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CALCULATING EVALUATION OF THERMAL EFFIICIENCY OF THE SOLAR DRYING INSTALLATIONS WITH STRAIN SOLAR COLLECTORS

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Abstract. *In this paper the estimated efficiency of solar drying plants with in-line solar collectors is given. The dependence of the thermal efficiency of solar drying plants with solar collectors is determined. It is possible to optimize the temperature of the essential agent at the outlet of the solar collector.*

Key words: *drying plant, solar air collector, chilled and drying chamber*

INTRODUCTION

An analysis of the experience of operating solar drying plants with demanding solar air collectors shows that the temperature rise of the drying agent at the outlet of the collector (i.e. at the entrance to the drying chamber), although it intensifies the drying process, leads to a significant decrease in the collector efficiency due to an increase in thermal losses due to the increased operating temperature of the latter. Lowering the temperature of the drying agent at the outlet from the collector in order to increase the efficiency of the latter leads to a decrease in the intensity of evaporation of moisture from the dried products, and accordingly to the thermal efficiency of the drying plant [1-2].

These contradictory conditions mean that there is an optimum value of the temperature of the drying agent at the outlet from the solar collector, which ensures the maximum value of the thermal efficiency of the drying plant. In this connection, it is of practical interest to search for and establish an optimal operating regime for solar drying installations of the type under consideration, in which the maximum thermal efficiency of the dryer is provided, with minimal thermal energy consumption per unit of production [3].

With this purpose, let us consider the regularity of the formation of the thermal efficiency of a chamber solar drying plant consisting of a solar air collector and a drying chamber (Fig.1).

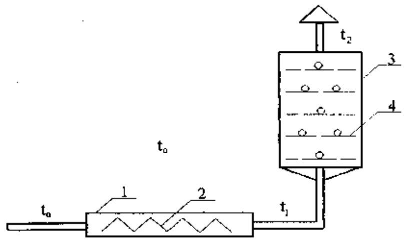

***Fig. 1. Schematic** diagram of a solar drying installation with a separate solar collector and a drying chamber: 1-solar air collector; 2-collectors; 3-drying chamber; 4-heat sink of solar drying products*

The drying agent (atmospheric air) with temperature t_o and relative humidity of φ_o is fed to the heat source – solar air collector of the heating pad. After heating in a solar air collector, a drying agent with temperature t_1 and relative humidity φ_1 is supplied to the vertical chamber through its lower end [4-5].

The dried products in the drying chamber are laid in layers in mesh trays that are at a distance from each other vertically. Spreading through the layer of dried wet products drying agent having a temperature of several tens of degrees higher than that of the dried products, causes evaporation of moisture from the latter. Cooled (due to adiabatic moisture evaporation from the dried products) and moistened drying agent with temperature t_2 and relative humidity φ_2 through the upper end of the drying chamber is removed into the environment.

$$Q_{sup} = Gc_p(t_1 - t_2) \qquad (1)$$

MATHEMATICAL DESCRIPTION

The thermal power supplied by the drying agent to the lower end of the drying chamber (Q_{sup}) is usually equal to the useful heat output of the solar collector, which in turn is determined by the formula [3-5].

$$Q_{sup} = \eta_{hea}\left[\eta_{opt} q_{fall} - k_{pow}\left(t_f - t_0\right)\right] F_{fro} \quad (2)$$

Where G and c_p – respectively, the consumption and specific heat of the drying agent; η_{hea}– coefficient of solar collector efficiency; η_{opt}- optical efficiency of the system "transparent coating of the housing – the absorber surface of the heat collector" of the solar collector; q_{fall} – the density of the flux of the total solar radiation incident on the frontal surface of the collector; k_{pow} – reduced to the unit of the frontal ray-receiving surface is the coefficient of the total heat loss of the collector; t_f – average (along the length of the collector) temperature of the heat carrier of the drying agent in the heat sink channel of the heat collector of the solar collector; F_{fro} – the area of the frontal ray-receiving surface of the solar collector. In turn, the thermal power generated in the solar collector is expended

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on evaporation of moisture from the dried products in the drying chamber (Q_{are}), to compensate for heat losses through the fencing elements (walls) of the drying chamber (Q_{hea}) and is carried away with the spent drying agent, as a waste thermal power (Q_{dis}), i.e.

$$Q_{sup} = Q_{are} + Q_{hea} + Q_{dis} \quad (3)$$

The meanings of Q_{are} Q_{hea} and Q_{dis} included in (3) are determined from the corresponding expressions:

$$Q_{are} = G_{moi} r \quad (4)$$

$$Q_{opt} = \Sigma k_i F_i (t_k - t_0) \quad (5)$$

$$Q_{dis} = G c_p (t_2 - t_0) \quad (6)$$

Where G_{mo} – the flux of moisture evaporated from the dried products; r – latent heat of vaporization, k_i and F_i – respectively, the heat loss coefficient and the heat exchange surface i – of that wall of the drying chamber; t_k is the average temperature of the drying agent in the drying chamber; t_2 – the temperature of the spent drying agent (at the outlet from the drying chamber).

