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Development and Installation of Optimum Operating Mode of an Indirect Solar Dryer with Natural Air Ventilation

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ABSTRACN: This article presents the results of the research work of an upgraded solar drying plant with indirect heat pipes and natural air ventilation. The dependences of temperatures, moisture content of the vapor-air mixture and on the surface of the drained grapes, the drying rate on the drying period time, are also compared with the results of the kinetics of the drying process of grapes obtained on a direct-acting solar drying plant, on the basis of which the purpose of this work is established. The average daily temperature of the steam-air mixture and the temperature on the surface of the drained grapes in a drying plant with a heat pipe, which during the drying period does not exceed (3-4) ºC during the drying period as a whole, have been established. On a direct-type solar drying plant, these values reached (11-19) ºC. The average daily drying rate of grapes during the drying period (for 8 days) decreases smoothly from 0.190 kg/m^2 hour to 0.020 kg/m^2 hour, on a direct-acting solar drying unit, the drying rate decreases from 0.137 kg/m^2 hour to (up to 5 days) 0.030 kg/m^2 hour, the remaining 12 days the drying rate it reaches from 0.030 kg/m^2 hour to 0.005 kg/m^2 hour. The reasons for such changes have been identified. The high drying temperature of the solid layer (crust formation) formed on the surface makes it difficult for the liquid to escape, which has not yet been removed from the inside, and prevents drying. This problem was solved by changing the drying conditions and was implemented by a solar drying plant with a heat pipe and natural air convection in the solar collector, with the following efficiency coefficients: heat pipes ($\eta_{HP} = 34\%$), heat exchangers ($\eta_{HE} = 25\%$) and a drying cabinet $\eta_{inst} = 11\%$.

I. INTRODUCTION

Grapes are one of the most popular and delicious fruits in the world. Grape preservation by drying is a major industry in many parts of the world where grapes are grown.

The relevance of the problem of drying grapes. To obtain finished raisins with a low average annual cost (in Greece, the average annual export value is 140-160 US dollars [1]), in agriculture it is necessary not only to save energy by intensifying the drying process, improving the improvement of the structural model of dryers, etc., but also by using renewable energy sources for the drying process. The author [6] found that for high-quality dehydration of agricultural products, low temperatures are desirable and maintaining an almost uniform temperature over the entire surface area of the drained product, which can be easily obtained using an indirect solar drying plant.

It is known that drying is a phenomenon that is known to be directly related to the structure of the product to be dried, it is the movement of fluid loss caused by external factors. The structure of the product to be dried is also a factor determining the drying rate [6]. Drying of agricultural products is observed in the form of characteristics of changes in drying rates, a period of constant speed and a period of decreasing speed [4]. Therefore, an important definition of drying processes is the drying speed. This is influenced by many factors that are important for influencing mass and heat transfer. These factors include characteristics such as temperature, humidity and air drying rate, as well as physical (geometric dimensions of fruits) properties and composition of the product to be dried [2].

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During and after drying, there are many physical and chemical changes in the structure of the product. Some of these changes are desirable and expected, and some are not desirable. Due to the high (more than 60-65 °C) temperature and uneven temperature distribution on the surface of the product, as well as sudden temperature changes on the surface of the product, solid layers (crusts) form during the drying process, making it difficult for the liquid to exit, which has not yet been removed from the inside, it prevents drying. This often happens, especially when drying fruits rich in sugar and similar substances [5].

Physical changes in the dried product lead to chemical changes. The main of these changes are color, nutritional value, taste, viscosity and storage stability. Both during drying and during storage, there is a loss of nutritional values of the product. These losses are based on vitamins C and A, which are the most susceptible to destruction. Thiamine (B1), which is very sensitive to heat, is also strongly lost during drying [1]. These losses mainly depend on the drying conditions. For example, it is known that the loss of vitamin C and carotene in products dried in the sun is much higher than when using other drying methods.

However, there may be color changes in products that are not caused by enzymes. This is also observed with an increase in temperature, especially with sudden temperature changes and an increase in the density of reacting substances in the environment. From the above information, it should be concluded that for high-quality dehydration of agricultural products, low temperature, uniform temperature distribution, and the prevention of sudden temperature changes on the surface of the dried products during the entire drying process are desirable.

