

Improve Performance Efficiency As A Result Of Heat Loss Reduction In Solar Air Heater

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Abstract – This article discusses the reduction of heat loss in the working chamber of a solar air collector as a result of the use of modern thermal insulation materials in solar collectors in order to increase the efficiency of solar air heaters. The technical and economic impact of the proposed modern thermal insulation material on the solar air collector, its thermal conductivity coefficient and application procedure are also presented.

Keywords – Sun rays, heat, heat transfer, heat insulation, insulation materials, temperature, thermal resistance.

I. INTRODUCTION

Currently, 20% of the energy consumed in the world is obtained from non-traditional energy sources, and 30% - from the extracted fuel.

Therefore, the implementation of comprehensive measures to solve the problems of energy conservation and the development of the use of non-traditional renewable energy sources is very relevant. In a sharply continental climate, 49.6% of the total annual energy consumption is accounted for by agricultural processing systems.

In agriculture, more than 50% of primary energy is consumed annually. [1] Currently, many researchers and scientists are conducting research on the introduction of advanced technologies and equipment into the heat supply system that can efficiently and economically use energy, fuel and energy resources. It is known that at present, the reserves of fossil fuels and energy resources used on an industrial scale are sharply reduced. Therefore, the use of renewable energy sources allows preserving natural resources and the ecological situation at the current level. [2]

Currently, renewable energy, including solar, is used in the natural resources conservation area. In order to reduce heat loss, several types of thermal insulation materials are used. Temperature resistance is one of the main properties of thermal insulation materials. Heat resistance is one of the main properties of heat-insulating materials. In industrial appliances operating at high temperatures, insulation must retain its properties. Heat resistance determines the highest temperature with which the material can be used. Under the technical temperature refers to the maximum temperature at which the material retains its operational properties.

The economic temperature limit depends not only on heat resistance, but also on thermal conductivity, price and assembly conditions. The use of heat-insulating materials indicates that materials with high thermal conductivity are not practical to use at high temperatures, even if the temperature of the technical boundary is high. [3] Corund thermal insulation materials are used as corrosion protection, thermal insulation, UV protection, and also have dielectric properties.

The economic limit temperature is not only related to temperature resistance, but also to thermal conductivity, price and installation conditions. The use of thermal insulating materials indicates that it is not advisable to apply materials with high thermal conductivity under conditions of high temperatures, even if the technical boundary temperature is high. [3] Corundum thermal insulation materials are used as corrosion protection, thermal insulation, protection from ultraviolet rays and at the same time have dielectric properties.

The main requirements for thermal insulation materials in the heat supply system: the technology of their use should be convenient, long-term operation, thermal conductivity small and environmentally friendly.

When using traditional thermal insulation materials in the heating networks there will be areas that are not insulated or partially made. A corundum coating can dramatically reduce additional heat loss. This insulation material can be used in areas other than solar air collectors. If at least halving these losses, the fuel economy will be 8.3%. Considering the advantages of corundum, it can be used both for thermal insulation of trunk pipes and in enclosed spaces (boiler units, pumping stations). The service life of corundum is at least 15 years[4].

II. DEVICE CHARACTERISTIC

A model of a semiconductor flat solar air heater with $l = 1350$ mm, width $a = 750$ mm, height $h = 62$ mm was developed. When using an air sprayer in a solar heater, the inlet and outlet pipes, which are $d = 15$ mm, are put into operation.

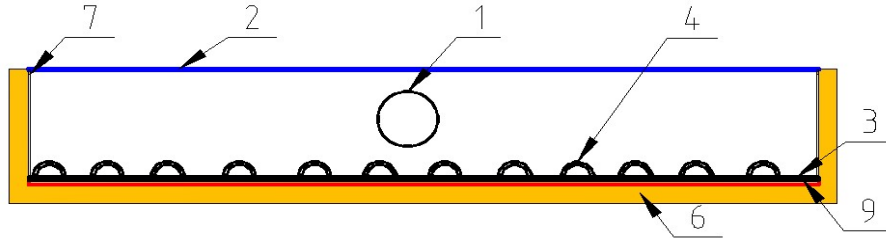


Fig1. Solar air heater in a cut.

