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# BUILDING HEAT SUPPLY SYSTEM BASED ON HYBRID SOLAR COLLECTORS

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**Increasing the efficiency of solar heat supply systems is one of the important problems of solar energy. The research presented in this article is aimed at improving the efficiency of hybrid solar collectors without a transparent coating for building heating systems. One of the key challenges in the field of solar energy is the development of new technologies to ensure high collection of solar energy and to integrate it into traditional heating and hot water systems. The study shows that hybrid solar collectors with the placement of heat carrier circulation circuit tubes above the heat absorber can increase the thermal efficiency factor with a certain change in the angle of inclination and the density of solar radiation. A nomogram was also developed that determines the dependence of this coefficient on the angles of arrival of solar radiation and its density.**

**Key words: solar collector, hybrid solar collector, heat absorber, solar energy, thermal efficiency coefficient, solar radiation.**

## Introduction

Currently, there are many modern technologies that will make it possible to provide humanity with nuclear energy and energy from fossil fuels for many years to come. But, despite the world community's attempt to implement a policy of decarbonization of production, the level of atmospheric pollution continues to grow, which leads to the destruction of the biosphere (Ricci et al., 2022). Waste storage, the consequences of accidents, thermal and radiation pollution are also a big problem.

All this encourages the intensification of the use of solar energy. This energy can be effectively and quickly transformed into heat or electricity and further used for the needs of heating and hot water supply systems (Patel et al 2012; Goel et al., 2022). Today, the improvement of existing solar collectors and solar heat supply systems is relevant for their maximum integration into traditional heat supply systems and wide application in practice (Kasynets et al., 2021). Known combined solar heaters do not ensure efficient use of solar energy during the day, as there are no energy-efficient and relatively cheap designs.

Today, the development of energy equipment requires new solutions (Ivashkiv & Trukhan, 2019; Arvizu et al., 2012). In particular, in the field of heat supply of buildings with the help of solar collectors. This field is constantly developing (Davidenko 2016, Zhelykh et al, 2020; He et al 2020,). Therefore, solutions for the introduction of new efficient hybrid solar collectors are promising (Kalogirou & Tripanagnostopoulos, 2006). Their peculiarity is that they are integrated into the external protection of the building (Venhryn et al 2020) .

At the same time, it is very important to take into account the potential of solar energy at the place of installation of solar collectors (Ulewicz et al, 2022; Goel et al, 2022). It is for this that further design improvements and research into the thermal characteristics of solar system elements are needed (Venhryn 2019). Such elements can be made of both metal and polymer materials, which helps them to be effectively integrated into the architecture of buildings (Priymak et all, 2020; Chen et al., 2013; Doroshenko & Khalak 2018).

## Materials and Methods

The main goal of this work is to determine the coefficient of thermal efficiency of a hybrid solar collector without a transparent coating with the placement of heat carrier circulation circuit tubes above the heat absorber in a solar heat supply system with natural circulation depending on the angles of arrival and the density of the radiation flow.

Based on a review of existing combined and hybrid solar heating systems, a design of a hybrid solar collector was created, which requires research.

The design of a hybrid solar collector is proposed, in which, in order to increase the area of heat absorption of solar radiation and in the case of reconstruction of the building coating, circulation tubes were placed above the heat absorber of the solar coating.

The scheme of the experimental setup is presented in Figure 1.

