

MODELING OF HEAT BALANCE EQUATIONS FOR AN AUTONOMOUS GREENHOUSE

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Abstract: the heat load of a even-span greenhouse with a useful area of 50 m² located in the city of Karshi for the period from November 15, 2023 to March 15, 2024 is determined taking into account the ambient temperature, solar radiation, and heat losses in the greenhouse. According to the results, it was calculated that the greenhouse will consume 14,800 kWh of thermal energy during this season.

Key words: modeling, heat balance, autonomous greenhouse, solar radiation, ambient temperature.

In autonomous greenhouses, it is important to save natural fuel sources, reduce exhaust gases into the atmosphere, and produce high-quality and affordable products by choosing a greenhouse design based on the location and climatic characteristics of the area, making maximum use of solar radiation in heating greenhouses, and installing renewable energy devices and highly efficient heat pumps in the greenhouse energy supply system.

The object under analysis is an autonomous greenhouse with a useful area of 50 m², located at the alternative energy sources polygon under the Karshi Institute of Engineering and Economics. Tomatoes and cucumbers are grown in the autonomous greenhouse, which require a temperature range of 15...22 °C during the growing season. The growth period of such crops is several months. However, due to the problem of maintaining the set temperature, the most critical period for heating the greenhouse is the four-month period from mid-November to mid-March. Therefore, the study of the operation of the heating and electrical system is carried out with an estimated air temperature inside the greenhouse of 15 °C in the evening and 22 °C in the daytime, and it covers the above-mentioned months.

The internal air temperature of an autonomous greenhouse varies depending on several external and internal factors. These factors depend on the amount of solar radiation penetrating the walls and ceiling of the greenhouse, the heat source operating on natural fuel and electricity, lighting, the amount of natural ventilation and air infiltration, the amount of constructive heat loss, the amount of heat lost through the soil, and the

amount of heat consumed by plants. All of the above values were taken into account when compiling the heat balance of an autonomous greenhouse in Fig.1.

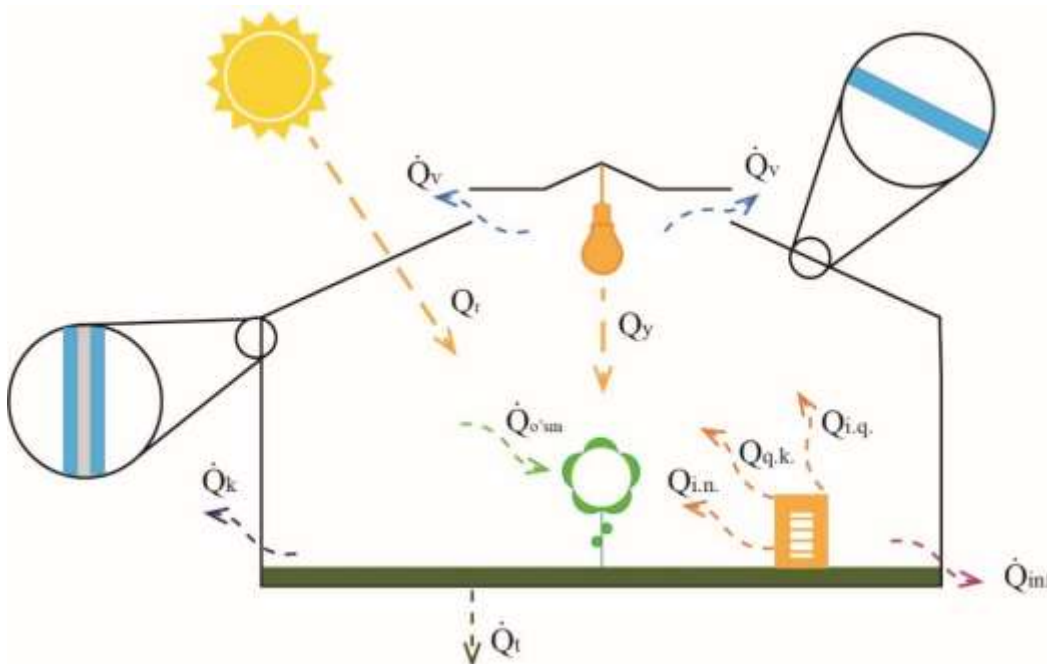


Fig. 1. Heat balance calculation scheme for an autonomous greenhouse

The mathematical model of the heat balance of the autonomous greenhouse under study is expressed by the following equations [1]:

