THERMAL EFFICIENCY OF SOLAR DRYERS WITH FLOW-THROUGH AIR SOLAR COLLECTORS

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ABSTRACT

The article discusses the design features and modes of operation of the air solar collector. The dependence of the coolant parameters on the design features of the collector is shown.

The article also discusses the design features and modes of operation of the air solar collector. The objective of this work is to create a solar collector that reduces the emission of solar radiation and increases the temperature of the coolant.

The collector glass, the surface of which is made in the form of hemispherical cells, concentrates the solar radiation incident on it on the ray-receiving surface of the metal plate. This provides heating of the radiation-receiving surface of the plate and the tubes in contact with it, and, consequently, the heat carrier passing through the tubes up to 2500C. Reducing the emission of solar radiation is also carried out due to the increased radiation reflectivity of the lower side of the metal plate.

The article also shows the mathematical modeling of drying hydropleural materials, such as raw cotton, cocoon, flax, the heat capacity of air fiber and seeds along the length of the pipeline in solar-drying installations.

Keywords: raw cotton, heat capacity, air temperature, pipeline length, moisture extraction process, temperature distribution, pipeline cross-sections, homogeneous medium, sunbeam, thermal conductivity, flow, coordinates, axis, speed, heat carrier, air solar collector, solar emission, micro magnifier, temperature.

Relevance of the problem

The Central Asian area is confronted with a number of acute obstacles as it attempts to transition to a long-term electrical power supply. Small-scale hydropower systems may be a viable answer to these problems. Central Asian nations' hydropower resources are allocated unevenly. Regardless, it remains the most exploitable renewable energy source in the area, with both Kyrgyzstan and Tajikistan possessing some of the world's highest hydropower potential. Nonetheless, for fossilfuel-rich nations like Uzbekistan, Turkmenistan, and Kazakhstan, hydropower will play a significant role in the future energy balance. Furthermore, because rivers often run across many boundaries, water security plays an important role in cross-border relations between Central Asian countries. To achieve effective exploitation of small hydropower potential, technological and financial expenditures are needed to improve the levelised cost of energy (LCOE) of diverse hydroelectric equipment by increasing lifetime, improving efficiency, and increasing yearly power output. Several of these issues can be resolved by installing small and micro hydropower plants in the many minor rivers and irrigation canals. A pumped hydro energy storage system should also be tested and certified for better usability. A hydrological digital twin of relevant river system and irrigation network should be constructed to increase the understanding for performance and enable system-level improvement. Furthermore, optimal performance necessitates constant monitoring of the network, necessitating the development of intelligent monitoring employing sensors in conjunction with control systems and smart grid interactions. This review focuses on the broad and efficient use of these existing resources, which are still underutilized.[1]

In the conditions of fuel shortage and continuous growth of fuel prices, the development of colossal solar energy resources is one of the most important scientific and technical problems.

The studies carried out in recent years, and the experience in the development and operation of solar installations, accumulated in a number of countries, have shown the possibility and economic feasibility of a wider and more diverse use of solar energy already now, at the current level of technical capabilities.[2].

Heat-technological processes and drying, which consume a significant amount of fuel and energy resources of the country, are widely used in the chemical, food, metallurgical and other industries. In the processing of raw cotton and its derivatives, drying is one of the most important stages that determine the technical and economic efficiency of productivity and the quality indicators of finished products.

Dryers used in this industry do not always take into account the specificity of the processed materials, which leads to a decrease in their productivity and an increase in energy intensity. Concerning the work solves the problem of developing scientific foundations for choosing a drying method and appropriate types of apparatus and, for this purpose, studying the hydrodynamic and kinetic laws of the drying process in apparatuses of various designs, [3]

All over the world, there is a transition of countries to the path of local generation, the situation is similar in Uzbekistan, although at a slow pace, but it is developing. In this case, special attention is paid to scientific projects and international programs for the development of the energy sector in the Republic of Uzbekistan, which provide for such goals as: deepening market reforms in this area, improving the management system, increasing the efficiency of the functioning of energy enterprises and on this basis ensuring stable operation of the country's energy system, and meeting the needs of the economy and the population in energy [4].

It is estimated that the mass introduction of installations in the southern regions of the CIS, whose operation is based on the direct conversion of solar energy into thermal energy in order to use it for heating buildings, hot water supply, air conditioning, drying agricultural products, allows saving 15-20 million tons of standard fuel per year.[5].