Setting the problem of high-quality drying. Many scientists of the world have published scientific works in the open press devoted to the research and development of indirect solar drying plants [1-6]. These solar dryers consist mainly of a flat solar collector for heating air and a drying chamber used to store trays in which grapes are laid out to be dried. The collector and the drying cabinet are arranged sequentially.

The solar collector consists of a transparent lid, foil and a black metal sheet of a solar radiation absorber, heat accumulators (rock rocks, jackdaws, potassium and sodium nitrate, etc.). The drying cabinet was covered with a transparent film or a thermally insulated wall that protects the grapes from rain, dust and spouts. Air ventilation is provided by natural convection inside the collector and the drying cabinet. The maximum temperature recorded in the drying chamber was 50 °C at an ambient temperature of 30 °C, and the capacity of the drying chambers is 100 kg of fresh (wet) grapes per square meter of the drying chamber.

These dryers reduce the drying time of grapes to seven to eight days, completely protect them from rain, dust and spouts, which helps to improve the quality of raisins. The disadvantage of these dryers is their low productivity [9]. It is concluded that a variety of food products can be dried in drying plants of this type efficiently, efficiently and economically. Despite the achieved positive characteristics in indirect solar dryers by natural air ventilation, scientific research works are rarely found in the open press, which fundamentally take into account sudden changes in temperature on the surface of the drained product during the entire drying process, due to which a sharp deterioration in the quality of the drained products is expected [1; 5].

Based on a comparative analysis of the scientific research works of scientists of the world in this area, it was found that in order to eliminate a sharp temperature drop (temperature pressure) on the surface of the dried product during the drying process, it is necessary to modernize the indirect solar drying plant with natural air ventilation. To solve such a requirement, the purpose of this scientific work was chosen: to develop a pilot design model of a solar installation with indirect action by natural air convection, evenly distributed also without sudden temperature changes on the surface of the drained product and, based on experimental studies, to establish the optimal mode of its operation under average cloud conditions in the regions where this installation is located.

II. MATERIALS AND METHODS

The device of the solar drying system. We have used an already designed and existing solar dryer with a flat solar collector. The collector was upgraded with a heat pipe connected in series to it by a heat exchanger, while most other parts of the solar dryer system remained in accordance with the original design. The materials used for this dryer are listed and shown in Figure 2.1.

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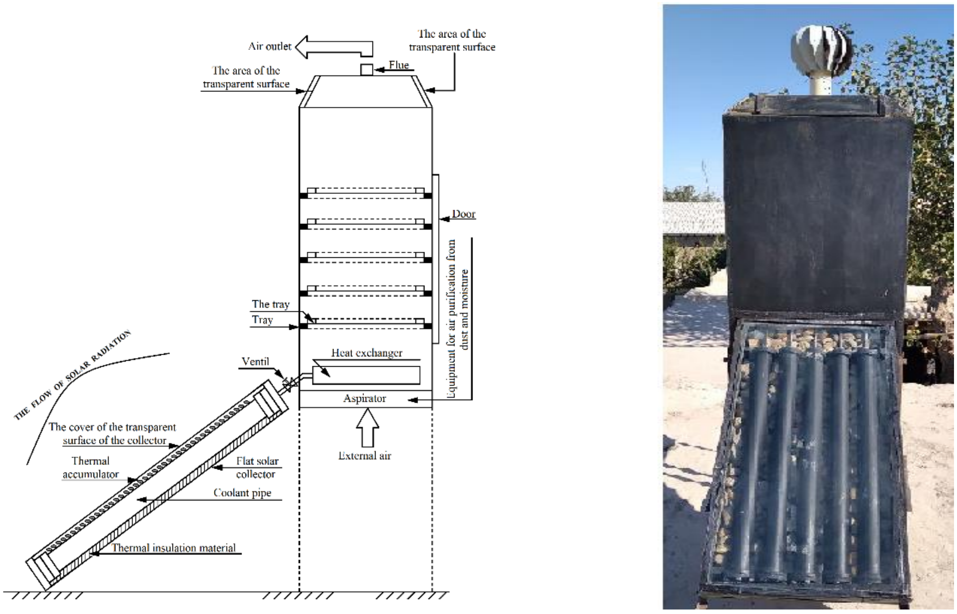
The area of the transparent surface of the collector is 0.6954 m^2. The collector measures 114 cm in length, 61 cm in width and 11 cm in height. The outer and inner housings were made of 0.5 cm thick plywood. A heat pipe and a heat accumulator (jackdaws) are located inside the collector. The heat exchanger corresponding to the heat pipe is located sequentially in the drying chamber. The flat solar collector is tightly sealed against the ingress of air from the environment into the drying unit. The collector and the drying cabinet chamber are arranged sequentially: the collector is located at 45 degrees and the drying chamber at 90 degrees relative to the horizon (i.e. vertically).

