

## CONSTRUCTION AND THERMAL PERFORMANCE EVALUATION OF FLAT PLATE SOLAR COLLECTORS

Darwesh, M.\*A. H. Elmetwalli\*, A. Derbala\*\*,  
T. Fouda\*\*\* and M. Morad\*\*\*\*

### ABSTRACT

*A solar energy systems (two solar water heaters and a storage tank) were constructed to determine their actual thermal performance under average weather conditions. The system consisted of five components; collector box, absorber plate, copper pipes, insulation material, and glass cover). The thermal test of performance for the two areas of solar collectors (2 and 2.994m<sup>2</sup>) with three flow rates of water (2, 7.5 and 12 l/min) were computed. The thermal performance of the solar collectors was evaluated in terms of the useful heat energy gain or the collector efficiency.*

*The main results of this research work can be summarized as follows:*

*The daily average absorbed solar radiation during these experiments were 14.31, 14.22 and 13.93 kWh/day at with the use 2.994 m<sup>2</sup> of solar collector area under water flow rates (2, 7.5 and 12 l/min), while they were 10.19, 9.77 and 9.31 kWh/day with the use of 2 m<sup>2</sup> of solar collector area under 2, 7.5 and 12 l/min water flow rates. The daily average absorbed solar radiation converted into useful heat gain during the experimental work were 11.08, 11.26 and 9.49 under (2, 7.5 and 12 l/min water flow rates, respectively) under the use of 2.994 m<sup>2</sup> of solar collector area. While they were 8.30, 7.41 and 6.88 kWh/day under 2, 7.5 and 12 l/min water flow rates with the use of 2m<sup>2</sup> of solar collector area. The daily average overall thermal efficiency during these experiments were 62 and 64 % with the use of 2.994 and 2m<sup>2</sup> of solar collector areas , respectively. Consequently 38% and 36% of the total solar energy available were lost.*

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\* Lecturer, Agric. Eng. Dept., Fac. of Agric., Tanta Univ., Egypt

\*\* Assoc. Prof. Eng. Dept., Fac. of Agric., Tanta Univ., Egypt

\*\*\* Prof., Agric. Eng. Dept., Fac. of Agric., Tanta Univ., Egypt

\*\*\*\* Prof., Agric. Eng. Dept., Fac. of Agric., Zagzig Univ., Egypt

## INTRODUCTION

In Egypt, the annual average of global solar radiation is 5.4-7.1 kW.h/m<sup>2</sup>/day, while the annual average solar radiation on full tracking system is 7.5 -10.5 kW.h/m<sup>2</sup>.day. From these numbers it can be concluded that Egypt has a great potential of solar energy, which can be considered as a reliable energy resource all over the year [N. R. E. A. and U. S. A. I. D. (1991)]. Saha (2003) reported that the flat-plate collectors have the advantages such as: they can use both beam and diffuse solar radiation, they do not need orientation towards the sun, they require little maintenance, and they are mechanically simpler and they easiest and least expensive to fabricate. Kalogirou(2004) stated that flat – plate solar collectors absorbs the incoming solar radiation and converts it into heat and also transfers this heat to a fluid flowing through the collector. These conversions depend on the absolute performances of many different materials such as glazing materials, collector absorbing plates and used fluids. The solar collector thermal efficiency was defined as the ratio of the useful energy delivered to the energy incident on the collector aperture. Awady and Atter (2005) filed an Egyptian Patent for an “Electronic Solar-Tracking System”. They declared that it improves the daily efficiency of solar-collecting panels by virtue of continual automatic aligning of their surfaces normal to incident radiation. In this invention, photo-electronic sensors detect incident-rays direction with a suitably designed shield assuring the normality of the plate-collector. A 40% increase in daily energy-reception is estimated over fixed plate-collectors. Abdellatif et al. (2006a,b) compared between two similar solar water heaters of flat plate type . They revealed that, the solar water heater which tracked the sun's ray once each half hour from sunrise by 20.98 %. The obtained results also showed that, the water inlet temperature was directly proportional to the solar energy system heat losses and consequently it was inversely proportional to the overall thermal efficiency. The daily average heat transfer efficiencies for the two solar panels using two different water inlet temperatures (29.5 and 18.8° C) were 81.12 % and 91.47%, consequently 18.88 % and 8.53% of the absorbed solar energy were lost, respectively. Nuntaphan et al. (2009) used the collector area of about 4m<sup>2</sup> and experimented the volume of

water in the storage tank between 100 and 300 liters with the mass flow rate of between 6 and 12 l/ min. They found that a single solar collector can produce approximately 48-56°C hot water at an average solar radiation of 600-700 W/ m<sup>2</sup> at mass flow rate 0.2 kg/s. Also, their results showed that the higher water volume exhibited lower water temperature and the mass flow rate of water had no effect on the water temperature under these conditions. Therefore the objectives of this study are to construct a solar energy system and optimize some operating parameters affecting the performance of the used system (collector area and fluid flow rate).

### **MATERIALS AND METHODS**

The flat plate solar collectors were designed and constructed in a private workshop, and installed on a roof of the house in Denosher village, El-Mehalla El-Kobra, ElGhrabia Governorate at latitude angle of (30.95°N and 31.09°E) in order to collect and utilize the solar energy available as a heat source. The thermal test of performance for the two areas of solar collectors of 2 and 2.994 m<sup>2</sup> (the combination between 0.994 m<sup>2</sup> and 2 m<sup>2</sup> connected in series) with three flow rate of water (2, 7.5 and 12 l/min) were used.