The concave angle of the nozzle, a channel for air flow, an insulating gasket between the bottom of the housing and the concave nozzle of a triangular shape are shown. 1 - channel for the removal of coolant, 2 - transparent coating, 3 - flat absorber, 4 - concave nozzles of a triangular shape, 6 - case, 7 - support holding a transparent coating, 9 - thermal insulation of the case, h_2 - nozzle height.[5]

III. METHOD AND THEORETICAL ANALYSIS

By reducing thermal loads in the working chamber of the solar collectors, an increase in the efficiency of the device is achieved. For this, the insulating material of corundum is covered with a thickness of 1 mm on the outer surface of the collector. When calculating heat losses in solar air collectors, it is necessary to rely mainly on the design of the collector. We agree that the coefficient of thermal conductivity of the material does not depend on the λ temperature. The temperature on the outer surfaces of the barrier is maintained unchanged $t_1 > t_2$; the temperature changes only in the direction of the x axis, perpendicular to the surface of the barrier, i.e., the temperature area is dimensional, the temperature gradient is dt/dx . We find the density of the heat flux passing through the barrier and determine the characteristic of the temperature change along the thickness of the barrier. Inside the barrier, we separate an elementary layer whose thickness is dx limited by two isothermal surfaces. The Fourier equation for this layer will look like this:

$$q = -\lambda \frac{dt}{dx} \quad (1)$$

or

$$dt = -\frac{q}{\lambda} dx \text{ or } t = -\frac{q}{\lambda} x + C$$

The integration constant C is determined from the boundary conditions: $t = t_1$ when $x = 0$. Hence $C = t_1$, so the equation looks like this:

$$t = -\frac{q}{\lambda} x + t_1 \quad (2)$$

From this equation, we can determine the density of the heat flux passing through the barrier in question. If we put the value $x = \delta$ in this equation, we get $t = t_2$, from this

$$q = \frac{\lambda}{\delta} (t_1 - t_2) = \frac{\lambda}{\delta} \Delta t \quad (3)$$

In a flat barrier, the heat flux density is proportional to the thermal conductivity to λ while the temperature difference ($t_1 - t_2$), and the thickness of the barrier is inversely proportional to δ . It should be borne in mind that the heat flux is determined not by the absolute value of the temperature, but by their difference — thermal pressure $t_1 - t_2 = \Delta t$.

The λ/δ ratio is called the thermal conductivity of the barrier; its size is $[W/(m^2 \cdot \text{grad})]$. Equation (3) can be written in another way:

$$q = \frac{t_1 - t_2}{\delta/\lambda} \quad (4)$$

The ratio of the barrier thickness to the thermal conductivity coefficient δ/λ is called the thermal resistance of the barrier.

In practice, the importance of the heat transfer process through a multilayer flat barrier made of materials with different thermal conductivity is much more important. For example, on the outside of this boiler with slag, and on the inside the metal wall covered with a funnel will be three-layer.

Let us consider the process of heat transfer through heat conduction through a flat three-layer barrier.

All layers of such a wall fit snugly together. The thickness of the layers is determined by δ_1 , δ_2 and δ_3 , and the thermal conductivity of any material is λ_1 , λ_2 and λ_3 , respectively. The temperatures of the outer surfaces t_1 and t_4 are also known, although the temperatures t_2 and t_3 are unknown. [6]

Due to the fact that we are considering a stationary state, the heat flux density remains unchanged in terms of q size and remains the same for all layers. Therefore, for any wall layer (9), according to the formula, we can write the following:

$$q = \frac{\lambda_1}{\delta_1}(t_1 - t_2); \quad q = \frac{\lambda_2}{\delta_2}(t_2 - t_3); \quad q = \frac{\lambda_3}{\delta_3}(t_3 - t_4)$$

From this equation the change in temperature in each layer can be determined:

$$\begin{cases} t_1 - t_2 = q\delta_1/\lambda_1 \\ t_2 - t_3 = q\delta_2/\lambda_2 \\ t_3 - t_4 = q\delta_3/\lambda_3 \end{cases} \quad (5)$$

