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Thermal Balance of the Solar Air Heater with a Heat Sink of Metal Shavings

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ABSTRACT: The article discusses how to remove heat from the surface of the heat sink of a solar heater. The equations of heat balance of the solar air heater are composed. Depending on the location of the heat sink and on the method of heat removal from the surface, a theoretical calculation of the effectiveness of the options has been made. Compared the results of calculations of the efficiency of the solar air heater with a smooth heat sink and with metal shavings. The calculations were carried out at a temperature difference between the coolant and the environment up to 60 ° C.

KEYWORDS: energy, thermal energy, traditional energy sources, non-traditional energy sources, solar collectors, solar air heater, heat sink, efficiency.

I.INTRODUCTION

The use of energy in various forms has played an important role in global economic progress and industrialization. Solar energy is considered a vital energy source to meet the ever-increasing energy demand in the process of sustainable development and monitoring global climate change, as it is a freely available, infinite, environmentally friendly energy resource [1 p 9; 2 p 228; 3 p 17; 4 p 32]. Currently, one of the most expensive types of energy generation is thermal energy. This is due to the peculiarities of its production and such factors as constantly increasing prices for fuel, reduced efficiency of heat generating plants caused by multiple conversion of thermal energy of heat exchangers Efficiency, which is about 40 - 70%, in the process of supplying heat to the consumer [5 p 253]. One of the promising areas of renewable energy is the direct production of environmentally friendly heat for the air conditioning system, the drying of agricultural products with the conversion of solar radiation [6 p 1].

The easiest way to convert solar radiation into heat energy is to use solar air heaters. Among various types of solar thermal installations, solar air heaters are widely used due to their lower cost and simplicity of design [7 p 7]. Solar air collectors are mainly used for air heating buildings and drying agricultural products. In the air heating system, the solar collector is the main component, which, when it receives solar radiation, receives, converts and collects direct and scattered sunlight in the form of heat and transfers thermal energy to the coolant [8 p 566]. The elements of the simplest solar air heater are (Fig. 1): a case for collecting heat 4, a transparent coating 2 that transmits solar radiation inside the collector and protects the radar absorbing surface (absorber) from the external environment and reduces heat loss from the front side of the collector. The absorber 3 absorbs solar radiation, converts it into heat and transfers it to the coolant. Thermal insulation 1 reduces the heat loss from the rear and side surfaces of the collector [9 p 15, 10 p 154, 11 p 64].

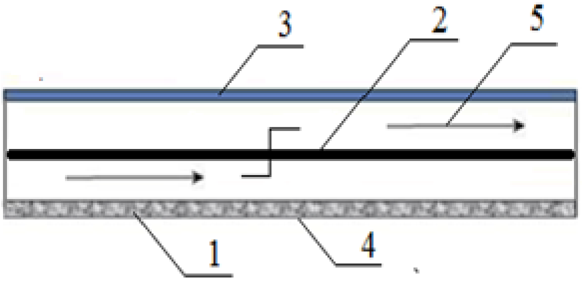
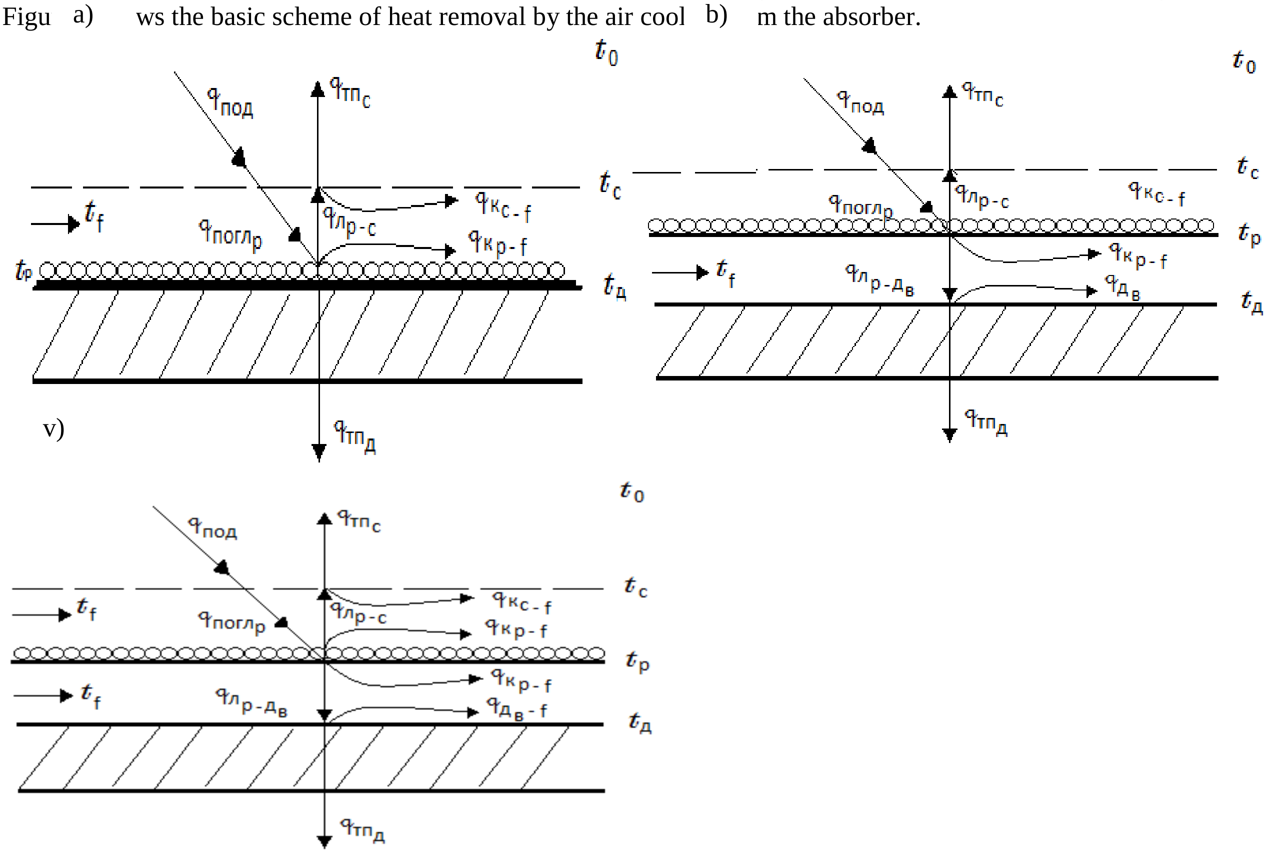