#### **Materials**

##### **Solar water heaters (solar collectors)**

Two solar collectors were used having a net surface area of 0.99 and 2m<sup>2</sup>. Each solar collector consisted of five components (collector box, absorber plate, copper pipes, insulation material, and glass cover), as demonstrated in Figures. (1and2).

- The solar collector boxes are rectangular in shape and made of aluminum bar 2 mm thick.
- The gross dimensions of the large-scale solar collector box are 2.8 m length, 1.8 m width, and 0.12 m depth, with a net upper surface area of 5.88 m<sup>2</sup>, while the gross dimensions of the small-size solar collector are 1.50 m length, 0.78 m width, and 0.12 m depth, with a net upper surface area of 1.17 m<sup>2</sup>.
- The absorber plate of both solar water heaters is rectangular in shape, and formed of an aluminum sheet which is a good conductor of heat. It was painted with matt black paint in order to

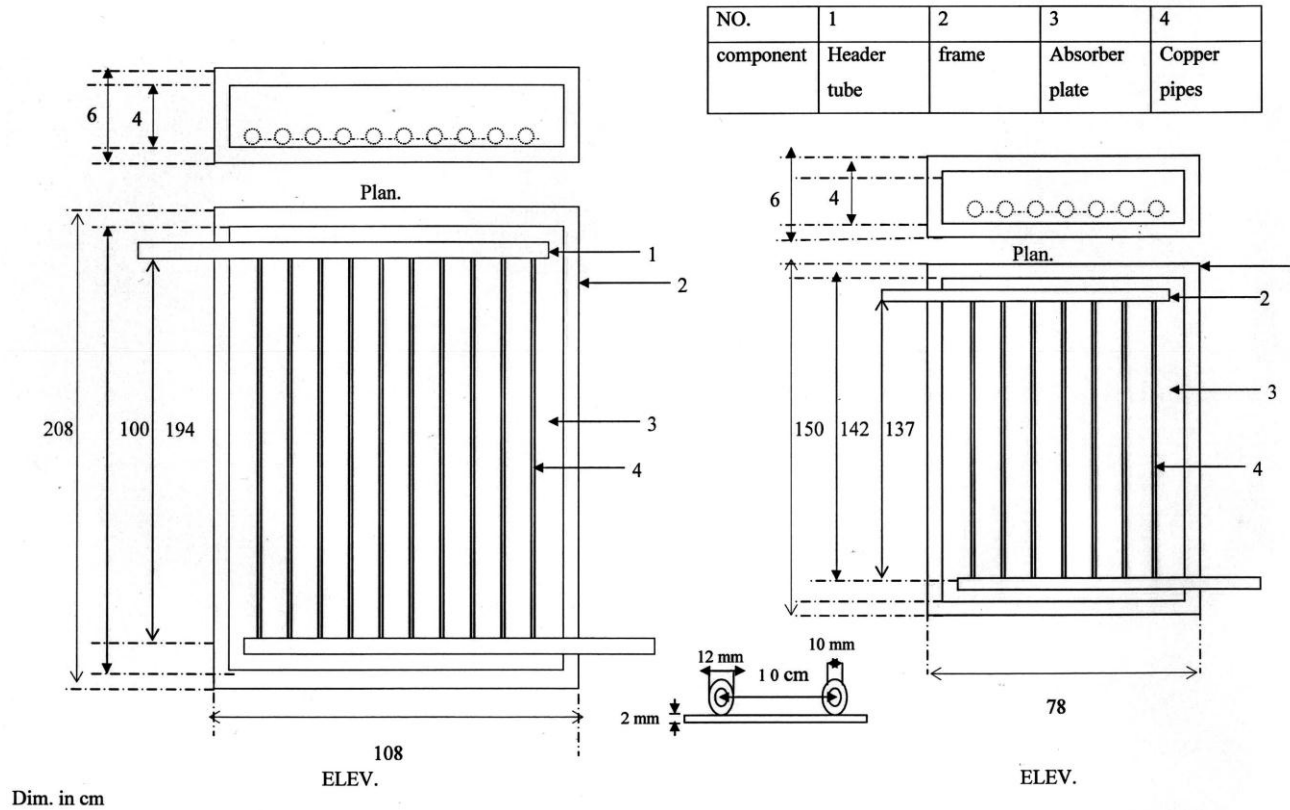


Fig. 1: Cross section of tubes bonded to backing large sheet    Fig. 2: Cross section of tubes bonded to backing small sheet

absorb the maximum amount of the solar energy incident on its surface. The gross dimensions of the absorber plate are 2 m length, 1 m width and 2 mm thick, 1.42 m length, 0.70 m width, and 2 mm thick with a net upper surface area of 2 m<sup>2</sup> and 0.99m<sup>2</sup> for large-size and small-size solar collectors respectively.

- A 12 mm diameter copper pipes (10 pipes and 7 pipes) are distributed at equidistant of 10 cm and attached to the upper surface of the absorber plate using slap ties each 10 cm long throughout the length of each pipe. A 12 mm diameter was functioned to increase the surface area of heat transfer per unit volume of water. These copper pipes were also painted with matt black paint.
- To reduce the solar collector heat losses from the sides and back of the collector 50 mm thick of insulation material (fiberglass wool) was placed in the bottom and sides of the solar collector.
- To minimize the reflection of radiation and reduce heat losses by convection, a clear glass cover 5 mm thick was situated to cover the solar collector box and a distance between the absorber plate and glass cover was 5 cm.