The outer body of the drying cabinet measures 66 cm in length, 48 cm in width and 120 cm in height. The outer and inner housings are also made of 0.5 cm thick plywood and a heat insulator is installed between them.

Figure 2.1 shows a schematic diagram and a real image of the solar drying installation we developed for indirect action with natural air ventilation in the drying chamber and with a heat pipe placed in a flat collector; Figure 2.1 also shows the signatures of the elements of the structural model. The complete physical characteristics of the structural model and its elements are established by semi-empirical calculation methods and calculated in accordance with the concepts and experimental results.



a) б)

Fig. 2.1 Indirect solar dryer: a) Schematic diagram; b) Real image.

The operating principle of the proposed solar drying installation is indirectly operated by natural convection. The flux of solar radiation falls on the surface area of the transparent cover of the installation. A small part of the flux is absorbed by a transparent material, the other part is reflected from it and the main part of the solar radiation flux enters the chamber of the flat collector. Solar radiation inside the collector is absorbed by the air, the heat accumulator, the metal body of the thermal pipe, the side walls, and the bottom of the collector body and heats them. The heat received by the side walls, bottom and transparent cover of the collector body is transferred to the environment. The heat received by the heat pipe heats the water inside, the water evaporates. Water vapor is transferred through pipelines to heat exchangers, which are located at the bottom of the drying cabinet chamber.

The wings of the heat exchangers heat up, and the air above the surface of the wings also heats up. The heated air receives additional internal energy (kinetic energy), due to which the flow of thermal air from the surface of the heat exchanger wings rises vertically upward in the direction of the chimney. At the same time, through the holes located at the bottom of the drying cabinet chamber, air from the environment enters the inside of the drying cabinet chamber.

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The heated air, sliding onto the surface of the drying product in the process of vertical lifting, transfers the heat to the product, which it receives from the heat exchanger. Water vapor evaporates from the product composition and a steam-air mixture is formed, which is released from the chimney into the environment.

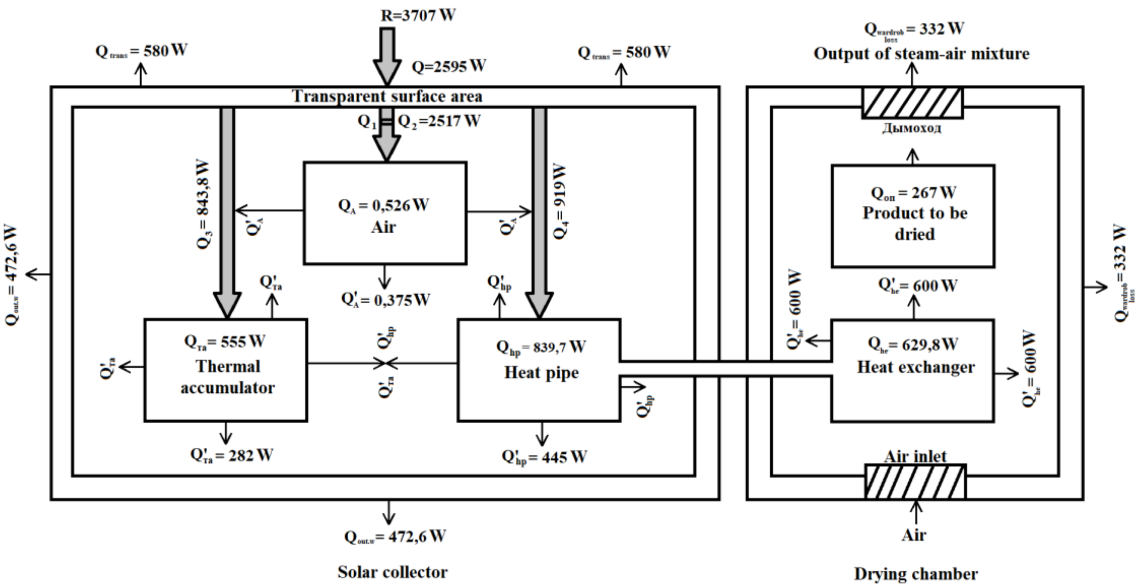

Fig. 2.2 Distribution of solar radiation flux and heat flux in the structural model of a solar dryer during the drying process of grapes

To present a description of the principle of operation of the recommended indirect solar drying installation, Figure 2.2 shows a schematic diagram of the distribution of solar radiation fluxes and heat fluxes into the structural model of the solar installation during the active period of the drying process.