Fig. 1 Solar air heater.

The principle of operation of the solar air collector is as follows: most of the solar radiation incident on the collector is absorbed by the absorber, which has a black surface in relation to solar radiation. Part of the absorbed energy is transferred by the air flow circulating in the collector, the rest is lost in the process of heat exchange with the environment. The heat carried away by the coolant is the useful heat that accumulates or is used to cover the heat demand [12 p 15; 13 p 21; 14 p 255].

Studies considered in [1-14 and 15 p 17; 16 p 23] showed that to increase efficiency, both from the economic and technical side, the character of the coolant movement and the design of the solar air heater have a strong influence. Figu ws the basic scheme of heat removal by the air cool m the absorber.



a— A VCS with an air channel between the translucent coating and the absorber with the absorber located at the bottom of the casing above the thermal insulation; b — SVK with the air channel for the movement of the heat carrier between the absorber and the bottom when the absorber is located in the middle of the installation; v - SAH with the air channel between an absorber and a bottom of installation and an absorber and a translucent covering.

Fig.2 Schematic diagram of the process of converting solar radiation into useful heat and how to remove useful heat from the surface of the absorber with its different location in the solar air heater (SAH).

From the above considered schematic diagrams, it can be seen that the value is large with an increase in the efficiency of the SAH, an increase in the contact area between the heat sink and the coolant plays. To achieve this goal, the author used drain metal shavings as an absorber, which transmit solar radiation inside the stove and block the rays reflected from the bottom of the collector. At the same time, the contact area of the absorber surface with air increases.

To clarify the effect of the method of discharge of useful heat from the surface of the SAH absorber with drain metal shavings, we consider a schematic diagram of the process of transformation of solar radiation (Fig. 2). In accordance with the schematic diagram, we compose the heat balance for the SAH design under consideration [17 c 255].

1. The amount of solar radiation absorbed by the surfaces of the heat sink $q_{погл_р}$, transfers o the coolant q_{k_p-f} veterans parent coating $q_{л_р-f}$ and is lost through the bottom insulation $q_{тп_д}$ chassis installation i.e.

$$q_{погл_р} = q_{к_р-f} + q_{л_р-с} + q_{тп_д}, \tag{1}$$

Heat produced by translucent coating $q_{\text{л}_{\text{р}}-\text{с}}$, transferred to coolant $q_{\text{к}_{\text{с}}-f}$ and is lost through the translucent coating into the environment $d_{\text{тп}_{\text{с}}}$, i.e.

$$q_{\text{л}_{\text{р}}-\text{с}} = q_{\text{к}_{\text{с}}-f} + q_{\text{тп}_{\text{с}}}, \tag{2}$$

The flow of useful energy obtained by the coolant $q_{\text{пол}}$, consists of energy flows from the upper surface of heat exchangers $q_{\text{к}_{\text{р}}-f}$ and the inner (facing the heat exchanger) surface of the translucent coating $q_{\text{к}_{\text{с}}-f}$, i.e.

$$q_{\text{пол}} = q_{\text{к}_{\text{р}}-f} + q_{\text{к}_{\text{с}}-f} + q_{\text{к}_{\text{ст}}-f} \tag{3}$$

Value $q_{\text{к}_{\text{р}}-f}, q_{\text{к}_{\text{с}}-f}, q_{\text{л}_{\text{р}}-\text{с}}, q_{\text{тп}_{\text{с}}}, q_{\text{тп}_{\text{д}}}$ is determined from the corresponding expressions:

$$q_{\text{к}_{\text{р}}-\text{с}} = \alpha_{\text{к}_{\text{р}}-\text{f}}(\text{t}_{\text{р}} - \text{t}_{\text{f}}), \tag{4}$$

$$q_{\text{к}_{\text{с}}-f} = \alpha_{\text{к}_{\text{с}}-\text{f}}(\text{t}_{\text{с}} - \text{t}_{\text{f}}), \tag{5}$$

$$q_{\text{л}_{\text{р}}-\text{с}} = \alpha_{\text{л}_{\text{р}}-\text{с}}(\text{t}_{\text{р}} - \text{t}_{\text{с}}), \tag{6}$$

$$q_{\text{тп}_{\text{с}}} = \alpha_{\text{нар}_{\text{с}}}(\text{t}_{\text{с}} - \text{t}_{\text{о}}), \tag{7}$$

$$q_{\text{тп}_{\text{д}}} = \text{К}_{\text{д}_{\text{р}}-\text{о}}(\text{t}_{\text{р}} - \text{t}_{\text{о}}). \tag{8}$$

