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A COMPARATIVE EXPERIMENTAL INVESTIGATION OF THERMAL PERFORMANCE OF THREE DIFFERENT SOLAR AIR HEATERS

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ABSTRACT

This study aims to compare three different types of solar air heaters, simple single pass (Type I), simple double pass (Type II) and double pass having aluminum cans (Type III). In type III used aluminum Beverage cans were attached to absorber plate, in order to provide better heat transfer surface. A 4 mm single glass plate used to cover the collector, to reduce convective loses to the atmosphere. These three types of experimental setup were tested for different air flow rates (3.25 m/s and 3 m/s) and temperature conditions versus time. The collector slope was adjusted to 26° and south faced, which is suitable for the geographical location of Jaipur (26.9260° N, 75.8235° E). Experiment on the solar air heaters were performed in the clear days of April, May and June 2014. The maximum thermal efficiency was achieved in type III at air flow rate 3.25m/s.

KEYWORDS: Solar Air Heater, Aluminum Cans, Thermal Efficiency, Solar Flux w/m^2 and absorber plate.

1. INTRODUCTION

Solar air heaters are simple devices to heat air by utilizing solar energy. Solar air heaters are employed for low to moderate temperature applications like space heating, crop drying, timber seasoning, paint spraying operations and other industrial applications. A glass or plastic cover is attached above the absorber plate and the system is insulated thermally from the back and from the sides. Solar air heaters are simple in design and maintenance. It has less corrosion and leakage problem compared with the liquid flat plate collector. The key weakness of a solar air heater is that the coefficient of heat transfer between the absorber plate and air stream is low, which result in less thermal efficiency of the solar air heater. Many modifications have been developed to improve the heat transfer coefficient between the absorber plate and air stream passing through. Factors which affect the solar air heater efficiency are collector depth, collector length, wind velocity, glass cover thickness, absorber plate material, falling solar flux, etc. Inserting fins or cans in the absorber plate will increase the heat transfer to the passing air but it will increase the pressure drop in the collector, resulting in Power consumption to pump the air through the collector increases.

Attempts have been made to improve the efficiency of solar air heaters by employing various techniques. Test has been made on different shape and dimension of air flow passage in plate type solar air collector. A range of theoretical models have been introduced to improve the disadvantage of solar air heaters. In order to improve the heat transfer area double flow solar air heater have been introduce, resulting in improve in thermal performance. Obstacles in the collector allow good distribution of fluid flow. Karim and Hawlader investigated both experimentally and theoretically in an effort to improve the performance of conventional air heaters using finned and v-corrugated air heaters.

This paper present thermal efficiency evaluation of a type I, type II and type III solar air heater respectively. In this study, the thermal efficiency analysis were done to compare the performance of designed simple solar air heater (type I), simple double pass solar air heater (type II) and double pass solar air heater with aluminum cans (Type III). An experimental set-up, described in the next section, is constructed and tested in roof of ISBM, Suresh Gyan Vihar University, Jaipur (latitude 26.9260° N, longitude 75.8235° E, altitude 431m above sea level), Rajasthan, India. The efficiency of the new SAH is determined from the experimental measurements. Thermal efficiency of solar air heaters were evaluated for various air flow rates (3.25 m/s, 3.0 m/s), and air temperature conditions versus time.

2. EXPERIMENTAL SET-UP AND MEASUREMENT PROCEDURE

Solar air heater mainly consists of wooden box, transparent cover (glass or plastic), absorber plate, insulating material, blower, and air passage. A schematic view of the constructed solar air heater system is shown in the Fig. 1(a-b) and photograph of Type I, Type II and Type III are shown in Fig. 2, respectively.