III. THE OBTAINED RESULTS OF EXPERIMENTAL STUDIES

When conducting real-natural experiments, measurements of the main thermal parameters were made at the appropriate points: temperature, humidity (air and steam-air mixture), atmospheric air pressure and relative pressure of the steam-air mixture, ambient air speed, drying speed, moisture content of dried products, steam-air mixture were identified etc.

Results of an experiment to study the process of drying kinetics of grapes on solar dryers and comparative analysis. To verify the reliability of the experimental results obtained on the solar installation with heat pipes we recommend, the authors of this article published a scientific work (article) [8], which presents the results of experimental studies on the kinetics of the grape drying process on a direct solar drying installation. The stages and periods of drying of grapes of the “Kishmish black” variety have been established. Figure 3.1 a) shows their experimental results, which were obtained on October 15-30, 2018 (drying chamber capacity 165 kg). Curves of the dependence of the temperatures of the drying agent and on the surface of the dried product, the humidity of the drying agent and in the composition of the dried product, and the drying speed versus drying time are presented.

Figure 3.1 b) presents experimental research results in the form of dependence curves during the drying of grapes of the “Kishmish Black” variety in an indirect solar drying installation with heat pipes, which were obtained on August 18-25. 2022 (drying chamber capacity 100 kg). Also shown in Figure 4 are curves of the dependence of the amount of direct solar radiation (W/m^2) on a horizontal surface under average cloudy conditions on daily intervals during the period of the experiments.

The experimental results obtained show that the average daily intensity of solar radiation flux during the experiment period (18-25.08.2022) in a drying installation with a heat pipe is twice as high (Fig. 3.2 b) than the average daily intensity of solar radiation flux during the period of experiments October 15-30, 2018 in a direct-type drying installation (Fig. 3.2 a). Although the conditions for conducting experiments in drying installations are different, the changes in the average

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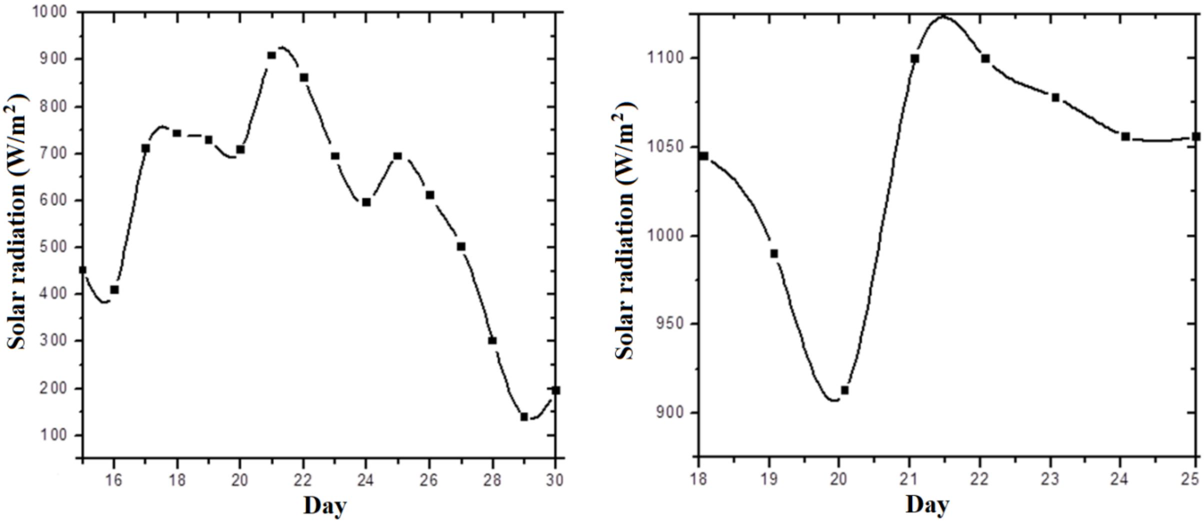
daily temperature (temperature pressure) of the steam-air mixture and the temperature on the surface of the grapes being dried in a drying installation with a heat pipe during the entire drying period do not exceed 3-4 °C (Fig. 3.1 b), 1. 3-curves. In a direct-type solar drying installation, these values reach 11-13°C.



a) (15-30).10. 2018 г. б) (18-25).08.2022 г.