$$\rho_h \cdot V \cdot C_h \frac{dt}{dt} = \left(Q_r(\tau) + Q_{i.n}(\tau) + Q_y(\tau) + Q_{q.k}(\tau) + Q_{i.q}(\tau) \right) - \left(\dot{Q}_v(\tau) + \dot{Q}_{inf}(\tau) + \dot{Q}_k(\tau) + \dot{Q}_t(\tau) + \dot{Q}_{o'sm}(\tau) \right) \quad (1)$$

Q_r - heat amount of solar radiation; Q_{in} - heat amount of heat pump; Q_y - heat amount of lighting lamps; Q_c - solar thermal collector; Q_{iq} - heat boiler; Q_v - heat amount lost through natural ventilation; Q_{inf} - heat amount lost through air infiltration; Q_k - heat amount lost through the greenhouse ceiling; Q_d - heat amount lost through the greenhouse walls; Q_a - heat amount lost through the greenhouse base; Q_t - heat amount lost through the soil; $Q_{o'sm}$ - heat amount lost through plants.

The amount of heat output of a solar thermal device (collector) is determined by the following formula, which depends on the external temperature and solar radiation [2,3]:

$$Q_{qk} = A_c \cdot F_R \cdot [Q_r \cdot \tau(\alpha) - U_L \cdot (t_k - t_t)] \quad (2)$$

Fig.2 shows a scheme for providing the greenhouse with thermal energy. In this case, solar radiation, solar thermal devices, heat pumps, and heat boilers are used as heat

sources to increase the reliability of heat supply in abnormal cold weather. Heat pumps are supplied from electrical networks integrated with solar photovoltaic devices.

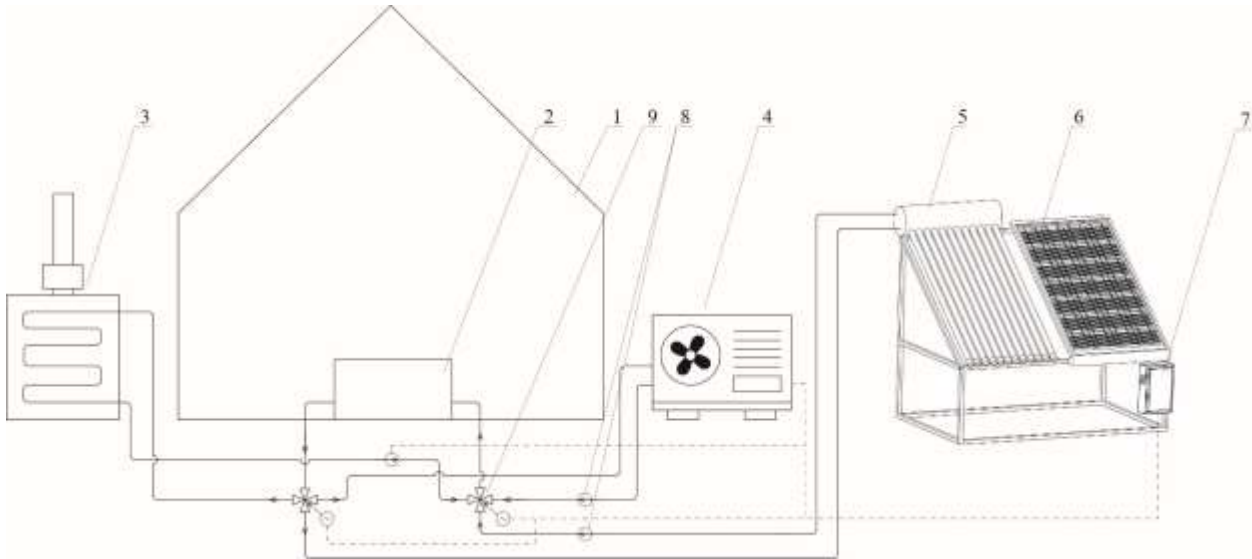


Fig.2. Scheme of providing greenhouse with thermal energy

1-greenhouse; 2-heat exchanger; 3-heat boiler; 4-heat pump; 5-solar thermal collector; 6-solar photovoltaic panels; 7-electrical equipment box; 8-circulating water pumps; 9-controlled water heaters.