For solar drying installations of this type, an increase in the temperature of the drying agent in the solar air collector (from t_0 to t_2) in the direction of its movement are characteristic. In connection with this, the average temperature of the drying agent (t_f) in formula (2) and (t_k) in formula (5) is determined from the ratios for the solar collector and the height of the drying chamber.

$$\bar{t_f} = \frac{t_1 - t_0}{\ln\frac{t_1}{t_0}} \quad (7)$$

and

$$\bar{t_k} = \frac{t_1 - t_2}{\ln\frac{t_1}{t_2}} \quad (8)$$

The values of the thermal efficiency of the solar collector (η_c) and the drying chamber are determined from the well-known relationships.

$$\eta = \frac{Q_{sup}}{Q_{fall}} \quad (9)$$

and

$$\eta = \frac{Q_{are}}{Q_{sup}} \quad (10)$$

Where Q_{fall} is the flux of total solar radiation incident on the frontal beam-receiving surface of the collector.

$$Q_{foll} = q_{fall} F_{fro} \quad (11)$$

Having determined the Q_{are} obtained from (3) and substituting the result obtained in (10), we obtain

$$\eta_k = 1 - \frac{Q_{pt} - Q_{dis}}{Q_{sub}} \quad (12)$$

The overall thermal efficiency of a drying plant of this type is determined from the ratio

$$\eta = \frac{Q_{are}}{Q_{fall}} . \quad (13)$$

As follows from the joint consideration of (9) and (10), the overall thermal efficiency of the drying plant can be defined as the product of the thermal efficiencies of the solar collector and the drying chamber, i.e.

$$\eta = \frac{Q_{sup}}{Q_{fall}} \cdot \frac{Q_{are}}{Q_{sup}} = \eta - \eta_k \quad (14)$$

Substituting the values of η_c and η_k, respectively from (9) and (10) into (14) and taking into account the Q_{sup}, Q_{are} and Q_{fall} from (1), (2), (4)-(6) and (11) and also t and t from (7) and (8) we obtain

$$\eta = \eta\left[\eta_{opt} - \frac{k_{pow}}{q_{fall}}\left(\frac{t_1 - t_0}{\ln\frac{t_1}{t_0}}\right)\right]$$

$$1 - \frac{t_2 - t_0}{t_1 - t_0} - \frac{\sum k_i F_i\left(\frac{t_1 - t_2}{\ln\frac{t_1}{t_2}} - t_0\right)}{F_{fro}\eta_{hear}\left[\eta_{opt} - \frac{k_{pow}}{q_{fall}}\left(\frac{t_1 - t_0}{\ln\frac{t_1}{t_0}} t_0\right)\right]} \quad (15)$$

RESULTS AND DISCUSSION

Figure 2 shows the graphical dependence of the thermal efficiency of the drying plant (η) from the heating temperature of the drying agent in the solar collector (t_1) and at the outlet from the drying chamber (t_2) built based on the solution (15) at η_{hea}=0.85;

Which correspond to conditions close to the actual operation of solar jets of the type considered. As follows from the graphs in Fig.2 with other things being equal, the increase in the temperature of the waste agent (t_2) leads to a decrease in the thermal efficiency of the dryer.

Thus, at t_1=80^{0}C increase in t_2 from 35^{0}C (in a period at a constant drying rate) to 50^{0}C (in the final stage of the drying process) the decrease h is from 0.41 to 0.25 i.e. 39%.

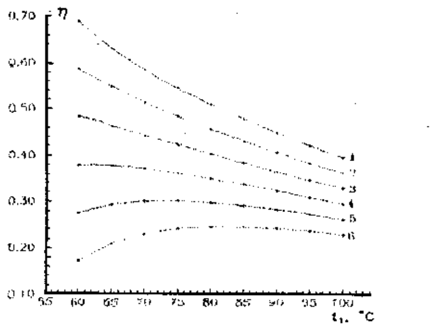

Fig.2. *Dependence of the efficiency of the drying plant on the heating temperature of the drying agent in the solar collector (t_1) and at the outlet from the drying chamber (t_2): 1, 2, 3, 4, 5 and 6, respectively, at t_2=25; 30; 35; 40; 45 and 50^{0}C*

It also follows from the graph in Fig.2 that the n=f (t) dependence is practically linear only at t_2=t_0=35^{0}C. At t_2=45^{0}C in increase T1 TO 75^{0}C the value n first increases (to 0.30), and then (after 75^{0}C and so on) decreases. At t_2=50^{0}C maximum efficiency of n is at t_1=80 and is 0.25.

CONCLUSION

Thus, based on the solution (15) and the graphical dependences of n=f (t_1,t_2) is possible to optimize the temperature of the drying agent at the exit from the solar collector (i.e. at the exit to drying chamber) during a period of falling drying speed.

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