AIP Conference Proceedings

AIP Publishing

Volume 3347

IV International Scientific and Practical Symposium “Materials Science and Technology” MST-IV-2024

Dushanbe, Republic of Tajikistan • 28–30 October 2024

Editors • Arthur Gibadullin, Ramazon Abdullozoda and Dmitry Morkovkin

Available Online: pubs.aip.org/aip/acp

Conference collection

IV International Scientific and Practical Symposium “Materials Science and Technology”

MST-IV-2024

Dushanbe, Republic of Tajikistan

28–30 October 2024

Editors

Arthur Gibadullin
Khujand Polytechnic Institute of Tajik Technical University named after academician M.S.Osimi, Dushanbe, Tajikistan

Ramazon Abdullozoda
Tajik Technical University named after academician M.S.Osimi, Dushanbe, Tajikistan

Dmitry Morkovkin
Financial University under the Government of the Russian Federation, Moscow, Russia

Sponsoring Organization
Tajik Technical University named after academician M.S.Osimi

All papers have been peer reviewed.

AIP Publishing

Melville, New York, 2025
AIP Conference Proceedings

Volume 3347

To learn more about AIP Conference Proceedings visit **http://proceedings.aip.org**

Editors

Arthur Gibadullin
Khujand Polytechnic Institute of Tajik Technical University named after academician M.S.Osimi
10, academicians Rajabov's avenue
Dushanbe, 734042
Tajikistan

Email: 11117899@mail.ru

Ramazon Abdullozoda
Tajik Technical University named after academician M.S.Osimi
10, academicians Rajabov's avenue
Dushanbe, 734042
Tajikistan

Email: art.tj@bk.ru

Dmitry Morkovkin
Financial University under the Government of the Russian Federation
49, Leningradsky Avenue
Moscow, 125993
Russia

Email: morkovkinde@mail.ru

ISBN 978-0-7354-5239-8
ISSN 0094-243X
Printed in the United States of America

AIP Conference Proceedings, **Volume 3347**
IV International Scientific and Practical Symposium
"Materials Science and Technology"
MST-IV-2024

Table of Contents

The Principle of Operation and the Device of an Indirect Solar Dryer With Heat Pipes

Sh. M. Mirzaev[1,a)], S. S. Ibragimov[1], A. H. Uzokov[1], J. O. Arabov[1] and B. H. Bobokhon[2]

[1]*Bukhara State University, 11, M. Ikbol, Bukhara, Republic of Uzbekistan*
[2]*Bukhara State Pedagogical Institute, 2nd house, Piridastgir street, Bukhara city, Republic of Uzbekistan*

[a)] Corresponding author: salim.ibragimov.89@mail.ru

Abstract. In this paper, the issues of organizing the operating mode of an indirect type solar dryer using solar thermal tubular collectors are considered. When installing an additional transparent cover near the chimney in the drying cabinet chamber of this device, it was found that the efficiency of the device increases by 5.73%, i.e. by 2.7% compared to the prototype. The change in the internal energy (energy flow) of the steam-air mixture in the drying chamber of the drying device, created without an additional transparent lid, amounted to 9.3 watts. It was found that in an upgraded solar dryer (a solar dryer with an additional transparent lid), the energy flow of the vapor-air mixture increased by another 5.7 watts.

INTRODUCTION

Historically, the production of raisins from grapes was recorded in Greece in 1490 BC by drying in the open air using sunlight [1]. Therefore, drying grapes using solar energy has long been considered a traditional method.

In the farms of the Republic of Uzbekistan, air-solar drying of grapes is carried out on specially equipped drying grounds, which are located on agricultural lands not used for cultivation.

The Republic of Uzbekistan is a major producer of agricultural products and therefore the country pays special attention to their deep processing [2, 14].

The size of the drying zone depends on the type of raw material, its quantity and the meteorological conditions of the area. A smaller area is required in areas with high temperatures and low relative humidity. On average, 12 to 16 kg of fresh grapes are dried on a drying area of 1 m^2 [1].

When drying in the open sun, some of the solar radiation can penetrate through the product and be absorbed by it, thereby releasing heat both from the inside and from its surface, thereby enhancing the heat transfer process. The ability of the product to absorb solar radiation is an important factor in direct drying in the sun.

One of the disadvantages of this method is that it does not protect products from precipitation and pollution. Light grape varieties lose their natural green color when dried, and have a dark brown color in the finished product.

The method of drying grapes using film coverings was developed and tested by employees of the Research Institute of Horticulture, Viticulture and Winemaking of Uzbekistan named after R.R. Schroeder. With this method, the grapes placed in the drying area are protected from the risk of bad weather and contamination. They are turned regularly by hand to dry evenly. In this case, the drying time is reduced by one day [3]. When dried with a transparent lid, the quality of raisins is environmentally better than when dried without a transparent lid.