Significant progress in this direction can be achieved by using solar energy to provide heat to large consumers in industry, utilities and agriculture. For example, a significant part of the heat consumed in light, food, chemical and other industries is heat of low potential at temperatures below 3000C. The need for it can be met through the use of solar energy.

At present, some progress has been made in the development and practical application of solar installations, but they are still expensive, which hinders their use on a large scale.

Therefore, one of the main tasks in the development of practical developments in the use of solar energy is the creation of solar power plants with acceptable technical and economic characteristics. This requires constant improvement of existing installations, as well as the creation and careful research of more advanced options for various design schemes.

On earth, the power of solar radiation is 1.3 kW/m^2. Theoretically available energy potential of solar radiation is able to satisfy all the needs of mankind. However, the existing solar power plants have a significant drawback - the uneven power output. This is due to the uneven flow of solar radiation reaching the surface of the Earth, due to its rotation around the axis (light and dark times of the day), and weather conditions (changes in the density of cloud cover).

For these reasons, the large-scale use of solar energy with modern technologies implies either the operation of solar power plants in conjunction with other energy sources, or the use of storage systems that supply the consumer with energy at night or in cloudy weather, which significantly increases the cost of solar energy technologies and sharply limits their scope.[6].

At present, among the important national economic problems facing the Republic of Uzbekistan are problems related to solving problems arising from the development of the fuel and energy complex and environmental problems.

These urgent challenges are being met by an increase in the use of renewable energy sources.

The use of solar energy in a rational combination with other energy sources in many cases saves a significant amount of fuel and energy resources. The effect of the use of solar energy is especially noticeable in the implementation of the most energy-intensive heat-technological processes in solar installations. These include processes, helio-drying technology of raw cotton. The implementation of solar technological processes is of great national economic importance.[7]

In this aspect, the creation of solar collectors providing an increase in the temperature of the coolant and a decrease in the emission of solar radiation is relevant. Known solar collector containing provided with a transparent coating of the housing, in the bottom of which are installed cells with absorbing material, such as water with a dye [8].

It should also be noted that the implementation of scientific research in the field of renewable energy and end-to-end technologies in this area should correspond to the sixth and seventh technological order in terms of value, which will simultaneously serve to develop innovative, competitive, as well as export-oriented and import-substituting products and technologies, promising to be in demand in the next 20 years from the high-tech sectors of the national economy.[9]

Theoretical part

An analysis of the operating experience of solar drying plants with flow-through solar air collectors [10,11,12] shows that an increase in the temperature of the drying agent at the outlet of the collector (i.e., at the inlet to the drying chamber), although it intensifies the drying process, however, significantly reduces the efficiency of the collector for by increasing heat loss due to its increased operating temperature. Lowering the temperature of the drying agent at the outlet of the collector in order to increase its efficiency leads to a decrease in the intensity of moisture evaporation from the dried products and, accordingly, the overall thermal efficiency of the drying plant.

These conflicting conditions mean that there is an optimum value for the temperature of the drying agent at the outlet of the solar collector, which ensures the maximum value of the thermal efficiency of the drying plant.

In this regard, it is of practical interest to search for and establish the optimal operating mode for solar drying installations of the type under consideration, which ensure the maximum thermal efficiency of the dryer at the minimum cost of thermal energy per unit of production. The wall of the drying chamber is made of sheet steel 0.7 mm thick. The outer surface of the wall of the drying chamber is painted black for maximum absorption of solar radiation.

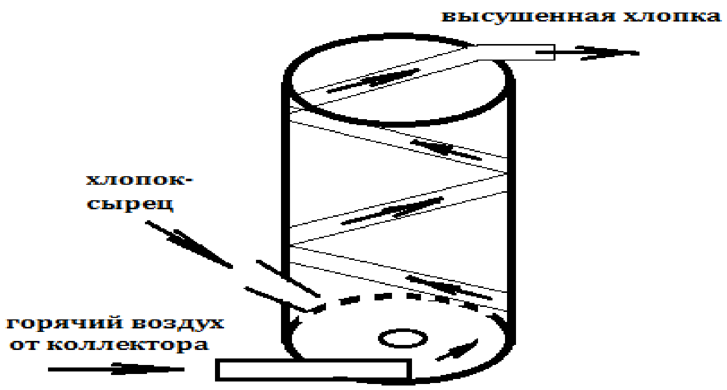

Fig. 1. Schematic diagram of a vertical dryer.

