneous and collector efficiency of (LVDG) obtain as a result of the overall top loss heat transfer coefficient (U_t) was reduced in (LVDG). The efficiency of (LVDG), (LDG) and (LSG) achieve around 79, 68 and 45 %, caused by the high heat increase at 12:00 pm.The efficiency decreased for (LSG) as a result of the high top loss heat transfer coefficient. The maximum overall top loss heat transfer coefficient U_t was recorded (2.51, 3.77, and 6.35 W/ m^2 K) for (LVDG), (LDG) and (LSG) at 12:00 pm, respectively.

Keywords: Local Vacuum flat plate; renewable energy; solar collector.

INTRODUCTION

The solar collector function is to heat water from the full of atmosphere temperature. The solar collector efficiency depend on many variables such as wind velocity, glass cover numbers, the space between glass cover to the absorber plate and the overall top loss heat transfer coefficient . Top loss heat transfer coefficient (U_t) is significant for construct and design a solar collector, the double glazing efficiency is higher compared to single glazing system at the same conditions. The double glazing system has higher efficiency as a consequence of the overall top loss heat transfer coefficient was reduced (Vettrivel and Mathiazhagan, 2017).

Locally available materials were used to construct and design the triple-glazed cover solar flat plate collector. The double-glazed flat plate collector was used to design a new flat plat collector. The solar radiation penetrates through cover of the solar collector and it is absorbed by the absorber plate, which has dark black coated with the purpose of absorb as a large amount of thermal energy. Three layers of glass cover used to trap, the heat energy which provide as a high-quality insulator, (Abdulmalik and Aliyu, 2019). The solar water heaters used to heat Water by only using the sun energy. The solar thermal collector absorbed the solar radiation and the water was heated (Munish and Sharma, 2014) and (Eze and Ojike , 2012). On the other hand, Amrutkar *et al*., 2012) were used a single-glazed flat plate collector to obtain thermal efficiency which recorded 42%. The flat plate collector performance of over different geometric absorber plate was analyzed and the efficiency obtained from 55 to 70 %.

The absorber plate covered with two glass plates at the same size to keep from heat loss to atmosphere. Double glazed solar water heater Performance for different geometries and mass flow rate (0.0125, 0.0083 and 0.0041kg/s) are recorded. The flat plate solar collector heat gain is increased as raise in water flow rate with time along light day. Highest temperature of the absorber plate was recorded with time along light day and compared with two plate collectors. A greatest heat gain and Thermal efficiency and useful heat gain are absorbed for the double glazed flat absorber plate then the v-grooved plate and finally the square pulse plates (Akbar *et. al*., 2019).

(Manikandan and Sivaraman ,2014) evaluate the performance of double glazed flat plate solar water heater (DGFPSWH) and single glass flat plate solar water heater (SGFPSWH). Flat absorber plates with Galvanized iron plate size of 1.42 x 0.7 m^2 was working. The SGFPSWH was used a cover with single glass plate and The DGFPSWH was used a cover with double glass plates of equal size with a gap of 2 cm. Performance of DGFPSWH and SGFPSWH at different mass flow rates (0.0125, 0.0083, 0.0041 kg/s) were examine and report. Thermal efficiency is found to be lower for SGFPSWH compared to DGFPSWH.

The aim of this research is to reduce the overall top loss heat transfer coefficient and improve the collector efficiency.

MATERIALS AND METHODS

The local flat plate solar water heater (LPSH) components were connected as shown in Fig (1), consists of:-

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- Local flat plate solar water heater collector
- Three solar panel "12V; 25W" were connected with charge control unit of 12Vand 10A to charge the battery "12V–9A". The output power of the panels used to operate the D.C pump "12V-15W".The D.C pump connected with the pressure control electronic circuit. The pressure control electronic circuit diagram was shown in Fig (2). The water flow from (LPSH) was controlled by the pressure control electronic circuit from 0 to 2 liter /minutes.
- Local flat plate solar heater tank 20 liters connected with heater system.

