EXPERIMENTAL STUDY ON SOLAR HEATING BY NATURAL HEAT CONVECTION AND RADIATION

SeifA. Ahmed

Mechanical Engineering Department, Faculty of Engineering,
Beni-Suef University, BeniSuef, Egypt

ABSTRACT

Heat storage is a good energy saving option these days. Heat storage makes it possible to use thermal energy at the required time. Solar water heaters for construction purposes and industrial purposes are the best source to maintain traditional energy sources and thus can maintain high quality energy and liquid or steel fuel due to the highest rise in their prices. In recent years, using solar energy has become remarkably cheap and especially noteworthy. The efficiency of natural solar water heater system depends on collector and reservoir setting, design and environmental factors such as solar intensity, ambient temperature and wind conditions. Also, the relative height of the tank and collector separation mainly affects the volume of the Siphon thermal flow rates, including both forward and reverse flow at night. In this pilot investigation, two parallel rectangular glass plates were connected to the hot water storage tank. The effect of the separation space between the plates (collectors) (D) was investigated and reported. The results reported that outlet temperature in case D= 15 cm for two plates decreased approximately 24% and 23% for two plates. Also, the heat radiated to the room decreased as the inner space between the two plates increased, and decreased to approximately 25% as compared to stack plates.

KEYWORDS

Solar thermal storage; solar thermal collectors; Naturalheat convection and Radiation.

1. INTRODUCTION

Heat transfer by natural convection in a tube (circular or square) has a large number of applications in industries and other purposes. These include solar water heating systems; cooling of gas turbine blades, heat exchangers etc. The characteristics of heat transfer and flow in relation to different parameters play a vital role in the design of these systems. The present work is aimed to a specific application in mind, i.e. solar water heating systems. Little information is available in the literature on the heat transfer characteristics for the effect of inner space between plates on the rate of heat transfer to the surrounding. So, the present work aims to study the effect of the space between two parallel rectangles and the time interval on heat transfer to a room model. Hence this work is undertaken. FouedChabaneaet. al [1] decided that for two air mass flow rates of 0.012 and 0.016 kg/ s, the maximum efficiency values obtained for them with and without fins were approximately 40%, 51.50 % and 35%, 44%, respectively. S.S. Krishnananthet al.

DOI : 10.14810/ijmech.2017.6402

[2] reported that the presence of the thermal storage medium in the absorber plate is the best quality. L.B.Y. Aldabbaghaet. al [3] suggested that increase efficiency with total flow rate of flow rate between 0.012 and 0.038 kg / s. For the same flow rate, double pass efficiency was found to be higher than a single pass by 34-45%.Furthermore, the maximum efficiency obtained for single and double pass air collectors is approximately 46% and 84% respectively for a mass flow rate of 0.038 kg / s.Xin-Rong Zhangaet. al [4] investigated that long-term decline and low solar radiation can cause the flow rate to be zero. Also, as increasing collection efficiency as the total coefficient increases. In addition, it shows that there is an optimal flow rate and the CO2 charge amount of the overall performance system. This type of solar thermal convection has the highest collection efficiency in the spring and winter of summer and autumn.

No better performance in the cold and low radiation area of hot zone and high radiation. Wei Chang et. al [5] reported that angle setting has no effect on thermal efficiency, while the average flow has a strong relation to it. In addition, the efficiency of heat collection can be improved by negative pressure in the collector, but it is dropped along with increased pressure. Jie Deng et. al[6] decided that the expected thermal efficiency in the case of heavy dust deposition decreases by 10.7% - 21.0% when the difference in normal temperature varies between 0 and 0.04. The optical efficiency of the solar air collector with the dust deposition surface is 8.4% as compared to the case of a clean cover surface. BalaramKundu[7] concluded that the heat transfer rate was lower than the rectangular cross section in maintaining the outer diameter of the continuous shell along with all the other parameters of the heat exchanger as design, the number of passes, the outer diameter of the tube, the pitch of the tube, etc.