### **Temperature Measurements**

The thermocouples were put in all system to measure temperatures of system components as shown in Figure 3 and Figure 4. Thermocouples were put in many locations including: glass, absorber plate, outlet hot water, inlet hot water. Some points took three sensors according to the nature and importance of this part. The three sensors distributed as a diagonal line on the absorber plate which took a rectangular shape, then the averages of temperatures were taken in the calculation.

### **Instrumentation**

**-The global positioning system (GPS).** The GPS was used to identify the actual coordinates for the experimental work area. The accuracy of the used GPS was  $\pm 5$  meters.

**-Data-loggers.** The components of two data loggers were eight channels for each other, keyboard, monitor, programmed card and controllers. The programmed card employed two programs (Visual Basic and Matlab).

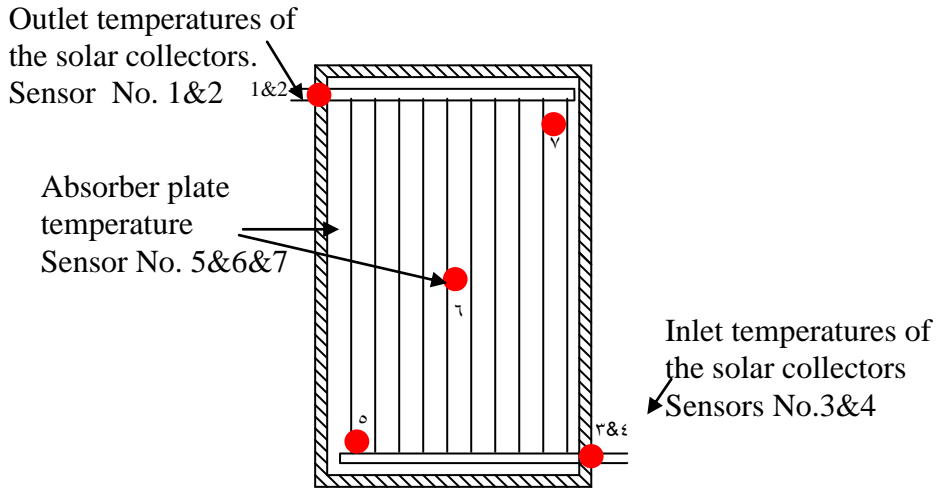


Fig. 3 : Positions of thermocouples on solar collectors.

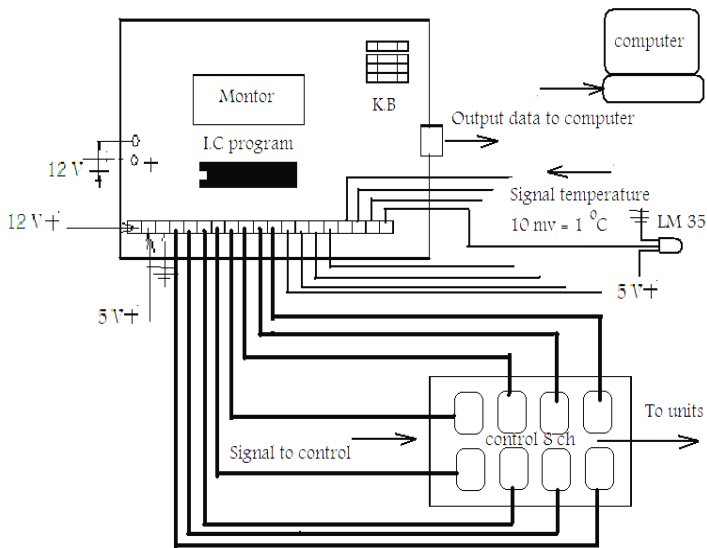


Fig. 4: Schematic diagram of data logger with computer.

The visual basic program is used to apply equation and Matlab is used to convert the information from analog to digital. The two data-loggers were connected by the fourteen sensors constructed from thermistors to measure the temperatures on limited positions in solar collectors and refrigerator unit. Figure (3) shows the schematic diagram about sensor channels and IC programmed computer and recording method. These sensors are attached with the IC computer program and data were stored in the computer.

**-Pyranometer.** The most commonly used commercial radiometer in different countries is the Kipp and Zohne solarimeter which is used in weather stations and field experiments for the measurement of radiation in the wavelength range of 0.3 to 3.0  $\mu\text{m}$ . A typical instrument has an output of approximately 0.5 mV per 100  $\text{W}/\text{m}^2$ . The expected solar radiation was in the range of 0 -1100  $\text{W}/\text{m}^2$ .

### Methods

Experiments were conducted using two solar collectors to study the effect of some operating parameters on its performance.

### The studied parameters

- 1- Two different solar collector areas ( 2 and 2.994  $\text{m}^2$ ).
- 2- Three different fluid flow rates ( 2, 7.5 and 12 l/min).