Drying is a common form of food preservation and extends its shelf life [4]. In solar dryers with natural air circulation, there is a convection mode, a comprehensive study of such processes is a very urgent problem of hydromechanics and heat transfer, since they are often found in many practical problems related to the efficient use of renewable energy sources, the relevance of which is reflected in numerous scientific papers related to them [5].

During the drying process of the product, water (moisture) evaporates, and the latent heat of evaporation increases the vapor pressure above the product. The installation requires an air flow to remove vapors released from

IV International Scientific and Practical Symposium "Materials Science and Technology"
AIP Conf. Proc. 3347, 020008-1–020008-6; https://doi.org/10.1063/5.0290358

the product during drying [6]. Therefore, in indirect solar dryers, the latent heat of evaporation is used in the drying process.

In order to further improve the efficiency of obtaining high-quality products in such devices, scientists will focus on the complete modernization of the elements of building models based on programs created on modern computer technologies [7].

This work is devoted to the issue of organizing the operating mode of an indirect type solar dryer using solar thermal tubular collectors.

DRYER ELEMENTS

On cloudy days, the temperature of the air heated in the solar collector changes dramatically. Such conditions lead to a deterioration in the quality of the grapes to be dried. The reason is that the temperature of the skin (core) of grapes decreases with a sharp decrease in the evaporation temperature of water. With a further increase in temperature, the upper layers can dry out and form solid layers until the water evaporates from inside the grapes.

A review of general information about solar dryers led to the following conclusion: five main characteristics, factors and requirements have been identified that directly affect the technical and economic performance of solar dryers for drying grapes.

To eliminate these shortcomings in solar dryers, it was recommended to use a heat pipe system.

According to the general analysis of heat pipes, they have a high level of heat transfer, a simple design that does not require a large amount of material, reliability of use, a degree of good adaptation to various conditions, the absence of moving mechanical elements in their composition, a very long service life, any phase (liquid and gas). The advantage lies in maintaining operational characteristics in working condition.

It is made in the form of a hot box with a flat solar collector (a chamber protected from heat loss from the environment), a heat pipe and a heat accumulator are installed inside the box, and a glass cover is installed on the side. sun (fig. 1a). The collector body is made of durable material that provides the required level of tightness.

The chamber of the drying device and the drying cabinet consist of the following structural elements: a chamber protected from heating by the environment; slots for introducing air flow from the environment into the drying chamber; air filter system (aspirator), heat exchanger, trays and racks for placing grapes to be dried; a chimney on the ceiling of the chamber, designed to release the steam-air mixture from the drying chamber into the environment; An additional glass cover is installed near the chamber chimney.

Solar collector. A flat solar collector with dimensions of 0.61 m × 0.11 m × 1.14 m and a transparent surface area of 0.7 m^2 was prepared in the form of a hot box (parallelepiped-shaped). The frame of the box consists of a tetrahedral wooden beam with a cross-section of 16·10-4 m^2, the collector beams on both sides are covered with a metal sheet (sheet) 0.0012 m thick (thickness 0.04 m), between fences made of metal sheet (thickness 0.04 m), filled with heat-resistant material (foam). A glass cover 0.04 m thick is installed in the upper part of the parallelepiped, i.e. at the installation site of the chimney, five holes are cut out in the upper side wall of the collector, intended for the exhaust of the chimney; the heat pipe pipes are connected to the heat exchanger from the collector.

The efficiency of the installation directly depends on the transparent surface of the solar collector, the amount of heat storage material, the performance of the heat pipe and the climate.

Five cylindrical heat pipes (fig. 2) made of stainless (instrumental) steel with a total length of 0.962 m, an external diameter of 0.074 m and an internal diameter of 0.068 m are installed inside this solar collector.

At both ends of the heat pipe, flanges with an outer diameter of 0.108 m, an inner diameter of 0.068 m, and a thickness of 0.01 m are welded; six holes with a diameter of 0,01 m are drilled in each flange (hex nut, M-10 screw ring).

Boiled water is poured into the pipe to the extent of 0.5% of the volume of the heat pipe, after which flanges are welded at both ends of the cylindrical pipe and the flange covers are fixed with metal nuts (bolts) with rubber (or sealed) gaskets.

Six holes with a diameter of 0.01 m are cut out in both flange covers (for metal bolts with six pointed M-10 heads). One of the flange covers is blank, the other has a hole in the center with a diameter of 0.015 m, a pipe (outer diameter 0.015 m) is attached (welded) to the hole, the other end of this pipe is welded to the heat exchangers, and the heat exchanger is located in the lower (bottom) part of the drying cabinet.