But when the total size of the fins on the constraint tube was maintained, using a trapezoid fins, it was found that the heat transfer rate increased, thus the pressure drop decreased much more in the case of the fins with a rectangular cross section. Zhang, Tao et. al[8] reported that increasing the effect of heat transfer and dissipation of input to the horizontal double collector is better than that of a single vertical collector. Because, the input height is higher than the single vertical collector. One-plate solar panels are to be used for normal pregnancies, and double-horizontal universities can be used in forced convection in the thermal field of fuel cells with solar help with low and medium temperatures. MoukhtarLati [9] suggested that the solar heater connected with the thermal storage tank delivers almost higher temperatures; thus, giving better efficiency than the air heater without thermal storage tank. S.S. Krishnananthet. alnoted that the central thermal storage in the absorption plate is the best configuration, because thermal efficiency has increased. H Terres1 et. al[11] decided that the heat transfer losses of the glasses by conductivity are greater than 75%. Because the heat loss values conduction is about 90%, which is very important. This allows determining that glass cover improvements can be made in this type of solar cooker.T Sitepu1 et. al[12] reported that a simple solar box cooker can use to boil water.

V. M. Kriplani et. al. [13] decided that the overall flow rate and heat transfer coefficient increases with an increase in heat transfer. Reduce the flow rate to increase the slope of the tube. N. K. Groenhout et al [14] observed that the core of the two-sided absorption system with low emission coupled with high static reflectivity reduces radioactive losses and passes through the back of the collector. This special design reduces net heat loss to be less than 30-70% of conventional systems.

2. FORMULATION OF THE PROBLEM

2.1 Experimental description of the model

The solar thermal water heater (SW) shown in Figure 1 works on the principle of thermal buoyancy and normal convection. The solar collector heats water in the two parallel rectangles raised by the riser tube from the collector panel storage tank. These two parallel rectangles heat a patterns room with a dimensions 2×2×3 m3 (length × width× height) by natural convection and radiation. These two equals parallel rectangles each have a dimensions 0.5×0.15×0.7 m3 (length × width× height), and are parallel to each other. Also, each one has fins on each surface exhibition to the sun. The heat transferred to the room by natural convection and radiation. The space between the two parallel rectangles is (0, 0.5, 1.0, and 1.5 Cm) as shown in Fig. 1.

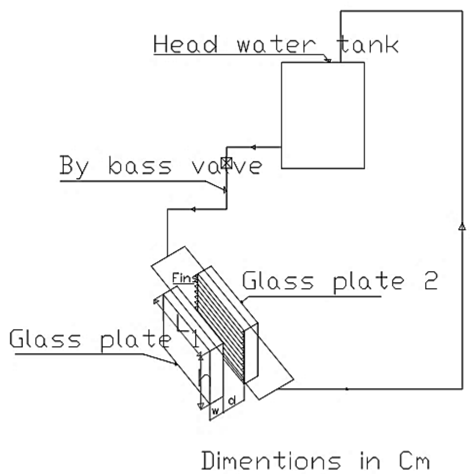


Figure 1 show the natural convection solar water heater (SWH)

The cold water is more intense in the tank flowing down the bottom of the next tube to take its place. This natural thermal flow water circulation occurs throughout the day as long as the heat is absorbed into the collector plate. As a result, hot water collects and stored in the hot water storage tank during the day. The same reverse flow and heat are lost from the collector to the chamber. It was assumed that the water temperature distribution in the reservoir was linear and the water temperature in the reservoir at the level at which the water enters the pool to the reservoir and the collector outlet temperature is equal.

2.2 Procedure for Analysis

The sensible heat is the thermal energy being stored or released by charging or discharging the material over the temperature without changing the phase during the process [4]. Charging occurs by raising the temperature of a solid or liquid, while heat is released when temperature decreases. The amount of stored energy depends on the amount of storage material, the specific heat capacity, and the change of the temperature.

It was calculate the sensible heat and convection heat transfer for each rectangular plate as follow:

$$Qs = m\ Cp\ (Ti - Tout) \quad (1)$$

$$QC = h\ A\ (Ti - Tout) \quad (2)$$

3. RESULTS AND DISCUSSION

Figure 2(a, b, c, d) showed the relation between inlet water temperatures at different inner spaces D=0, D=5, D=10 and D=15 and time. It is noted that both time interval and inner space affect

strongly in the inlet water temperature. This as a result of, as the two plates has a space, as the temperature change decreased. This as a result of the temperature difference (Ti and Tout) decreased. This refers to as the space increased, as the radiation heat transfer increased. It is noted also that Case d (D=15) is bad, because the inlet temperature reduced approximately by 27% as compared with Case a (D=0). This means that the heat radiating is poor.