The main advantages of such solar-fuel dryers include:

- reduction of heat losses through the walls of the drying chamber;
- reduction of material consumption of the wall of the drying chamber;
- transportability, due to the possibility of manufacturing the walls of the drying chamber from thin-sheet materials (steel);

The flanging on the spiral swirler can be made in the form of petals of a triangular, rectangular, trapezoidal shape or in the form of a segment. They provide an optimal hydrodynamic mode of airflow movement, which is important when choosing a fan.

The drying agent (atmospheric air) with temperature t_0 and relative humidity φ_0 is supplied to the heat source - a solar air collector for heating. After heating in the solar air collector, the drying agent with temperature t_1 and relative humidity φ_1 enters the vertical chamber through its lower end.

The dried raw cotton is fed into the drying chamber through the feeder into the loading hatch 8; Penetrating through the layer of wet cotton being dried, the drying agent, whose temperature is several degrees higher than that of the dried products, causes the moisture to evaporate from them.

Cooled (due to adiabatic evaporation of moisture 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.

Thermal power supplied with the help of a drying agent to the lower end of the drying chamber $Q_{\text{подв}}$ in the amount

$$Q_{\text{подв}} = Gc_{\text{p}}(t_1 - t_0), \quad (1)$$

as a rule, it is equal to the useful heat output of the solar collector, which in turn is determined by the formula .[8]

$$Q_{\text{подв}} = \eta_{mn}\left[\eta_{onm}q_{\text{пад}} - k_{\text{пр}}(\bar{t}_f - f_0)\right]F_{\text{фр}} \qquad (2)$$

where G and c_{p} are, respectively, the consumption and specific heat of the drying agent; $\eta_{\text{тп}}$ - coefficient of efficiency of the heat receiver of the solar collector;

$\eta_{опт}$ -optical efficiency of optical magnifiers; case cover - ray-absorbing surface of the heat-receiver" of the solar collector;

$q_{пад}$ is the flux density of the total solar radiation incident on the front surface of the collector;

$k_{пр}$ - the coefficient of total heat loss of the collector reduced per unit of the frontal beam-perceiving surface; *

t_1 - average (along the length of the collector) temperature of the heat carrier - drying agent in the heat-removing channel of the heat receiver of the solar collector;

$F_{фр}$ - the area of the frontal beam-receiving surface of the solar collector.

Thermal power generated in the solar collector. in turn, it is spent on the evaporation of moisture from the dried products in the drying chamber $Q_{пол}$, to compensate for heat losses through the enclosing elements (walls) of the drying chamber $Q_{тп}$ and is carried away with the spent drying agent as waste heat power $Q_{сб}$, i.e.

$$Q_{подв} = Q_{пол} + Q_{тп} + Q_{сб}, \qquad (3)$$

The values $Q_{пол}, Q_{тп}, u Q_{сб}$ included in (2) are determined from the corresponding expressions:

$$Q_{пол} = G_{вп} r, \qquad (4)$$

$$Q_{тп} = \sum k_i F_i (t_k - t_0), \qquad (5)$$

$$Q_{сб} = G c_p (t_2 - t_0), \qquad (6)$$

where $G_{вп}$ is the intensity of the flow 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 - that wall of the drying chamber; t_k - average (along the height of the drying chamber) temperature of the drying agent in the drying chamber; t_2 - temperature of the spent drying agent (at the exit from the drying chamber).

For solar drying plants of the type under consideration, an increase in the temperature of the drying agent in the solar air collector (from t_0 to t_1) and a decrease in the drying chamber (from t_0 to t_2) in the direction of its movement is typical. In this regard, the average temperature values of the drying agent t_f in formula (3) and t_1 in formula (4) over the length of the solar air collector and over the height of the drying chamber are determined from the ratios

$$t_1 - t_0, \qquad (7)$$

$$\bar{t}_k = \frac{t_1 - t_2}{\ln \frac{t_1}{t_2}}, \qquad (8)$$

The values of the thermal efficiency of the solar collector η_c and the drying chamber are calculated from the well-known relations

$$\eta_c = \frac{Q_{\text{подв}}}{Q_{пал}}, \qquad (9)$$

$$\eta_k = \frac{Q_{\text{пад}}}{Q_{подв}}, \quad (10)$$

where $Q_{\text{пад}}$ is the flux of total solar radiation incident on the frontal beam-receiving surface of the collector magnifier;

$$Q_{\text{пад}} = q_{\text{пад}} F_{\text{фр}}, \quad (11)$$

The overall thermal efficiency of the drying plant of the type under consideration is determined from the ratio

$$\eta = \frac{Q_{\text{пол}}}{Q_{пад}}, \qquad (12)$$

As follows from (10) and (11), the total thermal efficiency of the drying plant can be taken as the product of the thermal efficiencies of the solar collector and the drying chamber, i.e.