In this study three type of solar air heater were employed Type I, Type II and Type III respectively. The box was made of plywood 12 mm thick. The internal dimension of box was 1200 x 600 x 170 mm. Thermocole sheets of 22 mm thickness were used to insulate the collector box form sides and bottom. Fevicole adhesive is used to stick thermocole sheets to plywood box. Aluminum sheet of 30 gauge thickness was used for absorber plate. The aluminum sheet was coated with black dark rubber coating to absorb more heat. Normal window glass of 4 mm thickness was used as glazing. In all three types single glass cover was used. Exhaust fan of 60 watt was used as blower to force the air through the collector. A special nozzle type arrangement was provide to force the air through 57 mm diameter hole in the collector. LM-35 temperature sensor was used to measure the temperature at different point in the solar air heater, inlet, exit, absorber plate, inside between glass and absorber, and bellow glass cover respectively. The environmental temperature was measure with the help of alcohol thermometer. Digital solar power meter (TENMARS TM- 207) was used to measure the solar flux in w/m^2 at both the position horizontal as well 26° angle. Digital anemometer (METRAVI AVM-05) was used to measure the air velocity in m/s at the exit of solar air heater as well as surrounding air velocity. Cover glass was glued to collector box with wall putty. Rubber cushioning was provided between glass and collector box to avoid air gap. Incense stick was used to ascertain no air gap in the solar air heater. The absorber plate was placed in middle of the plywood box at the 85 mm depth from top of the box.

The wooden box was dark black painted from inside. In type I absorber plate complete enclose the collector box at the middle. In type II solar air heater a gap of 30 mm was provided to circulate the air from upper side of absorber plate to the bottom side of the plate. In type III aluminum cans were inserted in the absorber plate. Aluminum cans were painted in black. Each aluminum cans was opened on the top and bottom, their surface was cleaned using water. After installation, the three types of solar air heater were left operating several days under normal weather conditions. The LM- 35 temperature sensor wires were positioned at different point in the solar air heater. The solar air heater was tilted 26° angle and south faced. Experiment on the solar air heater was performed in the clear days of April, May and June 2014 in Jaipur, Rajasthan, India. The test was conducted between 10:15 AM and 3:15 PM solar time. The reading was taken at the interval of 30 minutes. The solar radiation(horizontal and 26° angle position), wind speed, air velocity at the exit of the heater, ambient air temperature, heater inlet and outlet air temperatures, absorber plate temperature, bellow glass temperature, and inside temperate were measured or each set of experiments during the steady state period by 30 min intervals. The temperature was measured at different point by LM-35 temperature sensor. The environmental temperature was measure with the help of alcohol thermometer. Digital solar power meter (TENMARS TM- 207) was used to measure the solar flux in w/m^2 at both the position horizontal as well 26° angle. Digital anemometer (METRAVI AVM-05) was used to the air velocity in m/s at the exit of solar air heater as well as surrounding air velocity.