Substituting the expressions (4) - (7) into the balance equations (1) - (3), we obtain (for Fig. 2. a)
for heat sink

$$q_{\text{погл}_{\text{р}}} = \alpha_{\text{к}_{\text{р}}-f}(t_{\text{р}} - t_f) + \alpha_{\text{л}_{\text{р}}-\text{с}}(t_{\text{р}} - t_{\text{с}}) + \text{К}_{\text{д}_{\text{р}}-\text{о}}(t_{\text{р}} - t_{\text{о}}) \tag{9}$$

for translucent coating

$$\alpha_{\text{л}_{\text{р}}-\text{с}}(t_{\text{р}} - t_{\text{с}}) = \alpha_{\text{к}_{\text{с}}-f}(t_{\text{с}} - t_f) + \alpha_{\text{нар}_{\text{с}}}(t_{\text{с}} - t_{\text{о}}), \tag{10}$$

for the flow of useful energy

$$q_{\text{пол}} = \alpha_{\text{к}_{\text{р}}-f}(t_{\text{р}} - t_f) + \alpha_{\text{к}_{\text{с}}-f}(t_{\text{с}} - t_f) \tag{11}$$

The balance equation for the concept in Figure 2b is as follows
for heat sink

$$q_{\text{погл}_{\text{р}}} = \alpha_{\text{к}_{\text{р}}-f}(t_{\text{р}} - t_f) + \text{К}_{\text{с}_{\text{р}}-\text{о}}(t_{\text{р}} - t_{\text{о}}) + \alpha_{\text{л}_{\text{р}}-\text{дв}}(t_{\text{р}} - t_{\text{дв}}) \tag{12}$$

for translucent coating

$$(\alpha_{\text{л}_{\text{р}}-\text{с}} + \alpha_{\text{к}_{\text{р}}-\text{с}})(t_{\text{р}} - t_{\text{с}}) = \text{К}_{\text{с}_{\text{р}}-\text{о}}(t_{\text{р}} - t_{\text{о}}) \tag{13}$$

for thermal insulation of the bottom of the case

$$\alpha_{\text{л}_{\text{р}}-\text{дв}}(t_{\text{р}} - t_{\text{дв}}) = \alpha_{\text{к}_{\text{дв}}-f}(t_{\text{дв}} - t_f) + \text{К}_{\text{дв}-\text{о}}(t_{\text{дв}} - t_{\text{о}}) \tag{14}$$

for the flow of useful energy

$$q_{\text{пол}} = \alpha_{\text{к}_{\text{р}}-f}(t_{\text{р}} - t_f) + \alpha_{\text{к}_{\text{дв}}-f}(t_{\text{дв}} - t_f). \tag{15}$$

The balance equation for the concept in Figure 2v is as follows

$$q_{\text{погл}_{\text{р}}} = 2\alpha_{\text{к}_{\text{р}}-f}(t_{\text{р}} - t_f) + \alpha_{\text{л}_{\text{р}}-\text{с}}(t_{\text{р}} - t_{\text{с}}) + \alpha_{\text{л}_{\text{р}}-\text{дв}}(t_{\text{р}} - t_{\text{дв}}) \tag{16}$$

for translucent coating

$$\alpha_{\text{л}_{\text{р}}-\text{с}}(t_{\text{р}} - t_{\text{с}}) = \alpha_{\text{к}_{\text{с}}-f}(t_{\text{с}} - t_f) + \alpha_{\text{нар}_{\text{с}}}(t_{\text{с}} - t_{\text{о}}) \tag{17}$$

for thermal insulation of the bottom of the case

$$\alpha_{\text{л}_{\text{р}}-\text{дв}}(t_{\text{р}} - t_{\text{дв}}) = \alpha_{\text{к}_{\text{дв}}-f}(t_{\text{дв}} - t_f) + \text{К}_{\text{дв}-\text{о}}(t_{\text{дв}} - t_{\text{о}}) \tag{18}$$

for the flow of useful energy

$$q_{\text{пол}} = 2\alpha_{\text{к}_{\text{р}}-f}(t_{\text{р}} - t_f) + \alpha_{\text{к}_{\text{дв}}-f}(t_{\text{дв}} - t_f) + \alpha_{\text{к}_{\text{с}}-f}(t_{\text{с}} - t_f). \tag{19}$$

In equation (11) due to the high value of the coefficient of thermal conductivityλsurfaces, we assume that heat transfer coefficients$\alpha_{\text{к}_{\text{р}}-f}$above and below the heat sink are equal.

From the above mentioned systems of equations (9) - (11) to represent the flow of useful energy as a function of$\alpha_{\text{нар}_{\text{с}}}, \alpha_{\text{к}_{\text{р}}-f}, \alpha_{\text{к}_{\text{с}}-f}, \alpha_{\text{к}_{\text{дв}}-f}, \text{К}_{\text{д}_{\text{р}}-\text{о}}, \text{К}_{\text{дв}-\text{о}}, \alpha_{\text{л}_{\text{р}}-\text{дв}}, \alpha_{\text{л}_{\text{р}}-\text{с}}, t_1 \text{и} t_0$ surface temperatures must be excluded$t_{\text{р}}$, $t_{\text{с}} t_{\text{дв}}$.