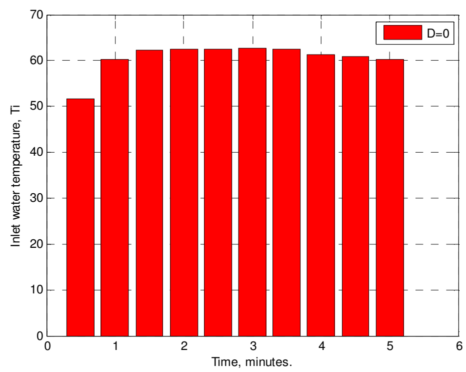


Figure 2-a, relation between inlet water temperature and time for D=0 cm

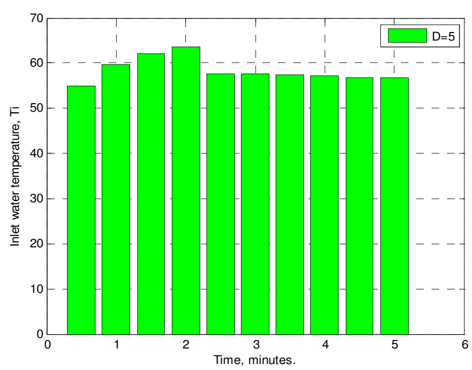


Figure 2-b, relation between inlet water temperature and time for D=5 cm

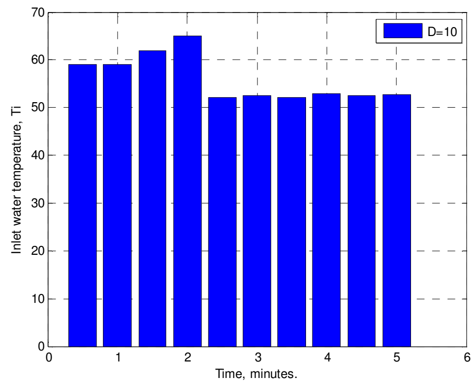


Figure 2-c, relation between inlet water temperature and time for D=10 cm

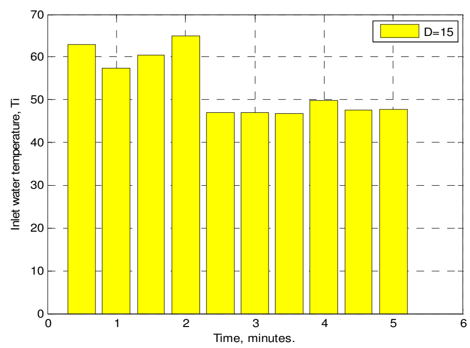


Figure 2-d, relation between inlet water temperature and time for D=15 cm

Figures3(a, b, c, d) and 4(a, b, c, d) decided the relation between outlet water temperatures (Tout1) for plate 1, plate 2 respectively, and time intervals at different inner spaces. It is noticed that both time interval and inner space effect on the outlet plate temperatures. This showed that, as the two plates has a space, as the temperature difference decreased. This refers to some heat transferred by radiation to the room. Also, noted that the outlet temperature decreased in (D= 15 cm) for two pates 1 and 2 approximately 24%, 22% respectively. This decided that the heat radiating is poor.

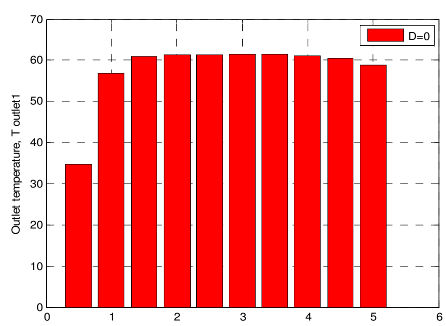


Figure 3-a, relation between outlet temperature , $T_{outlet1}$ and time for (Plate1), D=0 cm