$$\eta = \frac{Q_{\text{подв}}}{Q_{пад}} * \frac{Q_{пол}}{Q_{подв}} = \eta_c \eta_k, \quad (13)$$

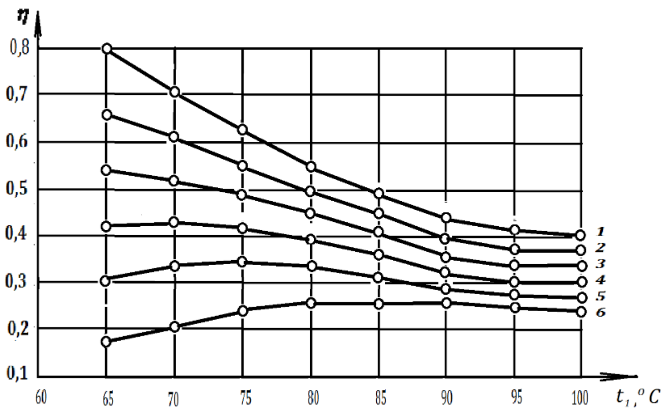

Fig.1. Dependence of the efficiency of the drying plant on the heating temperature of the drying agent in the solar collector *(t,) and at the outlet of the drying chamber *(t_2): 1, 2, 3, 4, 5 and 6 - respectively at* t_2=75; 80; 85; 90; 95 and 100°C.

In Fig.1. the graphical dependence of the thermal efficiency of the drying plant η on the heating temperature of the drying agent in the solar collector* (t_1) and at the outlet of the drying chamber is shown (t_2) constructed on the basis of solution (3.40) at $\eta_{mn} = 0{,}85$; $\eta_{опт} = 0{,}70$; $k = 7{,}0$ W/(m^2*°C); $q_{пад} = 700$ W/m^2; $\sum k_i F_i / F_{фр} = 1{,}0$ and $t_0 = 55$°C, which correspond to conditions close to the actual operation of solar installations of the type in question.

Thus, based on solution and graphical dependencies $\eta = f(t_1, t_2)$, it is possible to optimize the temperature of the drying agent at the outlet of the solar collector (ie, at the outlet of the drying chamber) during the period of decreasing drying rate.

Thus, the above schemes make it possible to control the parameters of the heat carrier by means of qualitative and quantitative regulation, which makes it possible to reduce the cost of solar thermally processed materials through the use of energy and resource-saving adjustable technological installations.[13]

Solar energy should rapidly move to a qualitatively new level of development in the regions, based on achieving parity in the cost of solar cells, compared with the cost of traditional energy sources. One of the main development factors of which is the constant improvement of solar energy technologies, increasing the efficiency of photovoltaic installations, including through the use of new compounds and materials. The development of solar energy technologies and related industries for the production of equipment, the search for and development of fundamentally new materials, are becoming a factor in the development and expansion of scientific research and the formation of an innovative structure of the economy on this basis.[14]

Experimental part

Research on increasing the thermal efficiency of solar dryers for drying raw cotton. Substituting the values $Q_{подв}$, Q_{mn} and $Q_{сб}$ - respectively, taking into account the value - from we can establish an expression for the thermal efficiency of "real" drying chambers of the type in question in the form:

$$\eta_k^{действ} = \eta_k^{теор} - \Delta\eta_k, \quad (14)$$

"theoretical" drying chamber; $\Delta\eta_k = \dfrac{\sum k_i F_i \left(\dfrac{t_1 - t_2}{\ln \dfrac{t_1}{t_2}} \right)}{Gc_p (t_1 - t_0)}$, (15)

decrease in the thermal efficiency of the drying chamber as a result of taking into account heat losses through the enclosing elements of the drying chamber to the environment.

