PERFORMANCE EVALUATION RESULTS OF EVAPORATIVE COOLING SYSTEMS USED IN AIR-CONDITIONING APPLICATIONS

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Abstract. *This study evaluates the performance of an evaporative cooling system (ECS) under the hot and dry climate of Karshi. Cooling air parameters and heat load were experimentally analyzed under two conditions: with and without blinds. Results showed that cooling air flow rate increased with heat load and averaged 162.8 m^3/h without blinds, while blinds reduced this value to 113.6 m^3/h. Heat gain occurred mainly through infiltration (37.51%), walls (26.71%), the ceiling (19.51%), and solar radiation (15.97%). The use of blinds reduced heat load by 21.4% and cooling air demand by approximately 38.48%, demonstrating improved ECS efficiency and reduced energy consumption.*

Keywords: *evaporative cooling system, cooling air flow rate, heat load, hot and dry climate, infiltration, blinds, energy efficiency.*

Introduction. The evaporative cooling system (ECS) operates on electrical power; however, only a small amount of energy is required to circulate air and water. Therefore, this system can provide up to 90% energy savings compared to other conventional cooling systems. The wet-bulb effectiveness of most modern ECS units ranges from 70% to 90%, depending on the geometry and thickness of the wetted medium, climatic parameters, and inlet air velocity [1, 2, 3]. Nevertheless, the performance of ECS and the parameters influencing it have not yet been investigated under hot and dry climatic conditions, including those of the city of Karshi. Considering the above, this study evaluates the cooling capacity, cooling efficiency, and COP of ECS under the climatic conditions of Karshi.

Materials and methods. To determine the performance of the evaporative cooling system (ECS), it is necessary to evaluate the parameters of the supply and exhaust air, as well as the required volume of cooling air. The temperature of the supply (cooled) air is determined using the following equation:

$$t_{c.a} = t_{in.a} - \Delta t_{allow} \quad (1)$$

where Δt_{allow}-the permissible temperature difference (℃), which depends on the selected principle of air distribution. For room heights of 2.5 m or greater, Δt_{allow}=4-6℃ is typically assumed.

It is known that during the cooling season, optimal indoor microclimate parameters for living spaces are as follows [4]: air temperature 22-25°C, relative humidity 30-60%, and air velocity ≤0.2 m/s. According to these standards, the design indoor air temperature is taken as 24°C. Thus,

$$t_{c.a} = 24 - 5 = 19℃$$

The temperature of the exhausted air, extracted using a suction fan, is determined as follows:

$$t_{ex.a} = t_{in.a} + (H - h)gradt \quad (2)$$

where H=2.7m-room height; h-height of the working zone, m; for standing work, h=2 m, and for seated work, h=1.5 m; $gradt$-vertical temperature gradient above the working zone, determined according to room-specific excess heat load [5].

The specific excess heat is determined by:

$$q_{s.e} = \frac{Q_{ex}}{V_r} \quad (3)$$

where Q_{ex}-excess heat generated in the room, W; $V_r = 32{,}4\ m^3$-indoor volume.

Based on the obtained value of $q_{s.e}$, the temperature gradient is determined as follows [5]: if $q_{s.e} > 23{,}2\ W/m^2$, then $gradt = 0{,}8 - 1{,}5$; if $q_{s.e} = 11{,}6 - 23{,}2\ W/m^2$, then $gradt = 0{,}3 - 1{,}2$; if $q_{s.e} < 11{,}6\ W/m^2$, then $gradt = 0 - 0{,}5$.

Based on the above, the cooling-air performance of the ECS is determined using:

$$V_{c.a} = \frac{3{,}6 \cdot Q_{ex}}{c_{p,a}\rho_{c.a}(t_{o.a} - t_{c.a})} \quad (4)$$

where $c_{p,a}$-specific heat capacity of cooling air, J/(kg·°C); $\rho_{c.a}$-density of cooling air, kg/m^3.

The performance of the exhaust-air system is then expressed as:

$$V_{ex} = V_{c.a} - kV_r \quad (5)$$

where k-excess airflow coefficient accounting for the fact that the supply air volume must exceed the exhaust air volume to maintain positive pressure in the cooled space; for a room with one window and door, k=1 is assumed [5].

Results and discussion. Considering the above and the presence of an internal excess heat load, the cooling-air performance of the ECS was determined for two cases (without blinds and with blinds) (Fig. 1). According to the results shown in Fig. 1a, the cooling air flow rate increases with increasing heat load. On 12 August 2024, during the period from 08:00 to 18:00, the outdoor air temperature varied within the range of 26-37°C, while the cooling air flow rate ranged from 23.2 to 204.7 m^3/h, with an average value of 162.8 m^3/h. The exhaust air volume varied from 9.18 to 172.3 m^3/h, with an average of 132.0 m^3/h.

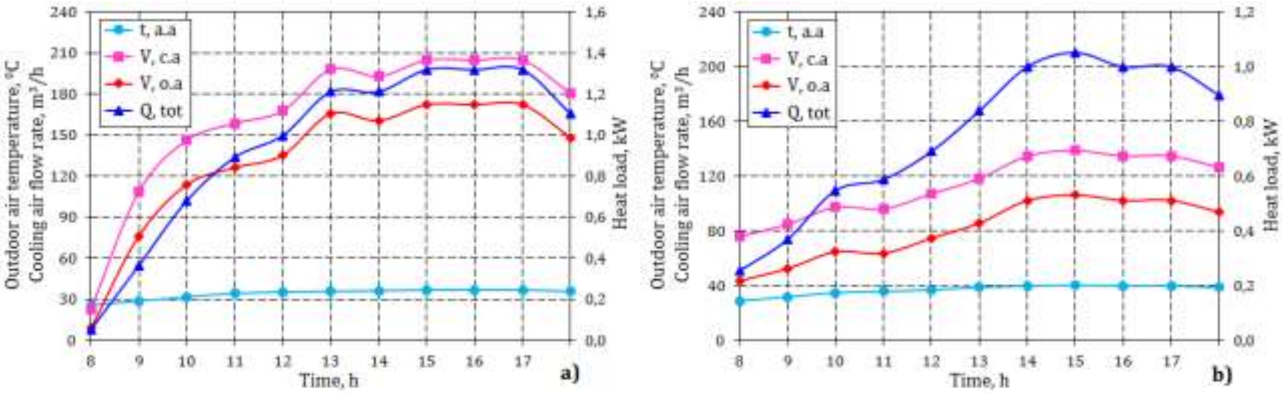

Fig. 1. Cooling air flow rate under conditions without blinds (a) and with blinds (b).

According to the results presented in Fig. 1b, on 13 August 2024, during the period from 08:00 to 18:00, the outdoor air temperature ranged from 29 to 40.5°C, while the cooling air flow rate varied between 76.15 and 138.7 m^3/h, with an average value of 113.6 m^3/h. The exhaust air volume varied from 43.75 to 106.3 m^3/h, with an average of 81.2 m^3/h.

Conclusion.

It was determined that 26.71% of this heat load was transferred through the walls, 19.51% through the ceiling, 15.97% due to solar radiation, and 37.51% through infiltration. In addition, the use of blinds reduced the total heat load by 21.4%. When the door and window of the test room were covered with blinds and the solar radiation intensity was 7.54 kWh/m^2, the average indoor air temperature was 37.05°C and the total heat load reached 8.23 kW. It was determined that 26.71% of this heat load was transferred through the walls, 19.51% through the ceiling, 15.97% due to solar radiation, and 37.51% through infiltration. In addition, the use of blinds reduced the total heat load by 21.4%.

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