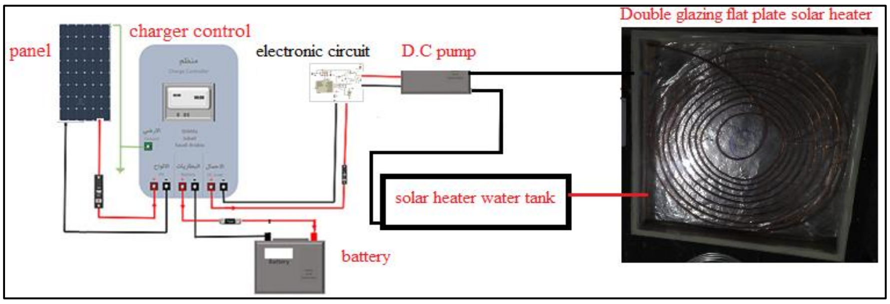

Fig .1.The components of "LPSH"

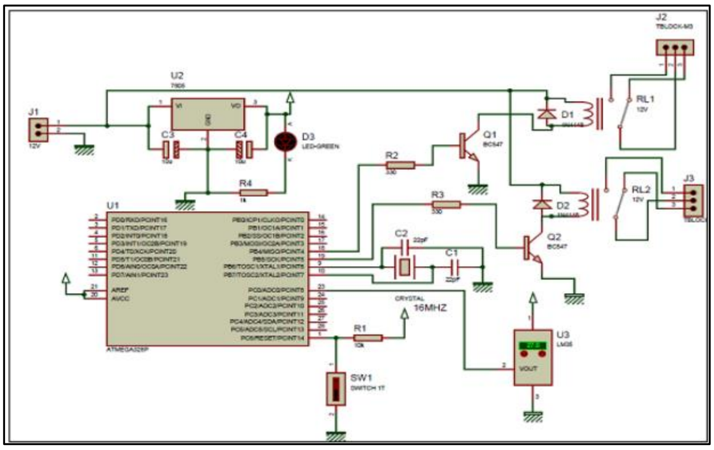

Fig .2. The pressure control electronic circuit diagram

The system of "LPSH" was placed on the roof of El Kaser research station, Matrouh (Latitude 31.363995 N and 27.134580 E) on a rack facing towards south with a fixed tilt angle of 31°. The experiment has been carried out at 24th March 2021 between 8.00 AM to 5.00 PM. Global solar radiation on horizontal surface and temperatures that corresponding experiment conditions were recorded per 30 minutes of times interval. A solar power meter (model: SPM-1116SD) was used to measure global solar radiation on horizontal surface.

Environment Meter (Model: EM-9300SD) was used to measure wind speed, relative humidity and ambient temperature. Temperatures were recorded per 30 minutes of time interval by using twelve sensors connected with Arduino-Uno microcontroller board based on the AT-mega 328 (data sheet).K-type of Thermocouples was used to measure temperatures. Twelve channels Arduino-Uno were used to scan and record temperatures during experimental process over a day.

Experimented conditions

Water heating was carried out under the following conditions:

- Flow rate of 0.67 x10^{-3} kg/sec.
- Temperature values for inner glass cover "T_{ga}", outer glass cover "T_{gb}", absorber plate "T_{lp}", water tank "T_w" and ambient temperature "T_{air}" were recorded under three different systems (local evacuated double glazing cover "LVDG", local double glazing cover "LDG" and local single glazing cover "LSG") as shown in Fig. (3).

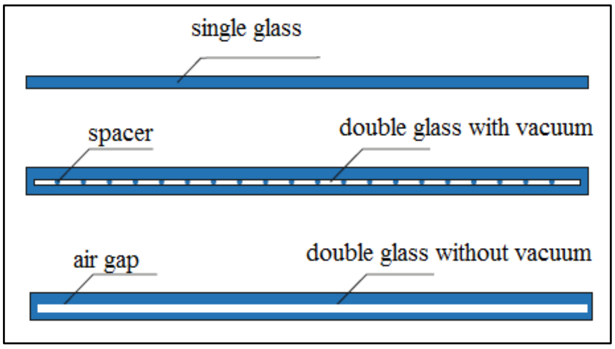

Fig . 3. Three systems conditions

The high vacuum space between the two sides glass decreases the thermal transmission. The thermal insulation performance of 15mm (5+5V+5) for evacuated glazing is high. The evacuated glazing is also made with 2 pieces single piece glass and spacer. Tempering process is used to increase high-quality of the glass. Before tempering process, the dimension of the glass must be cut accuracy as well as polishing the edges and at the same size of the sheets of (LPSH) because the glass after tempering cannot be re-worked. Local evacuated double glazing "LVDG" has a 5 mm vacuum space between 2 similar pieces glass, 36 square glasses with dimensions of (5 *5 mm^2 with 5 mm thickness); supporting points are placed between the glasses to ensure that the vacuum glass won't shrink. There is a hole at the end of the sealed edge to ensure the high vacuum between the glasses as shown in fig. (4).

