

EXPERIMENTAL INVESTIGATION OF TEMPERATURE REGIME IN A SOLAR AIR COLLECTOR WITH TURBULIZER

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Abstract: This paper presents an experimental investigation of heat transfer processes and the temperature regime in a turbulizer-equipped solar air collector. The experiments were conducted on May 23-24, 2025, during which the hourly variations of ambient air temperature, solar radiation intensity, and the temperatures of the transparent cover, absorber, and working air of the collector were analyzed. The ambient air temperature varied within the range of 29.9-39.2°C, while the solar radiation intensity ranged from 237.4 to 957.0 W/m². The results revealed that under solar radiation intensities of 800-1000 W/m², it is possible to obtain hot air with a maximum temperature of 74°C at the collector outlet. The findings demonstrate that the use of turbulizers enhances the intensity of heat transfer and significantly improves the thermal efficiency of the system.

Keywords: solar air collector, turbulizer, temperature regime, heat transfer, solar radiation, absorber, thermal efficiency, experimental study.

Numerous studies have been conducted on improving the thermal efficiency of solar air collectors (SACs) through the application of turbulizers. Chabane et al. [1] experimentally investigated a solar air collector equipped with rib-shaped turbulizers installed beneath the absorber plate. The experimental results were compared with those obtained for a conventional SAC, and it was found that when the air mass flow rate varied within the range of 0.012-0.016 kg/s, the maximum thermal efficiency of the conventional and ribbed SACs was 43.9% and 51.50%, respectively. Abuska [2] carried out an experimental study of a solar air collector with conical ribs mounted on the absorber plate. The air mass flow rates were set at 0.04, 0.08, and 0.1 kg/s, and under these conditions, the corresponding thermal efficiency values of the SAC were 6.0%, 9.8%, and 10.6%, respectively. Gilani et al. [3] experimentally analyzed a solar air collector equipped with protruding turbulizers on the absorber plate. The results indicated that when the pitch of the protruded turbulizers was 16 mm, the thermal efficiency of the turbulizer-equipped SAC increased by 26.5% compared to that of a conventional collector. Kumar et al. [4] conducted an experimental investigation of a solar air collector incorporating S-shaped ribs on the absorber plate. Within the Reynolds number range of 2400-20000, the Nusselt number and hydraulic resistance increased by factors of 4.64 and 2.71, respectively, while the thermo-hydraulic performance reached a value of 3.34. An analysis of the existing literature indicates that experimental investigations of heat transfer processes in solar air collectors with integrated (continuous) turbulizers remain insufficient. In this context, an experimental prototype of a turbulizer-equipped solar air collector, which constitutes one of the key components of the basin-type solar desalination system, was designed, constructed, and tested at the experimental site of the Department of Energy Engineering, Karshi State Technical University [5-7].

During the experimental investigations of the turbulizer-equipped solar air collector, the temperature regimes of each constituent component of the collector were examined. In this process, the temperatures of the transparent cover, absorber plate, as well as the inlet and outlet

temperatures of the working air were measured using appropriate measuring and control instruments. The determination of the heat transfer coefficient was further carried out through analytical calculations. The solar radiation energy supplied to the turbulizer-equipped solar air collector is expressed as:

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

where S is the solar radiation intensity, W/m^2 ; F_{ab} is the surface area of the absorber, m^2 ; τ represents the transmittance of the transparent cover; and α is the absorptivity coefficient of the absorber.

The useful energy transferred to the air in the turbulizer-equipped solar air collector is given by:

$$Q_a = \rho_a V_a c_{p,a} (t_a'' - t_a') \quad (2)$$

where ρ_a is the air density, kg/m^3 ; V_a is the volumetric flow rate of air, m^3/s ; $c_{p,a}$ is the specific heat capacity of air, $J/(kg \cdot ^\circ C)$; and t_a' and t_a'' denote the inlet and outlet air temperatures of the solar air collector, $^\circ C$.

From expressions (1) and (2), the outlet air temperature of the solar air collector can be determined as follows:

$$t_a'' = t_a' + \frac{SF_{ab}\tau\alpha}{\rho_a V_a c_{p,a}} \quad (3)$$

The experimental investigation of the temperature regime in the turbulizer-equipped solar air collector was conducted on May 23 and 24, 2025. The hourly variations of the ambient temperature and solar radiation energy during these days are presented in Figure 1.

