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THE EFFICIENCY OF COMBINED SOLAR COLLECTORS IN ENERGY EFFICIENT BUILDINGS

The ecological state of the environment and the increasing prices of the imported energy encourage the search for new energy sources, introduction of energy-saving technologies, reconstruction and improvement of the capacities of systems actually applied in building structures and in energetic sector. In the face of current energy crisis effective consumption of energy resources becomes an important problem as well as development and implementation of new energy-saving technologies. The efficiency of solar walls combined with the heating system of the building have been analyzed in laboratory and in practice in out-door conditions. It have been proved that it's possible to effectively use solar energy converted into thermal energy and accumulated in wall structure. The results of laboratory researches focused on the amount of energy obtained from solar wall functioning in gravity heating system have been described.

Keywords: solar panel, solar radiation, heat

INTRODUCTION

It's developed energy efficient walling in the form of roofs and external walls of buildings (residential, public, administrative, etc), and also as elements of surfaces of industrial objects (freezing, cooling and drying chamber, etc). Such constructions allow utilize for needs of hot water, air conditioning and industrial heat the energy of solar radiation, heat outdoor air and exhaust air, as well as an opportunity to implement the functions of the ejection out of the excess heat and regulate heat accumulation [1, 2]. It's widely used wall-mounted solar collectors, which simultaneously perform the function of walling [3, 4]. One of the simplest ways of using solar heat on the existing roofs is a transmittance of water or air through the surface of the roof [5]. The research of this system, which have been conducted showed that the coefficient of efficiency is low. But minor costs which are associated with converting your existing roof into a solar collector, justify a low efficiency.

It's known solar profile [6, 7], which is an elongated aluminum profile, which has perceiving heat surface, the channels for liquid and air coolant (the last may accommodate the heat storage liquid) and fixing edges with neighboring elements. However, its disadvantage is the low intensity of heat exchange between the coolant and the heat-absorbing panel, due to their small contact area. The way to solve these problems is a combination of a solar collector with the material of the wall of the building. In this case solar wall serves as both the solar collector and the house construction. This can significantly reduce the cost of the solar system and its payback period, as well as to simplify its construction.

The feature of the solar wall is that its heat sink is made of material of the building wall and the tube for the coolant are located above it. Under the solar energy absorber is placed the insulating layer and the reflective material.

1. ANALYSIS OF EXISTING STUDIES

Solar beam hits the tubes for the coolant and the outer surface of the coating which is made of a material of the wall. At this time it is heating. Heat is transferred to the tubes of circulation, where coolant circulates. Due to the temperature difference and therefore the density of the coolant in the area of the inlet and outlet ports creates a circulation of the coolant. The heated coolant is supplied to the consumer. Insulating layer and the upper transparent layer ensure a reduction of heat loss.

The researches were conducted in the laboratory conditions with simulation of solar emitter (Fig. 1).

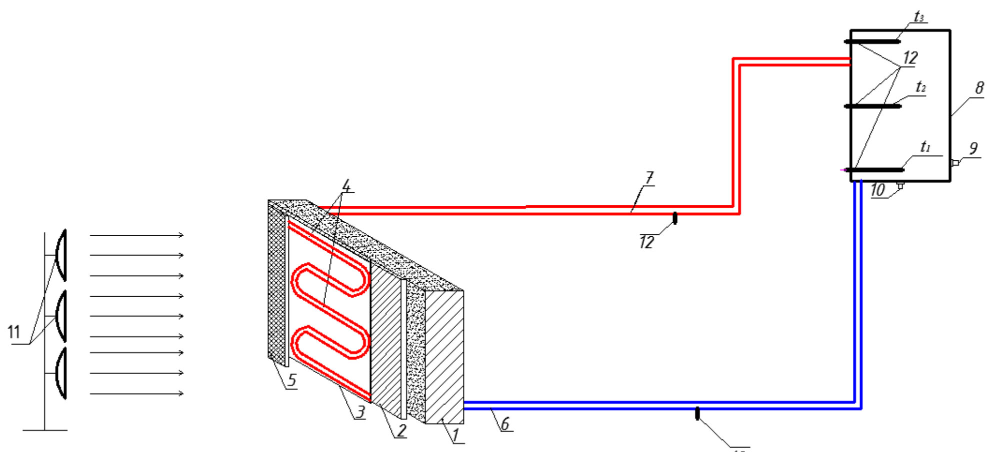

Fig. 1. Scheme of the experimental setup: 1 - construction of wall, 2 - insulating layer, 3 - foil, 4 - heat perceiving pipes, 5 - plaster, 6 - pipeline of cold coolant, 7 - pipeline of the heated coolant, 8 - storage tank, 9 - serving of hot water to the consumer, 10 - serving of cold water, 11 - the emitter of thermal energy

Throughout the experiment we monitored so that it is not affected by other factors (solar energy through the window, smooth surface, shading of the solar collector). Before each experiment the system was filled with a fresh portion of water. Air was removed from the system. Impermeability of the system was checked up at working pressure. We checked the operability of the instruments. During the experiment the intensity of the flow of energy; the temperature of the coolant at the inlet of solar wall; the temperature of the coolant at the outlet of the solar wall; the temperature of the coolant in the storage tank were measured.