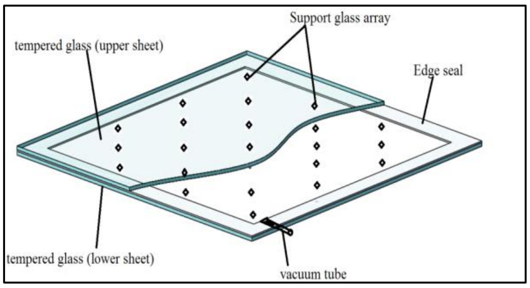

Fig .4. 3D schematic diagram of LVDG

Methodology

The main purpose of this study is to reduce the overall top loss heat transfer coefficient and improve the collector efficiency by measuring water temperature and calculate losses energy caused by (LSG) compared with (LDG) and (LVDG) as shown in Fig. (5).

Table1, showed the Specification of flat plate solar collector. Local flat plate solar water heater collector consists of three main parts: glass cover as shown in Fig.(3), absorbing plate made of aluminum and aluminum pipes. The aluminum pipes distribute from center to the out to ensure an exemplary flow of water to plate. The distances between tubes were 0.05 m .The aluminum pipes and plate painted with dark black to cover that area. The dark black color isn't shiny absorbent black and not to get lost in the thermal power and also to prevent the reflection of solar radiation. The battery is charged by the charging regulator connected to the panel and the pump flow rate is adjusted by the pressure control electronic circuit, the pump runs and thus the water is passes from the tank to flat plate solar water heater and comes again to the tank. It is economical for the customers and it is very easy to work.

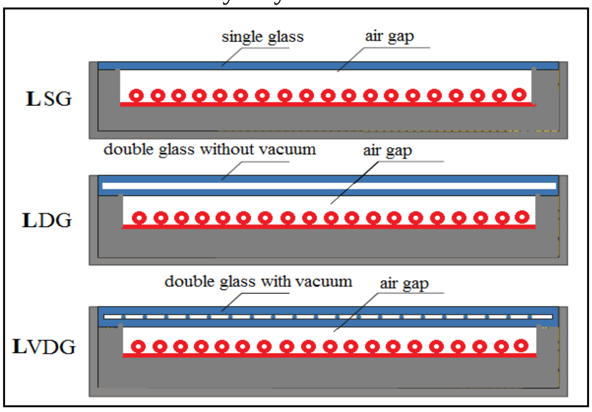

Fig . 5. Three types of (LPSH)

Table 1. Specification of (LPSH)

Length of collector	**0.7 m**	**Width of collector**	**0.7 m**
Glass cover emissivity (ε_g) / Transmittance (τ)	0.88	Absorber plate thickness	0.002 m
Collector area	0.49 m^2	Riser tube diameter	0.01 m
Collector depth for single/double glazing/ evacuated double Glazing	0.05/ 0.05/ 0.05 m	Absorber plate Emissivity (ε_p) / Absorbance (α)	0.95
Cover -to -cover space	0.005 m	Plate -to -cover space	0.05 m
Length of tubes	25 m	Insulating material	Wool glass
Material of absorber plate	Aluminum	Tube center to center distance	0.05 m

Energy Balance

Local flat plate solar water heater collector Equations for Energy balance can be expressed (Vettrivel and Mathiazhagan, 2017)

$$S_r\,(\tau_{lc}\,\alpha_{lp})\,A_{lc} = Q_u + Q_{hl} \qquad (1)$$

Useful collector heat gain

$$Q_u = A_{lc}\,[S_f - U_t\,(T_{lp} - T_{air})] \qquad (2)$$

Collector Solar flux absorbed can be expressed

$$S_f = S_r\,(\tau_{lc}\,\alpha_{lp}) \qquad (3)$$

The absorber plate Heat loss from the local collector to atmospheric can be expressed.

$$Q_{hl} = U_t\,A_{lc}\,(T_{lp} - T_{air}) \qquad (4)$$

Useful water heat absorbed can be expressed

$$Q_{hw} = m_w\,c_w\,(T_{out} - T_{in}) \qquad (5)$$

The efficiency of Collector is obtained by the ratio between the average collector heats outputs divided by the rate of the solar radiation strike the collector.