### **Flat plate solar collector performance**

To measure thermal performance, the useful energy gain or the collector efficiency, thus it is necessary to define step by step the singular heat flow equations in order to find the governing equations of the collector system. According to Duffie and Beckman (1980), Abdellatif (1985), Kassem et al. (2006) and Abdellatif et al. (2009). The amount of solar radiation received by solar collector is:

$$\text{Available solar energy } Q = RA_c \quad , \text{ Watt}$$

Where: R is the intensity of solar radiation, in  $\text{W}/\text{m}^2$ ,

$A_c$  collector surface area,  $\text{m}^2$

$$\text{Optical efficiency} = \tau \alpha$$

Where:  $\tau$  transmission and  $\alpha$ : effective absorptance

The rate of transmission of the cover  $\tau$  (effective transmittance of solar collector cover material) can be calculated from the following equation:

$$\tau = \tau_{\max} - 0.00437 \exp [0.0936 (\theta - 30)] \quad , \text{decimal}$$

$$\tau = 0.90 - 0.00437 \exp [0.0936(\theta - 30)] \quad , \text{decimal}$$

Thus, the absorbed solar energy  $Q_A$  can be found by the following equation:  $Q_A = R (\tau\alpha) A_c$ , Watt

The absorption rate of the absorber  $\alpha$  (effective absorptance of the absorber plate of collector) can be computed from the following equation:  $\alpha = \alpha_{\max} - 0.00476 \exp [0.0940 (\theta - 35)]$  , decimal

**The useful heat gain** represents the rate of extraction of heat from the collector may be measured by means of the amount of heat carried away in fluid passed through it.

$$Q_C = m C_p (T_{fo} - T_{fi}) \quad , \text{Watt}$$

Where:

$m$  = mass flow rate of fluid , kg/s

$C_p$  = specific heat of fluid , J/kg/°C

$T_{fo}$  = outlet temperature of fluid , °C

$T_{fi}$  = inlet temperature of fluid , °C

**The heat transfer efficiency** can be determined by dividing the useful heat gain and the absorbed solar energy as given in the following equation:

$$\eta_h = (Q_C / Q_A) * 100 \quad , \%$$

**The amount lost** by the collector to its surroundings ( $Q_L$ ), expressed as of extraction under steady state conditions, is proportional to the rate of useful energy absorbed by the collector, less the rate of useful energy extracted by the collector ( $Q_C$ ). This is expressed as follows:

$$Q_L = Q_A - Q_C \quad , \text{Watt}$$

Also, as the collector absorbs heat when its temperature is higher than that of the surrounding and heat is lost to the atmosphere by convection and radiation.

The rate of heat loss ( $Q_L$ ) depends on the collector overall heat transfer coefficient ( $U_o$ ) and the collector temperature:

$$Q_L = U_o A_c (T_p - T_a) \quad , \text{Watt}$$

Where:  $U_o$  = overall heat transfer coefficient , W/m<sup>2</sup>.°K

$T_p$  = mean temperature of the absorber plate , °K

$T_a$  = ambient air temperature surrounding the collector, °K



**The overall heat transfer coefficient ( $U_o$ ).**  $U_o$  is determined by adding together the top ( $U_t$ ), back ( $U_b$ ), and edge ( $U_e$ ) heat transfer coefficients referred to the solar collector area ( $A_c$ ):

$$U_o = U_t + U_b + U_e \quad , \text{ W/m}^2/\text{°K}$$

Overall thermal efficiency  $\eta_o$  : defined as the ratio of the useful energy gain ( $Q_C$ ) to the incident solar energy over a particular time period:

$$\eta_o = (Q_C / R A_c) * 100 \quad , \%$$

**Overall thermal efficiency  $\eta_o$**  defined as the ratio of the useful energy gain ( $Q_C$ ) to the incident solar energy over a particular time period:

$$\eta_o = ( Q_C / R A_c ) * 100 \quad , \%$$

**Temperature rise ( $D_T$ )** equal the different between fluid inlet temperature ( $T_{fi}$ ) and the ambient air temperature ( $T_a$ ) divided by solar energy flux incident ( $R$ ). can be determined from the following equation:

$$D_T = (T_{fi} - T_a) / R \quad , \text{ °C.m}^2 / \text{W}$$

## RESULTS AND DISCUSSION

There are many factors affecting thermal performance of solar collector such as, intensity of solar radiation flux incident, inlet water temperature, and ambient air temperature surrounding the solar collector.

### **1. Solar energy available**

Figure (5) indicates that the daily average solar energy available values of 12.11 and 14.46 kW.h/day were recorded for the fluid flow rate of 2 l/min and collector areas of 2 and 2.994m<sup>2</sup>, respectively. Meanwhile, the daily average solar energy available values for the fluid flow rate of 7.5 l/min and collector areas of 2 and 2.994 m<sup>2</sup> were 11.58 and 16.87 kW.h/day. Also, its respective values were 11.05 and 16.54 kW.h/day for the fluid flow rate of 12 l/min and collector areas of 2 and 2.994m<sup>2</sup>. These differences refer to the amount of solar radiation flux incident on solar collectors and net surface area of them. Fluid flow rates had no remarkable effects on solar energy available, as it only depends upon solar radiation and area of solar collector .

### **2. Absorbed solar radiation**

Figure (6) illustrated that the daily average absorbed solar radiation for fluid flow rate of 2 l/min with solar collector areas of 2 and 2.994 m<sup>2</sup> were 10.19 and 14.31 kW.h/day, respectively. Meanwhile, the daily average absorbed solar radiation for fluid flow rate of 7.5 l/mi