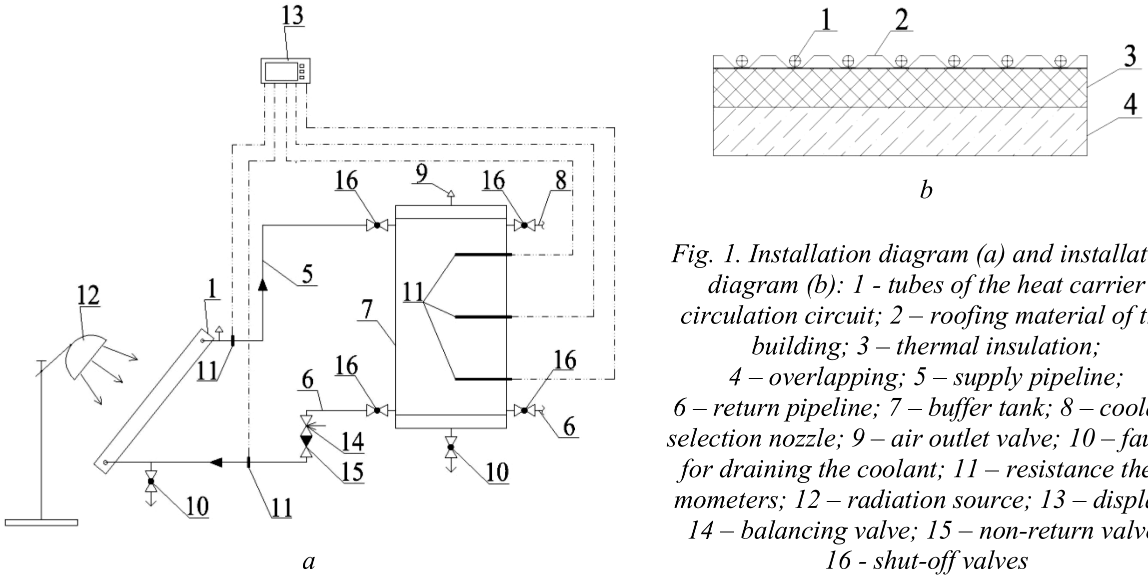



*Fig. 1. Installation diagram (a) and installation diagram (b): 1 - tubes of the heat carrier circulation circuit; 2 – roofing material of the building; 3 – thermal insulation; 4 – overlapping; 5 – supply pipeline; 6 – return pipeline; 7 – buffer tank; 8 – coolant selection nozzle; 9 – air outlet valve; 10 – faucet for draining the coolant; 11 – resistance thermometers; 12 – radiation source; 13 – display; 14 – balancing valve; 15 – non-return valve; 16 - shut-off valves*

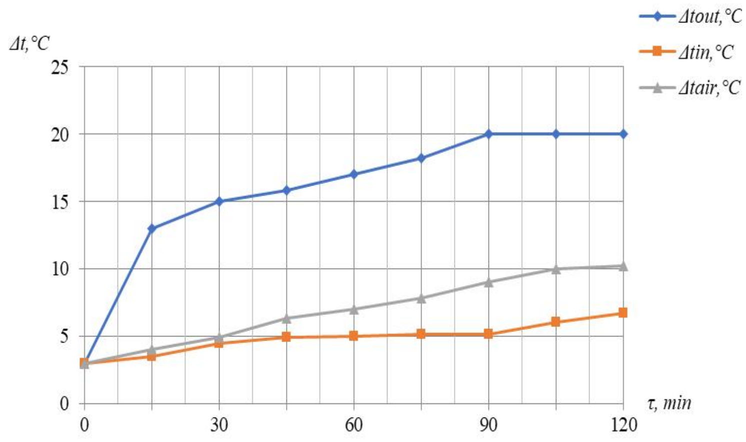
The temperature of the coolant in the inlet and outlet pipes of the solar collector was measured with the help of the experimental setup. Experiments were conducted for different radiation flux densities, as the intensity of solar radiation varies throughout the day.

## Results and discussions

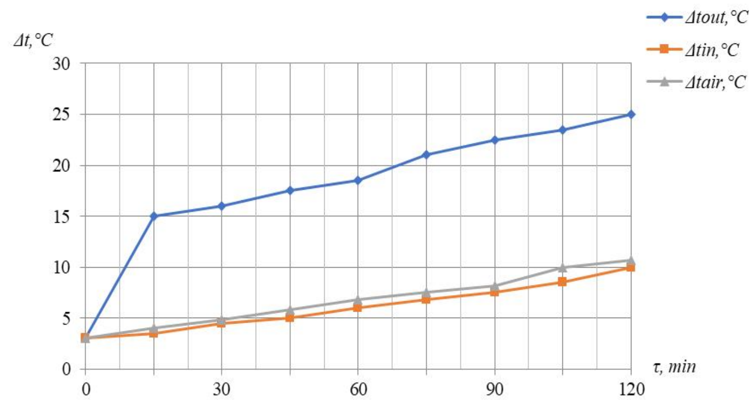
Further, on the basis of the implemented mathematical planning of the experiments, a matrix was compiled with three factors of influence on the response function, which served as the coefficient of thermal efficiency of the *Kef* heliocovering. The data obtained from the conducted own research are reproduced in the form of graphs in Figure 2.