From this

$$t_1 - t_4 = \Delta t = q \left[\frac{\lambda_1}{\delta_1} + \frac{\lambda_2}{\delta_2} + \frac{\lambda_3}{\delta_3} \right]$$

It is possible to determine the value of the specific heat flux q passing through the multilayer barrier from this ratio:

$$q = \frac{t_1 - t_4}{\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3}} \quad (6)$$

For the n layer barrier, formula (6) is written as follows.

$$q = \frac{t_1 - t_{n+1}}{\sum_{i=1}^n \frac{\delta_i}{\lambda_i}} \quad (7)$$

It follows from the equation (7) that the total thermal resistance of a multilayer plane barrier is equal to the sum of the thermal resistances of any layer:

$$R = \delta_1/\lambda_1 + \delta_2/\lambda_2 + \delta_3/\lambda_3 + \dots + \delta_n/\lambda_n.$$

Based on formulas (5) and (6), we can find the values of unknown temperatures t_2 and t_3 :

$$t_2 = t_1 - q \delta_1 / \lambda_1 \quad t_3 = t_2 - q \delta_2 / \lambda_2 = t_1 - q \left[\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} \right]$$

or

$$t_3 = t_4 + q \delta_3 / \lambda_3. \quad (8)$$

With $\lambda_i = \text{const}$, the type of temperature distribution in any wall layer obeys the line law, and for a multilayer wall in the form of a broken line.

The formula for determining the amount of heat lost from the external barriers of the device is as follows:

$$Q = qFn = \frac{\delta}{\lambda} \Delta t Fn \quad (9)$$

Here: F-the surface; n-the coefficient depending on the relationship of the outer surface of the barrier structure to the outside air. [7]

IV. EXPERIMENTAL RESULTS

Heat loss in the position of the solar air collector before applying the thermal insulation material is as follows:

14.08.2019 y. 13³⁰- 14⁰⁰ outside air temperature 34 °C air velocity in the collector 2,2 m/sec

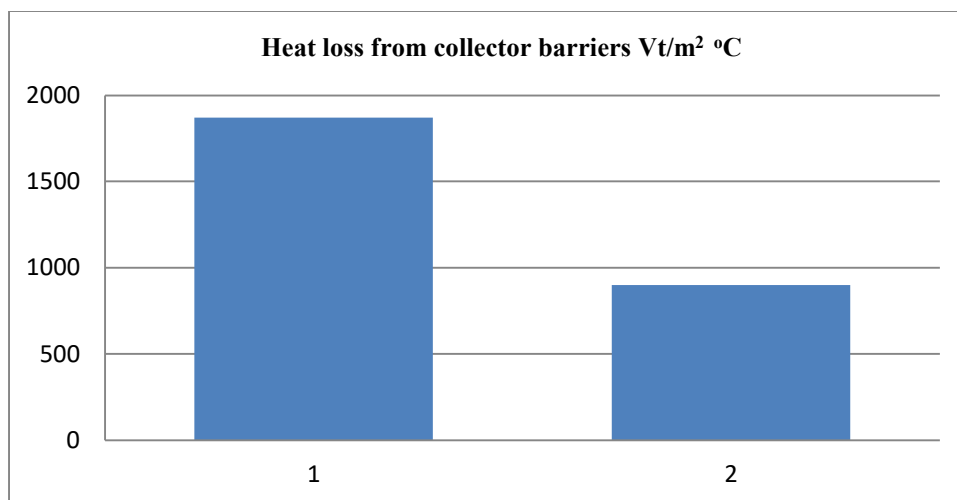


Fig.2 Heat loss from solar air collector: 1-isolated, 2- non-isolated

15.08.2019 y. 15⁰⁰- 15³⁰ outside air temperature 33 °C air velocity in the collector 3,4 m/sec

