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HEAT - TECHNICAL CALCULATION OF THE SOLAR COLLECTOR

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Annotation

this article shows how to determine the heat-technical calculation of a solar collector.

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A flow-through solar collector is a system in which water flows through parallel channels and cools the surface of solar panels. (Fig. 1, a)

The main elements of the flat flow solar collector are as follows: the housing containing the light-absorbing panel (absorber) 1, transparent panel 2, opaque thermal insulation. The total heat flow coming to the heat carrier is determined from the heat balance:

$$Q = Q_{swal} - Q_{waste} \qquad (1)$$

here: Q_{swal}, Q_{waste} – absorbed heat flow and collector heat losses, respectively.

The solar radiation flux absorbed by the receiving panel roof consists of the direct flux, the return flux and the reverse flux:

$$Q_{swal} = \eta_0 S_n E \qquad (2)$$

$$\eta_0 = \tau_{ст}(1-\rho_n)(1+(1-\tau_{ст})\rho_n) \qquad (3)$$

here: η_0 – optical UWC; S_n – the surface of the illuminated surface, м^2; E – solar flux density, Вт/м^2; $\tau_{ст}$ – the light transmission coefficient of the transparent panel (0,8 – 0,9); ρ_n – the reflection coefficient of the heat-absorbing panel.

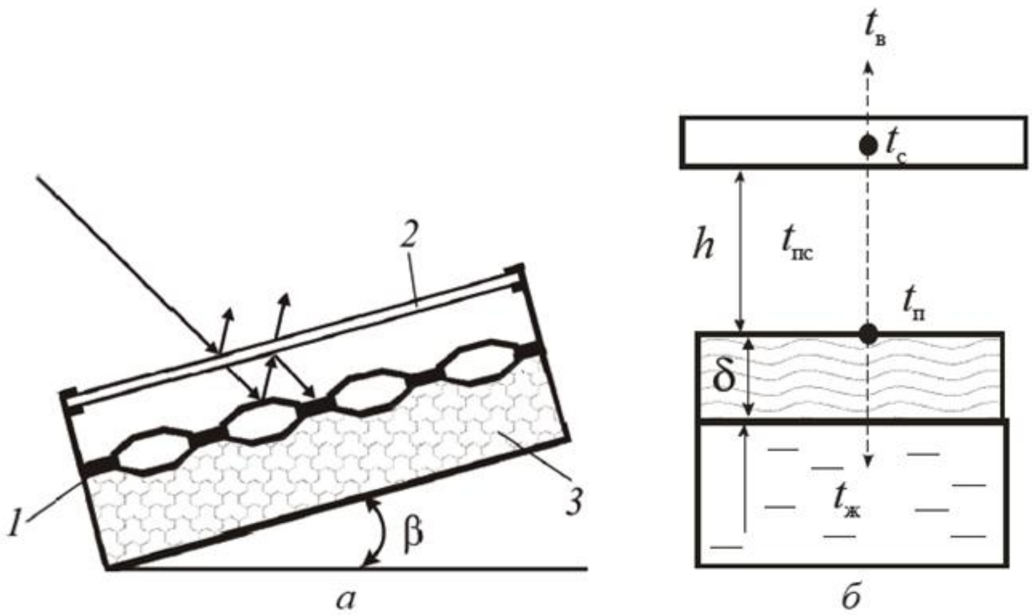
The temperature of the light-receiving surface during light absorption t_n (Fig. 1, b) increases. When the temperature of the light-absorbing panel exceeds the ambient temperature, t_b heat loss occurs:

$$Q_{ис} = K_{ис}(t_n - t_b)\,S_n; \qquad (4)$$

$$K_{ис} = \left(\frac{1}{\alpha_{пс}^{k}+\alpha_{пс}^{p}} + \frac{\delta_{ст}}{\lambda_{ст}} + \frac{1}{\alpha_{в}^{k}+\alpha_{в}^{р}}\right) \qquad (5)$$

here: $K_{ис}$ – effective coefficient of heat loss of the solar collector Вт/(м^{2}К); $\alpha_{пс}^{k}$, $\alpha_{пс}^{p}$ – convective heat transfer and radiant heat transfer coefficients between two inclined parallel (absorbing and transparent) panels Вт/(м^{2}К; $\delta_{ст}$, $\lambda_{ст}$ – the thickness of the transparent surface and the heat transfer coefficient;

$\alpha_{\text{в}}^{k}$ ва $\alpha_{\text{в}}^{\text{p}}$ - coefficients of heat transfer from the transparent panel to the environment by convection and radiation, $\text{Вт}/(\text{м}^2\text{К})$.



1 – picture. Solar collector design and distribution of sunlight (a) and heat flow (b).

1 – light absorbing panel; 2 – mirror; 3 – thermal insulation.

Heat losses from the top absorbing surface of the collector depend on radiation and convection between the absorbing and transparent plates. Energy loss, temperature of the glass cover through convection to the environment t_n the temperature of the plate t_{c} is equal to the amount of energy transferred to the glass coatin:

$$\alpha_{\text{пс}}^{k} = \frac{\lambda}{h}(0{,}060 - 0{,}00019\beta)G_r^{0{,}333} \quad (6)$$

here: β – angle of inclination of the collector relative to the horizon, grad;

$G_r = \frac{1/(273+t_{nc})g\Delta t h^3}{\nu_{nc}^2}$ - Grasgoff number; $t_{\text{пс}} = (t_n + t_c)/2$ – the average temperature of the medium in the channel between the absorbing and transparent panels; ^{0}C; h – distance between panels, м; $\nu_{\text{пс}}$ - of the environment $t_{\text{пс}}$ coefficient of kinematic viscosity at temperature, м^2/с; $t_{\text{пс}} = (t_n - t_c)$ – difference in average temperatures of absorbent and transparent panels, ^{0}C.

If we take into account the dependence of thermal-physical properties of air on temperature, formula 6 becomes simpler:

$$\alpha_{\text{пс}}^{k} = (0{,}060 - 0{,}00019\beta)(14{,}065 - 0{,}0248t_{\text{пс}})\Delta t^{0{,}333} \quad (7)$$

Temperature t_n from the plate, the temperature t_c the radiation coefficient of heat transfer to the glass coating is determined from the following equation:

$$\alpha_{\text{пс}}^{p} = \frac{G}{(t_n - t_c)(\frac{1}{\varepsilon_n} + \frac{1}{\varepsilon_c} - 1)}\left[\left(\frac{T_n}{100}\right)^4 - \left(\frac{T_c}{100}\right)^4\right] \quad (8)$$

here: $\varepsilon_{\text{п}}$ and ε_{c} – the degree of blackness of the plate and glass coating, respectively.

The coefficient of heat transfer in forced convection from a transparent surface to the environment is determined from the following formula:

$$\alpha_{\text{в}}^{k} = 5{,}7 + 3.8\nu \quad (9)$$

here: ν – the velocity of the outside air that washes the solar collector, m/s.

Free convection heat transfer coefficient from a transparent surface to the environment:

$$\alpha_{\text{в}}^{k} = (2{,}26 - 0{,}0067\beta)(t_{\text{с}} - t_{\text{в}})^{0{,}33} \quad (10)$$

Temperature $t_{\text{с}}$ is the radiation coefficient of heat transfer of the glass coating, temperature $t_{\text{в}}$ takes into account the heat exchange with the air. In that case, the radiation heat transfer coefficient is as follows:

$$\alpha_{B}^{P} = \frac{G\varepsilon_{c}}{(t_{c}-t_{B})}\left[(\frac{T_{c}}{100})^{4} - (\frac{T_{B}}{100})^{4}\right] \quad (11)$$

The useful heat flow entering the heat carrier is determined by the heat transfer equation:

$$Q = k(t_{n} - t_{\text{ж}})S_{n}' \quad (12)$$

here: k – coefficient of heat transfer from the outer surface of the absorbing panel to the heat carrier, Vt/m^{2}°C; $t_{\text{ж}} = (t_{\text{ж}_1} + t_{\text{ж}_2})/2$ – the average temperature of the heat carrier, °C; $t_{\text{ж}_1}$, $t_{\text{ж}_2}$ – the temperature of the liquid entering and leaving the collector, °C; S_{p}' - the surface of the inner surface of the absorbent panel, m^{2}.

Heat transfer coefficient for laminar flow from absorber panel to heat carrier:

$$\alpha_{\text{п}} = \frac{\lambda_{\text{ж}}}{d_{\text{экв}}} 0{,}15 Re_{\text{ж}}^{0{,}33} Pr_{\text{ж}}^{0{,}43} (\frac{Pr_{\text{ж}}}{Pr_{\text{п}}})^{0{,}25} \quad (13)$$

here: $\lambda_{\text{ж}}$ – heat transfer coefficient of the heat carrier, Vt/mК; $d_{\text{экв}}$ – equivalent diameter of the heat transfer channel, m; $Re_{\text{ж}} = \frac{d_{\text{экв}}V_{\text{ж}}}{\nu_{\text{ж}}}$ – Reynolds number; $Pr_{\text{ж}}$, $Pr_{\text{п}}$ – Prandtl number of the heat carrier, of the heat carrier $t_{\text{ж}}$ and plate t_{n} determined by the average temperature; $V_{\text{ж}}$ – average temperature velocity of the fluid in the channel m/s; $\nu_{\text{ж}}$ – coefficient of kinematic viscosity of the heat carrier, m^2/s.

Useful heat flow Q can also be determined by the heat absorbed by the heat carrier. In heating the flowing heat:

$$Q = GC_{\text{ж}}(t_{\text{ж}_2} - t_{\text{ж}_1}) \quad (14)$$

here: G – flowing fluid consumption, кg/s; $C_{\text{ж}}$ – specific heat capacity of the heat carrier, J/кg^{0}C.

The maximum temperature of the heat carrier in the collector $Q_{\text{ют}} = Q_{\text{ис}}$ determined by the condition.

In that case $\eta_{\text{о}}S_{n}E = (t_{\text{мех}} - t_{B})K_{\text{ис}}^{\text{мех}}S_{n}$

In this case, the maximum temperature of the heat carrier, °C: $t_{\text{мех}} = \frac{\eta_{\text{о}}E}{K_{\text{ис}}^{\text{мех}}} + t_{B}$

Solar collector U.W.C. is determined from the following formula:

$$\eta = \frac{Q}{S_{n}E} = \eta_{\text{о}} - K_{\text{ис}}\frac{t_{n} - t_{B}}{E}$$

here: $\eta_{\text{о}}$ – optical U.W.C., (0,78 – 0,85); $K_{\text{ис}}$ – coefficient of heat loss, Вт/м^{2}°C.

Description of the solar collector - η of $\frac{t_{n}-t_{B}}{E}$ dependence on is determined during its testing.

Effective optics for a south-facing single-glazed solar collector U.W.C. $\eta_{\text{э}} = 0{,}95\eta_{\text{о}}$ and for double glazing $\eta_{\text{э}} = 0{,}93\eta_{\text{о}}$

Solar energy flux density E is less than the critical value, the solar collector's U.W.C. will be zero:

$$E_{\text{кр}} = \frac{K_{\text{ис}}}{\eta_{\text{о}}}(t_{\text{ж}_1} - t_{B}) \quad (16)$$

The average U.W.C of the solar collector for a certain period of time (day, month, year).:

$$\eta_{\text{ўрт}} = \frac{\Sigma(\eta E)}{E_{\text{ўрт}}} \quad (17)$$

Sum only $E > E_{кр}$ is calculated for time intervals, $Вт/м^2$.

The effectiveness of the absorbent surface is determined by its construction. If we take into account that the absorbing panel performs two tasks: it absorbs sunlight and transfers heat to the heat carrier, then the design of the absorbing panel depends on the coefficient of heat loss $K_{ис}$ and affects the coefficient of heat transfer from the panel to the heat carrier. However, the method of calculating heat losses for the constructions of absorbing panels is not fundamentally different - only K, S_n, S'_n, A, $d_{экв}$ it is necessary to express the parameters correctly and use the formulas given above.

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