

TICAL MODELING OF HEAT ACCUMULATION IN PLASTIC VESSELS IN A SOLAR GREENHOUSE

Keywords. solar radiation, passive system, thermal accumulator.

Annotation. The paper considers the radiation regime of PB plastic bottles filled with water as heat storage elements for direct absorption of solar radiation in a solar greenhouse.

The efficiency of a solar greenhouse is determined by the ability to maximize the capture of solar energy and accumulate its heat with minimal heat loss.

Passive heat storage systems for direct solar energy capture have the lowest cost, long service life and very low operating costs. In such systems, the solar radiation coming through the translucent glazing surfaces is absorbed by the light-receiving surfaces. The heat storage capacity of sun-trapping elements depends on the material, its heat capacity, mass, and their location in the greenhouse. As a heat storage material, the most effective is the use of water. Effective methods of creating water heat accumulators of any capacity and configuration is the use of plastic bottles (PB) made of polyethylene terephthalate (PET) [1]. Used PB of various sizes and shapes (as scrap) are cheap materials. In addition to their industrial disposal, they are widely used as a secondary material for various purposes. In particular, they are used as elements of solar collectors and heat accumulators [1].

When determining the thermal balance of PB, the following condition is assumed: the surface temperature of PB is assumed to be equal to the average mass temperature of water in PB.

The thermal balance of PB is determined by the equation:

$$Q_{ak} = Q_{np} + Q_{mn} \quad (1)$$

where Q_{ak} – is the heat accumulated in PB, W; Q_{np} – is the total solar radiation passed in PB, W; Q_{mn} – is the heat loss in PB, W.

Qpr values are accepted based on the data. Heat loss in PB is expressed as the sum of

$$Q_{mn} = Q_{mnk} + Q_{mnu} \quad (2)$$

where Q_{mnk} and Q_{mnu} – are the heat loss by convection and radiation, W.

Heat loss by convection is determined by the formula

$$Q_{mnk} = \alpha_k F_k (t_{n\delta} - t_{am}) \quad (3)$$

where α_k – is the coefficient of convective heat transfer PB, W/(m² K); F_k – is the surface area of convective heat transfer PB, m²; $t_{n\delta}$ – is the average mass temperature of water in PB, deg; t_{am} – is the air temperature in the greenhouse, deg.

Convective heat transfer on the PB surface occurs by natural convection.

Naturally, the convective heat transfer for various geometric shapes and all values of the Prandtl numbers Pr and Rayleigh Ra is determined by the generalized equation [2]:

$$Nu = Nu_o + \left(\frac{Ra \cdot K}{5} \right)^{1/4} \quad (4)$$

where Nu – is the Nusselt number; Nu_o – is the limit value of the Nusselt number; Ra – is the Rayleigh number; K is the coefficient, a function of the Prandtl number Pr :

The Nusselt number

$$Nu = \alpha_\kappa h_n / \lambda \quad (5)$$

where h_n – is the determining size - the height of PB, m; λ – is the coefficient of thermal conductivity of air, W/(m K).

The limit value of the Nusselt number for vertical cylinders is assumed to be $Nu_o = 0,68$ [4].

Ray Number:

$$Ra = Gr Pr, \quad (6)$$

The Grashoff number

$$Gr = \frac{g \cdot \beta \cdot h_n^3 \Delta t}{\nu^2} \quad (7)$$

where g – is the acceleration of gravity, m/s²; $\beta = 1/273$ – is the temperature coefficient of volumetric expansion of air, K⁻¹; $\Delta t = t_{n\sigma} - t_{em}$ – is the temperature gradient at the PB–air boundary in the greenhouse, K; ν – is the coefficient of kinematic viscosity of air, m²/s.

Coefficient K:

$$K = \left[1 + \left(\frac{0,5}{Pr} \right)^{9/16} \right]^{-16/9} \quad (8)$$

Heat loss by radiation is determined by the formula:

$$Q_{mnu} = \alpha_u F_\kappa (t_{n\sigma} - t_{em}) \quad (9)$$

where α_u – is the coefficient of heat transfer by radiation PB, W/(m² K);

The coefficient of heat transfer by radiation is determined by the formula [3]

$$\alpha_u = \sigma \varepsilon (T_{n\sigma} - T_{em}) (T_{n\sigma}^2 - T_{em}^2) \quad (10)$$

where $\sigma = 5,67 \times 10^{-8}$ W/(m² K⁴) is the Stefan-Boltzmann constant; ε – is the degree of blackness of the PB surface.

PB packaging elements are considered effective if the temperature gradients in them are minimal [3,4]. To determine whether a particle washed by air has a negligible thermal resistance, the Bio Bi number is used under the condition

$$Bi < 0,1 \quad (11)$$

For the PB PET shell, expression (11) has the form

$$Bi = \frac{\alpha_n \cdot \delta_n}{\lambda_n} < 0,1 \quad (12)$$

where $\alpha_n = \alpha_k + \alpha_u$ – is the heat transfer coefficient at the air–PB interface, W/(m² K); $\delta_p=0.0006$ m is the thickness of the PB shell; $\lambda_n =0.17$ W/(m K) is the thermal conductivity coefficient of the PB PET material.

In cavities filled with a flowing medium (such as PB with water), in the presence of a temperature difference, the resulting natural convection affects the thermal conductivity of the medium. In spherical tanks, natural convection begins to affect heat transfer when the Rayleigh number $Ra > 10^3$ [4].

To determine the average mass temperature of a PB package, it is necessary to determine the coefficient of its effective thermal conductivity.

Heat transfer in the package occurs through thermal conductivity and PB radiation, as well as natural air convection in the gaps.:

$$\lambda_{\Sigma} = \lambda_E + \lambda_K \quad (11)$$

where λ_E - is the coefficient of equivalent thermal conductivity of the package PB, W/(m K); λ_K - is the coefficient of equivalent thermal conductivity by natural air convection in the gaps of the package, W/(m K).

Based on the thermal regime of a water heat accumulator, the total thermal balance of a solar greenhouse with a passive heat accumulator is determined.

List of used literature

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КЛАССИФИКАЦИЯ МИНЕРАЛЬНЫХ УДОБРЕНИЙ И СПОСОБЫ ИХ ВНЕСЕНИЯ

Ключевые слова: твердые минеральные удобрения, неравномерность, механизированное внесение, классификация удобрений.