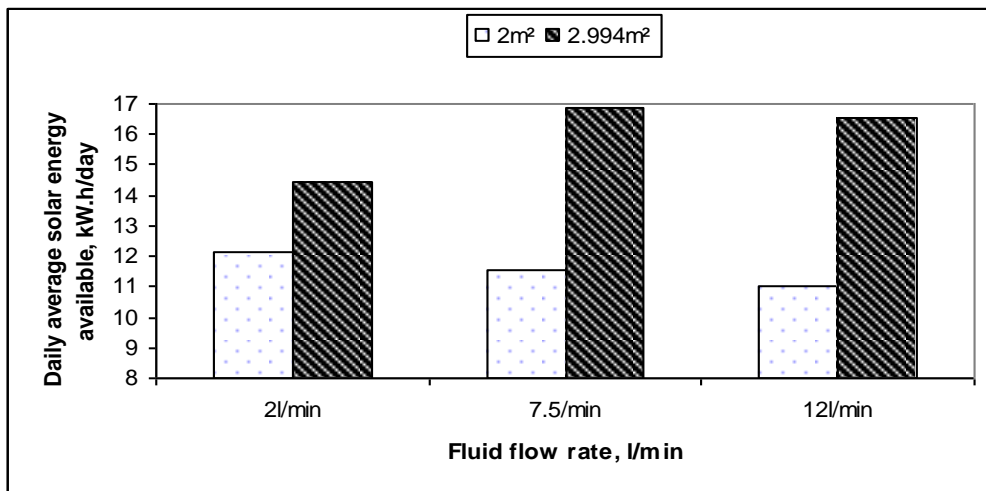


Fig. 5: The daily average solar energy available with different fluid flow rates and solar collector areas.

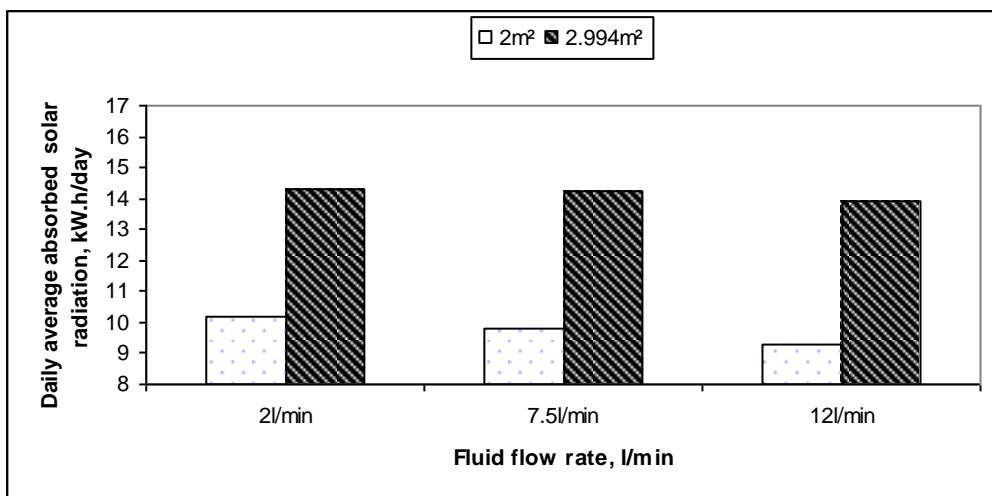


Fig. 6: The daily average absorbed radiation with different flow rates and solar collector areas.

were 9.77 and 14.22 kW.h/day, respectively. Also, the daily average solar energy available for fluid flow rate of 12 l/min were 9.31 and 13.93 kW.h/day, respectively. Furthermore, the results indicated that the fluid flow rates had no effect on the absorbed solar radiation.

### 3. Useful heat gain and heat transfer efficiency

Figures (7) and (8), illustrated that the daily average useful heat gain values were 8.30 and 11.08 kW.h/day and gave daily average heat transfer efficiency values of 81.64 and 77.20% for the fluid flow rate of 2l/min and solar collector areas of 2 and 2.994 m<sup>2</sup>, respectively. The values of useful heat gain for fluid flow rate of 7.5 l/min and solar collector areas of 2 and 2.994 m<sup>2</sup> were 7.41 and 11.26 kW.h/day, which gave an average heat transfer efficiency values of 75.12 and 79.13%, respectively. The heat transfer efficiency values were 73.84 and 67.81% when daily average useful heat gain values were 6.88 and 9.49 kW.h/day for fluid flow rate of 12l/min and the same collector areas.

### 4. Solar collector heat losses

Figure (9) indicates that the values of daily average solar collector heat losses were 1.88 and 3.22 kW.h/day for the fluid flow rate of 2 l/min and collector areas of 2 and 2.994 m<sup>2</sup>, respectively. Meanwhile, the daily average solar collector heat losses values for the fluid flow rate of 7.5 l/min and collector areas of 2 and 2.994 m<sup>2</sup> were 2.41 and 2.21 kWh/day. Also, its respective values were 2.45 and 4.46 kWh/day for the flow rate of 12 l/min and collector areas of 2 and 2.994m<sup>2</sup>.

### 5. Overall thermal efficiency and temperature rise

Figure (10) showed that the relationship between the daily average overall thermal efficiency and different fluid flow rates with two solar collector areas. For the duration of the 2 m<sup>2</sup> solar collector area, the daily average overall thermal efficiencies were 68.68, 63.30 and 61.84% with fluid flow rates of 2, 7.5 and 12 l/min, respectively. Consequently 31.32, 36.70 and 38.16% of the solar energy available was lost for different flow rates. The values of daily average overall thermal efficiency were 65.20, 66.71 and 57.14% for fluid flow rates 2, 7.5 and 12 l/min for 2.994 m<sup>2</sup>, respectively. Also, 34.80, 33.29 and 42.86% of the solar energy was lost for the long scale area of solar collector. The lower flow rate, the greater useful heat gain to storage because the high difference between inlet fluid

