

EXPERIMENTAL INVESTIGATION RESULTS OF THE TEMPERATURE REGIME IN A SOLAR AIR COLLECTOR WITH TURBULATORS

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Abstract. *This study presents an experimental evaluation of a turbulated solar air heater (SAH) aimed at improving thermal performance for solar desalination applications. Although previous studies have reported significant enhancements using various turbulator geometries, research on integral turbulators remains limited. In this work, a prototype turbulated SAH was developed and tested. The thermal behavior of the transparent cover, absorber plate, and working air was monitored, and heat transfer calculations were performed analytically. Experiments conducted on 23-24 May 2025 showed ambient temperatures of 29.9-39.2°C and solar irradiance up to 957 W/m². The absorber, cover, and outlet air temperatures reached average values of 60.9-61.4°C, 50.0-50.3°C, and 55.3-55.6°C, respectively, with strong agreement between theoretical and experimental data ($R^2 \geq 0.97$). At solar irradiance levels of 800-1000 W/m², the heater supplied hot air up to 74°C, suitable for enhancing evaporation in basin-type solar stills.*

Keywords: *solar air heater, turbulators, thermal efficiency, temperature distribution, heat transfer, solar irradiance, experimental analysis, desalination, basin solar still.*

Introduction. Numerous studies have been conducted to improve the thermal efficiency of solar air heaters (SAHs) through the application of turbulators. Chabane et al. [1] experimentally analyzed an SAH equipped with rib-type turbulators installed beneath the absorber plate. When the air mass flow rate ranged from 0.012 to 0.016 kg/s, the maximum thermal efficiency of the conventional and ribbed SAHs was 43.9% and 51.50%, respectively. Abuska [2] experimentally investigated an SAH fitted with conical ribs on the absorber plate. At air mass flow rates of 0.04, 0.08, and 0.10 kg/s, the corresponding thermal efficiencies were 6.0%, 9.8%, and 10.6%, respectively. Gilani et al. [3] studied an SAH modified with protruded turbulators on the absorber plate. Results showed that when the turbulator pitch was 16 mm, thermal efficiency increased by 26.5% compared to the conventional design. Kumar et al. [4] experimentally evaluated an SAH incorporating S-shaped ribs. At Reynolds numbers between 2400 and 20,000, the Nusselt number and hydraulic resistance increased by factors of 4.64 and 2.71, respectively, yielding a thermo-

hydraulic performance factor of 3.34. A literature review indicates that experimental investigations focusing on SAHs with integral turbulators remain limited. Therefore, a prototype of a turbulated SAH-one of the main components of the combined basin-type solar desalination system-was developed and tested at the experimental site of the Department of Energy Engineering.

Materials and methods. In the experimental investigation of the turbulated solar air heater (SAH), the temperature distribution within each component of the system was examined. The temperatures of the transparent cover, absorber plate, and inlet/outlet working air were measured using monitoring instruments. The heat-transfer coefficient was further determined through analytical calculations. The solar radiation energy supplied to the turbulated SAH is expressed as:

$$Q_s = SF_{ab}\tau\alpha \quad (1)$$

where S -solar irradiance, W/m^2 ; F_{ab} -absorber surface area, m^2 ; τ -transmittance of the transparent cover; α -absorptivity of the absorber plate.

The useful heat transferred to the air in the turbulated SAH is given by:

$$Q_a = \rho_a V_a c_{p,a} (t''_a - t'_a) \quad (2)$$

where ρ_a -air density, kg/m^3 ; V_a -volumetric airflow rate, m^3/s ; $c_{p,a}$ -specific heat capacity of air, $J/(kg \cdot ^\circ C)$; t'_a , t''_a -inlet and outlet air temperatures ($^\circ C$).

From Eqs. (1) and (2), the outlet air temperature can be expressed as:

$$t''_a = t'_a + \frac{SF_{ab}\tau\alpha}{\rho_a V_a c_{p,a}} \quad (3)$$

Results and discussion. Experimental studies of the temperature regime in the turbulated solar air heater were conducted on 23-24 May 2025. Hourly variations of ambient temperature and solar irradiance during these days are presented in Fig. 1.