The temperature measurement accuracy was equal ±0.01°C and the intensity of the flow of energymeasurement accuracy was equal ±0.1 W/m^2. The measurement errors were amounted to 1%.

After completion of the experiments thermal emitters were excluded, the circulation of the coolant was stopped, the coolant was merged and the system was filled with a new portion of the chilled coolant.

The thermal energy that was accumulated in the storage tank was determined by the equation:

$$Q_{ac} = c \cdot m \cdot (t_{aver,1} - t_{aver,2}) \tag{1}$$

where: c - specific heat capacity of the coolant [J/(kg·K)]; m - the mass of the coolant [kg], $t_{aver,1}$, $t_{aver,2}$ - the average temperatures of the coolant in the storage tank [K].

$$Q_{rad} = F_{sc} \cdot I \cdot \Delta\tau \tag{2}$$

where: F_{sc} - the area of the heat absorber of the solar collector [m^2], I - the intensity of the radiation source to the surface of the heat absorber of the solar collector, [W/m^2], $\Delta\tau$ - period of time [s].

As during receiving radiation energy by the solar wall, heat losses occur in the environment, that's why it is useful to analyze how much heat has been accumulated in the storage tank during the experiment. The efficiency of solar energy systems, η_{ses} is defined similarly to the efficiency of the solar collector for the amount of energy obtained by the storage tank Q_{ac}:

$$\eta_{ses} = \frac{Q_{ac}}{Q_{rad}} \tag{3}$$

where: Q_{ac} - the amount of heat that were received by the storage tank during the period of time $\Delta\tau$ [s], was determined experimentally; Q_{rad} - the amount of radiant heat that were received by the surface of the heat absorber of the solar collector during the same period of time $\Delta\tau$ [s].

2. RESULTS

This article presents the results of experimental researches of solar wall in the solar heating system when the diameter of tubes of the circulation d = 10 mm, the distance between tubes of the circulation is l = 5 mm. The thickness of plaster on top of tube of the circulation was set at 30 mm. The researches were carried out at the intensity of the heat flow of 300 W/m^2.

The results of experimental measurements of the temperature of the coolant at the inlet and outlet of solar wall, and average air temperature near the experimental setup is presented in Figure 2.

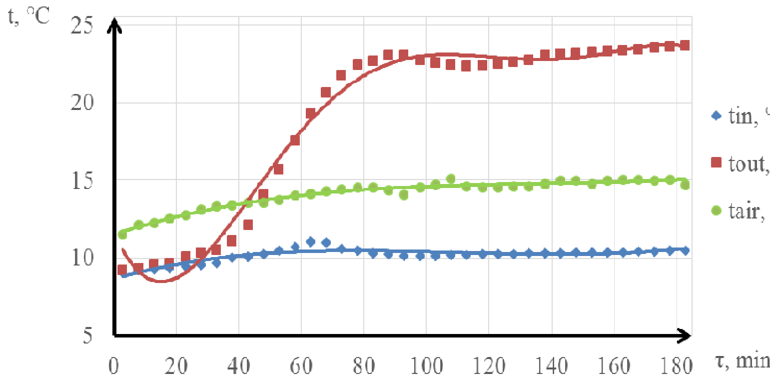

Fig. 2. The results of experimental researches of solar wall: t_{in} - the water temperature at the inlet to solar wall [°C], t_{out} - the water temperature at the outlet of solar wall [°C], t_{air} - average air temperature near the experimental setup [°C]

After analyzing the graph which is depicted in Figure 2, we can see a sharp increase in water temperature at the outlet of solar wall to 80th minute, and then a slight increase. However, the water temperature in the inlet of solar wall and the temperature of air grew evenly during the experiment. The water temperature at the outlet of solar wall reaches a value of 23.6°C, for 180 minutes of irradiation by heat flow intensity of 300 W/m^2 the temperature of the coolant at the outlet increased by 14.5°C.

It is also advisable to investigate the change of temperature with height in the storage tank during the experiment Figure 3.