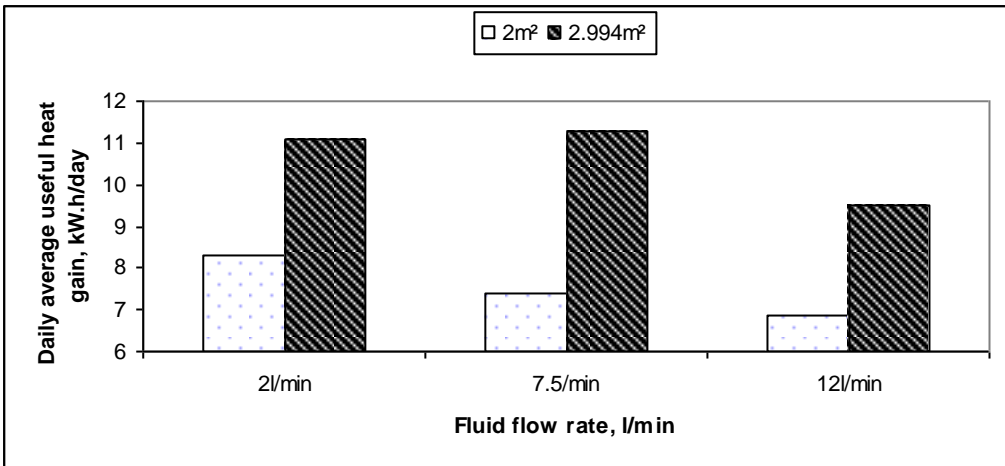


Fig. 7: The daily average useful heat gain with different fluid flow rates and solar collector areas.

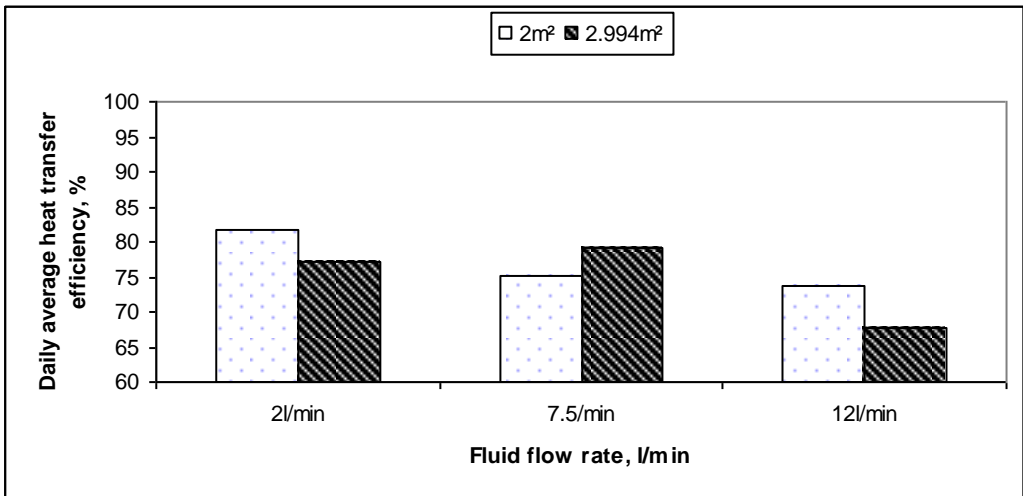


Fig. 8: The daily average heat transfer with different fluid flow rates and solar collector areas.

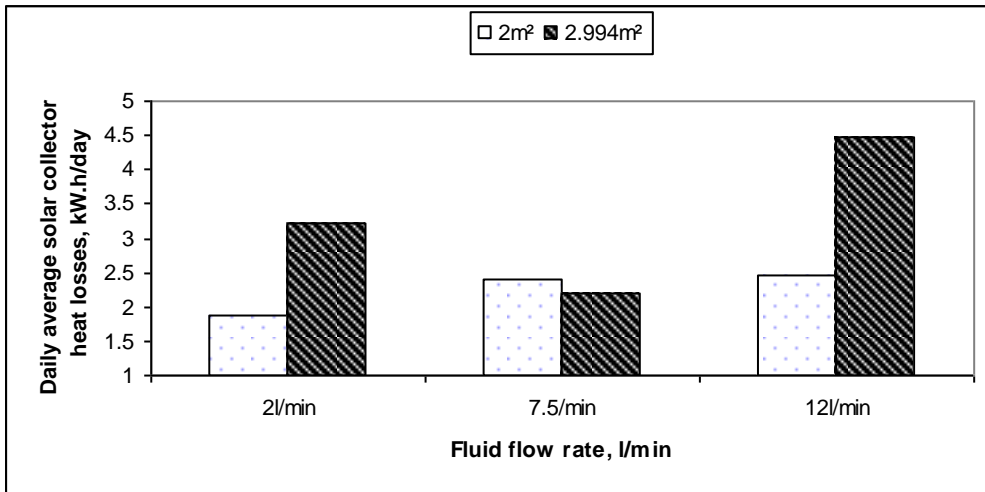


Fig. 9: The daily average solar collector heat losses with different fluid flow rates and solar collector areas.