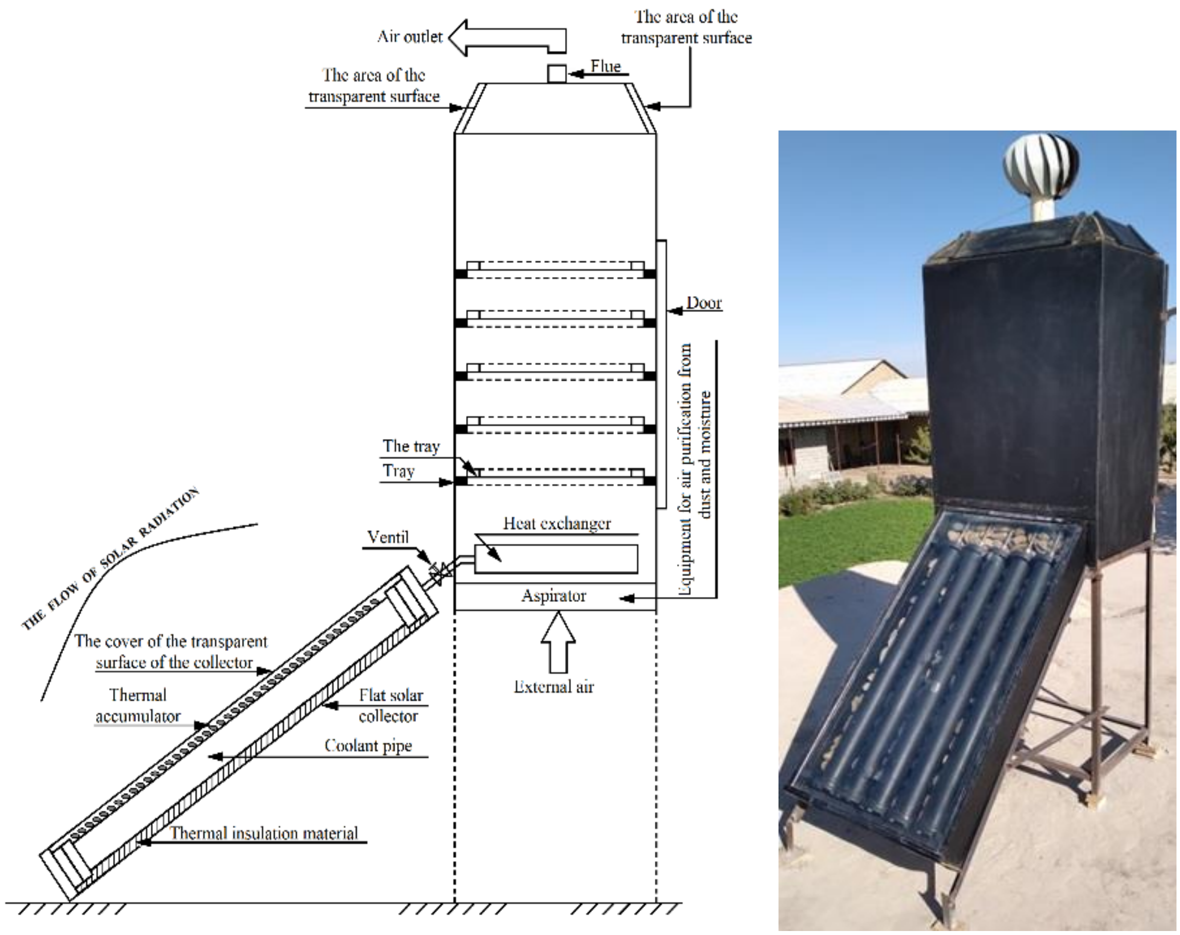

FIGURE 1. Schematic (a) and actual illustration (b) of a solar drying system coupled with a heat pipe drying cabinet and a flat panel solar collector thermal storage unit.

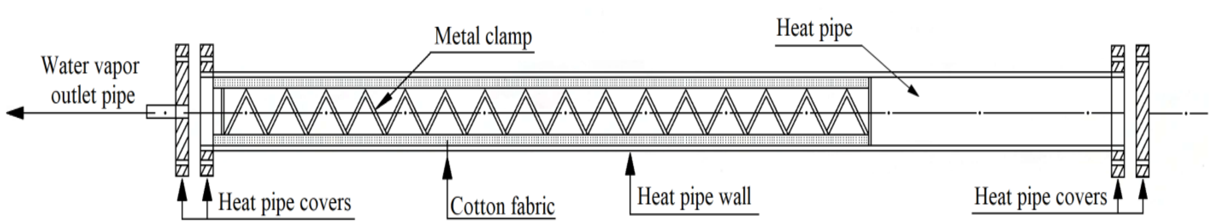

FIGURE 2. Heat pipe for indirect type solar dryer.