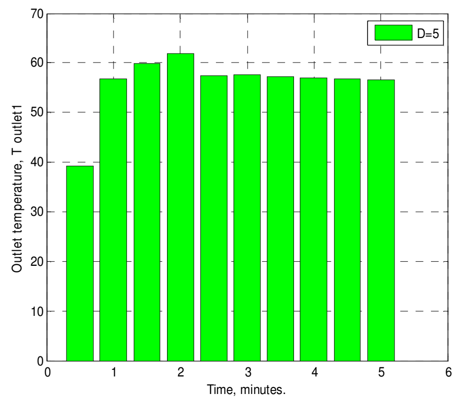


Figure 3-b, relation between outlet temperature , T $_{outlet1}$ and time for (Plate 1), D=5 cm

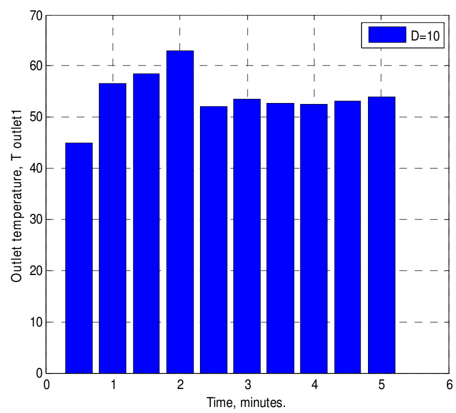


Figure 3-c, relation between outlet temperature , T outlet1 and time for (Plate 1), D=10 cm

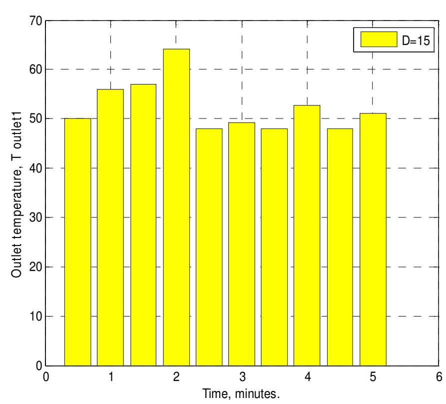


Figure 3-d, relation between outlet temperature , T $_{outlet1}$ and time for (Plate 1), D=0 cm

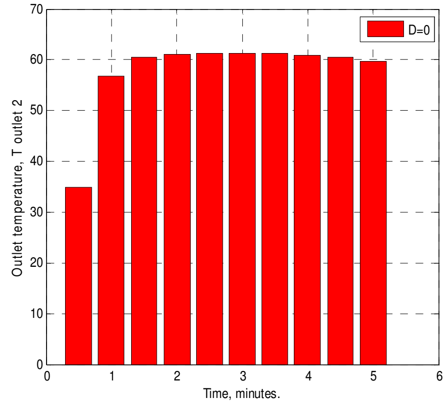


Figure 4-a, relation between outlet temperature , T $_{outlet2}$ and time for (Plate 2), D=0 cm

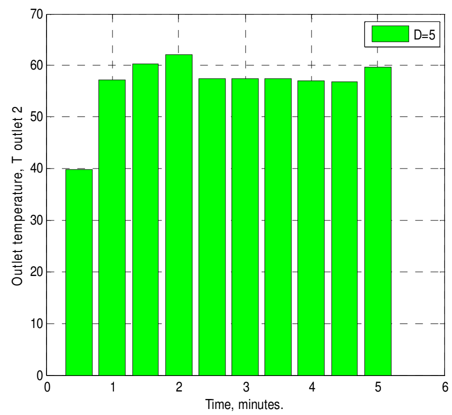
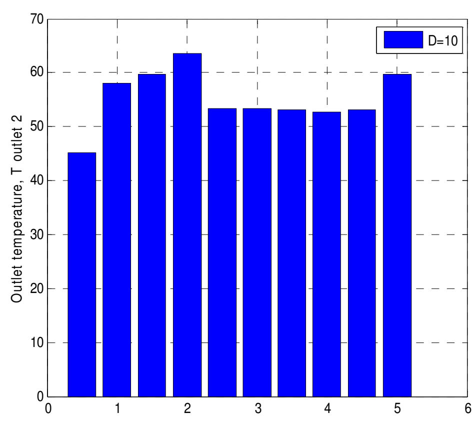