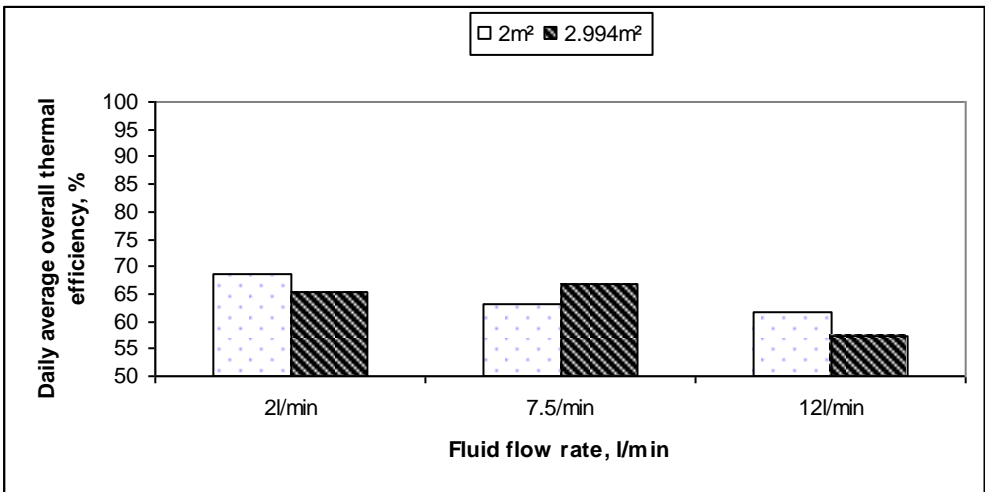


Fig. 10: The daily average overall thermal efficiency with different fluid flow rates and solar collector areas.

temperature and outlet fluid temperature. But, at 2.994 m<sup>2</sup> the 7.5 l/min flow rate greater than 2 and 12 l/min, in this case the lower temperature difference condensed by the higher mass flow rate. Regression analysis revealed a highly significant linear relationship between overall thermal efficiency and the temperature rise. The highly significant at 2m<sup>2</sup> solar collector area more than the 2.994m<sup>2</sup>. Also, for the 2.994m<sup>2</sup> solar

collector area, the greater significant relationship, the lower fluid flow rate. But, at the 2m<sup>2</sup> solar collector area the relationship was nearly constant. The greater significant relationship is caused by the lower heat losses from solar collectors. The regression equations for the 2, 7.5, and 12 l/min fluid flow rates with 2.994m<sup>2</sup> solar collector area for the best fit were:-

$$\eta_o = 65.131 - 66.44(D_T), R^2 = 0.9211$$

$$\eta_o = 69.49 - 169.48(D_T), R^2 = 0.9059$$

$$\eta_o = 69.65 - 167.61(D_T), R^2 = 0.8290$$

Also, the regression equations for the 2, 7.5, and 12 L/min with 2 m<sup>2</sup> solar collector area for the best fit were:-

$$\eta_o = 77.243 - 298.56(D_T), R^2 = 0.9944$$

$$\eta_o = 79.091 - 350.94(D_T), R^2 = 0.9947$$

$$\eta_o = 78.841 - 341.34(D_T), R^2 = 0.9961$$

The daily average total solar radiation flux incident on the horizontal and vertical surfaces during the experimental work were 4.066 and 5.623 kW.h/m<sup>2</sup>/day, whilst, the daily average total solar radiation flux incident on the tilted surface with an optimum tilt angles was 6.335 kW.h/m<sup>2</sup>/day.

### CONCLUSION

- The daily average absorbed solar radiation during these experiments were 14.31, 14.22 and 13.93 kW.h/day at 2.994 m<sup>2</sup> solar collector area for (2, 7.5 and 12 l/min) fluid flow rates, while they were 10.19, 9.77 and 9.31 kW.h/day at 2m<sup>2</sup> solar collector area for (2, 7.5 and 12 l/min) fluid flow rates.
- The daily average absorbed solar radiation converted into useful heat gain during the experimental work were 11.08, 11.26 and 9.49 for (2, 7.5 and 12 l/min fluid flow rates, respectively) at 2.994 m<sup>2</sup>. While at 2 m<sup>2</sup> they were 8.30, 7.41 and 6.88 kW.h/day for 2, 7.5 and 12 l/min fluid flow rates.
- The daily average overall thermal efficiency values during these experiments were 62 and 64 % at 2.994 and 2 m<sup>2</sup> solar collector areas, respectively. Consequently 38% and 36% of the total solar energy available were lost.

### REFERENCES

- Abdellatif, S. M.; A. M. Matouk and R. E. Matouk (2006a).** Effect of mass flow rate of operating fluid on solar panel thermal performance. J. Agric. Sci. Mansoura University, 31(7) : 479-496.
- Abdellatif, S. M.; A. M. Matouk and R. E. Matouk (2006b).** Effect of orientation, tilt angles and water inlet temperature on solar panel thermal performance. J. Agric. Sci., Mansoura University, 31(7): 497-510.
- Abdellatif, S. M (1985).** Solar energy collection, storage and utilization in protected cropping. Ph.D Thesis, Wye College, University of London, UK.
- Abdellatif, S. M.; A. Kassem and N. Elashmouy (2009).** Optimum tilt angle and orientation for a flat plate solar water heater under Egyptian conditions. Journal of Agricultural Machinery Science. 4(3): 253-258
- Awady, M.N. and Attar, M.Z. (2005).** An electronic solar tracking system, Egyptian Patent # 023899, [www.egypo.gov.eg/](http://www.egypo.gov.eg/), accessed on June 2nd . 2010.
- Duffie, J. A.; and W. A. Beckman (1980).** Solar engineering of thermal processes. Second Edition, JOHN WILEY AND SONS, New York, pp.762.
- Kalogirou, S. (2004).** Solar thermal collectors and applications. Progress in Energy and Combustion Science, 30( 3 ): 231-295.
- Leutz, R.; T. Ackermann.; A. Akisawa and T. Kashiwagi, (2001).** Solar radiation for sorption cooling in Australasia. Renewable Energy, 22 (1-3): 395-402.
- N.R.E.A. and U. S. A. I. D (1991).** Egyptian solar radiation atlas. New and Renewable Energy Authority.
- Kassem, A.; S. Abdullatif ; A. Kehta and A. Basuoni (2006).** Thermal solar energy systems. Dar El Eman for printing.977-5030-79-x
- Nuntaphan, A.; C. Chansena and T. Kiatsiriroat (2009).** Performance analysis of solar water heater combined with heat pump using refrigerant mixture. Applied Energy, 86: 748-756.