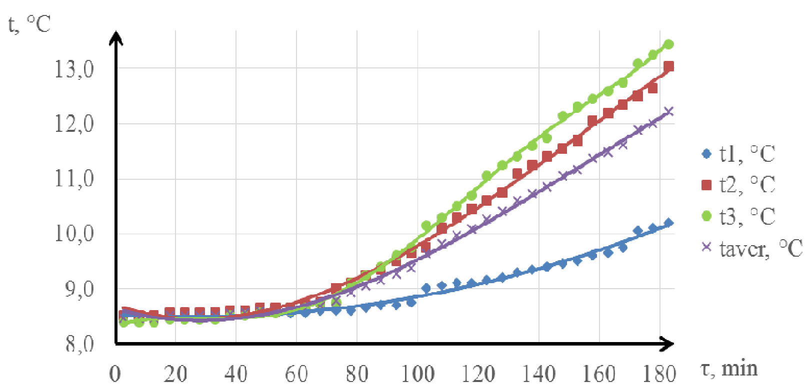

Fig. 3. The change of the water temperature in the storage tank: t_1, t_2, t_3 - the water temperature along the height of the storage tank [°C], t_{aver} - the average water temperature in the storage tank [°C]

Based on the data of Figure 3 we got the equation of dependence of the average temperature in the storage tank t_{aver} of irradiation time τ:

$$t_{aver} = -2E\text{-}06\tau^3 + 0{,}0005\tau^2 + 0{,}004\tau + 12 \quad (4)$$

where: t_{aver} - the average temperature in the storage tank [°C], τ - the duration of time of the radiation of solar wall [s].

On the basis of the results of measurements of work of solar wall in the system of solar heating by the equation (3) is constructed a graph of the coefficient of efficiency of the gravitational systems of solar heating based on solar wall (Fig. 4).

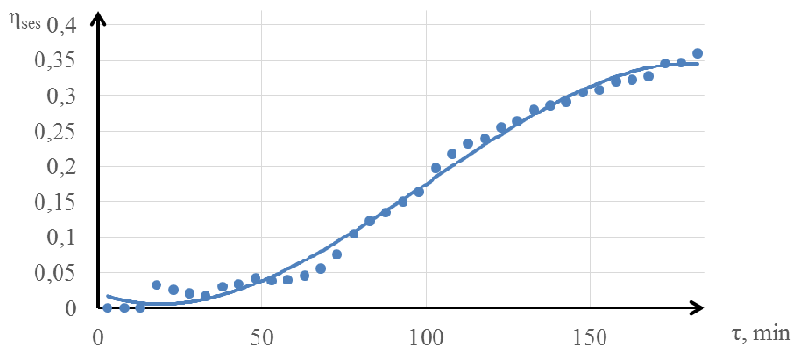

Fig. 4. The change of the coefficient of efficiency of solar gravitational system η_{ses} depending on the irradiation time τ

Based on the data of Figure 4 we got the dependence of the coefficient of efficiency of gravitational solar system η_{ses} depending on the irradiation time τ:

$$\eta_{ses} = 3E\text{-}07\tau^3 - 5E\text{-}05\tau^2 + 0.006\tau + 0.2 \quad (5)$$

where: η_{ses} - the coefficient of efficiency of gravitational solar system, τ - time [s].

CONCLUSIONS

The experience of the use of natural alternative renewable energy sources, to which primarily relates the Sun, demonstrates the great potential of making this form of energy into thermal energy, which can be successfully used to provide various technological and social needs. Commissioning of solar installations based on solar wall improves the ecological situation of the district in which it is used by reducing the volumes of waste contaminants, which include the products of combustion of conventional forms of energy. Therefore, development and improvement, implementation of solar installations to obtain low-grade thermal energy, which is used for hot water and heating of various facilities is promising. Since, laboratory researches showed the coefficient of efficiency of gravitational solar system based on solar wall can reach 35%.

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EFEKTYWNOŚĆ UKŁADU KOLEKTORÓW SŁONECZNYCH W BUDYNKACH ENERGOOSZCZĘDNYCH

Stan ekologiczny środowiska oraz rosnące ceny importowanej energii skłaniają do poszukiwania nowych jej źródeł, wprowadzania energooszczędnych technologii oraz do wymiany bądź poprawy sprawności istniejących systemów w budynkach i sektorze energetycznym. W obliczu obecnego kryzysu energetycznego istotną kwestią pozostaje efektywne korzystanie z istniejących zasobów energetycznych, a także rozwój i wdrażanie nowych technologii energooszczędnych. Badano efektywność zastosowania ścian z kolektorami w systemie ogrzewania budynku w warunkach laboratoryjnych i rzeczywistych. Wykazano, że można efektywnie wykorzystać ciepło skumulowane w ścianie, uzyskane z energii słonecznej. Opisano wyniki badań laboratoryjnych odnoszące się do ilości promieniowania słonecznego pochodzącego ze ściany solarnej wykorzystywanego w układzie grawitacyjnym ogrzewania słonecznego.

Słowa kluczowe: kolektor słoneczny, promieniowanie słoneczne, ciepło