Fig. 3.2 Change in the amount of direct solar radiation on a horizontal surface under average cloudy conditions in a daily interval: a) Experiments were carried out (15-30).10. 2018; b) Experiments were carried out (18-25).08.2022.

In a solar drying installation with heat pipes, the average daily rate of grape drying during the entire drying period for 8 days decreases smoothly (without sudden changes) from 0.190 kg/m^2·hour. up to 0.020 kg/m^2·hour, on a direct-acting solar drying unit the drying speed decreases (starting from the 2nd day of drying) from 0.137 kg/m^2 hour to (up to the 5th day of drying) 0.030 kg/m^2·hour, in the remaining 12 days drying speed reaches from 0.030 kg/m^2 hour to 0.005 kg/m^2 hour.

Comparing the 2 dependence curves presented in Figure 3.1 a) and b), it is clear that changes in the moisture content of the drying agent during the drying process in a direct solar dryer decreases with a difference (0.3-0.4 kg/kg) (curve 2, Figure 3.1 a), and in a solar dryer with heat pipes, such a change occurs smoothly (curve 2, Figure 3.1 b)).

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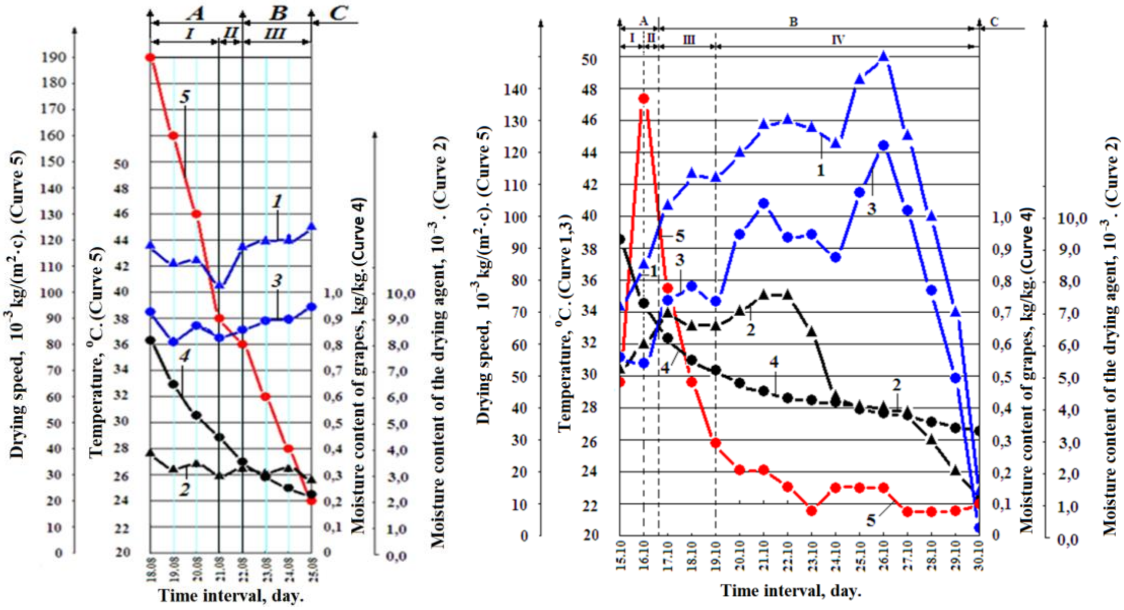

а) б)

Fig. 3.1 Stages and periods of the grape drying process: a, V and C - stages of moisture, hygroscopicity and equilibrium state of the grapes, respectively; I, II, III and IV - periods of sharp increase, sharp decrease, decrease and slow decrease in drying speed; 1 and 2 - temperature and humidity of the contents of the drying agent; 3 and 4 - temperature and humidity of grapes; 5-drying speed: a) (15-30) October 2018; b) (18-25) August 2022.