Since algebraic transformations are excessively cumbersome, we present the final results of the calculation of the flow of useful energy

$$q_{\text{пол}} = q_{\text{погл}_\text{р}} - \left\{\text{К}_{\text{д}_\text{р}-\text{о}} + \frac{\alpha_{\text{нар}_\text{с}}\left[\alpha_{\text{к}_\text{с}-f}\left(\text{К}_{\text{д}_\text{р}-\text{о}} + \alpha_{\text{к}_\text{р}-f} + \alpha_{\text{л}_\text{р}-\text{с}}\right) + \alpha_{\text{к}_\text{р}-f}\alpha_{\text{л}_\text{р}-\text{с}}\right]}{\alpha_{\text{к}_\text{р}-f}\left(\alpha_{\text{л}_\text{р}-\text{с}} + \alpha_{\text{к}_\text{с}-f} + \alpha_{\text{нар}_\text{с}}\right) + \alpha_{\text{к}_\text{с}-f}\alpha_{\text{л}_\text{р}-\text{с}}}\right\} \times$$

$$\times \frac{(t_f - t_0)}{1+\frac{\text{К}_{\text{др}-\text{о}}\left(\alpha_{\text{лр}-\text{с}}+\alpha_{\text{к}_\text{с}-f}+\alpha_{\text{нар}_\text{с}}\right)+\alpha_{\text{нар}_\text{с}}\alpha_{\text{лр}-\text{с}}}{\alpha_{\text{кр}-f}\left(\alpha_{\text{лр}-\text{с}}+\alpha_{\text{к}_\text{с}-f}+\alpha_{\text{нар}_\text{с}}\right)+\alpha_{\text{к}_\text{с}-f}\alpha_{\text{лр}-\text{с}}}}. \tag{20}$$

For the case under consideration

$$\text{К}_{\text{пр}}^{(1)} = \text{К}_{\text{д}_\text{р}-\text{о}} + \frac{\alpha_{\text{нар}_\text{с}}\left[\alpha_{\text{к}_\text{с}-f}\left(\text{К}_{\text{д}_\text{р}-\text{о}}+\alpha_{\text{к}_\text{р}-f}+\alpha_{\text{л}_\text{р}-\text{с}}\right)+\alpha_{\text{к}_\text{р}-f}\alpha_{\text{л}_\text{р}-\text{с}}\right]}{\alpha_{\text{к}_\text{р}-f}\left(\alpha_{\text{л}_\text{р}-\text{с}}+\alpha_{\text{к}_\text{с}-f}+\alpha_{\text{нар}_\text{с}}\right)+\alpha_{\text{к}_\text{с}-f}\alpha_{\text{л}_\text{р}-\text{с}}}, \tag{21}$$

$$\eta_{\text{тп}}^{(1)} = \left[1 + \frac{\text{К}_{\text{д}_\text{р}-\text{о}}\left(\alpha_{\text{л}_\text{р}-\text{с}}+\alpha_{\text{к}_\text{с}-f}+\alpha_{\text{нар}_\text{с}}\right)+\alpha_{\text{нар}_\text{с}}\alpha_{\text{л}_\text{р}-\text{с}}}{\alpha_{\text{к}_\text{р}-f}\left(\alpha_{\text{л}_\text{р}-\text{с}}+\alpha_{\text{к}_\text{с}-f}+\alpha_{\text{нар}_\text{с}}\right)+\alpha_{\text{к}_\text{с}-f}\alpha_{\text{л}_\text{р}-\text{с}}}\right]^{-1} \tag{22}$$

Where $\kappa_{\partial_{p-o}}$ is the heat transfer coefficient of the bottom of the installation case, W / m^2 ° C; $\alpha_{нар_c}$ heat transfer coefficient of the outer surface of the translucent coating; ; $\alpha_{\kappa_{c-f}}$ –the coefficient of the inner surface of the translucent coating; $\alpha_{\kappa_{p-f}}$ heat sink surface coefficient $\alpha_{\text{к}_\text{р}-\text{с}}, \alpha_{\text{л}_\text{р}-\text{с}}$radiant heat transfer coefficient between the heat sink and the translucent coating. For convenient and practical use, we use the expression proposed by the authors [17 p 255]

$$q_{\text{пол}} = \eta_{\text{тп}}^{(1)}\left[q_{\text{погл}_\text{р}} - \text{К}_{\text{пр}}^{(1)}\left(t_f - t_o\right)\right] \tag{23}$$

$\eta_{\text{тп}}^{(1)}$thermal efficiency of the heat sink SAH $\text{К}_{\text{пр}}^{(1)}$- the reduced heat transfer coefficient of the enclosing elements of the SAH receiver.

We use the expression of the thermal efficiency of the solar air heater obtained by the authors of [17].

$$\eta = \eta_{ТП}\left[\alpha_p\tau - \frac{\kappa_{np}}{q_{па\partial}}\left(t_f - t_o\right)\right]. \tag{24}$$