Figure 4-b, relation between outlet temperature , T $_{outlet2}$ and time for (Plate 2), D=5 cm



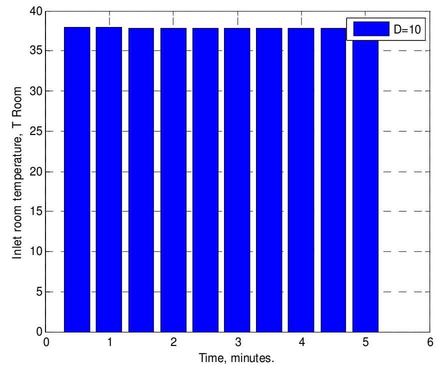


Figure 5-c, relation between inlet room temperature and time for D=10 cm

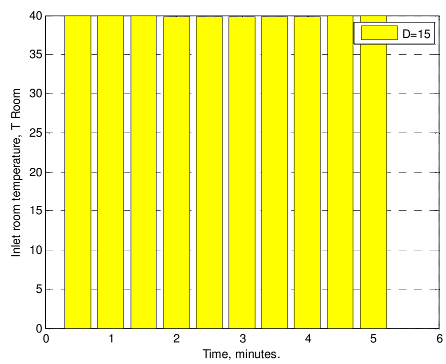


Figure 5-d, relation between inlet room temperature and time for D=15 cm

Figure 6(a, b, c, d) and Figure 7(a, b, c, d) demonstrated that the time interval space affect in the heat transfer rate. It is noted that at the beginning of the experiments (t =30 sec), the heat transferred is too high but could be neglected at the end of the experiment. This as a result of the temperature difference in the first is too high, so the heat transfer is too high. But, as the time increased as the room temperature increased. So, the heat transferred decreased, but the room begins to radiate heat. So, it must the inner space between the two plates did not increased above 5 cm. This decided the objective of the paper.