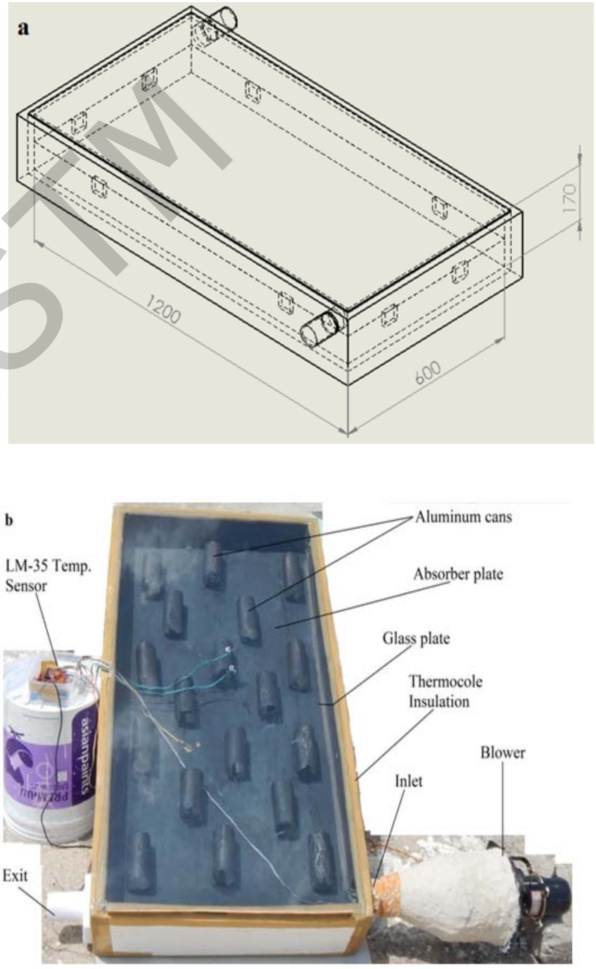

Figure 1: Schematic view of Solar air Heater

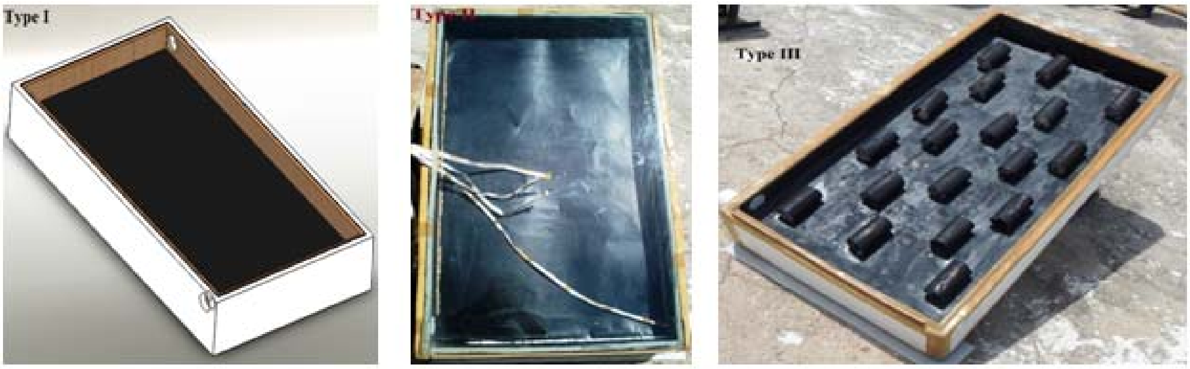

Figure 2: Types of solar air heaters

3. THERMAL PERFORMANCE ANALYSIS

Thermal efficiency (**η**) of the solar air heater is defined as the ratio of the useful energy gain to the solar radiation incoming to the solar air heater:

$$\eta = Q_u / I\,A_c \qquad \textbf{(1)}$$

Where **Q_u** is the collector useful energy gain (W), **I** is the solar radiation (W/m^2) on the heater surface, **A_c** is the surface area of the collector (m^2). The useful energy gain (Q_u) can be calculated by following equation:

$$Q_u=\dot{m}C_p(T_{a,out}-T_{a,in}) \qquad \textbf{(2)}$$

Where **ṁ** is the mass flow rate (kg/s), **C_p** is the specific heat of air at constant pressure (kJ/kg.K), **$T_{a,\ out}$** is the temperature of air at outlet, **$T_{a,\ in}$** is the temperature of air at inlet.

Putting **Q_u** from equation (2) in equation (1), we get:

$$\eta=\dot{m}C_p(T_{a,out}-T_{a,in})/IA_c \qquad \textbf{(3)}$$

Equation for Mass flow rate (**ṁ**) is:

$$\dot{m}= \rho AV \qquad \textbf{(4)}$$

Where **ρ** is the density of air (kg/m^3), **A** is the cross section area of pipe at exit (m^2) and **V** is the velocity of air at exit (m/s).

Density of air (**ρ**) can be calculated by following equation:

$$P\nu= RT \qquad \textbf{(5)}$$

Where **P** is the pressure (N/m^2), **ν** is the specific volume (m^3/kg), **R** is the specific gas constant (287 J/kg.K) and **T** is the temperature.

ν can be written as:

$$\nu= 1/\rho \qquad \textbf{(6)}$$

So, equation for **ρ** is:

$$\rho= P/RT \qquad \textbf{(7)}$$

4. RESULT AND DISCUSSIONS

Collector performance tests were conducted on days with clear sky condition. The collector slop was adjusted to 26° south facing, which is suitable for geographical location of Jaipur (latitude 26.9260° N, longitude 75.8235° E, altitude 431m above sea level). The collector was provided with LM-35 temperature sensor for measuring temperature of absorber plate, inlet air, outlet air, below glass cover and inside between glass and absorber.

The thermal efficiency of all three types, I, type II and type III solar air heaters, were calculated using equation (3) at different velocity of air(3.25 m/s and 3 m/s). Experiment on the solar air heater was performed in the clear days of April, May and June in Jaipur, Rajasthan, India (23/04/2014-05/06/2014) period. The test was conducted between 10:15 AM and 3:15 PM solar time.