$$\eta_{lc} = Q_{hw} / S_r\,A_{lc} \qquad (6)$$

The local flat plate efficiency η:

$$\eta = Q_u / S_r\,A_{lc} \qquad (7)$$

Where,

S_r - Solar radiation W/m^2
τ_{lc} - Cover transmittance
α_{lp} - Absorber plate absorptive
Q_u - Heat gain useful W
Q_{hl} – Local collector heat rate loss W
Q_{hw} - Absorbed heat energy by water W
A_{lc} - Area of local collector m^2
S_f - Collector solar flux absorbed W
U_t - Coefficient of overall top loss heat transfer W/m^2 K
T_{lp} - Mean temperature of absorber plate ^{0}C
T_{air} - Ambient temperature ^{0}C
V_{air} -Wind speed m/sec
m_w - Water flow rate kg/sec
C_w - Water specific heat J/kg K
T_{out}- Water outlet temperature ^{0}C
T_{in} - Water inlet temperature ^{0}C
η_{lc} - Local collector efficiency %
η -Instantaneous efficiency %

4. Overall Top Loss Heat Transfer Coefficient Calculations

For (LSG), the overall top loss heat transfer coefficient was calculated using thermal arrangement theory. The conduction heat loss from absorber plate to sides and bottom losses of the collector weren't consider. The overall top loss heat coefficient (U_t) for (LSG) can be expressed by

$$U_t = 1/(R_a + R_c) \qquad (8)$$

As shown in Fig. (6). R_a is the thermal resistance between the ambient temperature to single glass cover(combination of radiation and wind effect)and R_c is the thermal resistance between single glass cover to absorber plate(combination of free radiation and convection). The wind convection heat transfer coefficient (h_w) and T_{sky} calculated by using equations [10 and 12]. R_a and R_c calculated by using equations [9 and 13] (Vettrivel and Mathiazhagan, 2017).

$$R_a = 1/(h_w + h_{rsg}) \qquad (9)$$

$$h_w = 2.8 + 3.0V_{air} \qquad (10)$$

$$h_{rsg} = \sigma.\varepsilon_g\{T_{sg}^4 - T_{sky}^4\}/\{T_{sg} + T_{air}\} \qquad (11)$$

$$T_{sky} = T_{air} - 6 \qquad (12)$$

$$R_c = 1/(h_{cpsg} + h_{rpsg}) \qquad (13)$$

$$h_{cpsg} = K_a \times Nu_a / L_a \qquad (14)$$

$$h_{rlpsg} = \{\sigma/(1/\varepsilon_p + 1/\varepsilon_g - 1)\}(T_{lp}^2 + T_{sg}^2)\,(T_{lp} + T_{sg}) \qquad (15)$$

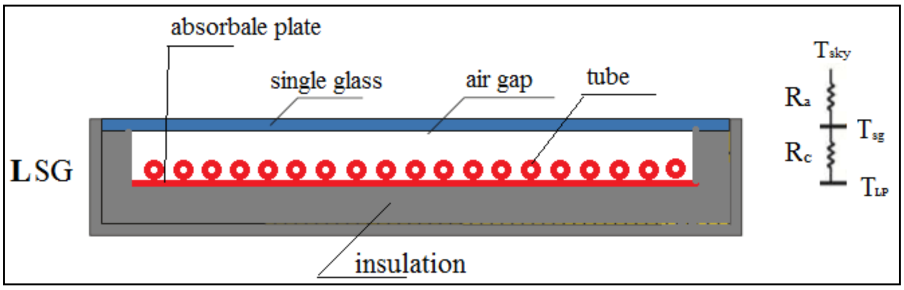

Fig. 6. Thermal resistance of (LSG)

For (LDG), the overall top loss heat transfer coefficient (U_t) was calculated using thermal arrangement theory. The "U_t" can be expressed from the following equations.

$$U_t=1/(R_{a1}+R_{b1}+R_{c1}) \quad \text{Vettrivel and Mathiazhagan, 2017).} \quad (16)$$

As shown in Fig. (7), (R_{a1}) is The Thermal Resistance between ambient temperature to the glass cover (a), R_{b1} is the resistance between the glass cover (a) to glass cover (b) and R_{c1} is the resistance between glass cover (b) to the absorber plate. The resistance R_{a1} is the combination of wind and radiation effects. R_{b1} is the amount of free radiation and convection heat transfer. R_{c1} is also the amount of free radiation and convection heat transfer. R_{a1}, R_{b1} and R_{c1} calculated by using equations [17, 19 and 22], respectively.