The results of the main parameters determining the thermal properties of a solar drying installation of indirect action by natural air convection. During the experiment, August 18.2022, solar radiation flux R is received per 1 m^2 of horizontal surface area; solar radiation flux Q = 0,7·R is received per transparent collector surface area of 0.7 m^2. Solar radiation penetrating through the transparent surface Q_1=(0.95-0.97)·Q, W; Q_2 is the flux of solar radiation penetrating the air inside the collector chamber, W; Q_3 is the flux of solar radiation falling on the surface of the heat accumulator, W; Q_4 is the flux of solar radiation incident on the surface of the heat pipe, W; Q_5 - loss of heat flow into the atmosphere through the side walls and bottom of the collector housing, W; Q_6 - loss of heat flow into the atmosphere through the transparent surface of the collector, W.

$$Q = 0{,}7 \cdot R = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$$

According to the results of the experiment conducted on August 18.2022, the distribution of the amount of solar radiation flux among the elements of the structural model of a solar drying installation inside a flat solar collector and their quantitative values are shown in Figure 2.2 and Table 3.1.

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Table 3.1.
Distribution of the amount of solar radiation flux among the elements of the structural model of a solar drying installation

Hourly interval (True solar time)	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	Total
R, W/m^2	418	484	528	528	517	462	352	253	110	55	3707
Q, W	292,6	338,8	369,6	369,6	361,9	323,4	246,4	177,1	77,0	38,5	2595
Q_1=Q_2, W	283,8	328,6	358,5	358,5	351,0	313,7	239,0	171,8	74,7	37,4	2517
Q_3, W	95,1	110,1	120,1	120,1	117,6	105,1	80,07	57,6	25,03	12,5	843,3
Q_4, W	103,6	119,9	130,9	130,9	128,3	114,5	87,2	62,7	27,3	13,7	919

Note: the area occupied inside the collector chamber of the heat accumulator is 0.335 m^2, heat pipes - 0.365 m^2.

Below we present the basic designations of measured, calculated and initial data, as well as formulas for their determination and quantitative values.

Измеряемые величины.

Average temperature change:

-$\overline{\Delta T}_{HA}$- on the surface of the heat accumulator during periods of an hour interval per day, $\overline{\Delta T}_{HA} = 11.04^oC$ and $|-8.42^o|C$;

-$\overline{\Delta T}_{A}$- air inside the collector chamber during periods of hourly intervals on days $\overline{\Delta T}_{A} = 8.50^oC$ and $|-9.28^o|C$;

-$\overline{\Delta T}_{HZ}$ - in the heating zone of the heat pipe during periods of an hour interval per day, $\overline{\Delta T}_{HZ} = 9.78^oC$ and $|-7.75^o|C$;

-$\overline{\Delta T}_{TZ}$ - in the heat pipe transport zone during periods of hourly intervals per day, $\overline{\Delta T}_{TZ} = 5.63^oC$ and $\overline{\Delta T}_{TZ} = 5.63^oC$;

-$\overline{\Delta T}_{CZ}$ - in the condensation zone during periods of an hour interval per day, $\overline{\Delta T}_{CZ} = 2.66^oC$ and $|-0.8^o|C$;

-$\overline{\Delta T}_{PD}$ - in the inner and outer surfaces of the transparent surface during periods of an hourly interval per day, $\overline{\Delta T}_{PD} = 7.79^oC$;

-$\overline{\Delta T}_{KK}$ - in the internal and external walls of the collector housing during hourly intervals, $\overline{\Delta T}_{KK} = 31.53^oC$;

-$\overline{\Delta T}_{EEE}$ - on the surface of the metal wings of the heat exchanger and the external environment during periods of an hour interval, $\overline{\Delta T}_{EEE} = 2.62^oC$;

-$\overline{\Delta T}_{Air}$ - at the incoming air into the drying chamber during the hourly interval, $\overline{\Delta T}_{Air} = 0.4^oC$;

- $\overline{\Delta T}_{out}$ - at the outlet of the steam-air mixture during periods of an hour interval, $\overline{\Delta T}_{out} = 1.58^oC$.
Measured humidity of the steam-air mixture:

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-$\varphi -$ average humidity value of the steam-air mixture;

-$d -$ air moisture content and partial pressure of the steam-air mixture at their corresponding humidity and temperature are determined based on the id-diagram.

Formulas for determining parameters:

- The formula for determining and the average value of the change in the amount of heat flow that a heat accumulator receives from the flow of solar radiation:

$$Q_{HA} = \mathrm{C}_{HA} \cdot G_{HA} \cdot \overline{\Delta \mathrm{T}}_{HA} = 555.1\ W,$$

here the initial data is C_{HA} - specific heat capacity of the heat accumulator material, $\mathrm{C}_{HA} = 754 \frac{J}{kg \cdot \mathrm{K}}$; G_{HA} - mass of battery material, $G = 40\ \ kg$.