Fig. 3 shows the hourly temperature variations of Type I collector and exit air velocity is 3.25 m/s, during the experiments. The solar flux (W/m^2) is also shown in the secondary axis. The highest daily solar flux is obtained as 1248 W/m^2. As expected, it increases in the morning to a peak value 1248 W/m^2 at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 94.45, 37.90, 65.5, 71.26, 74.77 and 36.08°C respectively. Daily mean solar flux is measured as 1119.36 W/m^2. The mean thermal efficiency is calculated as 29.01%. The difference between the mean daily exit and inlet temperature of type I at exit air velocity 3.25 m/s is measured as 27.6 °C.

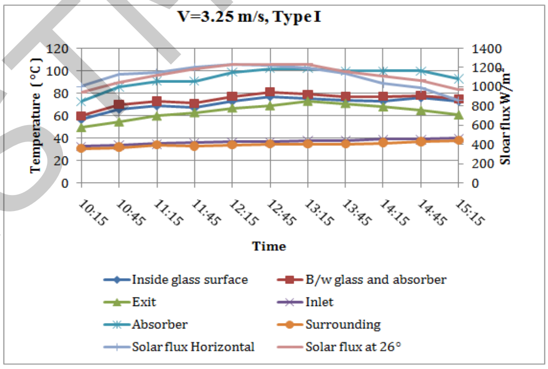

Figure 3: Temperature variation of type I collector at 3.25 m/s

During the experiments, the hourly variations of temperatures of Type I at exit air velocity 3 m/s is shown in Fig. 4. The solar flux (W/m^2) is also shown in the secondary axis. The highest daily solar flux is obtained as 1253.5 W/m^2. As expected, it increases in the morning to a peak value 1253.5 W/m^2 at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 94.18, 43.86, 73.13, 76.76, 79.13 and 40.81°C respectively. Daily mean solar flux is measured as 1075.45 W/m2. The mean thermal efficiency is calculated as 28.67%. The difference between the mean daily exit and inlet temperature of type I at exit air velocity 3 m/s is measured as 29.27 °C.

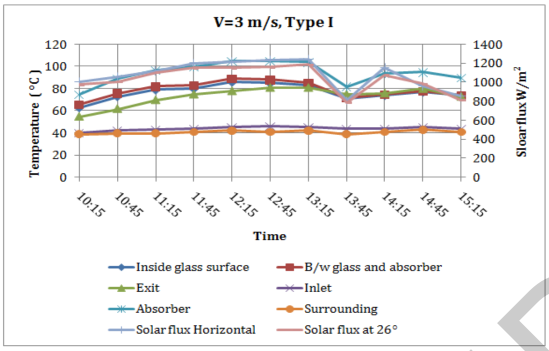

Figure 4: Temperature variation of type I collector at 3 m/s

The hourly temperatures variations of Type II at exit air velocity 3.25 m/s is shown in Fig. 5. The solar flux (W/m²) is also shown in the secondary axis. The highest daily solar flux is obtained as 1265 W/m². As expected, it increases in the morning to a peak value 1265 W/m² at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 96.81, 39.81, 71.45, 82.81, 86.09 and 38.90°C respectively. Daily mean solar flux is measured as 1154.63 W/m2. The mean thermal efficiency is calculated as 31.75%. The difference between the mean daily exit and inlet temperature of type II at exit air velocity 3.25 m/s is measured as 31.64 °C.

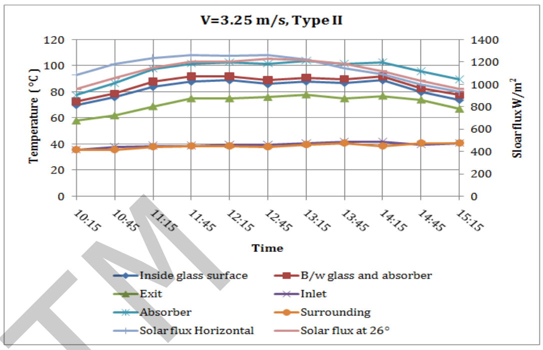

Figure 5: Temperature variation of type II collector at 3.25 m/s

Fig. 6 shows the hourly variations of temperatures of Type II and exit air velocity is 3 m/s, during the experiments. The solar flux (W/m²) is also shown in the secondary axis. The highest daily solar flux is obtained as 1284 W/m². As expected, it increases in the morning to a peak value 1284 W/m² at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 94, 38.54, 70, 80.09, 83.72 and 37.81°C respectively. Daily mean solar flux is measured as 1085.72 W/m2. The mean thermal efficiency is calculated as 31.31%. The difference between the mean daily exit and inlet temperature of type II at exit air velocity 3 m/s is measured as 31.46 °C.