$$R_{a1}=1/(h_w + h_{rdga}) \quad (17)$$

$$h_{rdga}= \sigma.\, \varepsilon_g\{T_{ga}^4 - T_{sky}^4\}/\{T_{ga}+T_{air}\} \quad (18)$$

$$R_{b1}=1/(h_{cgagb}+h_{rgagb}) \quad (19)$$

$$h_{cgagb} = K_2 * N_{u2}/L_2 \quad (20)$$

$$h_{rgagb} =\{\sigma/(2/\varepsilon_g-1)\}(T_{ga}^2+T_{gb}^2)(T_{ga}+T_{gb}) \quad (21)$$

$$R_{c1}= 1/(h_{cpgb}+h_{rpgb}) \quad (22)$$

$$h_{cpgb} =K_1 \times N_{u1}/L_1 \quad (23)$$

$$h_{rlpgb}=(\sigma/(1/\varepsilon_p+1/\varepsilon_g-1))(T_{lp}+T_{gb})(T_{lp}^2+T_{gb}^2) \quad (24)$$

The natural convection heat transfer coefficient between the absorber plates to first cover or between two covers is calculated from the Rayleigh numbers (R_{aL}) and Nusselt number (N_{uL}). (Dagdougui *et. al.*, 2011).

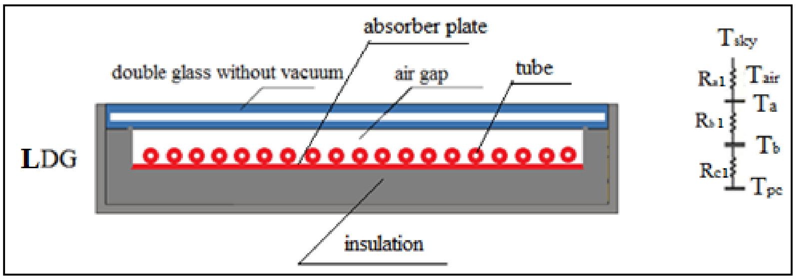

Fig. 7. Thermal resistance of (LDG)

For (LVDG), the overall top loss heat transfer coefficient was calculated using thermal arrangement theory. The overall top loss heat coefficient (U_t) can be expressed from the following equations.

$$U_t=1/(R_{a1}+R_{b2}+R_{c1}) \quad (25)$$

As shown in Fig. (8), R_{b2} is the resistance between the glass cover (a) to glass cover (b). Three different heat transfer mechanisms contribute to the total heat transfer coefficient h_{rgagb} of the glazing: thermal conduction through a residual gas, thermal conduction through spacers, and radiation heat transfer between the two sheets in vacuum glazing. The total heat transfer coefficient h_{rgagb} between the glasses sheets of a vacuum glazing can be can be expressed from the following equations.

$$R_{b2}=1/(h_{gagb}) \quad \text{(Viacheslav and Mathiazhagan, 2017)} \quad (26)$$

$$h_{rgagb} = 0.8P + 4\varepsilon_{eff}\,\sigma T^3_{mean} + 2\lambda r/d^2 \quad (27)$$

$$\varepsilon_{eff} = 1/(2/\varepsilon_g - 1) \quad (28)$$

Where;

***P* is internal pressure, σ is the Stefan-Boltzmann constant (5.67×10^{-8} W/m^{2}K^4), T_{mean} is the average of temperatures T_{ga} and T_{gb} of the glass sheets, λ is the thermal conductivity of glass pillars, *r* is the radius of glass pillars, *d* is the distance between the pillars and the effective emittance (ε_{eff}).**

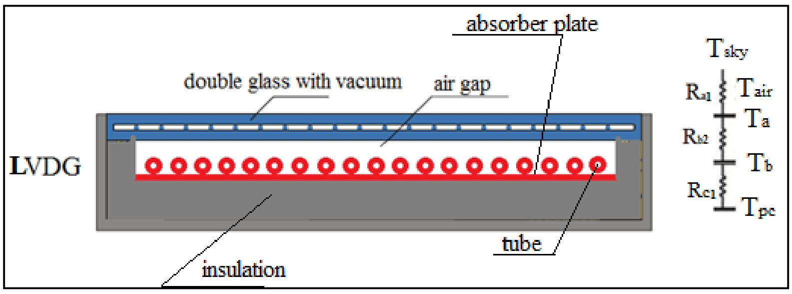

Fig. 8. Thermal resistance of (LVDG)

RESULTS AND DISCUSSIONS

Solar radiations via time

The results of solar radiations via operating time (h), as shown in Fig. 9, indicated that the solar radiations increases with time until recorded the maximum (950 W/m^{2}h) that observed at 12:00 pm after that it has decreases with time due to low solar radiations (200W/m^{2}h).