To calculate the concept 2.1 b, c $\eta_{\text{тп}}^{(1)}$и$\text{К}_{\text{пр}}^{(1)}$ heat removal from the surface of the heat sink has the following appearance

$$\text{К}_{\text{пр}}^{(2)} = \text{К}_{\text{ср}-\text{о}} + \text{К}_{\text{дв}-0}\frac{\alpha_{\text{к}_{\text{дв}}-f}\left(\text{К}_{\text{ср}-\text{о}}+\alpha_{\text{к}_\text{р}-f}+\alpha_{\text{лр}-\text{дв}}\right)+\alpha_{\text{к}_\text{р}-f}\alpha_{\text{лр}-\text{дв}}}{\alpha_{\text{к}_\text{р}-f}\left(\text{К}_{\text{дв}-\text{о}}+\alpha_{\text{к}_{\text{дв}}-f}+\alpha_{\text{лр}-\text{дв}}\right)+\alpha_{\text{к}_{\text{дв}}-f}\alpha_{\text{лр}-\text{дв}}} \tag{25}$$

$$\eta_{\text{тп}}^{(2)} = \left[1 + \frac{\text{К}_{\text{ср}-\text{о}}\left(\alpha_{\text{лр}-\text{дв}}+\alpha_{\text{к}_{\text{дв}}-f}+\text{К}_{\text{дв}-\text{о}}\right)+\text{К}_{\text{дв}-\text{о}}\alpha_{\text{лр}-\text{дв}}}{\alpha_{\text{к}_\text{р}-f}\left(\alpha_{\text{лр}-\text{дв}}+\alpha_{\text{к}_{\text{дв}}-f}+\text{К}_{\text{дв}-\text{о}}\right)+\alpha_{\text{к}_{\text{дв}}-f}\alpha_{\text{лр}-\text{дв}}}\right]^{-1} \tag{26}$$

$\text{К}_{\text{с}_\text{р}-0}$the heat transfer coefficient between the heat sink and the environment is the following formula

$$\text{К}_{\text{с}_\text{р}-0} = \left(\frac{1}{\alpha_{\text{нар}_\text{с}}} + \frac{1}{\alpha_{\text{к}_\text{р}-\text{с}}+\alpha_{\text{л}_\text{р}-\text{с}}}\right)^{-1} \tag{27}$$

$$\text{К}_{\text{д}_\text{в}-\text{о}}\left\{2\alpha_{\text{к}_\text{р}-f}\left[\left(\alpha_{\text{л}_\text{р}-\text{с}} + \alpha_{\text{к}_\text{с}-f} + \alpha_{\text{нар}_\text{с}}\right)\left(1 + \frac{\alpha_{\text{к}_{\text{д}_\text{в}}-f}}{\alpha_{\text{л}_\text{р}-\text{д}_\text{в}}}\right) + \frac{\alpha_{\text{нар}_\text{с}}}{\alpha_{\text{л}_\text{р}-\text{д}_\text{в}}}\left(\alpha_{\text{л}_\text{р}-\text{с}} + \alpha_{\text{к}_{\text{д}_\text{в}}-f}\right)\right] +\right.$$

$$\left. + \alpha_{\text{к}_{\text{д}_\text{в}}-f}\left[\left(\alpha_{\text{л}_\text{р}-\text{с}} + \alpha_{\text{к}_\text{с}-f} + \alpha_{\text{нар}_\text{с}}\right) + \frac{\alpha_{\text{л}_\text{р}-\text{с}}}{\alpha_{\text{л}_\text{р}-\text{д}_\text{в}}}\left(\alpha_{\text{к}_\text{с}-f} + \alpha_{\text{нар}_\text{с}}\right)\right] + \right.$$

$$+\alpha_{\text{К}_c-f}\left[\alpha_{\text{К}_c-f}\left(1+\frac{\alpha_{\text{л}_{\text{р}-c}}}{\alpha_{\text{л}_{\text{р}-\text{дв}}}}\right)+\alpha_{\text{л}_{\text{р}-c}}\right]\Bigg\}+\alpha_{\text{нар}_c}\left[2\alpha_{\text{К}_{\text{р}}-f}\left(\alpha_{\text{К}_c-f}+\alpha_{\text{л}_{\text{р}-c}}\right)\times\right.$$

$$\times\left(1+\frac{\alpha_{\text{К}_{\text{дв}}-f}}{\alpha_{\text{л}_{\text{р}-\text{дв}}}}\right)+\alpha_{\text{кс}-f}\alpha_{\text{К}_{\text{дв}}-f}\left(1+\frac{\alpha_{\text{л}_{\text{р}-c}}}{\alpha_{\text{л}_{\text{р}-\text{дв}}}}\right)+$$

$$\text{К}_{\text{пр}}^{(3)}=\frac{\left.+\alpha_{\text{л}_{\text{р}-c}}\left(\alpha_{\text{К}_{\text{дв}}-f}+\alpha_{\text{К}_c-f}\right)\right]}{\left[2\alpha_{\text{К}_{\text{р}}-f}\left(1+\frac{\alpha_{\text{К}_{\text{дв}}-f}+\text{К}_{\text{д}_{\text{в}}-0}}{\alpha_{\text{л}_{\text{р}-\text{дв}}}}\right)+\alpha_{\text{К}_{\text{дв}}-f}\right]\times}$$

$$\times\left(\alpha_{\text{л}_{\text{р}-c}}+\alpha_{\text{К}_c-f}+\alpha_{\text{нар}_c}\right)+\alpha_{\text{л}_{\text{р}-c}}\alpha_{\text{К}_c-f}\left(+1\,\frac{\alpha_{\text{К}_{\text{дв}}-f}+\text{К}_{\text{дв}-0}}{\alpha_{\text{л}_{\text{р}-\text{дв}}}}\right) \qquad (28)$$

Calculations of the effect of heat sink intensification will be carried out with the following accepted values of the coefficients:

$\kappa_{\partial_{p-o}}=0{,}8\ Bm/м^2\ {}^\circ C$, $q_{\text{под}}=700$ Вт/м^2, $\alpha_p\tau=0{,}60$, $\alpha_{нар_c}=15\ Bm/м^2{}^\circ C$, (which relates to the speed of wind – 2,6 м/с) $\alpha_{\text{К}_c-f}=3{,}0$Вт/м^{2o}С, $\alpha_{\text{л}_{\text{р}}-f}=6$Вт/м^{2o}С; $\alpha_{\text{л}_{\text{р}}-c}=6{,}0$Вт/м^{2o}С; $\alpha_{\text{К}_{\text{дв}}-f}=3{,}0$Вт/м^{2o}С.

