The use of solar collectors combined with a roof for heating supply of buildings

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In this article the author considers the method of efficiency increase of solar energy use by a solar collector combined with a roof of a building. He describes the results of the research on solar radiation input on a helio-roof. He also shows that the heat of the roofing material of the building can be efficiently used. The author determines the interdependency between different orientations of the solar collector combined with the roof of the building and its efficiency.

Keywords - solar collector, solar radiation, solar heating supply, roof, efficiency.

I. Introduction

The issues related to the future ways of energy development escalate more and more every year. On the one hand, the population growth, the desire to improve the living standards of people dictate the expediency of accumulation of energy capacity, moreover, on gigantic rates, on the other hand, the environmental problems arising, exhaustion of natural sources of raw materials, and, above all, oil and gas, require more economic and efficient use of the energy obtained. Fuel and energy resources become more expensive every year both for the industry, and for the population.

Therefore there is a need to implement complex measures on the use of new alternative energy sources. The solution of this problem requires significant changes in the global energy balance. An alternative in this field is the use of non-conventional renewable energy sources: energy of the sun, wind, entrails of the earth, the heat of industrial and sewerage waste, waters etc.. They are completely free for the mankind and given to us in virtually unlimited quantities.

Currently there is a number of solar collectors that are different in design, and technical and economic indicators. Flat solar collectors have proved themselves as quite effective and easy to use. But these solar collectors are expensive, elaborately designed and have low solidity of the top covering because of the application of glass or plastic as the transparent top cover. Consequently, at present it is important to improve and develop new combined solar collectors where the top covering of the solar collector is made of corrugated roofing material of the building. This kind of the solar collector will allow to reduce its cost maximally and increase its durability.

II. Presentation of the Basic Material

Many studies of solar power plant are devoted to the determination of the optimal angles of slope of the flat solar collector to the horizon and the azimuth of its rotation, and also to the improvement of their design [1]. An effective method to increase the efficiency of solar collectors and to reduce their cost is to make the top covering of the solar collector from the roofing material of the building.

The experimental power plant consists of a solar collector combined with the roof, accumulator box, source of radiation and measuring devices.

The main target of the solar collector combined with the roof of the building is to improve the flat solar collector in which the new kind of the top transparent cover would allow to reduce costs, increase flexibility and simplify the design of the solar collector.

The set tasks can be solved in a way that the solar collector comprises top and bottom corrugated coverings, between which there are the pipes of circulation circuit attached to the top covering and connected to the input and output branch pipes, the inner surface of the lower corrugated covering is overlaid with a mirror layer and the upper corrugated covering is made of roofing material of the building. The insulating layer which is placed under the bottom cover reduces the heat loss.

The upper corrugated covering of the solar collector which is made of the roofing material of the building increases its durability and simplifies design, considerably reduces the cost of the solar collector, allows to use the heat of the roofing material efficiently.

We controlled the experiment so that it could not be affected by other factors (solar energy through the window, smooth surfaces, shading of the solar collector etc.). Natural air flow did not exceed 1 m/s, which did not influence on the results of the experiments, but allowed to remove the surplus heat during the experiment, as a result of which the ambient temperature slightly increased during the experiment.

The intensity of the flow of the energy emanated by the source was measured by an actinometer. The temperature of the heat carrier was measured at three points of the system (at the outlet of the collector, at the collector inlet and in the accumulator box) by the mercury thermometer. Environment air temperature and its speed was measured by the thermoelectric generator anemometer TESTO 405 - V1.

Each time before the experiment was started the system was filled with a portion of fresh water. We checked the hermeticity of the system at the operating pressure. The good condition of measuring devices was also tested.

We made up the three-factor planning matrix with the factors interaction. As the factors we chose:

- azimuthal angle of turning of the solar collector, α^o;
- the angle of slope of the collector, β^o;
- the heat flow intencity, W/m^2.