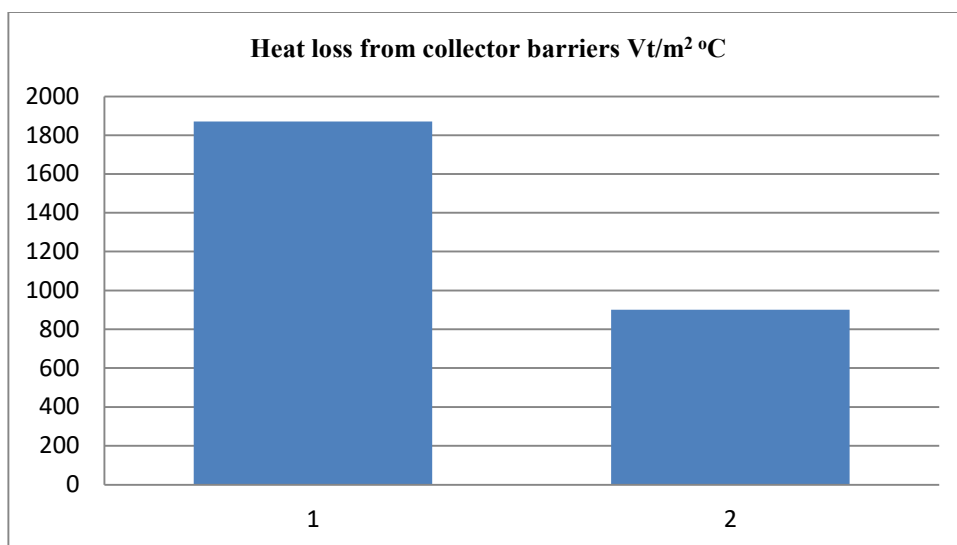


Fig.3 Heat loss from solar air collector: 1-isolated, 2- non-isolated.

16.08.2019 y. 14³⁰- 14³⁰ outside air temperature 35 °C air velocity in the collector 2,8 m/sec

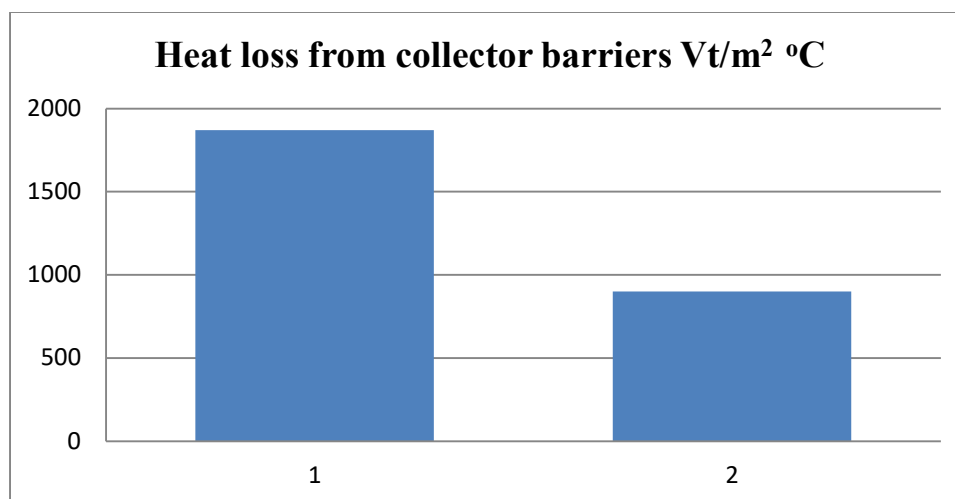


Fig.4 Heat loss from solar air collector: 1-isolated, 2- non-isolated

V. EXPECTED EFFICIENCY

- Relative to a common full-channel solar air heater, the air duct consumption is halved.
- Through the geometric shape specified by the air channel, the rotational movement of air is transmitted and the possibility of maximum increase in air temperature is created.
- Relative to a common full-channel solar air heater, the local resistance coefficient of the device will be reduced.
- Due to the reduction of local resistance, the device works efficiently even at low speeds.

As a result of the application of thermal insulation materials, an increase in the efficiency of the device is achieved by 15-20%[8].

VI. CONCLUSION AND FUTURE WORK

A solar air collector device was developed, and experimental studies of this device at different times were also conducted[9-28]. Based on the results, a calculation was made of the amount of heat that is lost from the working chamber of the collector. The results of this collector after isolation and in the previous state were compared. Based on these experiments, the development of a mathematical model of the device is required.

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