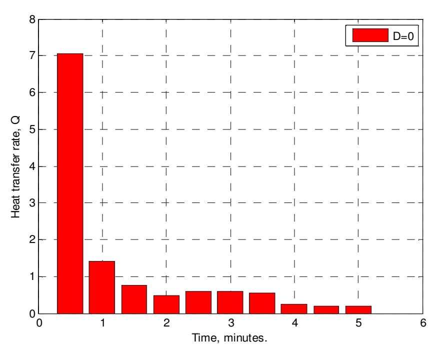


Figure 6-a, relation between heat transfer and time for D=0 cm

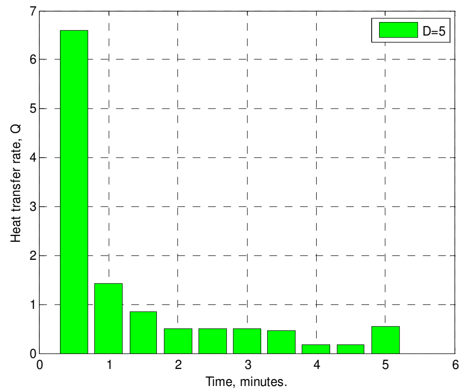


Figure 6-b, relation between heat transfer and time for D=5 cm

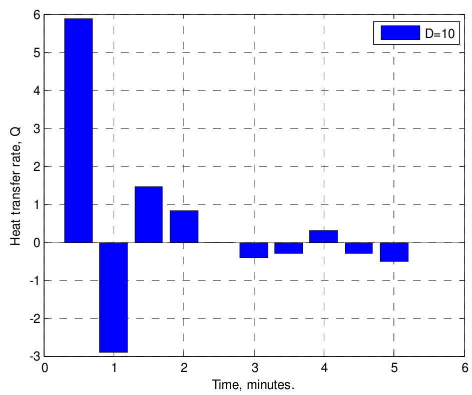


Figure 6-c, relation between heat transfer and time for D=10 cm

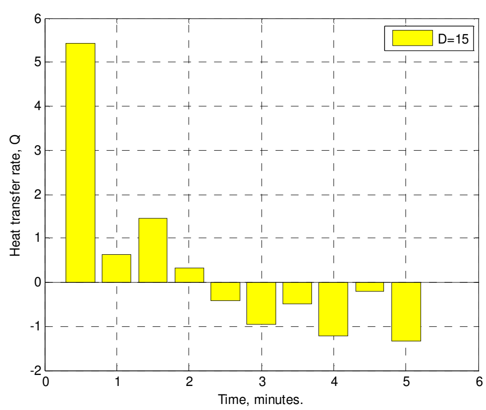


Figure 6-d, relation between heat transfer and time for D=15 cm

It is shown from Fig. 7(a, b, c, d) the relation between the radiation heat transfer to the room and the time intervals for different gaps (D). It is noted that the radiation heat transfer rate to the room is high in Case D= 0, and reduces as D increased. It is noticed also thatthe radiationheat transfer rate to the room is reduced to approximately 25% as compared with D=0. This as a result of the temperature difference is decreased as inner space increased. Also, there is a convection heat transfer to the room, thus the room is too warm and satisfied. So, the radiation to the room becomes limited at D= 15 mm. Fig. 5 proved that also.

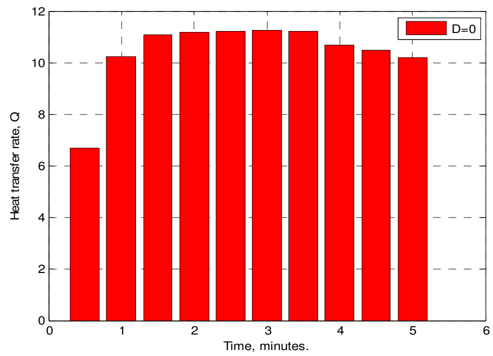


Figure 7-a, relation between radiation heat transfer to the room and time for D=0 cm

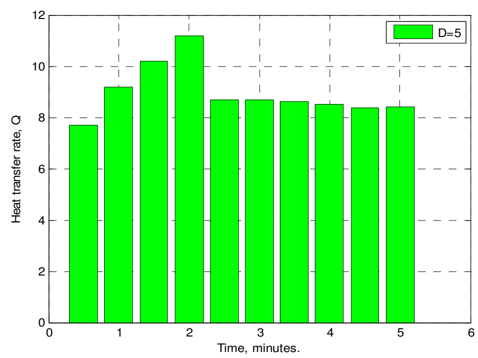


Figure 7-b, relation between radiation heat transfer to the room and time for D=5 cm

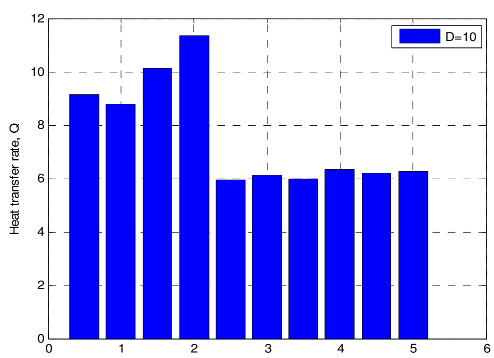


Figure 7-c, relation between radiation heat transfer to the room and time for D=10 cm

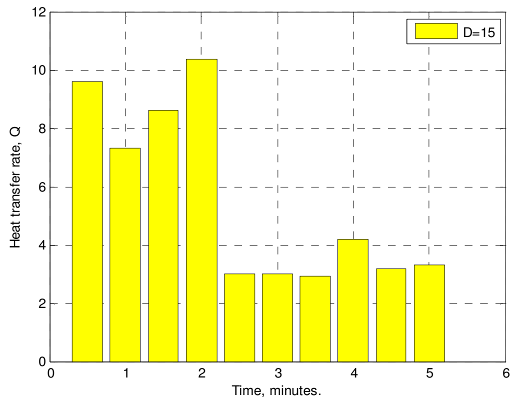


Figure 7-d, relation between radiation heat transfer to the room and time for D=15 cm

4. CONCLUSIONS

- Both the inner space between two parallel plates and small time intervals affect strongly in the heat transfer to the surrounding.

- In the beginning of the experiments (t =30 sec), the heat transferred to the room is too high but could be neglected at the end of the experiment as a result of room satisfaction.