Formula for determining and average value of change in air density in the collector chamber:

$$\Delta\rho = \frac{\Delta \mathrm{P}}{R \cdot \overline{\Delta T}_A} = 1.027 \frac{kg}{m^3},$$

here R is the universal gas constant, 8.314 Jmol/(mol·K); ΔP-portional pressure of the steam-air mixture, (id-diagram).

The formula for determining and the average value of the change in heat flux that the air in the collector chamber receives from the flow of solar radiation.

$$Q_A = \mathrm{C}_A \cdot G_A \cdot \overline{\Delta \mathrm{T}}_A = 0.526\ \text{Вт},$$

here C_A is the average value of the specific heat capacity of air, 1.005 kJ/(kg·K); G_A-average value of air mass inside the collector chamber, G_A = 0.037 kg.

The heat capacity that the heat pipe receives from the flow of solar radiation is determined by the formula:

$$Q_{HP} = \mathrm{C}_{HP} \cdot G_{HP} (\mathrm{T}_{HZ}^2 - \mathrm{T}_{HZ}^1) = 839.7\ W,$$

here is the C_{HP}-specific heat capacity of the heat pipe, in place of which the equivalent specific thermal capacity (of the system) is taken:

$$\mathrm{C}_{HP} = \frac{\mathrm{C}_{\text{steel}} \cdot m_{\text{steel}} + \mathrm{C}_{\text{water}} \cdot m_{\text{water}}}{m_{\text{steel}} + m_{\text{water}}} = 1.1 \frac{\kappa J}{kg \cdot \mathrm{K}},$$

where m_{steel} is the mass of the heat pipe, 40 kg; m_{water}-mass of water used for the heat pipe 7,5 kg; $\mathrm{C}_{\text{steel}}$ is the specific heat capacity of a steel pipe, $\mathrm{C}_{\text{steel}}$=500J/(kg·K); $\mathrm{C}_{\text{water}}$ - specific heat capacity of water, $\mathrm{C}_{\text{water}}$=4200 J/(kg·K).

The efficiency of the heat pipe in relation to the solar radiation flow entering through the transparent surface into the inside of the collector:

$$\eta_{HP} = \frac{Q_{HP}}{Q_1} = \frac{840\ W}{2517} = 0.34 = 34\%.$$

According to the instructions of scientists around the world, 0.59 - 0.75 parts of the heat are transferred from the heat pipe to the heat exchanger (condenser) through the water vapor coolant:

$$Q_{HE} = (0.59 - 0.75) \cdot Q_{HP} = 629.8\ W.$$

where Q_{HE} is the total heat flux developed by the heat pipe.

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Net efficiency of heat pipe heat exchanger:

$$\eta_{HE} = \frac{Q_{HE}}{Q} = \frac{630\ W}{2517} = 0.25 = 25\%$$

To create confidence that heat transfer actually occurs in the process occurring in the heat pipe, the heat transfer coefficients in the heating and condensation zones of the heat pipe, using experimental results, were determined by formulas (12) and (13).

$$\bar{\sigma}_{HZ} = \frac{Q_{HP}}{F_{HZ} \cdot \left(\frac{\bar{T}^{n}_{HZ} + \bar{T}^{(n+1)}_{HZ}}{2} - \frac{\bar{T}^{n}_{TZ} + \bar{T}^{(n+1)}_{TZ}}{2}\right)} = 168 \frac{W}{m^2 \cdot K};$$

$$\bar{\sigma}_{CZ} = \frac{Q_{к}}{F_{CZ} \cdot \left(\frac{\bar{T}^{n}_{TZ} + \bar{T}^{(n+1)}_{TZ}}{2} - \frac{\bar{T}^{n}_{CZ} + \bar{T}^{(n+1)}_{CZ}}{2}\right)} = 103.1 \frac{W}{m^2 \cdot K};$$

here F_{HZ} is the surface area of the heated zone of the heat pipe, 0.555 m^2; F_{CZ} - surface area of the heat pipe condensation zone, F_{CZ}=1.03 m^2.