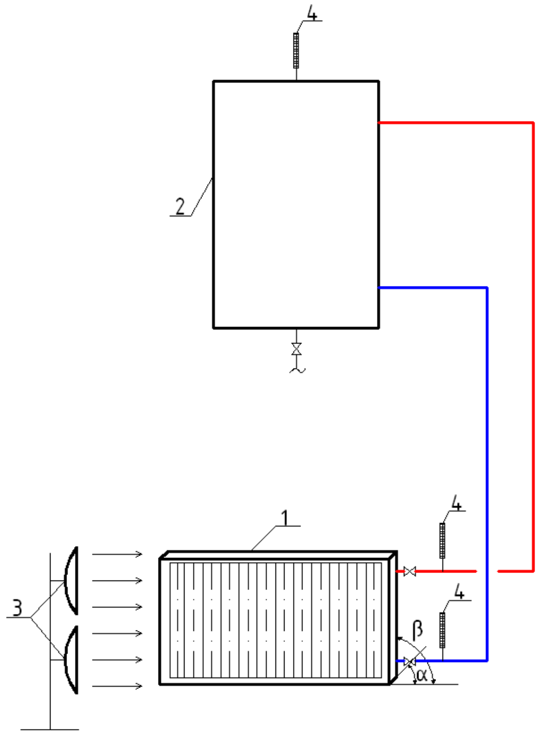

Fig. 1. Chart of the experimental unit:
1 – solar collector combined with the roof of the building; 2 – accumulator box; 3 – source of radiation; 4 – mercury thermometer

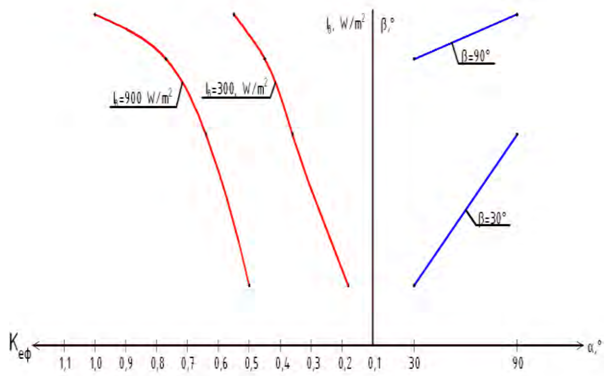

Fig. 2. Results of the experimental research

The optimization parameter was the efficiency coefficient $K_{eф}$, as the change of the fall angle of beams influences on the efficiency of the solar collector combined with the roof of the building.

$$K_{eф} = \frac{y_i}{y_{cm}}, \tag{1}$$

where y_i – the heat energy received by the solar collector combined with the roof of the building at the fall angle of beams $\alpha = 90^o$, $\beta = 90^o$ and $I_в = 900$ W/m^2; y_{cm} – the heat energy received by the solar collector combined with the roof of the building at different fall angles of beams and different radiation intensity.

We get the following equation of regression on the basis of the data in table 1:

$$K_{eф} = 0{,}56 + 0{,}08x_1 + 0{,}14x_2 + 0{,}17x_3 + \\ + 0{,}01x_1x_2 + 0{,}02x_2x_3 + 0{,}02x_1x_2x_3 \tag{2}$$

On the basis of the results of experimental research we have built the nomogram of dependency of azimuthal angle of turning of the solar collector *α,* angle of rotation of the solar collector *β,* the intensity of the heat flow $I_в$ and the efficiency coefficient $K_{eф}$.

From the nomogram (fig. 2) we see that the efficiency of the solar collector combined with the roof of the building at the change of the fall angle α and β from 90^o to 30^o falls on 45,5%.

An insignificant fall of the helio-roof efficiency will be at the change of the fall angle of solar radiation.

TABLE 1

MATRIX OF EXPERIMENTAL DESIGN

№	x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	$K_{eф}$
1	+	–	–	–	+	+	+	–	0,18
2	+	+	–	–	–	–	+	+	0,36
3	+	–	+	–	–	+	–	+	0,45
4	+	+	+	–	+	–	–	–	0,55
5	+	–	–	+	+	–	–	+	0,50
6	+	+	–	+	–	+	–	–	0,64
7	+	–	+	+	–	–	+	–	0,77
8	+	+	+	+	+	+	+	+	1

Conclusion

The research showed the high efficiency of the combined solar collector, that allows to talk about its wide use in the systems of solar heat supply. The efficiency coefficient $K_{eф}$ at the intensity of the heat flow of $I_в$ = 900 W/m^2 changes from 1 to 0,55, which means the ability to catch radiation efficiently at different deviations of fall angles of the heat flow from 90^o.

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