It can be seen from Fig. 2 that at a radiation flux density of 300 W/m², the temperature of the coolant at the exit from the hybrid solar collector varied from 13 to 30 °C. At a higher radiation flux density, namely 600 W/m², the temperature of the coolant varied from 13°C to 35 °C. This indicates that hybrid solar collectors can efficiently collect solar energy in different climatic conditions and provide heat supply with high coolant temperatures.

Figure 3 shows the dependence of the coefficient of thermal efficiency of hybrid solar collectors on the angles of inclination of solar radiation $\alpha$ and $\beta$ and the density of the radiation flux *Ir*. When the angle of inclination and the density of the radiation flow increase, the coefficient of thermal efficiency of such collectors increases.

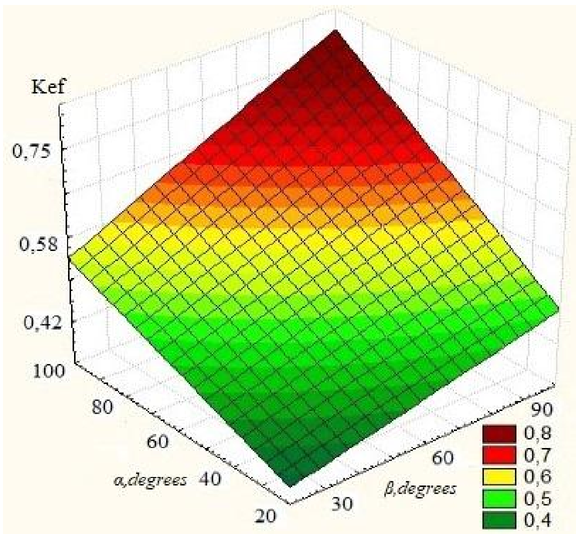



*a*

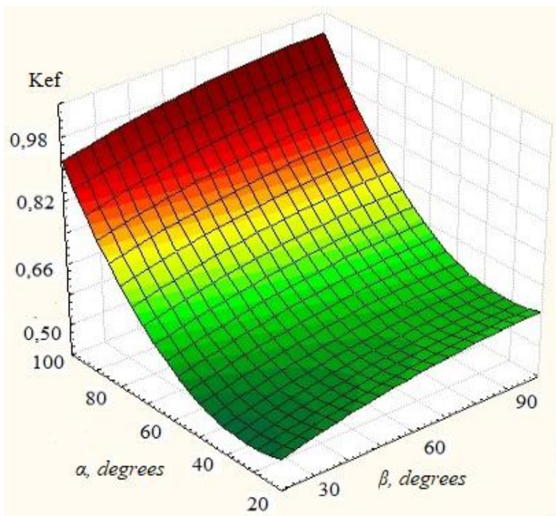



*b*

*Fig. 2. Temperature change of the coolant in the inlet $t_{in}$ and outlet $t_{out}$ nozzles of the hybrid solar collector without a transparent coating with tubes of the circuit of the coolant circulation above the heat absorber in the buffer tank at the angles of arrival of the radiation flux α = 60° and β = 60° and its density Ir = 300 W/ m$^2$ (a); Ir = 600 W/m$^2$ (b)*




*A*




*b*

*Fig. 3. Dependence of the coefficient of thermal efficiency of a hybrid solar collector without a transparent coating with the placement of tubes of the circuit of the coolant circulation above the heat absorber for the radiation flux density Ir = 300 W/m$^2$ (a); Ir = 900 W/m$^2$ (b)*

This is an important indicator, as it indicates the ability of hybrid solar collectors to work more efficiently in conditions of high solar activity. The analysis of the results of the experimental data (Fig. 3) showed that the coefficient of thermal efficiency of the solar coating without a transparent coating with the placement of pipelines of the circulation circuit of the heat carrier above the heat absorber when the angles α and β change from 30 ° to 90 °, increases by 50%.