Substituting the coefficients into formulas (2.17) and (2.18) gives the following expressions:

$$\text{К}_{\text{пр}}^{(1)}=0{,}8+\frac{15\lfloor 3(0{,}8+\alpha+6)+6\alpha\rfloor}{\alpha(6+3+15)+3\cdot 6}$$

$$\eta_{\text{пр}}^{(1)}=\left[1+\frac{0{,}8(6+3+15)+15*6}{\alpha(6+3+15)+3\cdot 6}\right]^{-1}$$

$$\text{К}_{\text{с}_{\text{р}}-0}=\left(\frac{1}{15}+\frac{1}{8}\right)^{-1}=5{,}2$$

$$\text{К}_{\text{пр}}^{(2)}=5{,}2+\frac{3(5{,}2+\alpha+6)+\alpha\cdot 6}{\alpha(1+3+6)+3\cdot 6}$$

$$\eta_{\text{пр}}^{(2)}=\left[1+\frac{5{,}2(6+3+1)+6}{\alpha(6+3+1)+3\cdot 6}\right]^{-1}$$

$$\text{К}_{\text{пр}}^{(3)}=\frac{\begin{Bmatrix}2\alpha\left[(6+3+15)\left(1+\frac{3}{6}\right)+\frac{15}{6}(6+3)\right]+\\+3[(6+3+15)+(3+15)]+3[15\cdot 2+6]\end{Bmatrix}+\\+15\left[2\alpha(3+6)\left(1+\frac{3}{6}\right)+3\cdot 3\cdot 2+6(3+3)\right]}{\left[2\alpha\left(1+\frac{3+1}{6}\right)+3\right](6+3+15)+6\cdot 3\left(1+\frac{3+1}{6}\right)}$$

$$\eta_{\text{пр}}^{(3)}=\left[1+\frac{(6+3+15)+6\cdot 15\left(1+\frac{3+1}{6}\right)}{\left[2\alpha\left(1+\frac{3+1}{6}\right)+3\right]\cdot(6+3+15)+6\cdot 3\left(1+\frac{3+1}{6}\right)}\right]^{-1}$$

here$\alpha_{\text{К}_{\text{р}}-f}=\alpha$

To estimate the thermal efficiency of the installation with an absorber of drain metal shavings, we take the following dimensions of the VCS: collector height 7.3 cm, absorber width 60 cm, air channel length 1.5 m, coolant velocity u = 1.0 m / s. Calculate the Reynolds number

$$d_э=\frac{4S}{\Pi}=\frac{4\cdot 0{,}0438}{2(0{,}073+0{,}6)}=0{,}13\ м$$

$$Re = \frac{vd}{\nu} = \frac{1 \cdot 0{,}13}{15 \cdot 10^{-6}} = 8666$$

What corresponds to the turbulent motion regime$Re > 2300$, for a flat smooth absorber, the heat transfer coefficient is found by the formula

η

$$\mathrm{Nu} = 0{,}018\ \mathrm{Re}^{0,8} = 0{,}018\ (8666)^{0,8} = 25{,}4$$

$$\alpha = \frac{Nu * p}{d_э} = \frac{25.4 * 0.0259}{0.13} = 5.1 \text{Вт/м}^{2\text{o}}\text{C}$$

In the SAH with the absorber of the drain metal shavings at the speed of the coolant U = 1.0 m / s take $\alpha_{\text{К}_{\text{ст}-f}} = 10$Вт/м$^{2\text{o}}$C (as with the use of metal shavings, the radiation absorption surface area increases 2 ÷ 3 times relative to a smooth surface)

For the obtained values of the convective heat transfer coefficients, we calculate the thermal efficiency of the heat sinks and the reduced heat transfer coefficients enclosing the elements of the heat sink of the solar air heater.

We have:

a) for a smooth plate solar collector $\alpha = 5.1$Вт/м$^{2\text{o}}$C

$$\text{К}_{\text{пр}}^{(1)} = 0{,}8 + \frac{15[3(6{,}8+\alpha)+6\alpha]}{24\alpha+18} = 7{,}08 \text{ Вт/м}^{2\text{o}}\text{C}$$

$$\eta_{\text{тп}}^{(1)} = \left[1 + \frac{109}{24\alpha + 18}\right]^{-1} = 0{,}56$$

$$\text{К}_{\text{пр}}^{(2)} = 5{,}2 + \frac{3(11{,}2+\alpha)+6\alpha}{10\alpha+18} = 6{,}35 \text{ Вт/м}^{2\text{o}}\text{C}$$

$$\eta_{\text{тп}}^{(2)} = \left[1 + \frac{58}{10\alpha + 18}\right]^{-1} = 0{,}54$$

$$\text{К}_{\text{пр}}^{(3)} = \frac{(102\alpha+234)+15[27\alpha+54]}{24[3{,}4\alpha+3]+30} = 6 \text{ Вт/м}^{2\text{o}}\text{C}$$

$$\eta_{\text{тп}}^{(3)} = \left[1 + \frac{174}{24[3{,}4\alpha + 3] + 30}\right]^{-1} = 0{,}75$$

b) for drain metal shavings $\alpha = 10$Вт/м$^{2\text{o}}$C

$$\text{К}_{\text{пр.стружж}}^{(1)} = 6{,}4 \text{ Вт/м}^{2\text{o}}\text{C}; \quad \eta_{\text{тп.стружж}}^{(1)} = 0{,}7$$

$$\text{К}_{\text{пр.стружж}}^{(2)} = 6{,}247 \text{ Вт/м}^{2\text{o}}\text{C}; \quad \eta_{\text{тп.стружж}}^{(2)} = 0{,}67$$

$$\text{К}_{\text{пр.стружж}}^{(3)} = 5{,}549 \text{ Вт/м}^{2\text{o}}\text{C}; \quad \eta_{\text{тп.стружж}}^{(3)} = 0{,}84$$