Expressing the weight flow rate of the drying agent G in formula (15) in terms of its linear velocity (v), i.e.

$$G_{ca} = vF_{nc}\rho_1, \quad (16)$$

given the meaning $k_i = 7{,}6$ Вт/(м^2*°С), $F_i = 16{,}9646$м^2. F_{nc}=0.6362м^2 for the experimental drying installation with a vertical chamber that we created and examined [9, 10], as well as the values c_p and p, can be rewritten as: $\Delta\eta_k = 202{,}658$

$$v(1010{,}1+0{,}6t_1)(1{,}2-2{,}7*10^{-3}t_1)\frac{t_2}{(t_1-t_0)} \quad (17)$$

So, when increasing t_2 from 55 before 70°C relative decline is respectively 80% (from 0.5935 before 0.1184) at t,=80°C; 56.2% (from 0.6625 before 0.2902) at t,=90°C; 43.5% (from 0.7351 before 0.4734) at t_1=100°C and the relative increase $\Delta\eta_k$ - 38.5% (from 0.1208 before 0.1673) at t,=70°C; 33.7% (from 0.1 153 before 0.1542) at t,=80°C; 30.3% (from 0.1129 before 0.1471) at t,=90°C an 27.8 (from 0.1111 before 0.1420) at 100°C.

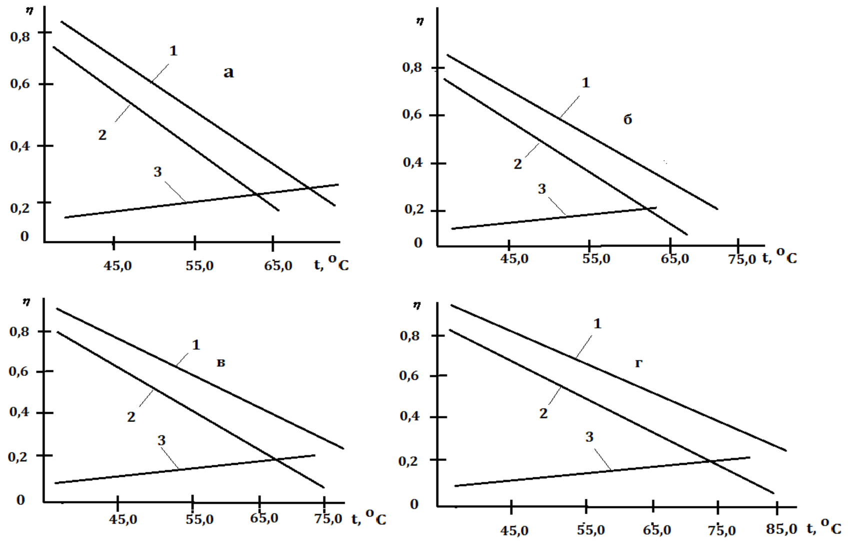

Fig.4. Dependences of the thermal efficiency of drying chambers "theoretical" "real" (2), as well as its decrease $\Delta\eta_k$ (3) on the temperature of the drying agent at the outlet of it (t_2) respectively at $t_{1,}{}^{\circ}C: t_1 = a - 70°$; b-80°; at-90°; and g-100°C.

Therefore, any possible reduction in t_2 should be a positive factor in increasing the thermal efficiency of the drying chambers. However, it should be noted that with a decrease in t_2, as a rule, the relative humidity of the drying agent in the drying chamber increases accordingly. This, in turn, leads to a decrease in the intensity of moisture vapor diffusion in the drying agent and, accordingly, to a decrease in the flux density of moisture evaporated from dried cotton.

CONCLUSIONS

It should also be noted that the favorable climatic and geographical conditions of the country provide a promising future for the use of renewable energy.[15]

The solar-drying installation provides for cloudy or rainy days when the intensity of the sun's rays is lower than required, a heater is also installed, the power of which corresponds to the drying regimes of 75-80 ° C, when leaving it) and which is connected if necessary.[16]

As a result of theoretical and experimental studies, the following main regularities of solar-drying installations for drying hygroscopic materials were obtained:

- obtained graphic dependences of the change in the speed of air and raw cotton for various methods of drying raw cotton;

- the dependences of the efficiency of the drying plant on the heating temperature of the drying agent in the solar collector were obtained.

- the process of drying cotton during the time t=0-10s. Depends on the temperature of the heated air flow at T<40°C, cotton does not have time to dry and does not meet the requirement, at T>100°C, on the contrary, some fibers may lose their natural quality. It turns out that at a temperature of T = 80-90 ° C, drying of cotton meets the optimal requirement.

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