E-ISSN: 2997-9382
American Journal of Technology Advancement
https://semantjournals.org/index.php/AJTA

| Research Article

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Solar Collector Performance Enhancement by Using a Penetrated Microporous Heat Absorbing Plate

Mohammed H. Dawood
Alkarkh Uuniversity of Sscience, Baghdad, Iraq

Annotation
Solar collectors are the core of solar heat utilization technologies, and the thermal performance and heat collecting efficiency determines the development and popularization of solar utilization technologies. In this paper, the typical methods and application areas of solar thermal utilization are summarized, the heat collecting principles and type structures of solar collectors are described and analyzed. results show that the outlet temperature and heat collection efficiency of the flat-plate solar air collector using penetrated microporous absorber plates are significantly higher than those of the solar air collector using non-porous corrugated absorber plates. The collector can increase the absorption of solar radiation heat energy and strengthen the convective heat exchange between the absorber and the air. Therefore, the former solar air heater was proved to be able to absorb more radiant heat energy from the sun to increase the heat convection between the absorber flat plate and the air to get the best heat observation.

Keywords: Renewable energy /Solar air collector/ Wavy absorbing plate/ Solar heat storage / Porous heat collector.

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INTRODUCTION

The working principle of solar air collector is to absorb solar radiation heat through the heat absorber, exchange heat with the heat carrier and then send it to the heat use place, using air as the heat carrier, heating the air and sending it into the room to provide heating for the room. [1] Glass cover flat plate solar air collector is one of the most common solar air collectors at present. [2] It mainly consists of a shell, a heat absorbing plate, an air inlet, an air outlet and a transparent cover covering the surface of the collector. The working principle is: solar radiation heat passes through the glass cover to heat the heat absorbing plate, and the air enters from the air inlet, is heated when it flows through the flat heat absorbing plate, and enters the room through the air outlet to provide heating for the room. [3]

1. COLLECTOR HEAT COLLECTION PERFORMANCE EXPERIMENT

1.1 Introduction to the design model

This paper studies the heat collection efficiency of two types of solar flat-plate collectors. Except for the different structures of the heat absorbing plates, the other dimensions, methods, materials and test instrument test conditions of the two flat-plate air collectors are the same. The purpose is to test the heat collection efficiency of penetrated plate heat absorbing elements and non-porous heat absorbing elements. Through previous research, it has been scientifically proven that the use of nano-particles in the field of heat transfer improves the heat transfer rate process by 15% to 25% [10].

1. Experimental setup:

The experimental apparatus was designed as a standard solar air heater with minor modifications and installation of aids to achieve the objectives of the study. The test apparatus was assembled at the Solar Thermal Energy Research Center, Al-Kharkh University of Science, Baghdad, Iraq. The test apparatus refers to an automatic air heating system that uses solar energy to heat air from 47 to 68 °C (daily average). To control and increase the hot air temperature, a microporous heat absorbing plate was added, the model heat absorbing element is a metal corrugated plate with a black coating. Model (1) in Figures (1,2) is a penetrated microporous heat absorbing plate, and model (2) is a non-porous heat absorbing plate. The model size is 200cm×100cm.

The main components are briefly introduced as follows:

1. The heat absorbing plate is the core component of the collector. It is rolled from a 0.6mm thick thin steel plate and has a size of 200cm×100cm. The outer surface of the heat absorbing plate is coated with black to facilitate the absorption of solar radiation heat; [4] the inner surface is painted with a light color to reduce the radiation heat loss of hot air [5]. The cross section of the heat absorbing plate is wavy, and vertical stripes are formed on the heat absorbing plate to increase the absorption of solar radiation and the heat exchange area with the air. In the model, the heat absorbing plate is arranged vertically in the collector interlayer.
2. Insulation layer: A 40mm thick extruded board insulation layer is set around the collector shell and on the back plate to reduce the heat transfer loss of the collector through the shell and ensure the accuracy of the test results.
3. cold and hot air vents: Two upper and lower cold air vents are set on the back of the collector, and hot air vents are set on the sides of the collector.
4. Fan: For the collector, the fan is an important component to provide negative pressure for the air interlayer. [6] In terms of engineering applications, axial flow fans, cross-flow fans and centrifugal fans can be used. The air volume required in this test is small, and it requires a simple structure, small size, stable performance, low price and easy installation. In addition, the noise should be as small as possible, so a simple axial flow fan is selected [7].

