COMBINED EVAPORATIVE COOLING SYSTEM FOR RESIDENTIAL BUILDINGS

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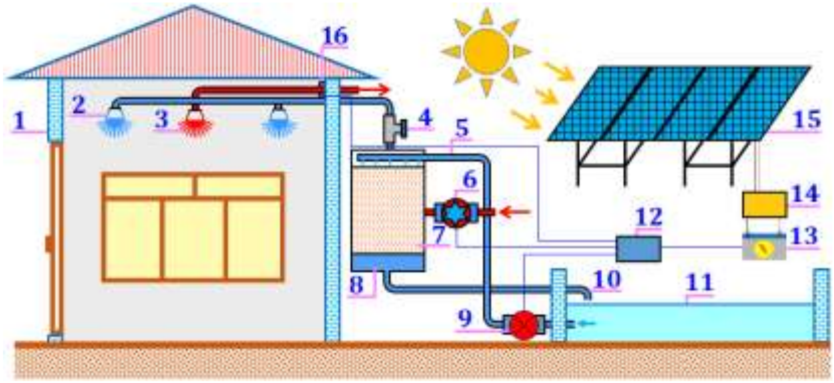
Abstract. *This study examines a combined evaporative cooling system (CECS) integrated with a photovoltaic module for improving indoor comfort in residential buildings. An experimental house equipped with the CECS was tested under real climatic conditions. Solar radiation intensity on August 12, 2024, ranged from 243.8 to 926.2 W/m², while the indoor air temperature varied between 27-40℃. The total thermal load of the experimental house was 10.47 kW, of which 19.73% was transmitted through walls, 14.63% through the ceiling, 37.77% due to solar radiation and windows, and 27.87% due to infiltration. Results indicated that solar radiation constitutes the largest share of the thermal load. The findings confirm that applying CECS with solar energy can reduce cooling energy demand and enhance indoor thermal comfort.*

Keywords: *evaporative cooling, thermal load, indoor temperature, solar radiation, photovoltaic, infiltration, energy efficiency.*

Introduction. To ensure a comfortable indoor environment in residential buildings, the temperature and humidity levels of the indoor air play an important role. Various ventilation and air-conditioning systems are used to maintain the required indoor air parameters at a stable level. The use of such systems significantly increases energy consumption for space cooling. At present, the reduction of energy consumption in cooling systems and the improvement of their efficiency through the use of solar energy are considered highly relevant. The utilization of solar energy in air-cooling systems enhances their energy efficiency and significantly reduces their negative impact on the environment. To ensure the efficient operation of an air-cooling system, it is necessary to achieve optimal distribution of indoor air temperature and airflow. These processes are studied based on theoretical models and experimental investigations.

Materials and methods. Experimental studies to determine the thermal load of the test house were conducted in the experimental building shown in Figure 1 [1-5]. The thermal load was calculated as the total amount of heat transferred into the house through its external envelope, windows, and doors, depending on the outdoor air temperature and solar radiation intensity. The thermal load of the house was evaluated for two conditions: with windows and doors covered by curtains and without curtains. When the windows and doors of the test house were not covered, the variations in solar radiation intensity, outdoor air temperature, and indoor air temperature were obtained and are presented in Figure 2, while the variation of the thermal load is shown in Figure 3. The experimental investigation was carried out on August 12, 2024, between 08:00 and 18:00.



1-residential building; 2-cool air diffuser; 3-hot air exhaust; 4-vent; 5-supply of cooling water; 6, 16-fans; 7-humidifying material; 8-residual water; 9-pump; 10-residual water discharge; 11-water reservoir; 12-inverter; 13-battery; 14-controller; 15-photovoltaic solar module

Figure 1. Schematic diagram of the combined evaporative cooling system with photovoltaic solar module for residential buildings