On the basis of experimental data, a nomogram of the relationship between the coefficient of thermal efficiency *Kef* in the heat supply system with the natural circulation of the heat carrier and the angles of arrival of the heat flow *α* and *β* on the plane of the heat absorber of the solar coating without the presence of a transparent coating with the placement of tubes of the circuit of the heat carrier above the heat absorber was developed (Fig. 4).

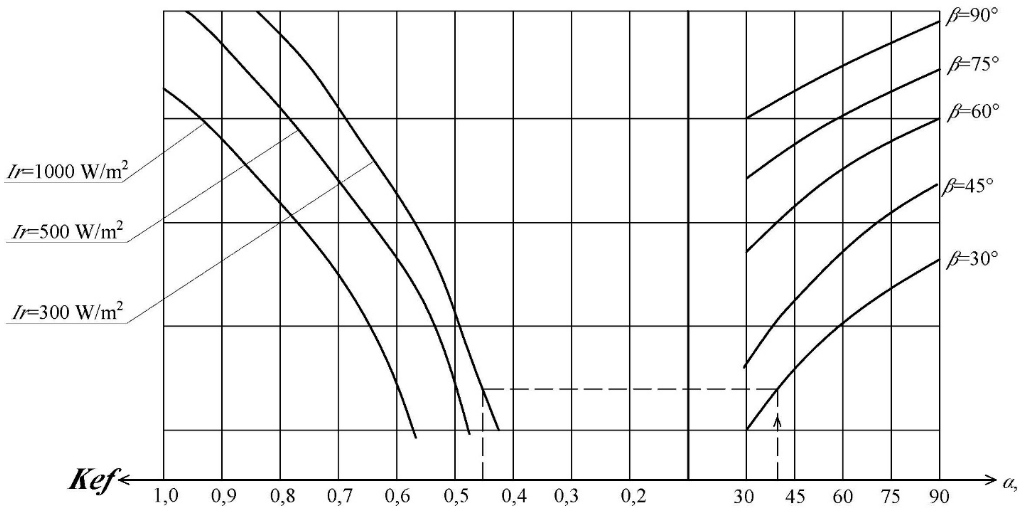



*Fig. 4. Thermal efficiency of hybrid solar collectors without transparent cover at different angles of solar radiation incidence*

According to the above nomogram of the relationship between the coefficient of thermal efficiency and the angles of inclination of solar radiation *α* and *β*, as well as the density of the radiation flux $I_r$, which makes it possible to accurately determine the coefficient of thermal efficiency for specific parameters and input data, the following functional dependence was obtained:

$$K_{ef}= (0,1108+0,0005\cdot I_r)+(0,0003+3,5\cdot 10^{-6}\cdot I_r)\cdot\alpha+(0,0082-1,7167\cdot 10^{-5}\cdot I_r)\cdot\beta+(6,173\cdot 10^{-6}-$$
$$-2,778\cdot 10^{-8}\cdot I_r)\cdot\alpha^2+(4,1667\cdot 10^{-5}-4,6667\cdot 10^{-8}\cdot I_r)\cdot\alpha\cdot\beta+(-5,679\cdot 10^{-5}+1,6667\cdot 10^{-7}\cdot I_r)\cdot\beta.^2$$

Using the above relationship, it is possible to obtain the value of the coefficient of thermal efficiency of a hybrid solar collector without a transparent coating with the placement of heat carrier circulation circuit tubes above the heat absorber in a solar heat supply system with natural heat carrier circulation depending on the angles *α* and *β* of arrival and the radiation flux density $I_r$.

According to the results of the experiments, the coefficient of thermal efficiency of hybrid solar collectors without a transparent coating with the placement of tubes of the circulation circuit of the heat carrier above the heat absorber increased by a significant amount, namely by 50%. This effect was detected by changing the angles of inclination α and *β* from 30° to 90° and the density of the solar radiation flux from 300 W/m² to 900 W/m².

From the processing of the research results, it can be seen that at a radiation flux density of 300 W/m², the temperature of the coolant at the exit from the hybrid solar collector varied from 13 to 30 °C, and at 600 W/m² - from 13 to 35 °C. This highlights the importance of hybrid solar collectors to ensure efficient solar energy collection in different climates.

