Study of the heating temperature of film and glass transparent fences of solar installations

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Abstract. A non-stationary thermal model for determining the temperature and humidity conditions in a greenhouse is considered, based on the method of elementary balances. The accuracy of the method was assessed based on the heating temperatures of film and glass transparent fences of the greenhouse. Research was carried out on changes in temperature and humidity in a greenhouse during the day.

1 Introduction

Energy saving issues are relevant in construction (buildings and structures), in solar thermal installations, as well as in greenhouses. To solve energy saving problems, in particular, it is necessary to create non-stationary thermal models of such objects that take into account their main parameters as much as possible. The multifactorial nature of the problem leads to the fact that currently simplified methods of their computational analysis are mainly used, mainly based on stationary models [1-4].

In [5-6], a non-stationary single thermal model of a solar water heater is considered, which makes it possible to study the dynamics of heating temperatures of the main elements of the solar water heater (transparent fence, receiver, heat-insulating soil bottom) non-stationary models in solar installations.

Research on the main design parameters of energy-efficient solar greenhouses and their main components to determine the light transmission coefficients of a transparent fence are considered in [7].

The study of the thermal regime of solar greenhouses for individual purposes, taking into account their design features, is considered in [8-9]

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2 Materials and methods

In this work we present the results of creating a non-stationary model of greenhouses, the diagram of which is shown in Figure 1.

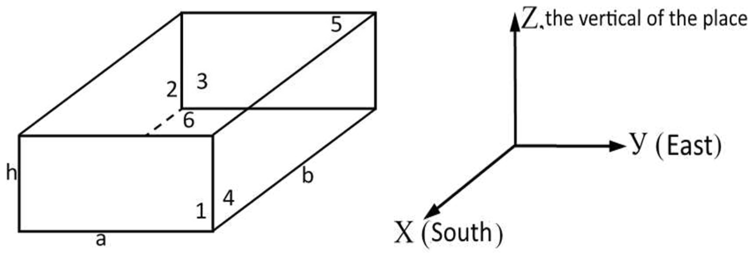

Fig. 1. Scheme of a ground greenhouse and its orientation: 1-4 – side walls, 5 – roof, 6 – ground (soil); a – width, b – length, h – height; Sc - area of the sides.

As in collectors, or "hot boxes", the main element of the greenhouse is transparent fences (), which not only provide the greenhouse effect, but also determine their main heat losses, and significantly influence the temperature and humidity conditions in the greenhouse, as well automatic control system for greenhouse soil moisture using research on solar photovoltaic systems [10-11].

The complexity of the task also lies in the fact that not only thermal processes, but also evaporation and condensation processes occur simultaneously in the greenhouse. Also, transparent greenhouse fencing (film, glass) is translucent, i.e. The concepts of an "optically thick" or "optically thin" layer do not apply to them; they also have (especially glass) selective radiation absorption [12-13].

In this regard, we will build a non-stationary greenhouse model based on the assumption that there is a balance of all thermal processes during an elementary time interval.

The essence of the method is that in a short time interval we assume that heat exchange by convection and radiation, as well as moisture exchange, occurs at a constant temperature of the transparent fence and air in the greenhouse and its humidity, and at the end of this elementary time interval new temperatures and humidity at which heat and moisture exchange occurs at the next elementary point in time, etc. Those. in this model, the temperatures of the transparent fence and air in the greenhouse and its humidity change abruptly at the end of each elementary point in time.

3 Results

When creating a non-stationary volumetric model of a greenhouse, the following assumptions were made:

- The air condition in the greenhouse is the same throughout the entire volume.
- Temperatures within the area of each side are constant.
- Internal flows reflected from the walls of the greenhouse are not taken into account.

That is, the model uses average temperatures of elements, which are defined as the ratio of their heat content to mass and heat capacity. For unsteady processes, the heat content can be written as:

$$Q_{i+1} = Q_i + dQ_i \tag{1}$$

Where Qi+1 is the heat content of the element (wall, soil, air in the greenhouse) at the end of the elementary moment of time dτ, dQi – total heat received and lost from the element during time moment dτ.

For example, for air in a greenhouse dQB is equal to

$$dQ_B = (F_{pad} - F_{pot} + m_i C_V V(t_j - t_B) - \sum_{j=1}^{j=5} m_k c_v (t_B - t_j) * d\tau \quad (2)$$

Where Fadi – fluxes by radiation and convection entering the air (for air fluxes by radiation are equal to zero, since they are not absorbed), Fpot – heat losses of the element in the general case by radiation and convection (for air only by convection), $m_{иi}c_V(t_i\text{-}t_B)$– heat, introduced by water evaporated from the soil, like water (note that the heat of evaporation of water introduced by steam into the air does not appear until it condenses on one of the surfaces, i.e. cv here is the heat capacity of water.

Accordingly, the air temperature (walls, roof) at the end of elementary time dτmoment in time will be equal

$$t_{i+1} = \frac{Q_{i+1}}{m_j * C_j} \quad (3)$$

As you can see, the heat balance equations are quite simple, but it is obvious that the use of average temperatures of bodies in practical cases of studying non-stationary processes requires being limited by the possible temperature difference in these bodies. In this case, this condition is satisfied for transparent fences (in [7] it is shown that even in glass transparent fences, it does not exceed 1ºC), and we will also assume that it is also true for the volume of air in the greenhouse. The question of average soil temperature is more complicated. In this model, taking into account the low intensity of thermal processes in the greenhouse, we will assume that the soil represents a certain volume of water with a layer thickness such that the temperature difference in it is also small.

One of the issues of the model is the choice of an elementary point in time and the correspondence of the temperature change curve in the elements to real processes.

4 Discussion

In Figure 2. for glass and film transparent fence the change in temperatures over time and their approach to average equilibrium temperatures at different values of the elementary moment of time d is given τ (or number of partitions N, time interval τ_0 for which temperature transparent fence reaches average equilibrium values.

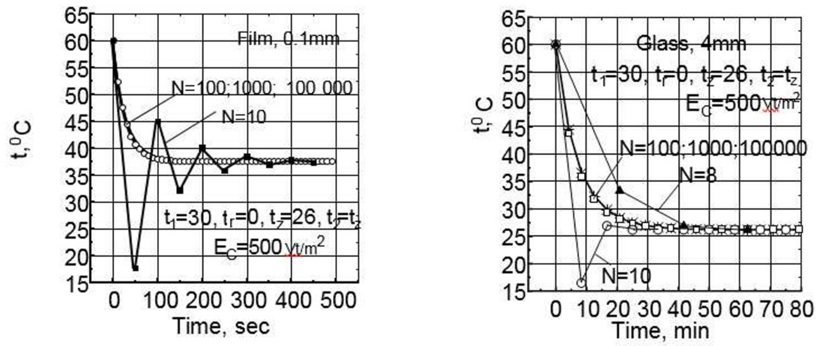

Fig. 2. Influence of the number of partitions N of the time interval for the output of heating temperatures transparent fence to stationary values.

As you can see, the time it takes for temperatures to reach stationary values□0for film and glass are significantly different, so if for glass it is about 80 minutes, then for film it is about 8 minutes. Moreover, it is clear that under the same external conditions, the heating temperature of the film is noticeably higher than that of glass, almost 11 ^{0}C. This is due to the significant difference in their radiation characteristics. So, if the film is almost "gray", i.e. has the same absorption coefficient for all wavelengths, then glass is significantly selective; up to 2.7 μm it absorbs little, then its absorption coefficient increases tens of times.

It is also clear that even with a sufficiently small number of partitions (for glass from 8, for film from 10) the equilibrium temperatures are well determined, but the nature of its change over time requires that the number of partitions be at least 1000.

Figure 3 shows the approach of such a heat exchange process to the average equilibrium heating temperature transparent fence at different initial temperatures transparent fence.

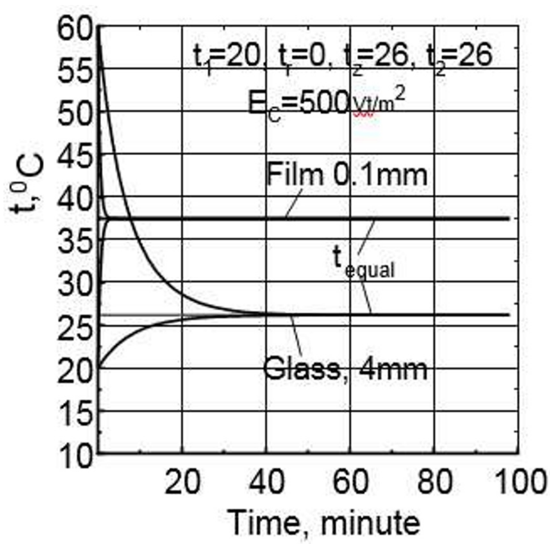

Fig. 3. Approximation of glass and film temperatures to equilibrium values at different initial temperatures.

As can be seen, we have a fairly good approximation to the average equilibrium temperatures, regardless of their initial temperature. Note that we can determine the equilibrium temperatures independently. In the first case, using the energy balance in a stationary mode (solving a fourth-degree equation by dividing a segment in half) and the second using the elementary balance method. It is interesting that if in the first method about 27 iterations are needed to determine the equilibrium temperature with an error of less than 0.001%, then in the elementary balance method in this case, in principle, 10 steps are sufficient.

At the same time, the structure of losses of a flat solar collector from glass and film is of practical interest transparent fence (Figure 4) in an equilibrium state.

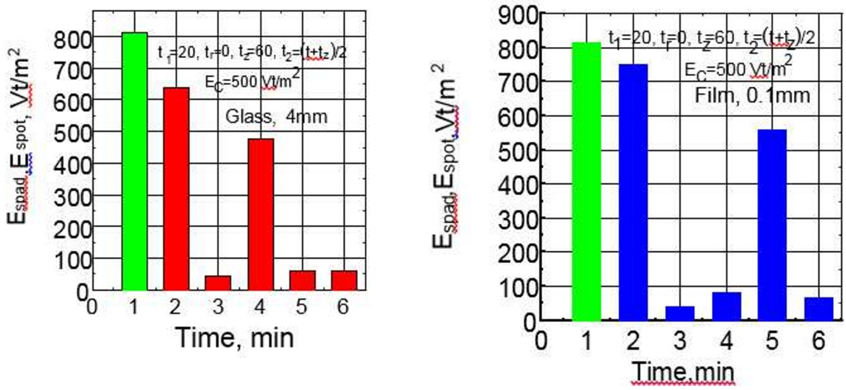

Fig. 4. Loss structure of a flat solar collector (SC) in equilibrium with glass (a) and film transparent fencing(b): 1 - total incident flux, 2 - total losses of the solar collector through the transparent fence, 3 - reflection losses, 4 - radiation losses, 5 - transmission losses of receiver radiation, convection losses of the transparent fence.

As you can see, the structure of losses is significantly different. So in film transparent fence significantly less radiation loss, but much more transmission loss. In general, film transparent fence losses are 17% greater than glass transparent fence (this is for the receiver temperature t_z = 60ºC). As the receiver temperature decreases, the difference decreases, for example, at t_z = 30ºC it is about 8%.

Figure 5 shows the results of modeling the temperature and humidity conditions in a greenhouse measuring 10x10x10 with vertical wall 1 oriented to the South (Figure 1) at a constant outside air temperature t_{c1} = 20 ºC, sky temperature t_r = 0 ºC, normal solar radiation Ec = 600 W/m^2 initial temperature in the greenhouse 20º C and humidity 60% for latitude 41º and solar declination δ=00.

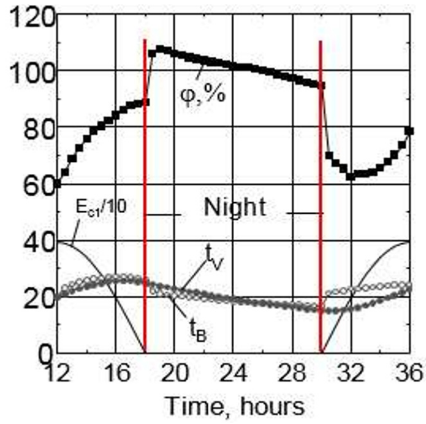

Fig. 5. Temperature and humidity conditions in a greenhouse with film transparent fencing; E_{c1}, W/m^2 – density of solar radiation on wall 1, t_v, ^0C – temperature of the water layer in the greenhouse 10 cm thick, t_B, ^0C – air temperature in the greenhouse, φ, % - air humidity in the greenhouse.

As you can see, air humidity and water and air temperatures change noticeably during the day. In this case, not only the processes of water evaporation are observed, but also the condensation of steam from the air. So if about 10.8 kg evaporates per day. water, then about 8.5 kg condenses during the same time. water from the air in the greenhouse (condensation begins at approximately 15.30).

5 Conclusion

Based on the results of the work, the following conclusions can be drawn:

- A method for calculating non-stationary temperature and humidity conditions in a greenhouse has been proposed and an algorithm and program for its numerical solution have been developed.
- The heat loss of film transparent fences is about 10% greater than that of glass transparent fences. At the same time, for film transparent fences, the main source of heat loss is the transmission of radiation from the greenhouse, and for glass transparent fences it is the loss of radiation from the glass itself.
- Film heating temperature transparent fence always higher than the glass heating temperature transparent fence.
- In general, the developed non-stationary thermal model of the greenhouse reflects real processes, however, experimental studies are necessary to verify and refine it.

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References

1. V.N. Kupriyanov, Designing of heat protection of enclosing structures, Kazan, 163 (2011)
2. Manual on thermotechnical calculation and design of building envelope structures, Stroyizdat, Moscow, 141 (1985)

3. R.R. Avezov, A.Yu. Orlov, Solar Heating and Hot Water Supply, Nauka Publishing House, Tashkent, 284
4. V.V. Pokotilov, M.A. Rutkovsky, Utilisation of solar energy to improve energy efficiency of residential buildings, Minsk, 64 (2015)
5. B. Rasakhodjaev, A.I. Ismanzhanov, Sh.I. Klychev, Solar installations for individual use in rural locality and horn regions, RF. Izd. NOO "Professional Science", 131 (2020)
6. A.I. Ismanzhanov, Sh.I. Klychev, B.S. Rasakhodzhaev, T.S. Tokonova, D.V. Borodin, The heat efficiency of solar ground water-heating collectors, Appl. Sol. Energy, **47**, **4**, 318–320 (2011)
7. A.I. Ismanzhanov, Sh.I. Klychev, B.S. Rasakhodzhaev, Z.K. Ermekova, Studies to determine the light transmission coefficients of a transparent protection, Geliotekhnika, **6**, 84–87 (2018)
8. S.I. Klychev, B.S. Rasakhodzhaev, Z.Z. Akhadov, U.Z. Akhmadjonov, C.A. Adylov, Study of the Thermal Regime of Solar Greenhouses for the Individual Purpose for Their Design Features, Applied Solar Energy (English translation of Geliotekhnika) This link is disabled, **58**, **1**, 121–126 (2022)
9. B.S. Rasakhodjaev, M.O. Boboeva, O.U. Dilishatov, I.R. Mashrapova, S.B. Bekchanov, Calculation specifics in the study of solar greenhouses with thermal energy accumulator in mind, IOP Conference Series: Earth and Environmental Science, **1212**, **1**, 012041 (2023)
10. E.M. Sparrow, R.D. Sess, Heat transfer by radiation, "Energia", 294 (1977)
11. B. Rasakhodzhaev, Z. Mingzhi, U. Akhmadjonov, Yingjie Liu, Y. Rong, J. Shoimov, Automatic control system of greenhouse soil moisture using solar photoelectric systems research, E3S Web of Conferences, **461**, 01080 (2023)
12. V.A. Grigoriev, V.M. Zorin, Heat Power Engineering and Heat Engineering, General Questions, Book 1, Reference Book, Energoizdat, Moscow, 455 (1987)
13. Sh.I. Klychev, S.A. Bakhramov, V.V. Kharchenko, V.A. Panchenko, A.A. Tsukervanik, D.E. Kadyrgulov, T. Fayziev, A Procedure for Calculating the Heating Temperatures of Flat Transparent Screens for Solar Power Plants. Applied Solar Energy, **58**, **2**, 259–263 (2022) DOI: 10.3103/S0003701X22020104
14. B. Rasakhodzhaev, S. Makhmudov, F. Muminov, Selection of a heating system based on climatic conditions of Uzbekistan and on calculations of the technical and economic indicators of alternative systems: A case study of the solar greenhouse with a transformable building, IOP Conference Series: Earth and Environmental Science, **939**, **1**, 012003 (2021)
15. M.A. Mikheev, I.M. Mikheeva, Fundamentals of Heat Transfer, Energia, Moscow, 380 (1997)
16. KMK 2.01.01-94 RUz. Climatic and physico-geological data for designing, Gos-komarkhiturastroy RUz, Tashkent, TIPO named after Ibn-Sino, 28 (1997)
17. KMK 2.09.08-97 "Greenhouses and greenhouses", Ministry of Construction of the Republic of Uzbekistan, Tashkent (1997)
18. KMK 2.04.05-97*, Heating, ventilation and air conditioning, O'zR Period Architecture, Tashkent, AQATM, 212 (2011)
19. Yu.N. Malevsky, Solnechnaya Energetica, Mir, Moscow, 196 (2001)
20. B. Rasakhodzhaev, S. Makhmudov, F. Muminov, Selection of a heating system based on climatic conditions of Uzbekistan and on calculations of the technical and economic

indicators of alternative systems: A case study of the solar greenhouse with a transformable building, IOP Conference Series: Earth and Environmental Sciencethis link is disabled, **939**, **1**, 012003 (2021)

21. A.I. Ismanzhanov, B.S. Rasakhodzhaev, Investigation of the soil thermal field in a soil solar water heating collector, Applied Solar Energy (English translation of Geliotekhnika), **47**, **2**, 134–136 (2011)