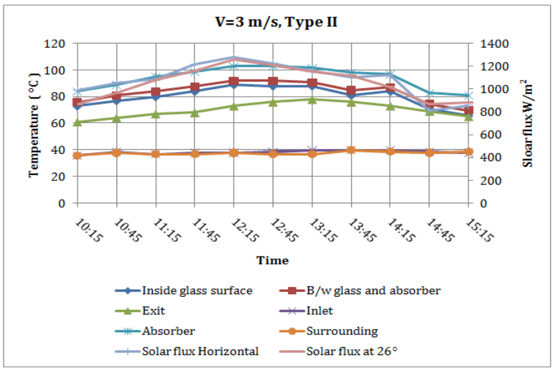

Figure 6: Temperature variation of type II collector at 3 m/s

Fig. 7 illustrates the hourly variations of temperatures of Type III and exit air velocity is 3.25 m/s, during the experiments. The solar flux (W/m²) is also shown in the secondary axis. The highest daily solar flux is obtained as 1230 W/m². As expected, it increases in the morning to a peak value 1230 W/m² at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 97.90, 42.04, 77.72, 85.27, 89.63 and 39.5°C respectively. Daily mean solar flux is measured as 1085.72 W/m2. The mean thermal efficiency is calculated as 36.12%. The difference between the mean daily exit and inlet temperature of type III at exit air velocity 3.25 m/s is measured as 35.68 °C.

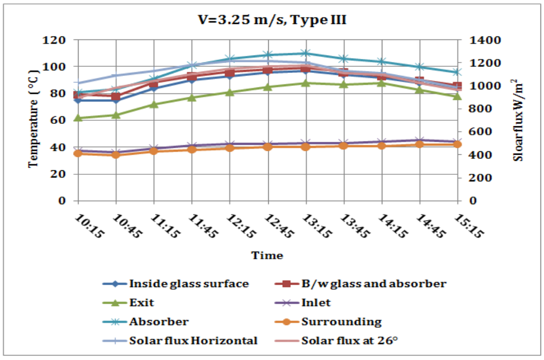

Figure 7: Temperature variation of type III collector at 3.25 m/s

During the experiments, the hourly variation of temperatures of Type III at exit air velocity is 3 m/s is shown in Fig. 8. The solar flux (W/m²) is also shown in the secondary axis. The highest daily solar flux is obtained as1260.5 W/m². As expected, it increases in the morning to a peak value 1260.5 W/m² at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 94.31, 43.54, 77.59, 78.95, 84.49 and 41.86 °C respectively. Daily mean solar flux is measured as 1085.72 W/m2. The mean thermal efficiency is calculated as 32.18%. The difference between the mean daily exit and inlet temperature of type III at exit air velocity 3 m/s is measured as 35.68 °C.

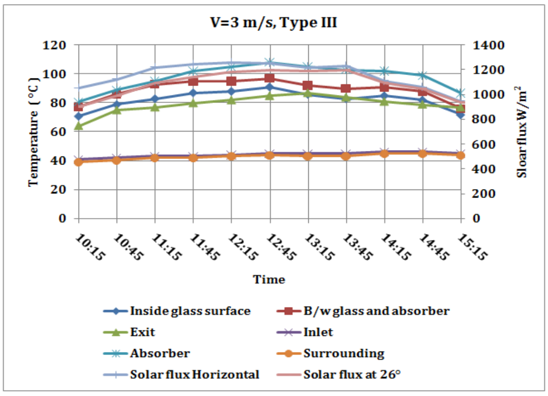

Figure 8: Temperature variation of type III collector at 3 m/s

Efficiency versus time at various air velocity and collector type is shown in Fig. 9. From the figure it can be seen that thermal efficiency increases to a maximum value at 14:15-14:45 PM and then they start to decrease in the afternoon. The efficiency of Type III at air velocity 3.25 m/s is higher than that of Type I and that of Type II, respectively. The study has shown that the using aluminum cans in the absorber plate lead to a very significant improvement in the efficiency.