According to the opinion and conclusion of the authors [1], heat transfer is carried out by the process of thermal conductivity, in which the heat transfer coefficient in the heating zone of the heat pipe should be no more than (400-450) $\frac{W}{m^2 \cdot K}$, and in the condensation zone - no more than (200-300) $\frac{W}{m^2 \cdot K}$. Such indicators ($\bar{\sigma}_{HZ} = 168 \frac{W}{m^2 \cdot K}$, $\bar{\sigma}_{CZ} = 103 \frac{W}{m^2 \cdot K}$) make it possible to verify that the experimental results are indisputably confirmed by the heat transfer process in the proposed heat pipe heat exchanger.

Heat flux Q'_{HE} transferred from the surface of the heat exchanger to the drying oven was determined by the following formula:

$$Q'_{HE} = к_{HE} \cdot F_{CZ} \cdot \overline{\Delta T}_{CE} = 602\ W,$$

here $\bar{K}_{HE}$ is the average value of the thermal conductivity coefficient, $\bar{K}_{HE} = 11{,}94 \frac{W}{m^2 \cdot K}$; $\overline{\Delta T}_{CE}$ - average value of temperature change on the surface of the heat exchanger and the environment, $\overline{\Delta T}_{CE} = 24{,}4^{o}C$.

Thus, the chamber of the drying cabinet receives Q'_{HE}=602 W from the solar collector through a heat pipe and a heat exchanger. The experiment showed that the heat flow received by the drying cabinet is distributed to the following parts of the device: for drying the product (per day) Q_{prod} =267 W; removal of thermal $Q_R = 332$ W. flow into the environment from the side walls, the bottom of the heating cabinet chamber and the exit of the steam-air mixture through the chimney.

The effective performance of the drying cabinet in relation to the incoming heat flow into the flat solar collector was determined (the first day of the experiment) by the formula:

$$\eta_{inst} = \frac{Q_R}{Q_1} = \frac{267\ W}{2517\ W} \approx 0.11 = 11\%.$$

IV. CONCLUSION

Based on a comparative analysis of the results of experimental studies, it was found that the size of the dried grapes (capillaries) does not matter at the initial stage of drying, while at later stages it affects the drying rate. Also, due to the high drying temperature, the hard layer (crust formation) that forms on the surface makes it difficult for the liquid that has not yet been removed from the inside to escape and prevents drying. The formation of a crust should be avoided, as this affects the drying speed and quality of the product to be dried [5]. This problem can be solved by monitoring or changing the drying conditions. In this scientific work, the drying conditions were undoubtedly realized through a solar drying installation with thermal exhaust and natural air convection in the solar collector and the following efficiency factors: heat pipes ($\eta_{HP} = 34\%$), heat exchangers ($\eta_{HE} = 25\%$) and drying cabinet $\eta_{inst} = 11\%$.

REFERENCES

[1]. Michael Tsamparlis. Solar drying for real applications. Drying Technology 1990; 8 (2): 261-85.
[2]. Gee M. Some flavor and color changes during low temperature dehydration of grapes. Journal of food science 1980; 45: 146-147.
[3]. Safarov Zh.E., Sultanov Sh.A., Dadaev G.T., Zhumaev B.M. Study of an innovative method of drying medicinal plants. Monograph 2017. 106-107.
[4]. Rahman M, Pereira S, Tebboune K.O. Isotherm desorption and kinetics of pea drying by heat pump. Food Research International. 485-491 p. (In Russian)
[5]. Dadaev G.T., Safarov Zh.E. Modeling of the Process of Drying Food Grasses in Natural Natural and Climatic Conditions. Universes: technical sciences: electron. Scientifically. Journ. 2022. 4 (97).
[6]. Safarov Zh.E., Dadaev G.T. Results of the study of the technology of drying medicinal herbs. Chemical technology. Control and management. -Tashkent. 2017.- №3. - P. 27-31.
[7]. Dadaev G.T. On the Issue of the Development of Technology for Obtaining Dried Products with New Qualities. Universes: technical sciences: electron. Scientific. journal. 2017. №12 (45). – P. 31-33.
[8]. Sh.M. Mirzaev, S.S. Ibragimov. Study of the stage and periods of the process of drying grapes on a solar dryer and the choice of drying technology. Scientific and technical journal (STJ FerPI, NTJ FerPI, 2022, T.26, No6)
[9]. Sharma V K, Sharma S, Ray Ray R A, Garg HP. Design and performance of a dryer suitable for rural applications. Energy Convers Mgmt. 1986; 26 (1): 11-9.