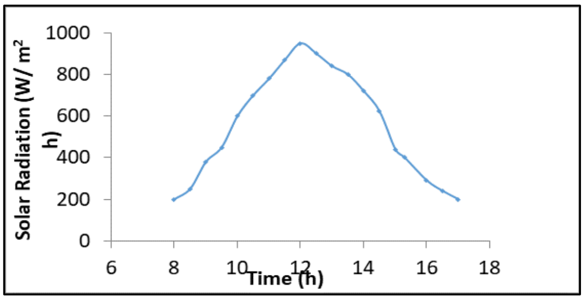

Fig. 9. The solar radiation via time

LSG heat loss coefficient

As shown in Fig. 10, heat loss coefficient for "LSG" increased while the resistance values (R_a and R_c) were reducing due to high wind velocity. After 10.00 AM, resistance value (R_a) steady because there is little variation of wind speed. On the other hand, the resistance R_a is less compare to R_c for the reason that of wind interrelates with the outside of glass cover. The difference of temperature (ΔT) between the tempered glass and absorber plate has high value since of wind convective (h_w) increased. In "LSG", the temperature of glass obtain 59 ^{0}C. On the other hand the temperatures of "LDG" (T_{ga} and T_{gb}) were achieved 55 ^{0}C and 75 ^{0}C and the temperature of "LVDG" (T_{ga} and T_{gb}) were achieved 23 ^{0}C and 91 ^{0}C at 12:00 pm.

LVDG heat loss coefficient

Fig.11. illustrated the overall top loss heat transfer coefficient of LVDG compared to "LDG" and "LSG". A lot of parameter such as wind speed, solar radiation, the distance between the absorber plate and the glass cover affected to the overall top loss of heat transfer coefficient. The results show that, the overall top loss coefficient is lower for local evacuated double glazing cover compare to local double glazing cover and local single glazing due to effect of wind speed. The maximum overall top loss of heat transfer coefficient "U_t" was recorded (2.51;3.77; and 6.35W/m^{2}K) for "LVDG", "LDG" and "LSG" at 12:00pm, respectively.

The useful heat gain (Q_u)

As shown in Fig.12, the useful heat gain (Q_u) is lower for (LSG) and (LDG) compared to (LVDG) by reason of top heat loss coefficients are less for evacuated double glazing cover and reheat water directly as a result of more useful gain absorbed in (LVDG). The maximum useful heat gain (Q_u) was recorded (285, 273, and 243 W) for (LVDG), (LDG) and (LSG) at 12:00 pm, respectively.

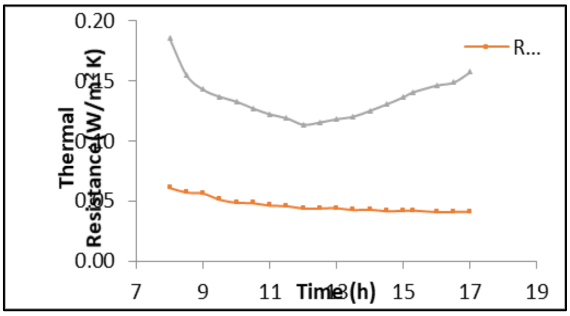

Fig.10. Single glass thermal resistance VS time

The absorbed much heat

As shown in fig.13, the (LVDG) absorbed much heat compared to (LSG) and (LDG). This as a result of the overall top loss heat transfer is fewer for (LVDG).the Heat absorbed by water Q_w was recorded (145, 125, and 83 W) for (LVDG), (LDG) and (LSG) at 12:00 pm, respectively.