### الملخص العربي

## تصنيع وتقييم الاداء الحرارى للمجمعات الشمسية المسطحة

د.محمد درويش د. عادل هلال د. اسعد دريالة ا.د طارق فودة و.ا.د محمد مراد

أجريت الدراسة فوق سطح منزل بقرية دنوشر – مركز المحلة الكبرى في خلال صيف ٢٠٠٩ ولذلك تم تصميم و تنفيذ نظام كامل للطاقة الشمسية يتكون من ثلاث عناصر أساسية (سخان ماء شمسي مساحته ٢م<sup>٢</sup> وأخر مساحته ٠.٩٩٤م<sup>٢</sup> حيث يقوم السخان الشمسي بتحويل الطاقة الضوئية للأشعة الشمسية إلي طاقة حرارية يتم إزاحتها بواسطة مائع السريان (الماء) المار خلاله يتكون سخان الماء الشمسي من ستة أجزاء رئيسية ( صندوق المجمع collector box – لوح الامتصاص absorber plate – مواسير النحاس copper pipes – المادة العازلة insulated material – الغطاء الزجاجي glass cover – ظلمبة دفع المياه water pump). صندوق المجمع الكبير تم تصنيعه من أعمدة من الألوميتال بأبعاد ٢.٨\*١.٨\*٠.١٢ م بمساحة إجمالية ٥.٨٨م<sup>٢</sup> ، لوح الامتصاص عبارة عن لوح من الألومنيوم طوله ٢م و عرضه ١ م وسمكه ٢مم تم طلائه بطلاء أسود مطفي لزيادة معامل الامتصاص ، تم تركيب مبادل حراري من مواسير النحاس الأحمر بقطر ١٢.٧ مم علي لوح الامتصاص و طلاء المواسير بنفس نوع مادة الطلاء ، تم تزويد جوانب و قاع الصندوق بمادة عازلة من الصوف الزجاجي لتقليل الفواقد الحرارية بالحمل و الإشعاع ، تم تغطية صندوق المجمع بلوح من الزجاج بسمك ٥ مم بحيث يوفر مسافة رأسية بينه و بين لوح الامتصاص مقدارها ٠.٥ سم لتوفير سريان بالدفع لمائع التشغيل تم تزويد السخان الشمسي بظلمبة قدرتها ٣٧٥ وات. أما بالنسبة للمجمع الصغير تم تصنيعه من أعمدة من الألوميتال بأبعاد ١.٥\*٠.٧٨\*٠.١٢ م بمساحة إجمالية قدرها ١.١٧ م<sup>٢</sup> ، لوح الامتصاص عبارة عن لوح من الألومنيوم طوله ١.٤٢\*٠.٧٠\*٠.٠٢ م

### إجراء التجارب Produce of experiments

تم تشغيل نظام التسخين الشمسي من الساعة التاسعة صباحا و حتي الرابعة مساء . تم توصيل المجمعين الكبير و الصغير علي التوالي ( ٢.٩٩٤م<sup>٢</sup> ) للحصول علي أعلى درجة حرارة و مقارنة ذلك باستخدام مساحة ٢ م<sup>٢</sup> منفردة. تم تشغيل ثلاث معدلات سريان ماء وهي ( ٢ ، ٧.٥ ، ١٢ لتر / دقيقة) تم تشغيل النظام علي مساحتين من المجمع الشمسي ( ٢ ، ٢.٩٩٤ م<sup>٢</sup> )  
**أهم النتائج المتحصل عليها:-**

- بلغ متوسط الكفاءة الحرارية الكلية لنظام التسخين الشمسي في حالة مساحة ٢.٩٩٤م<sup>٢</sup> ٦٢% أما في حالة مساحة ٢م<sup>٢</sup> كان متوسط الكفاءة الحرارية الكلية 64% . مما يعني أن الفاقد من كمية الطاقة الشمسية المتاحة هو ٣٨% و ٣٦% للمساحتين الكبيرة و الصغيرة من المجمع علي التوالي.

- بلغ متوسط الكفاءة الكلية الحرارية ٦٦.٧١% عند استخدام مساحة ٢.٩٩٤م<sup>٢</sup> من المجمع و معدل سريان ٧.٥ لتر/ دقيقة بينما عند استخدام مساحة ٢م<sup>٢</sup> من المجمع و معدل سريان ٢ لتر/ دقيقة بلغ متوسط الكفاءة الكلية الحرارية ٦٨.٦٨%.

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- ١،٢ مدرس الهندسة الزراعية – قسم الهندسة الزراعية – كلية الزراعة – جامعة طنطا
  - ٣ أستاذ الهندسة الزراعية المساعد – قسم الهندسة الزراعية – كلية الزراعة – جامعة طنطا
  - ٤ أستاذ الهندسة الزراعية – كلية الزراعة – جامعة طنطا
  - ٥ أستاذ الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق