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Study of the combined solar heating system of residential houses

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Abstract. The use of renewable energy sources in the heat supply systems of residential houses is one of the urgent issues today. Since solar energy has the highest potential among renewable energy sources, it is widely used in residential heat supply systems. Although solar energy is used in heating systems until now, due to the large number of factors affecting the heating system, research in this field is accelerating. In this research work, a combined scheme for using solar energy in the heating system of residential houses is proposed and the results of pilot studies conducted in the season from November 2020 to February 2021 in the heating system implemented according to this scheme are presented. According to the results of the research, it is possible to cover up to 70% of the heat load in the heating system of residential houses. The information presented in the research work can be used in the design and implementation of energy-efficient solar heating systems.

1. Introduction

Currently, special attention is being paid to the use of renewable energy sources in the heat supply systems of buildings and structures, and the issues of saving traditional fuel and energy resources in the heat supply systems of residential houses. In the world, up to 40% of traditional fuel-energy resources are consumed in the heat supply systems of buildings, of which 50% of primary fuels are used by residential houses. Therefore, it is important to save natural organic fuels in residential heat supply systems, diversify the fuel-energy balance due to the development of renewable energy sources, and introduce energy-efficient combined heat supply systems [1-5].

Scientific research aimed at improving the heat supply systems of residential buildings, improving the energy efficiency of the heat supply system and reducing the consumption of traditional energy resources through the use of renewable energy sources and optimization of heat-technical parameters is a priority [6-10]. Therefore, according to the goal set in the article, the development of combined heat supply systems based on heliodevices, which enable the efficient use of solar energy and traditional fuels, and the scientific justification of energy efficiency is one of the urgent issues [11-14].

Experimental studies of the combined solar heating system of the solar house were conducted according to the scheme shown in figure 1. The heating system includes elements of a solar collector, a heating coil, a water heating boiler and a water-based warm floor.

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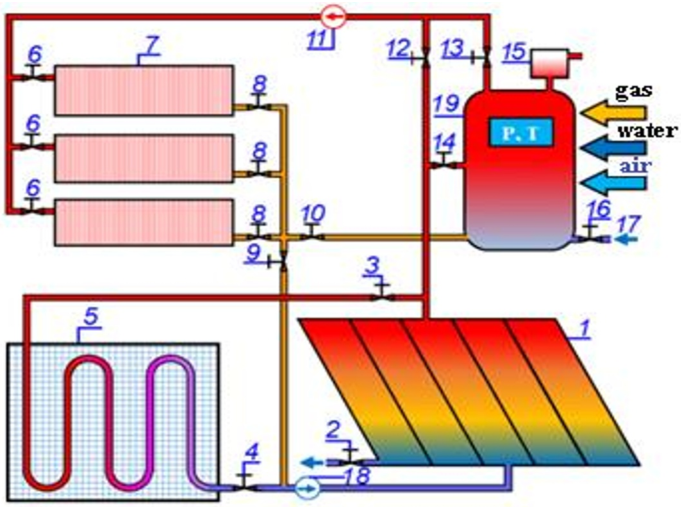

Fig.1. The principle scheme of the combined heating system.

Here-1-solar collector; 2, 3, 4, 6, 8, 9, 10, 12, 13, 14, 16 valves; 11, 18-circulation pumps; 5-water warm floor system; 7-heating batteries; 15-expansion tank; 17 additional water; 19-water heating boiler.

The combined heating system of the solar house consists of four circuits:

- Flat solar water heating collector and heating battery circuit (I circuit) tubular flat solar water heating collector 1, valves 12, 6, 8, 9, 10, circulation pump 11, heating batteries 7, control for measuring temperature and pressure in the circuit - consists of measuring instruments.
- Water heating boiler and heating batteries circuit (II circuit) water heating boiler 19, valves 16, 14, 13, 6, 8, 10, circulation pump 11, heating batteries 7, control-o for measuring temperature and pressure in the circuit consisting of measuring instruments.
- Flat solar water heating collector and water warm floor system (III circuit) tubular flat solar water heating collector 1, valves 2, 3, 4 water warm floor system 5, circulation pump 18, control-o for measuring temperature and pressure in the circuit consists of measuring instruments.
- Flat solar water heating collector, water heating boiler and heating battery circuit (IV circuit) tubular flat solar water heating collector 1, valves 12, 13, 14, 16, 6, 8, 9, 10, water heating boiler 19, circulation pump 11, heating batteries 7, consists of control-measuring devices for measuring temperature and pressure in the circuit.

The heating system of the solar house works in the following four modes:

- Circuit I - the heating system works only with the help of a solar water collector, in which the solar collector heats the water required for the heating system to 55-60°C and transfers it to the heating batteries inside the house. rides.
- The heating system works only with the help of a water heating boiler, this mode is activated only on cloudy days, at night, on cold days of the year and when the amount of solar radiation is insufficient.
- Solar collector water warm floor heating system is an auxiliary system to the general heating system of the house, this system is not connected to the water heating boiler and works continuously with the help of the solar collector, and due to the heat of the water heated in the collector, the average temperature of the surface of the floor inside the house is 24-26°C produces.

- Solar collector and water heating boiler combined heating system works in conditions of moderate solar radiation and lower outdoor air temperature during the day, in which water is initially heated in the solar collector and introduced into the water heating boiler, where it heats up to the required temperature and is transferred to the heating coils. The temperature of the water entering the water heating boiler is adjusted using three-way adjustment valves.

2. Materials and methods

Experimental studies of the combined solar heating system of the experimental solar house were conducted in the heating season from October 2020 to March 2021. The dimensions of the experimental house are as follows: length 4 m, width 3 m, height 3 m. The ratio of the total surface of the windows to the total surface of the outer wall $\varphi = 0.2$ [13]. Heat transfer coefficients: through the wall $k_{wall} = 0.64\,Vt/(m^2 \cdot °C)$ through a double-glazed window $k_{window} = 0.42\,Vt/(m^2 \cdot °C)$, through the ceiling $k_{ceiling} = 0.72\,Vt/(m^2 \cdot °C)$, through the floor $k_{floor} = 0.36\,Vt/(m^2 \cdot °C)$. Coefficients of reduction of the calculated temperature difference: $\psi_{wall} = \psi_{window} = 1$, $\psi_{ceiling} = 0.8$, $\psi_{floor} = 0.6$. Indoor air temperature $t_{internal} = 18°C$, calculated temperature of the outside air during the heating period $t_{outside} = -13°C$ [14;17].

The total surface of the outer wall of the house:

$$F_{wall} = (3+4) \cdot 2 \cdot 3 \cdot 0.8 = 33.6\,m^2$$

The total surface of the windows:

$$F_{windows} = (3+4) \cdot 2 \cdot 3 \cdot 0.2 = 8.4\,m^2$$

The total surface of the ceiling and floor:

$$F_{ceiling} = F_{floor} = 3 \cdot 4 = 12\,m^2$$

External dimensions of the building:

$$V = 3 \cdot 4 \cdot 3 = 36\,m^3$$

Relative heat loss through the outer wall of the house:

$$q_0 = \frac{\sum kF\psi}{V} = 0.98\,Vt/(m^3 \cdot °C)$$

Heat loss through the outer wall of the house:

$$Q'_{loss} = q_0 V(t_{internal} - t_{outside}) = 0.98 \cdot 36(18+13) = 1.094\,kVt \quad (1)$$

Or 3.94 Mj/h in 1 hour.
Living space of the house:

$$F_{living} = \frac{V}{K_{vol}} = \frac{36}{6.4} = 5.62\,m^2 \quad (2)$$

Here $K_{volume} = 6.4\,m^3/m^2$ volume coefficient of the building [13].

$$F_{ceiling} = F_{floor} = 3 \cdot 4 = 12\,m^2$$

Internal heat dissipation in the house:

$$Q_{internal.heat} = q_{h.d} F_{living} = 20 \cdot 5.62 = 0.112\,kVt \quad (3)$$

Or 0.403 MJ/hr in 1 hour.

$t_{outside} = -13°C$ heat loss due to infiltration when:

$$Q'_{infiltration} = \mu Q'_{loss} = b\sqrt{2gL\left(1-\frac{T_t}{T_i}\right)+K_{aer}(w\beta)^2}Q'_{loss} = 0.101\ kVt \quad (4)$$

Or 0.364 MJ/h in 1 hour, where b is a constant quantity, $b = 0.035\ s/m$; $g = 9.81\ m/s^2$ free fall acceleration; $L = 0.25{\cdot}3 = 0.75\ m$ the calculated height of the house; $T_{extemal}$, $T_{internal}$ – external and internal air temperature, K; $K_{aer} = 0.6$; $w = 5\ m/s$ average wind speed; $\beta = 0.6$ a correction factor that takes into account the discrepancy between the wind speed and the outside air temperature received during the calculation.

Heat load for heating the house

$$Q_{heating} = Q'_{loss} + Q'_i - Q_{internal.heat} = 3.94 + 0.364 - 0.403 = 3.901\frac{MJ}{hour} \quad (5)$$

Average heating load during the heating season:

$$Q_h^{average} = Q_h\frac{t_{in}-t_{out}^{average}}{t_{in}-t_{out}} = 3.901\frac{18-t_t^{average}}{18+13} = 0.126\left(18-t_t^{average}\right), \frac{MJ}{hour} \quad (6)$$

Here $t_{outside}^{average}$ - the average temperature of the outside air during the heating season, °C.

3. Results and Discussion

Experimental studies of the combined solar heating system of the solar house during the heating season from October 15, 2020 to March 15, 2021 in the section of months (October, November, December, January, February, March) and on characteristic days of each month (5th, 15th and 25th) o was carried out. The experimental studies carried out in November, December, January and February are shown in figures 2-5 (labels in the figures are as follows: 1. Outdoor air temperature; 2. Heat load; 3. Useful energy received from the solar collector; 4. Energy transferred from the water heating boiler; 5-internal air temperature).

Figure 2 shows the results of the experiment conducted in the combined heating system in November 2020 and on typical days of November. On November 5, 2020, the total load on the heating system was 24.08 MJ, 25.18 MJ of useful energy was received from the solar collector, 2.65 MJ was used for the load, and the internal air temperature increased to 27°C due to 22.53 MJ of excess energy. stretched 21.48 MJ of the load during the non-sunny time of the day is covered by the water heating boiler. On November 15, 2020, the total load on the heating system was 57.82 MJ, 21.85 MJ of useful energy was received from the solar collector, 13.30 MJ was used for the load, and the internal air temperature increased to 23°C due to 8.55 MJ of excess energy. stretched 44.52 MJ of load is covered by the water heating boiler during the non-sunny time of day. On November 25, 2020, the total load on the heating system was 57.66 MJ, 19.37 MJ of useful energy was received from the solar collector, 7.58 MJ was used for the load, and 11.79 MJ of excess energy increased the internal air temperature to 25°C. stretched 50.08 MJ load is covered by the water heating boiler during the non-sunny time of day. In November, the total load on the heating system was 1379.85 MJ, 662.07 MJ of useful energy was obtained from the solar collector, 543.31 MJ was spent on the load, and the coverage coefficient was 0.4.

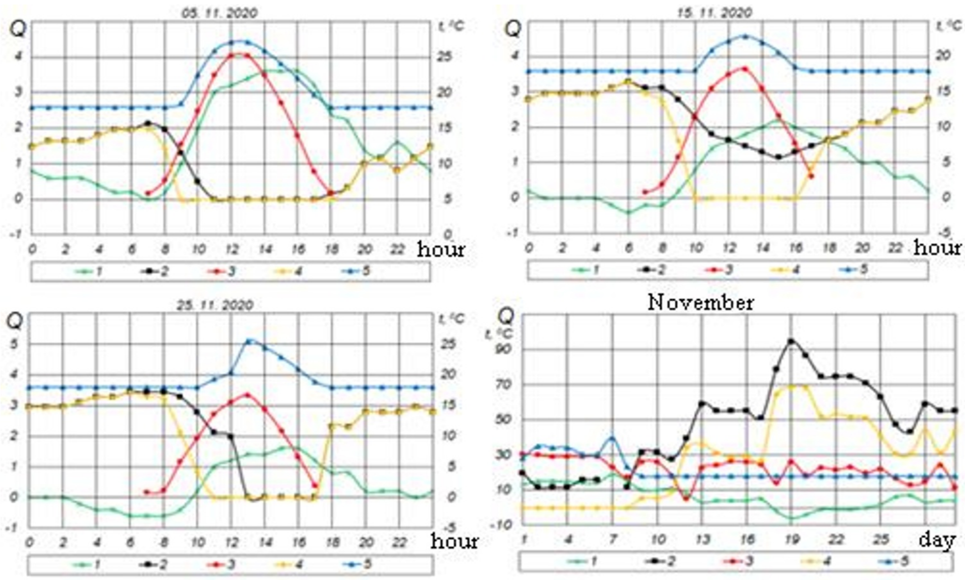

Fig. 2. Results of experiments conducted in the combined heating system in November 2020 and on typical days.

Figure 3 shows the results of the experiment conducted in the combined heating system in December 2020 and on typical days of December. On 5.12.2020, the total load on the heating system was 63.72 MJ, 17.98 MJ of useful energy was received from the solar collector, 13.67 MJ was spent on the load, and due to 4.31 MJ of excess energy, the internal air temperature increased to 21°C. stretched 50.05 MJ of the load during the non-sunny time of the day is covered by the water heating boiler. On 15.12.2020, the total load on the heating system was 91.89 MJ, and 17.13 MJ of useful energy was obtained from the solar collector and used for full load. The coverage ratio was 0.19. 74.77 MJ load is covered by the water heating boiler during the non-sunny time of day. On December 25, 2020, the total load on the heating system was 47.67 MJ, and 17.13 MJ of useful energy was received from the solar collector and used for full load. The coverage ratio was 0.36. In December, the total load on the heating system was 2091.40 MJ, and 398.07 MJ of useful energy was received from the solar collector and used for full load. The coverage ratio was 0.19.

Figure 4 shows the results of the experiment conducted in the combined heating system in January 2021 and on typical days of January. On January 5, 2021, the total load on the heating system was 101.72 MJ, and 17.59 MJ of useful energy was received from the solar collector and used for full load. The coverage ratio was 0.17. 84.13 MJ of the load during the non-sunny time of the day is covered by the water heating boiler. On 15.01.2021, the total load on the heating system was 39.49 MJ, 18.60 MJ of useful energy was obtained from the solar collector, 5.88 MJ of it was spent on the load, and due to 12.72 MJ of excess energy, the internal air temperature increased to 24°C. stretched In the sunless time of the day, 33.60 MJ of load was covered by the water heating boiler. On 25.01.2021, the total load to the heating system was 66.18 MJ, 20.12 MJ of useful energy was obtained from the solar collector, 15.48 MJ of it was spent on the load, and 4 Due to excess energy of .75 MJ, the internal air temperature rose to 21°C. In January, the total load on the heating system was 1875.18 MJ, and 558.24 MJ of useful energy was received from the solar collector and used for full load. The coverage ratio was 0.30.

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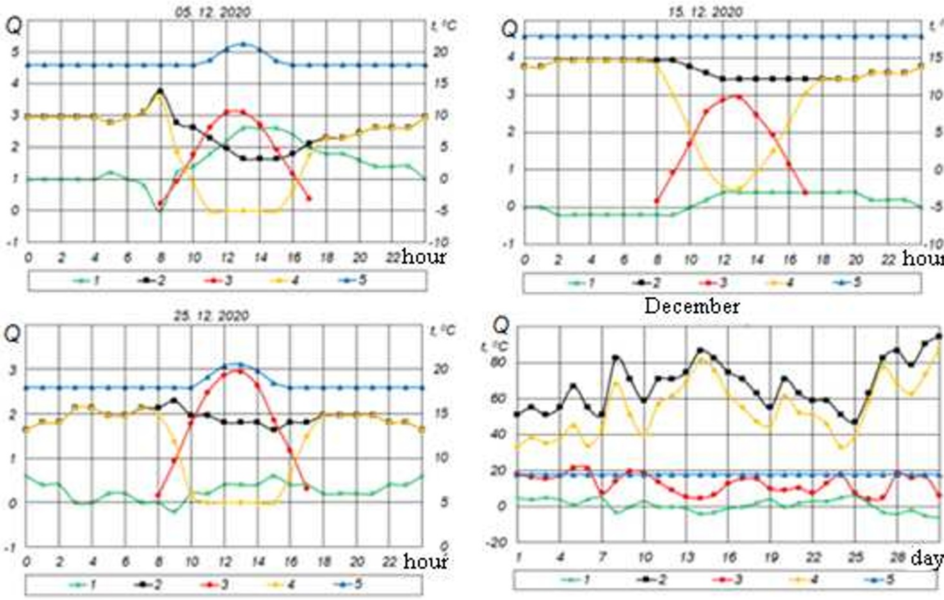

Fig. 3. The results of the experiment conducted in the combined heating system in December 2020 and on typical days.

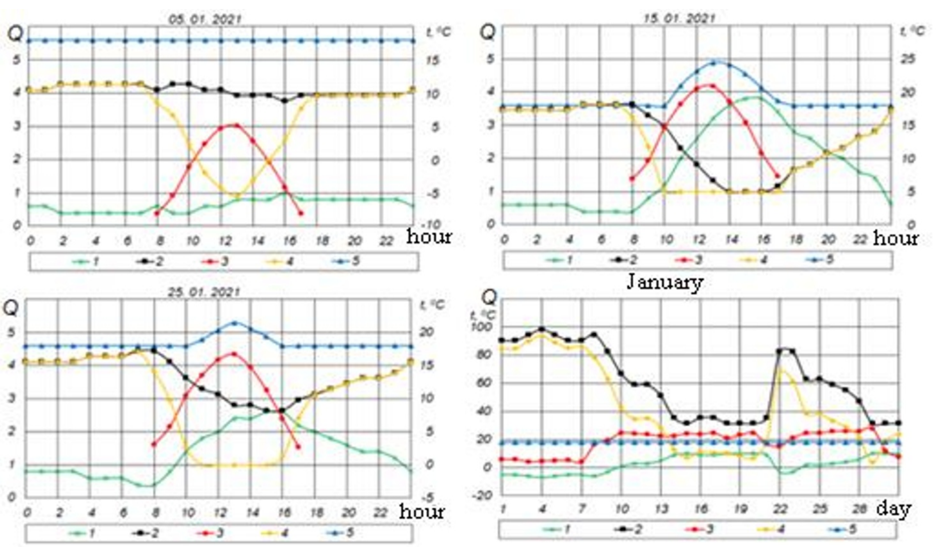

Fig. 4. Results of the experiment conducted in the combined heating system in January 2021 and on typical days.

Figure 5 shows the results of the experiment conducted in the combined heating system in February 2021 and on typical days of February. On February 5, 2021, the total load on the heating system was 30.79 MJ, 23.17 MJ of useful energy was received from the solar collector, 4.37 MJ was spent on the load, and the internal air temperature increased to 26℃ due to 18.80 MJ of excess energy. stretched 26.48 MJ of the load during the non-sunny time of the day is covered by the water heating boiler. On 15.02.2021, the total load on the heating system was 24.08 MJ, 25.65 MJ of useful energy was received from the solar collector, 3.86

MJ of it was spent on the load, and due to 21.79 MJ of excess energy, the internal air temperature increased to 27°C. stretched 20.22 MJ load is covered by the water heating boiler during the non-sunny time of day. On 25.02.2021, the total load on the heating system was 96.31 MJ, 29.14 MJ of useful energy was received from the solar collector, 27.61 MJ of it was spent on the load, and due to 1.53 MJ of excess energy, the internal air temperature increased to 20°C. stretched In February, the total load on the heating system was 908.11 MJ, 626.66 MJ of useful energy was received from the solar collector, 521.39 MJ was spent on the load, and the coverage coefficient was 0.57.

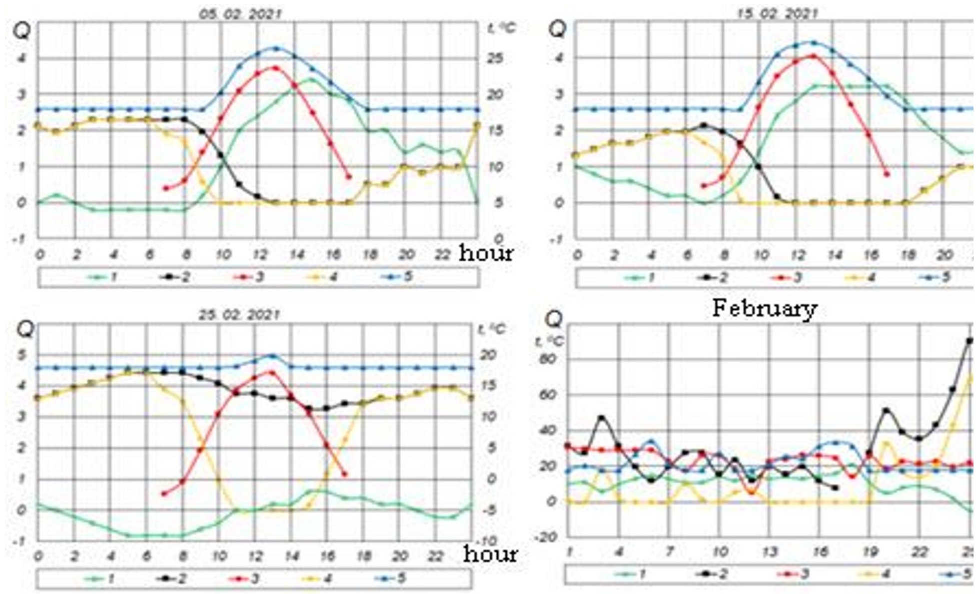

Fig. 5. Results of the experiment conducted in the combined heating system in February 2021 and on typical days.

4. Conclusion

Based on the analysis of the results of experimental studies conducted in the combined heating system during the heating season from October 2020 to March 2021, the amount of solar radiation in the heating season is 7.96...17.96 MJ/m^2·day, and the useful area is 3.5 m^2 It was found that using the solar collector, it is possible to obtain useful energy in the amount of 17.13...38.67 MJ/day and store excess energy in the amount of 1.53...37.27 MJ/day during the heating season.

When using a combined heating system, heating the indoor air of the house up to 18...30°C when the amount of solar radiation is 7.96...17.96 MJ/m^2·day and the average outside air temperature is 0...14.1°C and during the heating season, it was found that the coverage coefficient of solar collectors changes to 0.15...0.76 on average.

References

1. Allayev K R 2021 Modern energy and its development prospects. Academician A.U. Under the general editorship of Salimov. *Fan teknoloks publishing house* 952
2. Avezov R R, Vokhidov A U, Ibragimov U H and Usmanov A Y 2020 Increasing the

convective heat transfer coefficient inside heat removal channels of sheet-piped light-absorbing panels of flat-plate solar collectors in the laminar flow regime of heat transfer fluid. *Applied Solar Energy (English translation of Geliotekhnika)* **56(2)** 114–117

3. Uzakov G N, Khamraev S I and Khuzhakulov S M 2021 Rural house heat supply system based on solar energy. *IOP Conf. Series: Materials Science and Engineering* **1030** 012167
4. Khamraev S I, Ibragimov U Kh and Kamolov B I 2022 Removal of hydrodynamic lesions of a heated floor with a solar collector. *IOP Conf. Series: Earth and Environmental Science* **1070** 012018
5. Ergashev Sh H, Faiziev T A, Mamedova D N and Khuzhakulov S M 2022 Results of mathematical modeling of nostatic temperature temperature heating of "Livestock heat complex" through the use of solar and bio energy. *Proceedings of SPIE - The International Society for Optical Engineering* **12296** 122960
6. Ergashev Sh H, Fayziev T A, Tilavov Yu S, Sattorov B N, Khidirov M M and Mirzayorova S U Mathematical modeling of greenhouse-livestock complex heated by solar and bioenergy sources. *IOP Conference Series: Earth and Environmental Scienc* **1070(1)** 012031
7. Kodirov I N, Toshmamatov B M, Aliyarova L A, Shomuratova S M and Chorieva S 2022 Experimental study of heliothermal processing of municipal solid waste based on solar energy. *IOP Conference Series: Earth and Environmental Science* **1070(1)** 012033
8. Toshmamatov B, Davlonov Kh, Rakhmatov O, Toshboev A and Rakhmatov A 2023 Modeling of thermal processes in a solar installation for thermal processing of municipal solid waste. *AIP Conference Proceedings* **2612** 050027
9. Uzakov G N, Shomuratova S M and Toshmamatov B M 2021 Study of a solar air heater with a heat exchanger – Accumulator. *IOP Conference Series: Earth and Environmental Science* **723(5)** 052013
10. Mirzaev Sh, Kodirov J and Khamraev S I 2022 Method for determining the sizes of structural elements and semi-empirical formula of thermal characteristics of solar dryers. *IOP Conf. Series: Earth and Environmental Science* **1070** 012021
11. Davlonov X, Almardanov X, Khatamov I, Urunboev S, Kalandarov P and Olimov O 2022 Study on heat and material balance of heliopyrolysis device. *AIP Conference Proceedings* **2686** 020023 (2022)
12. Vardiyashvili A A, Zakhidov R A, Vardiyashvili A B, Faiziev T A and Uzakov G N 1999 Utilization of conventional source waste heat in solar greenhouses. *Applied Solar Energy (English translation of Geliotekhnika)* **35(1)** 20-23
13. Uzakov G N, Novik A V, Davlonov X A, Almardanov X A and Chuliev S E 2023 Heat and Material Balance of Heliopyrolysis Device. *ENERGETIKA. Proceedings of CIS higher education institutions and power engineering associations* **66(1)** 57-65
14. Komilov A G and Rakhimov N R 2014 A Solar Desalination Plant Containing Separate Chambers for Evaporation and Condensation with Air Heating after the Condenser Part 2 Calculating the Operation Mode of the Plant and Condenser Parameters. *Applied Solar Energy* **50** 233-235