Calculate the efficiency of the SAH with a smooth and shaving absorber provided $t_f - t_0$=10 gain:

$$\eta_{\text{гл}}^{(1)} = \eta_{\text{тп}}\left[\alpha_{\text{р}}\tau - \frac{\text{К}_{\text{пр}_{\text{гл}}}}{q_{\text{пад}}}(t_f - t_0)\right] = 0{,}56\left(0{,}6 - \frac{7{,}08}{700} \cdot 10\right) = 0{,}279$$

$$\eta_{\text{гл}}^{(2)} = 0{,}275\eta_{\text{гл}}^{(3)} = 0{,}385$$

$$\eta_{\text{стружж}}^{(1)} = \eta_{\text{тп}}\left[\alpha_{\text{р}}\tau - \frac{\text{К}_{\text{пр}_{\text{стружж}}}}{q_{\text{пад}}}(t_f - t_0)\right] = 0{,}7\left(0{,}6 - \frac{6{,}4}{700} \cdot 10\right) = 0{,}356$$

$$\eta_{\text{стружж}}^{(2)} = 0{,}342\eta_{\text{стружж}}^{(3)} = 0{,}437$$

Calculations show that the location of the absorber on the schematic diagram of Fig. 2 in higher efficiency relative to the location of the remaining a, b.

The efficiency of solar installations is greatly influenced by the degree of solar radiation and the ambient temperature. At small values of the coolant velocity, the coolant temperature at the outlet of the SAH increases, which leads to an increase in the temperature of the heat sink and, accordingly, an increase in heat loss through the translucent coating and the housing to the environment? For the optimal temperature of the SAH with an absorber of metal shavings, we calculated the dependences of the efficiency of the SAH on the temperature difference between the coolant temperature tf and the environment to for the two types of absorbers under consideration (Figure 3-5).

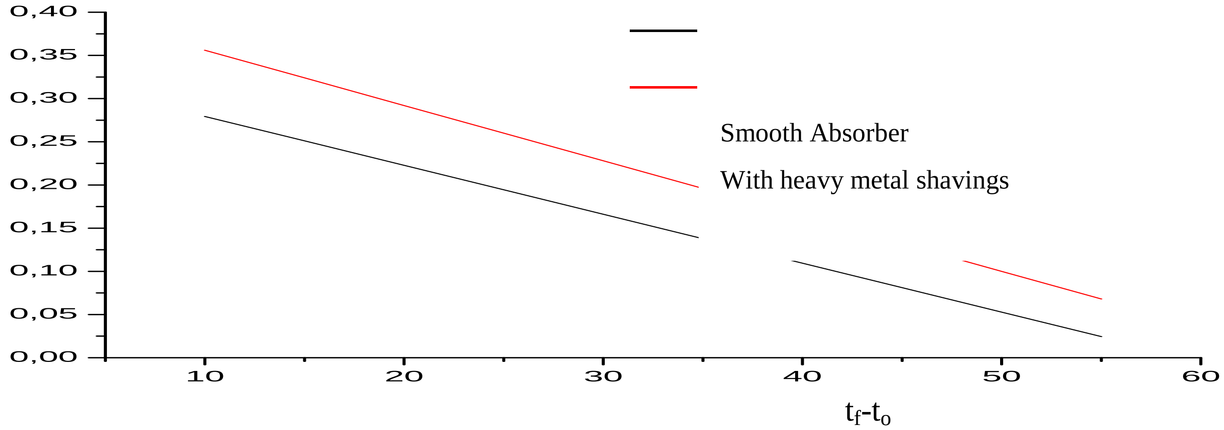


Fig. 3 Comparison of the efficiency of the SAH with drain metal shavings and a smooth absorber according to the scheme of Fig. 2 a