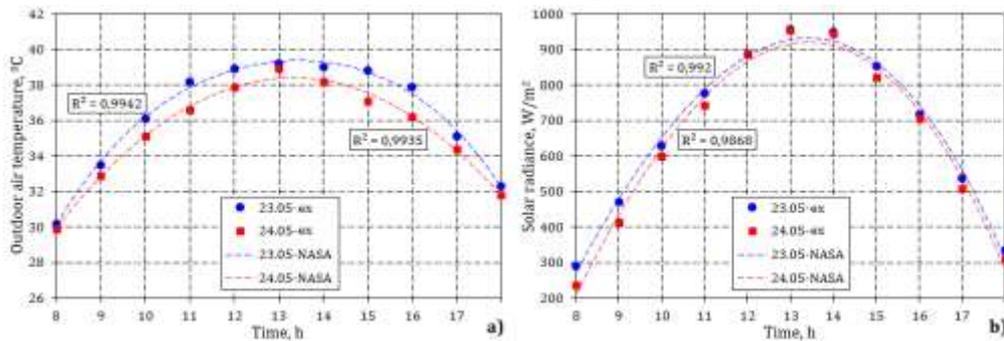
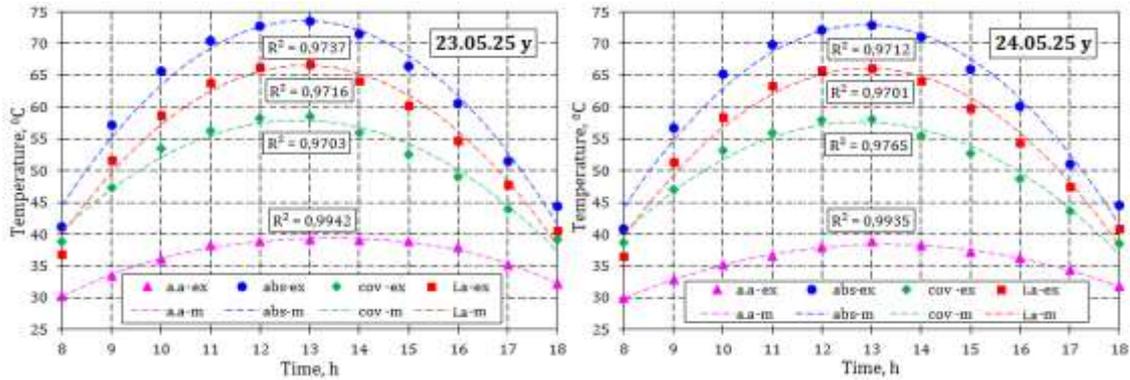


Figure 1. Variation of ambient air temperature (a) and solar irradiance (b).

According to the experimental results (Fig. 1a), on 23 May 2025 the ambient air temperature varied between 30.2 and 39.2 $^\circ C$, with an average value of 36.3 $^\circ C$. The correlation between theoretical and experimental data was $R^2=0.9942$. On 24 May 2025, the ambient temperature ranged from 29.9 to 38.9 $^\circ C$, averaging 35.4 $^\circ C$, with a correlation of $R^2=0.9935$. As shown in Fig. 1b, solar irradiance on 23 May 2025 varied from 290.4 to 957.0 W/m^2 , with total daily radiation of 7.41 kWh/m^2 and a correlation of $R^2=0.992$. On 24 May 2025, it ranged from 237.4 to 954.2 W/m^2 , with total daily radiation of 7.13 kWh/m^2 and $R^2=0.9868$. Hourly temperature variations of the transparent cover, absorber, and working air in the turbulated solar air heater are presented in Fig. 2.



a.a-ambient air; abs-absorber; cov-transparent cover; i.a-indoor air; t-experimental; m-model

Fig. 2. Temperature variation results in the turbulated solar air heater.

The temperature variation results for the turbulated solar air heater (SAH) show that on 23 May 2025, the transparent cover temperature ranged from 38.9 to 58.6°C, with an average of 50.3°C and a correlation coefficient of $R^2=0.9703$. The working air temperature ranged from 36.8 to 66.7°C, averaging 55.6°C with $R^2=0.9716$, while the absorber temperature ranged from 41.2 to 73.5°C, averaging 61.4°C with $R^2=0.9737$. On 24 May 2025, the transparent cover temperature ranged from 38.5 to 58.2°C, with an average of 50.0°C and $R^2=0.9765$. The working air temperature varied from 36.5 to 66.2°C, averaging 55.3°C with $R^2=0.9701$, while the absorber temperature varied from 40.9 to 72.9°C, averaging 60.9°C with $R^2=0.9712$. Analysis of the results indicates that at a solar irradiance level of 800-1000 W/m², the turbulated SAH can deliver hot air at temperatures up to 74°C. Such high-temperature air can be effectively utilized in basin-type solar stills to enhance the evaporation rate of saline water.

Conclusion. Experimental investigations demonstrated that the application of turbulators effectively improves the thermal performance of solar air heaters. Strong correlations ($R^2 \geq 0.97$) between theoretical and measured temperature profiles indicate good model accuracy. The absorber, transparent cover, and outlet air showed temperature increases consistent with variations in solar radiation. Maximum air temperature reached 74°C under solar irradiance of 800-1000 W/m². These results confirm that turbulated SAHs can provide sufficiently high-temperature air to significantly enhance evaporation processes in basin-type solar desalination units, thereby improving freshwater yield.

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