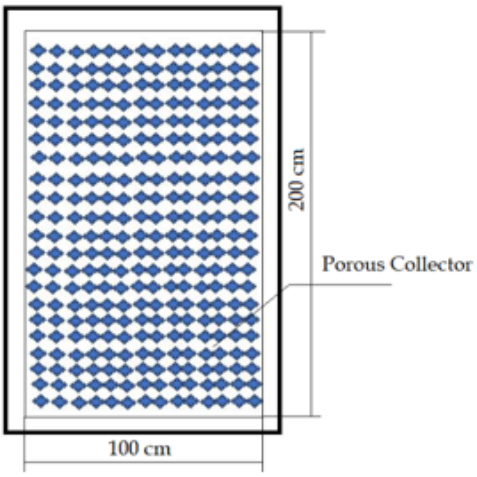

Fig. 1 Collector elevation with microporous

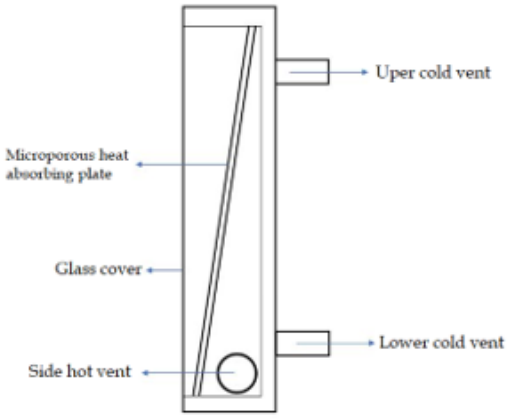

Fig. 2 collector section side view.

1.2 Outdoor climate conditions and experimental methods

The test time was selected in November 2024, and two types of collectors were tested for a two week. The experiment done in Iraq/ Baghdad, the measuring points were arranged on the wall of the heat absorbing plate and the air outlet. The temperature of the above two points was tested and the heat collection efficiency of the collector was calculated.

1.2.1 Experimental equipment:

(CETC 41) outdoor environment test system (include wind speed, solar intense, humidity, ambient temperature) the device can measure all the variables that mentioned previously as a package of data and save it with axel sheet in connected computer and calibrated from Standardization and Quality Control Department in Baghdad/Iraq as a scientific laboratory device, (TM-947SD) temperature recorders with four channels. Figure 3 shows the test site of the solar flat-plate collector. The measuring points arranged on the wall of the heat absorber measure the temperature of the heat absorber wall. When arranging the measuring points on the wall, first apply butter on the temperature sensor probe of the (TM-947SD) multi-point temperature detection system to make it in close contact with the wall of the heat absorber to eliminate the contact thermal resistance (both devices (TM-947SD) and (CETC 41) are calibrated and Certified from Standardization and Quality Control Department in Baghdad/Iraq). Then use tape to fix the probe on the wall of the heat absorber. After it is firmly fixed, cover it with tape above the measuring point to reduce the measurement error caused by radiation and ensure the accuracy of the test. The measuring points arranged at the collector outlet measure the temperature of the air heated by the collector. Use tape to fix the temperature measuring point at the collector outlet so that the probe faces the airflow direction.

Test items:

- ✓ Ambient Temperature.
- ✓ Solar Radiation.
- ✓ Wind Speed.
- ✓ Solar Collector Air Supply Temperature.
- ✓ Wall Temperature, Etc.

Fig. 3 The experiment with environmental test system.

1.2.2 Data output:

Figures 4 to 6 show the ambient temperature, wind speed and total radiation on the test day (13th of November). As shown in Figure 4, the ambient temperature on the test day was between 5 and 13°C from 8:00 am to 15:30 Pm, and the average temperature was 11.33°C. Although there was a certain fluctuation, the fluctuation was not large, and the test analysis can be carried out. Figure 5 is the curve of the change of solar total radiation intensity on the test day. As shown in the figure: the maximum solar total radiation on the test day was 479.2 W/m^2, the average radiation intensity was 351.21 W/m^2, the weather was fine, and the radiation fluctuation was not large, which met the requirements of the dynamic experiment. Figure 6 shows the curve of the wind speed change on the test day. As shown in the figure, the maximum wind speed on the test day was 3.5 m/s, and the average wind speed was 1.33 m/s, which is typical.