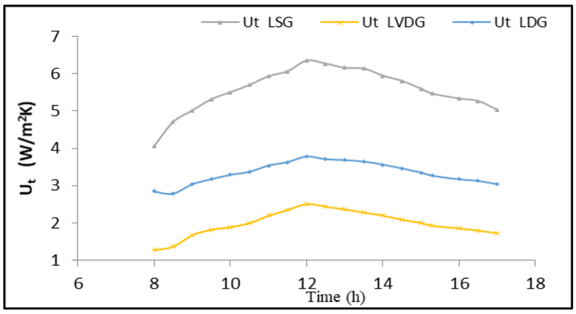

Fig.11. the overall top loss of heat transfer coefficientfor "LVDG"; "LDG" and "LSG"

The outlet temperatures of water

Fig.14. showed the effect of local evacuated double glazing cover compared to double glazing cover and single glazing cover for, the outlet temperatures of water incased to 74 ^{0}C for (LVDG) but no more than 65 and 52 ^{0}C achieve for (LDG) and (LSG) at 12:00 pm, respectively, under the same conditions. The outlet temperatures of water for (LVDG) increased by 14% than (LDG) and by 42 % than (LSG) at 12:00 pm. The (LVDG) outlet temperature around 7 ^{0}C - 9 ^{0}C and 15 ^{0}C - 22 ^{0}C more compared (LDG) and (LSG), respectively.

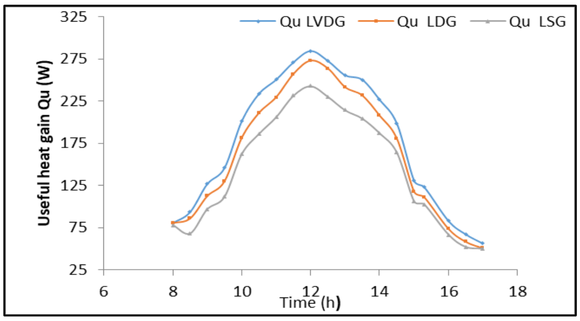

Fig.12. the useful heat gain (Q_u) for the three systems.

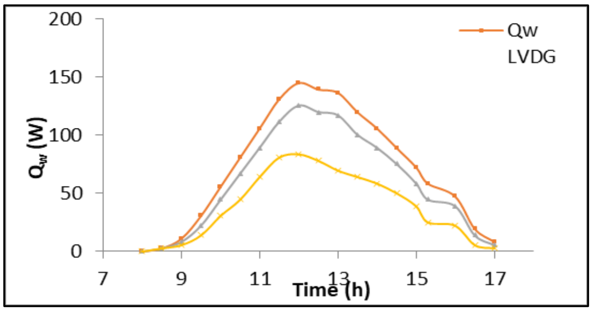

Fig.13. the Heat absorbed by water Q_w for the three systems.

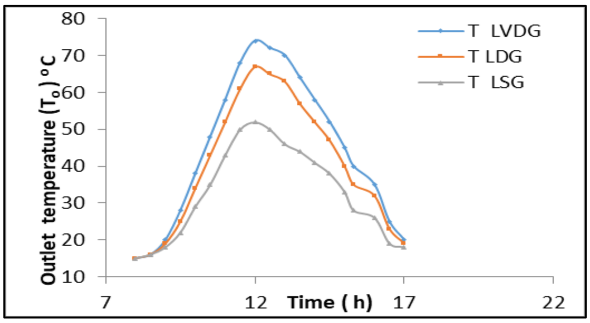

Fig.14 .the outlet temperatures of water for the three systems

From the Fig. 15.the efficiency of (LVD), (LDG) and (LSG) achieve around 79, 68 and 45 %, caused by the high heat increase at 12:00 pm, respectively. The efficiency decreased for (LSG) as a result of the high top loss heat transfer coefficient.

The instantaneous efficiency

Fig.16. Shows the comparison graph between the instantaneous efficiency via Time, The results show that The Instantaneous efficiency η (%)at 11:00 am obtained higher value for (LVD) compared to (LDG) and (LSG) this due the temperature difference between mean plate and ambient temperature higher values that is higher loss from the (LDG) and (LSG).