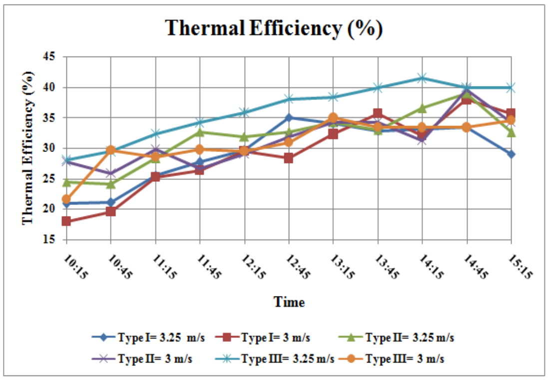

Figure 9: Efficiency versus time at various air velocity and collector type

5. CONCLUSIONS

A detailed experimental study was conducted to evaluate the energy efficiencies of three types, Type I, Type II and Type III solar air heaters. According to the to the result of the experiments, the double flow solar air heater having aluminum cans introduced for increasing the heat-transfer area at exit air velocity 3.25 m/s, leading to improved thermal efficiency.

REFERENCES

1. Filiz Ozgen, Mehmet Esen and Hikmet Esen. Experimental investigation of thermal performance of a double-flow solar air heater having aluminium cans. Renewable Energy 34 (2009) 2391–2398.
2. Deniz Alta, Emin Bilgili, C. Ertekin, Osman Yaldiz. Experimental investigation of three different solar air heaters: Energy and exergy analyses. Applied Energy 87 (2010) 2953–2973
3. S.P. Sukhatme. Solar energy principles of thermal collection and storage. Second edition ISBN 0-07-462453-9.

4. H.P. Garg and J. Prakash. Solar energy fundamentals and applications. First revised edition ISBN-10: 0-07-463631-6.

5. G. D. Rai. Non-conventional sources of energy. Fourth edition, 29th reprint:2010, ISBN NO. : 81-7409-073-8.

6. Ho-Ming Yeh, Chii-Dong Ho, Chi-Yen Lin. Effect of collector aspect ratio on the collector efficiency of upward type baffled solar air heaters. Energy Conversion & Management 41 (2000) 971-981

7. Paisarn Naphon. Effect of porous media on the performance of the double-pass flat plate solar air heater. International Communications in Heat and Mass Transfer 32 (2005) 140–150.

8. Ebru Kavak Akpinar, Fatih Koçyigit. Energy and exergy analysis of a new flat-plate solar air heater having different obstacles on absorber plates. Applied Energy 87 (2010) 3438–3450.

9. M.K. Gupta, S.C. Kaushik. Exergetic performance evaluation and parametric studies of solar air heater. Energy 33 (2008) 1691– 1702.

10. A.P. Omojaro, L.B.Y. Aldabbagh. Experimental performance of single and double pass solar air heater with fins and steel wire mesh as absorber. Applied Energy 87 (2010) 3759–3765.

11. S.S. Krishnananth, K. Kalidasa Murugavel. Experimental study on double pass solar air heater with thermal energy storage. Engineering Sciences (2012).

12. Abhishek Saxena , Nitin Agarwal, Ghansyham Srivastava. Design and performance of a solar air heater with long term heat storage. International Journal of Heat and Mass Transfer 60 (2013) 8–16.

13. Hikmet Esen. Experimental energy and energy analysis of a double-flow solar air heater having different obstacles on absorber plates. Build Environ 2008; 43(6):1046–54.

14. Zaid AA, Messaoudi H, Abenne A, Ray ML, Desmons JY, Abed B. Experimental study of thermal performance improvement of a solar air flat plate collector through the use of obstacles: application for the drying of “yellow onion’’. Int J Energy Res 1999; 23(12):1083–99.

15. Moummi N, Ali SY, Moummi A, Desmons JY. Energy analysis of a solar air collector with rows of fins. Renew Energy 2004; 29(13):2053–64.