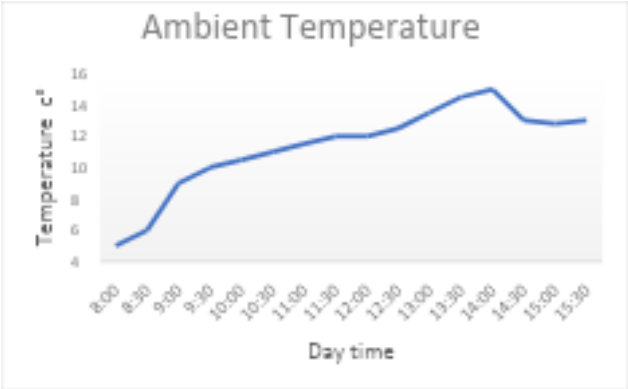

Fig. 4 Ambient temperature in test day.

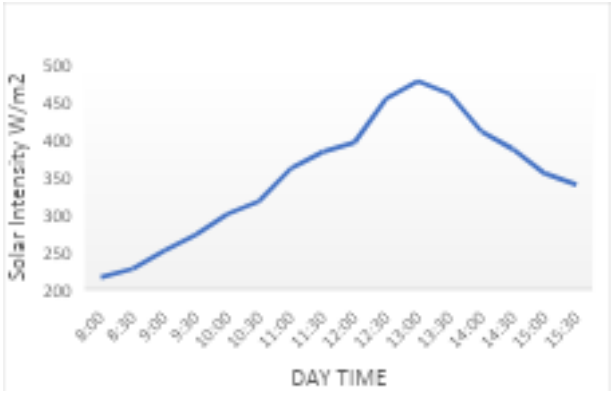

Fig. 5 Solar intensity curve in test day.

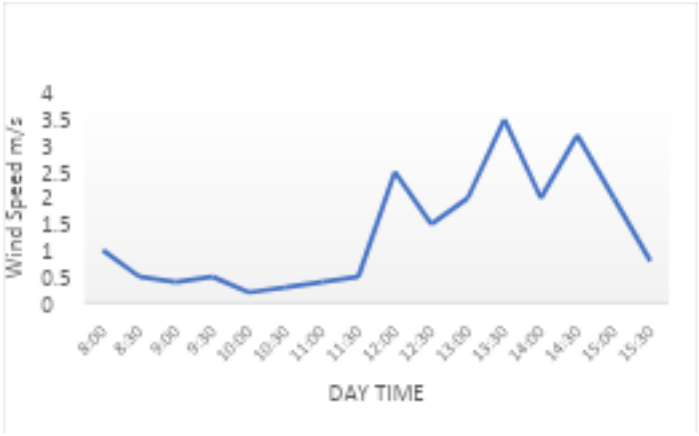

Fig. 6 Wind speed test curve.

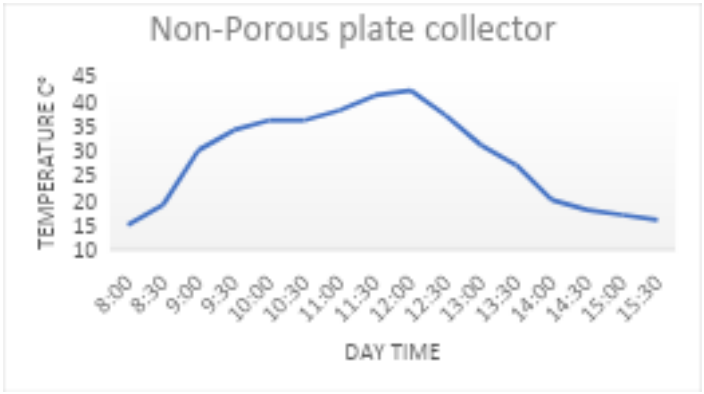

Fig. 7 Non porous absorbing plate collector heat supply curve.

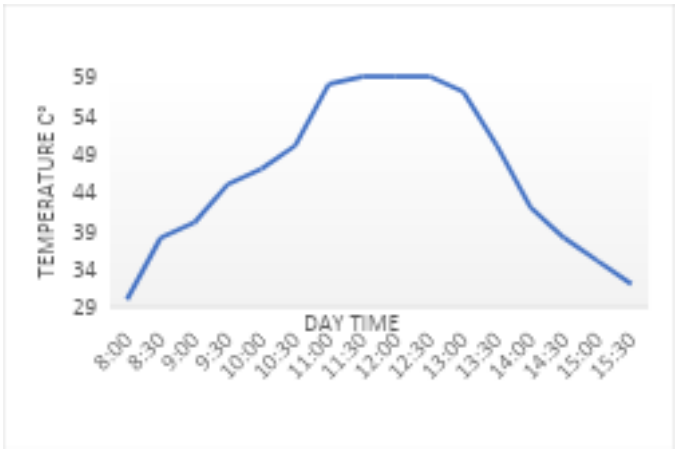

Fig. 8 Penetrated absorbing Plate Collector Heat supply curve.