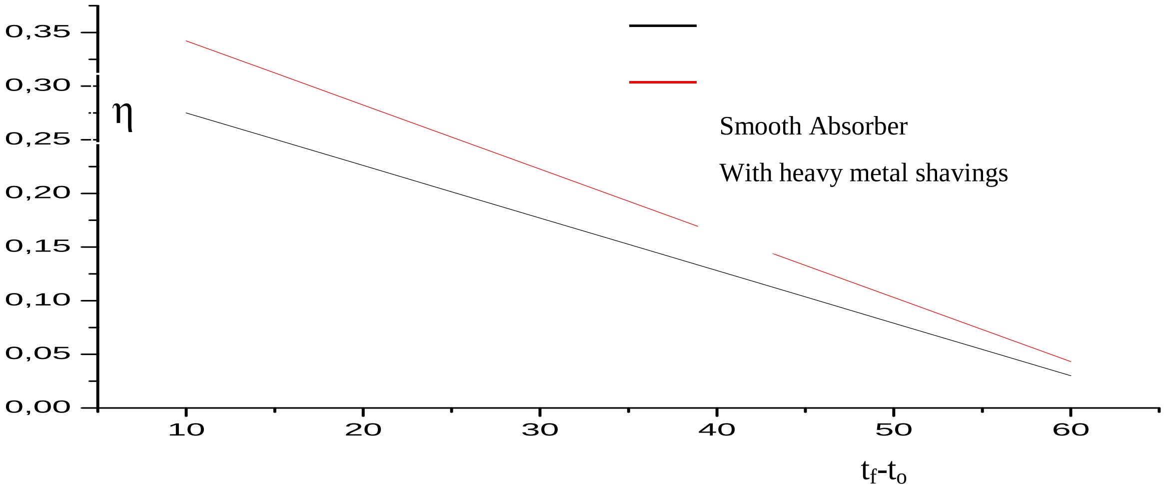


Fig. 4 Comparison of the efficiency of the IC with drain metal shavings and a smooth absorber according to the scheme of Fig. 2 b

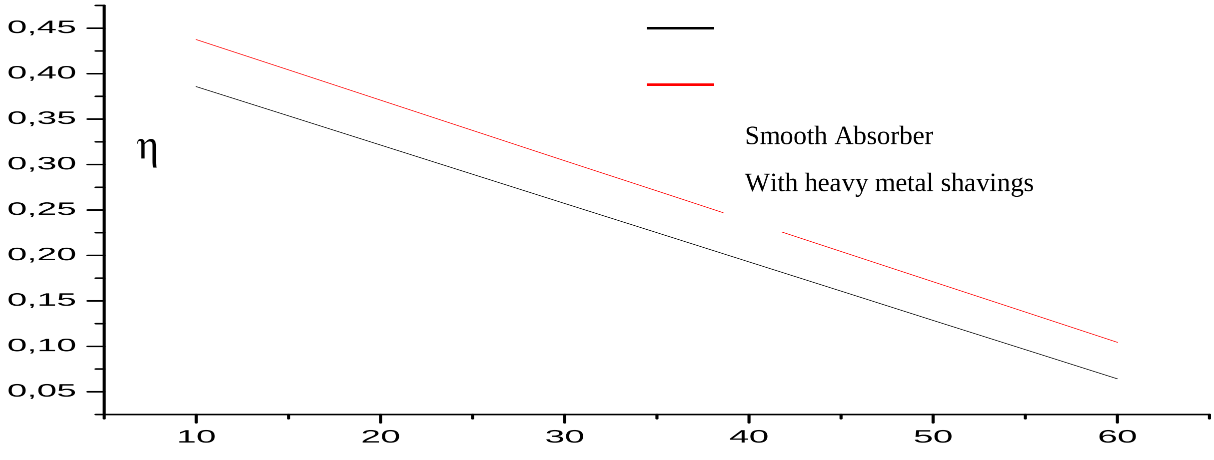


Fig. 5 Comparison of the efficiency of the VCS with drain metal shavings and a smooth absorber according to the scheme of Fig. 2v

Analysis of the graphs shown in Fig. 3-5, that for different values of the temperature difference between the coolant and the environment $t_f - t_0 < 60^\circ C$ CBKwith metal shavings absorber is more effective than a smooth-

absorber SVK in all three cases considered. The highest efficiency rates are achieved with$t_f - t_0 < 20^\circ C$ from 37 to 43. At high values of the temperature difference between the environment and the coolant$t_f - t_0 < 40^\circ C$
The effectiveness of a SAH with metal shavings absorber is the same as that of a smooth surface.

II. RELATED WORK

Large-scale research aimed at creating new energy-resource-saving technologies, improving solar air systems and solar conversion plants, conducting research in higher education institutions and advanced training centers, including the University of Wisconsin-Madison (USA),Indian Institute of Technology Dehli (India), Indian Institute of Technology Roorkee (India), National Institute of Technology Hamirpur (India), TamkangUnversitiy (Taiwan), Unversitiy of Tanta (Egypt), UniversitiKebangsaan Malaysia (Malaysia), Alternate Hydro Energy Center (India), Xi'an jiaotong University (China), Shanghai jiao Tong University (China), King Mongkut's University of Technology Thonbure (Thailand), University of Tokyo (Japan), at the Moscow Energy Institute - National Research University - Research Institute of Thermal Physics of the Siberian Branch of the Academy of Sciences (Russia), at the Scientific-Research Association “Physics-Sun” of the Academy of Sciences (Uzbekistan) and at the Fergana Polytechnic Institute (Uzbekistan).

In world practice, methods have been developed for designing solar heating systems, as well as for calculating the intensification of hydrodynamic and thermal processes occurring in advanced solar-transforming structures. The study of the characteristics of increasing the efficiency of solar air heaters are considered in the works of a number of authors such as: S.E. Popel, G. Rettih Fried, J. Duffy, W.A. Beckman, W. Black, G.Ts. Hottel, V.A. Butuzov, B. B. Wörz, J. Twidell, A. Weir, J.S. Saini, K. Sopian, V.K. Sharma, Varun, C. Choudhury and others. In these studies, we studied the influence of design and operating parameters on the efficiency of solar air heating installations.

The results of studies of heat and mass transfer processes in various media, as well as the corresponding calculation methods are given in the well-known works of M.V. Kirpicheva, A.A. Gukhman, Z. Chukhanov, G. Schlichting, MA Mikheeva, V.P. Isachenko, V.K. Migay, P.A. Garg, V.A. Kirpikov, G.N. Shorin, V.V. Olimpiev, V.G. Gagarin, J.S. Saini and other authors.

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