Fig.3. shows the dynamics of the greenhouse heat load change in the absence of changes in ambient temperature and solar radiation. The average temperature inside the greenhouse is assumed to be 20 °C. It was found that in January, due to the maximum temperature drop, the heat load increases to 12 kWh. At such times, natural fuel boilers are started in parallel at short wattage to heat the greenhouse.

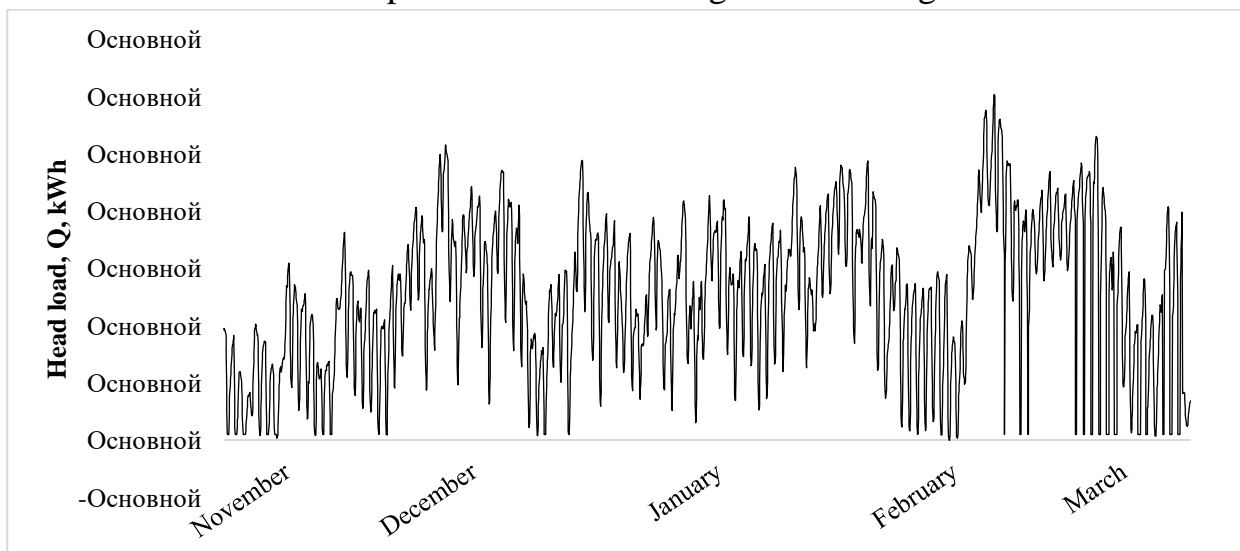


Fig.3. Dynamics of greenhouse heat load changes

The dynamics of ambient temperature changes in the city of Karshi for the period from November 15, 2023 to March 15, 2024 is presented. The temperature change was determined in a 1-hour time interval. The maximum temperature during this season was 26 °C and the minimum temperature was -10 °C.

Conclusion: the calculations were carried out from November 15 to March 15, 2023, at 1-hour intervals. The average internal temperature of a greenhouse with a glass cover of 50 m² was assumed to be 20 °C. Taking into account the ambient temperature changes and heat losses in the greenhouse, it was modeled that the greenhouse would consume 14,800 kWh of thermal energy during this season. It was determined that the heat pump produced 11,150 kWh of thermal energy when heating the greenhouse during periods of no sunlight. The heat pump consumes 2,710 kWh of electricity in this case.

Literature

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