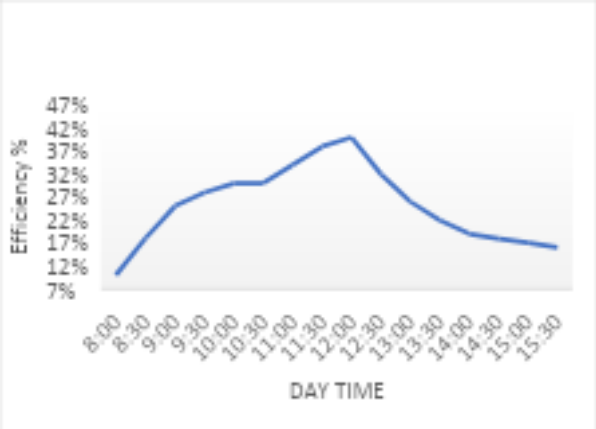

Fig. 9 Non porous plate collector efficiency.

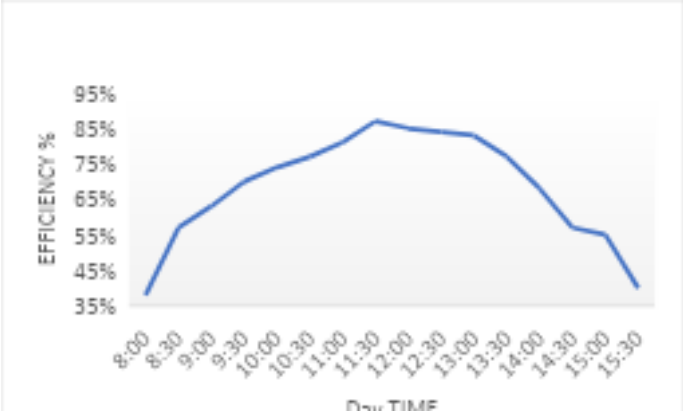

Fig. 10 Penetrated plate collector efficiency.

Fig. 11 solar intensity and ambient temperature relation.

2. EXPERIMENTAL DATA AND ANALYSIS

2.1 Temperature

The air supply temperature is an important parameter of the solar air collector. The air supply temperature determines the amount of hot air provided by the air collector to the room during the day. Generally speaking, the higher the air supply temperature in winter, the better. Figures 7 and 8 show the air supply temperature comparison curves of the two air collector models. The curves are the dynamic experimental temperature curves of the collector models. It can be seen from the figure that the air outlet temperature of the non-penetrated heat absorber collector is as low as 15℃, reaching more than 41℃ between 8:00 and 11:30, and the highest temperature reaches 42℃; the air supply temperature of the penetrated heat absorber collector can reach more than 60℃ between 11:00 and 13:00, and the wall temperature reaches 90 ℃ at the highest. It gradually decreases with the decrease of solar radiation, and the average air outlet temperature reaches 46.25℃. As can be seen from the figure, both types of collectors can heat up the outdoor cold air, but the air supply temperature of the penetrated flat plate collector is significantly increased, and the air supply time in the medium temperature area is significantly lengthy, which is better than the non-porous collector.

2.2 Heat collection efficiency

The collector efficiency is defined as the useful energy gain of the collector with respect to the incoming solar radiation falling on the aperture area which is equal to the collector area in a flat plate collector A_c. Similar to the useful energy output of a solar collector, the efficiency can be

related to the average absorber temperature and the average fluid or fluid inlet temperature as shown in Equations (1,2) below[8][9]:

The rate of useful energy collected is also expressed by considering enthalpy rise of the air as:

$$Q_u = mC_P(T_O - T_i) \quad \text{.....(1)}$$

Thermal efficiency can, now be expressed as:

$$\eta_{th} = \frac{Q_u}{IA_P} \quad \text{.....(2)}$$

Figures (9,10) are the average efficiency curves of the two collectors working for 17 days in November. It can be seen from the figure that the highest time of heat collection efficiency is generally at mid-day, and it increases with the increase of solar radiation intensity. The highest heat collection efficiency of the non-porous heat absorption plate collector is 40%, and the lowest is 10%; the highest efficiency of the penetrated heat absorption plate collector is 87%, and the lowest efficiency is 38%. It can be seen that the penetrated heat absorption plate collector has a high heat collection efficiency. Figure 11 explain the relation between solar intensity and ambient temperature which shows that the maximum ambient temperature was above 470 W/m^2 when the ambient temperature was 14 °C.