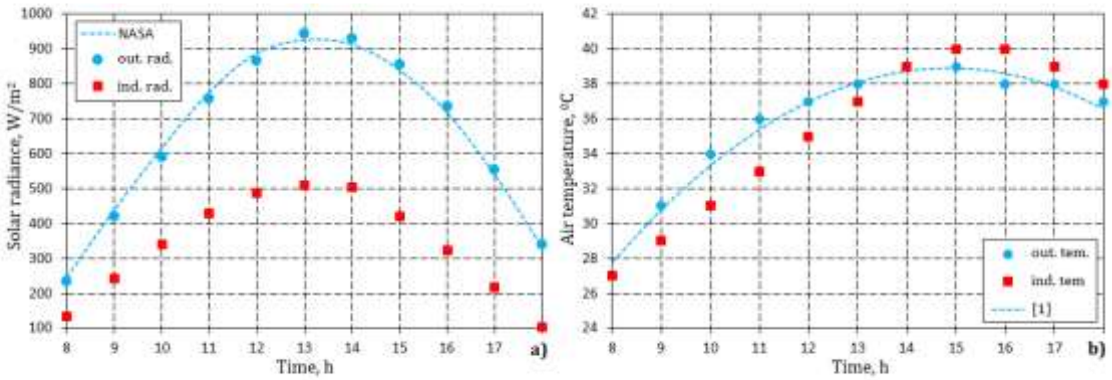


Figure 2. Results of variations in solar radiation intensity (a) and air temperatures (b) (August 12, 2024)

Results and discussion. According to the results presented in Figure 2a, on August 12, the solar radiation intensity varied within the range of 243.8-926.2 W/m², totaling 7.23 kWh/m². The solar radiation transmitted into the room through the windows and doors varied between 102.8-509.4 W/m², amounting to a total of 3.70 kWh/m². According to the results shown in Figure 2b, the outdoor air temperature varied between 27-39°C, with an average temperature of 35.82°C. The indoor air temperature varied between 27-40°C, with an average of 35.27°C. The indoor temperature exceeded the outdoor temperature at 14:00 and reached 38°C by the end of the day. Based on the results presented in Figure 3, the total thermal load transmitted through the exterior wall of the experimental house was 3.42 kW, the total thermal load transmitted through the ceiling was 2.54 kW, the total thermal load transmitted through solar radiation and the window was 6.56 kW, and the total thermal load due to infiltration was 4.84 kW. Taking into account the heat lost through the floor, the total thermal load of the experimental house was 10.47 kW. The proportion of the components of the thermal load was as follows: 19.73% through the wall, 14.63% through the ceiling, 37.77% through solar radiation, and 27.87% through infiltration. Thus, the highest thermal load was caused by solar radiation.

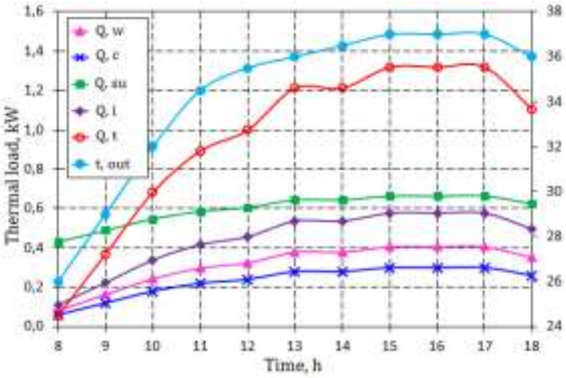


Figure 3. Variation in thermal load of the experimental house on August 12, 2024

Conclusion. The following conclusions were drawn regarding the development of the combined evaporative cooling system (CECS):

1. The thermal–technical parameters of the CECS for residential buildings were justified, an experimental house equipped with a CECS was constructed, a methodology for conducting experimental investigations in the CECS was developed, and the system was subjected to experimental testing.

2. When the doors and windows of the experimental house were not covered with curtains and the solar radiation transmitted into the room reached 3.70 kWh/m², the average indoor air temperature was found to be 35.27 °C, and the total thermal load was determined to be 10.47 kW. It was identified that 19.73% of this thermal load was transmitted through the wall, 14.63% through the ceiling, 37.77% through solar radiation, and 27.87% through infiltration.

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