The dependence of the coefficient of thermal efficiency on the angles of inclination of solar radiation *α* and *β* and the density of the radiation flux *Ir* is presented in Figure 3 and the nomogram in Figure 4. The obtained functional dependence allows you to accurately determine the coefficient of thermal efficiency for hybrid solar collectors depending on the input parameters.

The efficiency of solar cover was determined by the equation:

$$\eta_{h_c} = \frac{Q_{h_c}}{I_r} \cdot 100\ \%,$$

where $Q_{hc}$ is a instantaneous thermal power of solar cover, W/m$^2$ ;

$$Q_{h_c} = G_s \cdot F_{hc} \cdot c \cdot \left(t_{in} - t_{out}\right),$$

where $G_s$ is a specific heat transfer fluid consumption, kg/(s·m²); $F_{hc}$ – solar cover area, m²; $c$ is a specific heat capacity of the heat transfer fluid, J/(kg·°C).

Therefore, the results of this study confirm the significant potential of using hybrid solar collectors to improve the efficiency of solar energy collection and emphasize the importance of further research and design improvement of such systems to reduce environmental pollution and improve the sustainability of heating systems.

## Conclusions

Based on the review of the existing combined solar heat supply systems, the design of a hybrid solar collector without a transparent coating is proposed, in which the circulation tubes are placed above the heat absorber of the heliocoating. In this case, it is a roof covering. Research confirms the great potential of hybrid solar collectors to improve the efficiency of solar energy collection for building heating systems. Variations in tilt angles and solar radiation density can significantly affect the efficiency of such collectors, making them attractive for use in different geographic areas. The nomogram is a useful tool for engineers and researchers in improving the design and optimization of hybrid solar heating systems. Experiments show that hybrid solar collectors increase the efficiency of the solar system. These researches also emphasize the importance of improving solar energy technologies to reduce environmental pollution and improve the sustainability of heat supply systems

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## СИСТЕМА ТЕПЛОЗАБЕЗПЕЧЕННЯ БУДІВЕЛЬ НА ОСНОВІ ГІБРИДНИХ СОНЯЧНИХ КОЛЕКТОРІВ

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Запровадження нових технологій у будівництві та підвищення енергозберігаючих властивостей матеріалів дає поштовх для розробки ефективних методів для збору сонячної енергії, з подальшим її використанням у системах теплозабезпечення будівель різного призначення. Але збір та накопичення отриманого тепла супроводжуються постійними втратами, які пов’язані з кліматичними умовами, географічним розташуванням, конструктивними особливостями елементів сонячних систем та правильністю вибору типу сонячного колектора. Дані проблеми є одними з основних у сонячній енергетиці. Вирішити їх можливо із застосуванням інноваційних комплексних методів, які мають за основу впровадження нових елементів у конструкцію сонячних перетворювачів.

Проведені досліди показують, що використання гібридних сонячних колекторів є одним із способів підвищення ефективності геліосистем уцілому. У статті розглянуто конструкцію сонячного колектора з розташуванням трубок циркуляції над теплопоглинаючою поверхнею без прозорого покриття. Досліджено геліосистему із природною циркуляцією теплоносія-води. На основі проведених експериментів розроблено номограму взаємозв'язку коефіцієнта теплової ефективності $K_{еф}$, кутів нахилу встановлення гібридного сонячного колектора $\alpha$ і $\beta$ та густини потоку випромінювання *Ів.* За допомогою даної номограми отримано функціональну залежність, яка дозволяє точно визначати коефіцієнт теплової ефективності в залежності від вхідних параметрів. Розрахунки показали, що за певних кутів нахилу і відповідної інтенсивності сонячного випромінювання значення $K_{еф}$ зростає і може досягати 50%.

Наведені дослідження вказують на потребу у застосуванні гібридних сонячних колекторів для забезпечення ефективного збору сонячної енергії в різних кліматичних умовах та підкреслюють важливість подальших досліджень і вдосконалення конструкції таких систем для зменшення забруднення навколишнього середовища і підвищення стійкості систем теплопостачання.

**Ключові слова: геліоколектор, геліосистема, гібридний сонячний колектор, теплопоглинач, сонячна енергетика, коефіцієнт теплової ефективності.**