3. CONCLUSIONS

The Adjective test of two solar air collectors shows that under the same outdoor climate conditions, the outlet temperature of the penetrated plate collector is significantly higher than that of the non-penetrated plate collector, because its heat absorber is composed of porous plates, the effective heat collection area is increased, and the hot air can repeatedly exchange heat in the penetrated plate during the rising process, so its temperature rise is relatively large; while the non-penetrated plate collector only relies on laminar heat exchange of the heat absorbing plate, so its temperature rise and heat exchange efficiency for outdoor cold air are not as good as those of the penetrated plate heat exchanger. Therefore, penetrated plate heat exchangers can be used in heating places with high requirements for supply air temperature, such as residential buildings and small public buildings in areas without central heating. However, due to the addition of perforation technology, the cost is about 15% higher than that of non-penetrated heat absorbing plate collectors. Since non-penetrated heat absorbing plate collectors can also reach a certain supply air temperature and corresponding heat absorption efficiency in winter, they are generally used in places with high requirements for fresh air, such as factories, stations and other large public places. Through the test and analysis of the heat absorption efficiency of penetrated and non-penetrated heat absorbing plates, it can be seen that although only the heat absorbing plate is changed accordingly, there are obvious differences in their temperature rise and heat absorption efficiency. Therefore, in the actual engineering application of solar energy technology, it is necessary to carefully select solar energy components and technology integration according to local geographical and climatic conditions and regional characteristics after strict calculation, so as to achieve the optimal combination with the building and the best economic use effect.

REFERENCES:

1. Salawu, S. O., Obalalu, A. M., & Akinola, E. I. (2023). Current density and thermal propagation of electromagnetic CoFe2O4 and TiO2/C2H6O2+ H2O hybridized Casson nanofluids: a concentrated solar power maximization. *Results in Engineering*, *18*, 101200.
2. Vengadesan, E., & Senthil, R. (2020). A review on recent developments in thermal performance enhancement methods of flat plate solar air collector. *Renewable and Sustainable Energy Reviews*, *134*, 110315.

3. Shamsul Azha, N. I., Hussin, H., Nasif, M. S., & Hussain, T. (2020). Thermal performance enhancement in flat plate solar collector solar water heater: a review. *Processes*, *8*(7), 756.

4. Singh, A. K., & Verma, S. K. (2024). Passive techniques for the thermal performance enhancement of flat plate solar collector: A comprehensive review. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, 09544089241270833.

5. Boussouar, G., Rostane, B., Aliane, K., Ravi, D., Gęca, M. J., & Gola, A. (2024). Study of the Thermal Performance of Solar Air Collectors with and without Perforated Baffles. *Energies*, *17*(15), 3812.

6. Abd-Elhady, M. M., Elhendawy, M. A., Abd-Elmajeed, M. S., & Rizk, R. B. (2025). Enhancing photovoltaic systems: A comprehensive review of cooling, concentration, spectral splitting, and tracking techniques. *Next Energy*, *6*, 100185.

7. Yuchen, D., Manxiang, S., Donghai, J., Xingmin, G., & Xiaoheng, L. (2024). Modeling and validation of the volume effect on the axial fan transient performance. *International Journal of Turbo & Jet-Engines*, *40*(s1), s565-s581.

8. Kumar, A., Saini, R. P., & Saini, J. S. (2014). A review of thermohydraulic performance of artificially roughened solar air heaters. *Renewable and Sustainable Energy Reviews*, *37*, 100-122.

9. Abed, R. H. (2024). INVESTIGATION OF HYBRID PHOTOVOLTAIC/THERMAL SOLAR SYSTEM PERFORMANCE UNDER IRAQ'S CLIMATE CONDITIONS. *Kufa Journal of Engineering*, *15*(1), 1-18.

10. Salih, S. M., & Yaseen, D. T. (2020). NUMERICAL MODELING OF LAMINAR FORCED CONVECTIVE ENHANCEMENT OF (AL2O3-WATER) NANOFLUIDS IN A CIRCULAR PIPE. *Kufa Journal of Engineering*, *11*(4), 19-30.