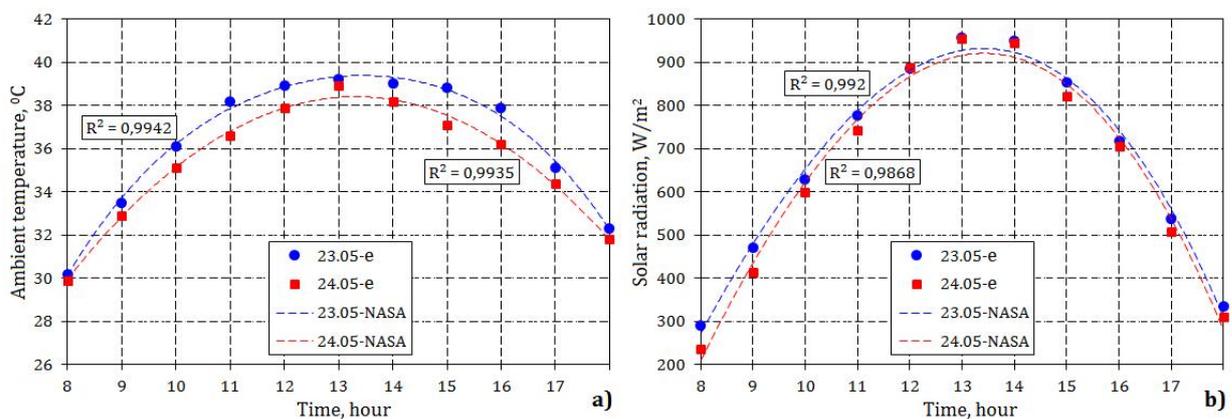
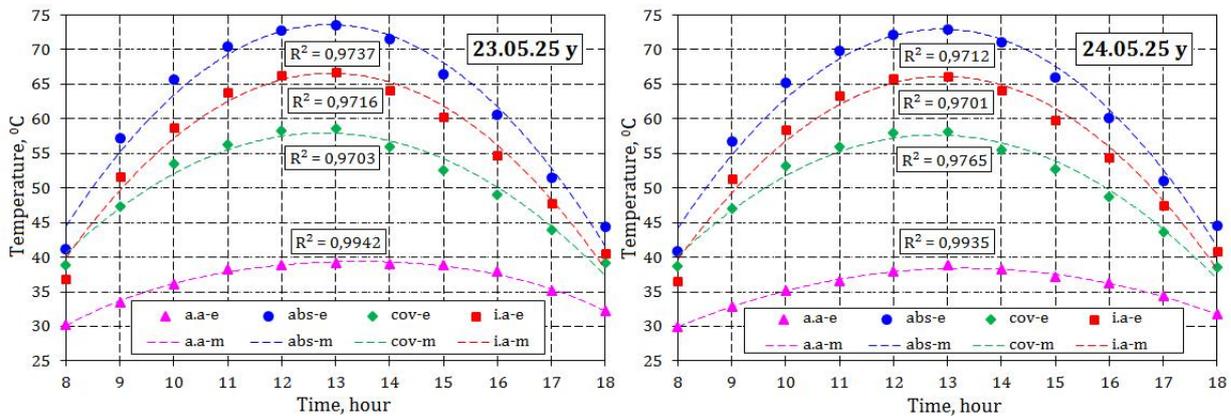


Figure 1. Hourly variation of ambient air temperature (a) and solar radiation intensity (b).

According to the experimental results (Figure 1a), on 23.05.25 the ambient air temperature varied within the range of 30.2–39.2 $^\circ C$, with an average value of 36.3 $^\circ C$, and the coefficient of determination between the theoretical and experimental results was $R^2=0.9942$. On 24.05.25, the ambient temperature ranged from 29.9 to 38.9 $^\circ C$, with an average of 35.4 $^\circ C$, while the agreement between theoretical and experimental data was characterized by $R^2=0.9935$. The solar radiation intensity (Figure 1b) on 23.05.25 varied within the range of 290.4–957.0 W/m^2 , with a total daily solar energy of 7.41 kWh/m^2 , and the reliability of agreement between theoretical and experimental results was $R^2=0.992$. On 24.05.25, the solar radiation intensity ranged from

237.4 to 954.2 W/m², with a total daily value of 7.13 kWh/m², and the corresponding coefficient of determination was R²=0.9868. The hourly variations in the temperatures of the transparent cover, absorber, and working air of the turbulizer-equipped solar air collector are presented in Figure 2.



a.a-ambient air; abs-absorber; coc-transparent cover; i.a-internal air;

e-experiment; m-model

Figure 2. Results of temperature variation in the turbulizer-equipped solar air collector

The results of temperature variations in the turbulizer-equipped solar air collector indicate that on 23.05.25 the temperature of the transparent cover varied within the range of 38.9-58.6°C, with an average value of 50.3°C, and the coefficient of determination for the agreement between theoretical and experimental results was R²=0.9703. The temperature of the working air ranged from 36.8 to 66.7°C, with an average of 55.6°C, and the corresponding coefficient of determination was R²=0.9716. The absorber temperature varied between 41.2 and 73.5°C, with an average of 61.4°C, and the agreement between theoretical and experimental data was characterized by R²=0.9737. On 24.05.25, the transparent cover temperature ranged from 38.5 to 58.2°C, with an average of 50.0°C and a coefficient of determination of R²=0.9765. The working air temperature varied between 36.5 and 66.2°C, with an average of 55.3°C (R²=0.9701), while the absorber temperature ranged from 40.9 to 72.9°C, with an average value of 60.9°C and R²=0.9712. Analysis of the experimental results demonstrates that when the solar radiation intensity lies within the range of 800-1000 W/m², the turbulizer-equipped solar air collector is capable of producing hot air with a maximum temperature of 74°C. Evidently, such high-temperature air can be effectively utilized to intensify the evaporation process of saline water in basin-type solar desalination systems, thereby significantly enhancing their operational performance.

Conclusion. The results of the study demonstrate that the heat transfer process in the turbulizer-equipped solar air collector is significantly intensified. During the experimental period, the ambient air temperature averaged approximately 35-36°C, and when the solar radiation intensity approached 900 W/m², the outlet temperature of the working air reached 70-74°C. The stable correlation among the temperatures of the absorber, transparent cover, and internal air confirms the effective progression of the heat transfer process. The findings indicate that the application of turbulizers not only enhances the thermal efficiency of solar air collectors but also enables their effective use as a heat source for accelerating the evaporation process in basin-type solar

desalination systems. This approach possesses considerable scientific and practical significance for the efficient utilization of renewable energy resources.

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