- The room temperature at D=15 increased approximately by 10% as compared with at (D=0), this as a result of both radiation and natural convection heat transfer.

- It must be the inner space between the two plates did not increased above 5 cm. Above this, the room is satisfied, and the room can reject the heat.

- The out let temperature in case D= 15 cm for two plates decreased approximately 24% and 23% for two plates. This means that the Inner space effects on the convection heat transfer rate.

- The heat radiated to the room decreased as the inner space between the two plates increased, and decreased to approximately 25% as compared to stack plates

Nomenclature:

Ta	The ambient temperature (K).
T_i	Inlet water temperature.
T_{out}	Outlet water temperature.
Tr	The room temperature (C°).
Q_s	Sensible heat stored.
m	Water mass flow rate.
C_p	Specific heat capacity at constant pressure.

ACKNOWLEDGEMENTS

Thanks for the Assoc. prof. Mahmoud Salem, Faculty of Industrial Education, Sohag University for his kinds and encouragement. Also,full acknowledgment for solar energy laboratory staff.

REFERENCES

[1] FouedChabaneaet. al., Experimental study of heat transfer and thermal performance with longitudinal fins of solar air heater, Journal of Advanced Research, Vol. 5, Issue 2,(2014),183–192.

[2] S.S. Krishnananth, K. KalidasaMurugavel, "Experimental study on double pass solar air heater with thermal energy storage", Journal of King Saud University - Engineering Sciences, Vol.25, Issue 2,(2013), 135–140.

[3] L.B.Y. Aldabbaghaet. al., Single and double pass solar air heaters with wire mesh as packing bed, Energy, Vol. 35, Issue 9, (2010), 3783–3787.

[4] Xin-RongZhangaet. al., Experimental study on solar thermal conversion based on supercritical natural convection, Renewable Energy, Vol. 62 (2014), 610–618.

[5] Wei Chang et. al., The Theoretical and Experimental Research on Thermal Performance of olar Air Collector with Finned Absorber, Energy Procedia, Vol.70, (2015), 13-22.

[6] Jie Deng et. al. ,Experimental Study of a Single-pass Flat Plate Solar air Collector with Severe Dust Deposition on the Transparent Glass Cover, Energy Procedia, Vol. 70, (2015), 32-40.

[7] BalaramKundu ,Beneficial design of unbaffled shell-and-tube heat exchangers for attachment of longitudinal fins with trapezoidal profile, Case Studies in Thermal Engineering, Vol. 5, (2015), 104–112.

[8] Zhang, Tao et. al.Experiment and simulation for convective heat transfer in all-glass evacuated tube solar collectors", Transactions of the Chinese Society of Agricultural Engineering, Vol. 32, No.5, (2016), 206-212.

[9] MoukhtarLati, SlimaneBoughali, Experimental study on flat plate air solar collector using a thin sand layer, AIP Conference Proceedings, Vol. 1758, Issue 1, (2016), 030018-1: 030018-6.

[10] S.S. Krishnananthet. al. Experimental study on double pass solar air heater with thermal energy storage, Journal of King Saud University - Engineering Sciences, Vol. 25, Issue 2, (2013), 135–140.

[11] H Terres1 et. al. Energy applied to the heat conduction analysis in glass covers of a solar cooker box-type with internal and external reflectors, Journal of Physics: Conference Series, Vol. 792, No.1,(2017), 1742-1753.

[12] T Sitepu1 et. al., Experimental Study on Performance of a Box Solar Cooker with Flat Plate Collector to Boil Water, IOP Conference Series: Materials Science and Engineering,, Vol. 180, No. 1, (2017), 1-7.

[13] V. M. Kriplani et. al., Natural Convection In Tubes – A Solar Water Heating Application, WIT Transactions on Engineering Sciences, Vol. 59, (2008), 401-408.

[14] N. K. Groenhout et al., Experimental measurement of heat loss in an advanced solar collector, Experimental Thermal and Fluid Science, Vol. 26, No. 8, (2008), 131–137.

AUTHOR

Seif A. Ahmed:

Mechanical Engineering Department Faculty of Engineering, Beni-Suef University, BeniSuef, Egypt.