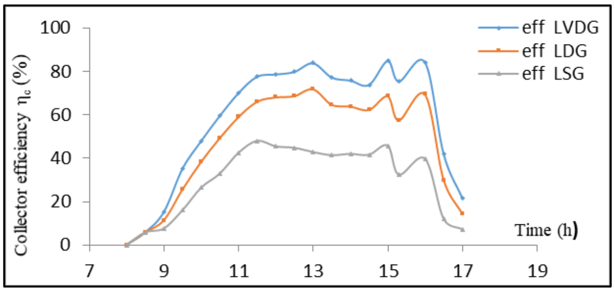

Fig.15. Collector efficiency for the three systems

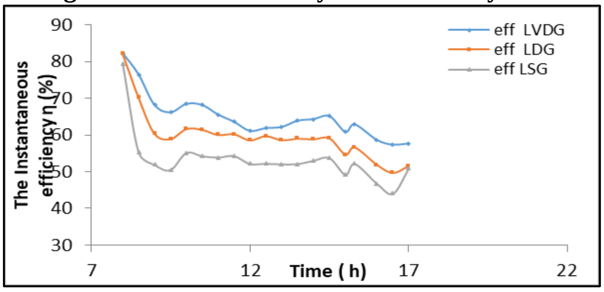

Fig. 16.The Instantaneous efficiency η (%) for the three systems

CONCLUSION

The local flat plate solar water heater "LPSH" is used to heat water from the atmospheric temperature. Three conditions of collector surface were investigated local single glazing "LSG", local double glazing "LDG" and local evacuated double glazing "LVDG". The flat plate solar water heaters were fabricate with the accurate dimensions and installed at a latitude angle of 31 degree facing towards N-S direction. The experiment has been carried out between 8.00 AM to 5.00 PM. The efficiencies of "LVDG", "LDG" and "LSG" achieve around 79, 68 and 45 %, caused by the high heat increase at 12:00 pm. From the result obtained it is evident that the optimized local flat plate solar water heater is including a "LVDG". It performs much better than the "LDG" and "LSG".

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تطوير سخان شمسى مسطح محلى الصنع

اسلام محمد السيد السباعى

معهد بحوث الهندسة الزراعية – مركزالبحوث الزراعية- جيزة

يوصى باستخدام السخان الشمسى الجديد المحلى الصنع وذلك فى عملية تسخين المياه من أجل تعظيم استخدامات الطاقة الشمسية بديلا عن الطاقة التقليدية.ونجد ان السخان الشمسى يقوم بتسخين المياة بداية من درجات حرارة الهواء العادية .فى هذا البحث تم استخدام 3 انظمة لتسخين المياة وهم سخان شمسى محلى الصنع والغطاء الخارجى مصنوع من الزجاج المفرغ .والاخر عبارة عن سخان شمسى محلى الصنع والغطاء الخارجى مصنوع من الزجاج المزدوج .والاخير عبارة عن سخان شمسى محلى الصنع والغطاء الخارجى مصنوع من لوح زجاج واحد. وتم تصنيع السخانات الثلاثة بنفس الابعاد والمواصفات والمواد المستخدمة وكان الاختلاف الوحيد فى نوع الغطاء الموجود على سطح المجمع الشمسى.تم وضع السخانات الثلاثة اعلى سطح محطة البحوث الزراعية بالقصر بمطروح فى الاتجاة الصحيح من الجنوب للشمال وبزاوية ميل مقدارها 31 °.وتم تنفيذ التجربة فى شهر مارس 2021فى الفترة من الساعة 8 ص – 5 م.ونجد ان كفاءة السخان الشمسى تعتمد على كثيرمن المتغيرات واهمها شدة الرياح ونوع الغطاء الزجاجى مما يترتب علية تغير معامل الفقد الحرارى من السطح العلوى للمجمع الشمسى. ونجد ان معامل الفقد الحرارى من السطح العلوى للمجمع الشمسى هو عامل مهم جدا فى تصميم المجمعات الشمسية. ويتم وضع هذة النقطة الهامة فى الاعتبار عند تصميم المجمعات الشمسية وذلك حتى يتم تخفيض معامل الفقد الحرارى من السطح العلوى للمجمع الشمسى مما يؤدى الى رفع كفاءتة. اوضحت النتائج ان كفاءة السخان الشمسى المحلى الصنع والغطاء الخارجى مصنوع من الزجاج المفرغ افضل من السخان الشمسى المحلى الصنع والغطاء الخارجى مصنوع من كلا من (الزجاج المزدوج - من لوح زجاج واحد).حيث نجد ان كفاءة السخان الشمسى المحلى الصنع والغطاء الخارجى مصنوع من الزجاج المفرغ كانت 79 % عندما كانت كفاءة السخان الشمسى المحلى الصنع والغطاء الخارجى مصنوع من (الزجاج المزدوج - ومن لوح زجاج واحد) كانت 68 و 45 % بالترتيب.وذلك ناتج عن ان معامل الفقد الحرارى(U_t) لكل منهم 2.51 و 3.77 و 6.35 (وات / م2 كلفن) بالترتيب.