Inside the heat pipe there is a pile selected from natural fabric - cotton. The ability to absorb water depends on the density of the fabric. Pile density is the number of cotton threads tied per centimeter of fabric, the density value is expressed in grams per 1 square meter; cotton fabric with an average density of 450-600 g/m was used [8].

Also inside the heat pipe there is a mesh cylindrical cavity made of mesh metal (polycylinder), the diameter of the mesh wires is 0.002 m, the distance between the mesh wires is 0.01 m. The function of the cylindrical cavity is to keep the coil attached to the inner wall of the heat pipe.

The outer diameter of the heat pipe cylinder is 0.068 m, length – 0.95 m. The volume of pile material is 0.013 m^3, water-absorbing, speed 17.5·10-6 m^3/h; density – 1650 kg/m^3, specific heat capacity – 0.88 kJ/kg·garad), thermal conductivity – 0.291 W/(m·garad).

WORKING PRINCIPLE OF SOLAR DRYER

Solar radiation enters the chamber through the transparent glass cover of the flat-plate collector, passes through the layer of air and heats it. Then the sun's rays fall on the outer metal surface of the heat pipe, on the surface of the heat accumulator, and the surface of the heat pipe is heated. The heated heat pipe transfers heat to the water inside the pipe and evaporates it. Water vapor completely occupies the volume of the heat pipe and heat exchanger. As the surface temperature of the heat pipe increases, the temperature and pressure of water vapor in the volume of the heat exchanger increase [9].

Water vapor transfers heat to the heat exchanger at a high rate since the heat pipe and heat exchanger are arranged in series [9-10, 12-13]. Accordingly, the temperature of the heat exchanger fins also increases.

Air flow from the environment enters the cabinet chamber through holes drilled in the bottom of the drying chamber. Due to the large difference between the temperature of the heat exchanger fin and the ambient air temperature, the steam-air mixture rises vertically upward inside the chamber.

A flow of heated air passes over the surface of the product (grapes) placed in the trays, while giving them its own amount of heat, due to which the moisture evaporates from the product. As a result, a flow of steam-air mixture is formed around the dried product, which is directed towards the chimney and forming a zone of steam-air mixture under the chimney. The steam-air mixture is released from the chimney into the environment. The infrared rays of the Sun penetrate the vapor-air field through an additional transparent surface and increase its internal energy. As a result, the mixture flies out of the chimney into the environment at high speed.

Experimental studies were carried out on February 2023, 19 on a modernized solar dryer.

As a product for research in a solar drying plant (fig. 1 (b)), a cotton fabric weighing 130 g was selected, the original image of which is presented above. It contained 270 grams of water, the total weight of the drying product was 400 grams. To dry the product (soaked cloth) was placed on a tray and placed in the middle of the drying cabinet. Table 1 below shows the results of the experiment (drying) from 13:00 to 17:00 on February 19, 2023 (the maximum amount of solar radiation on this day is accepted).

TABLE 1. The results of experimental studies of the drying process in a drying device with an additional transparent surface lid and without a lid.

Measurement time, hour.	Average hourly solar radiation, W/m^2.	The average temperature under the chimney without a lid, ºC.	The average temperature under the chimney hood, ºC.	Temperature difference, ºC.
13:00	385	29.12	37.80	8.68
14:00	374	30.44	39.5	9.06
15:00	319	32.69	42.81	10.12
16:00	231	32.13	37.26	5.13
17:00	121	29.69	33.36	3.67

By installing an additional transparent cover on the solar dryer, the temperature of the steam-air mixture was increased by more than 10 °C. This phenomenon was caused by the absorption of infrared radiation by a vapor-air mixture as part of the sunlight spectrum. (λ=2.2-3.0 microns, (1.36-1.0 Hz); 4.8-8.5 microns, (0.63-0.35 Hz); 12-30 microns, (0.25-0.1 Hz) or $\Delta\lambda$=0.8 microns; 3.7 microns; 18 microns) [11].

It is known that infrared radiation is part of the thermal radiation of the solar spectrum. Thermal radiation is in the infrared part of the spectrum from 0.74 microns to 1000 microns, which is almost 50% of the total solar radiation.

Water vapor continuously emits and absorbs energy only in a certain wavelength range (reflected). For rays of other wavelengths, the vapor-air mixture is transparent and their radiation energy is zero. The processes of emission and absorption of radiation energy in gases (vapor-air mixture) always occur in the volume of the mixture. When photons pass through a volume of gas, some of them are absorbed by gas molecules. The energy of photons changes the internal energy of the molecules, as a result of which the gas heats up, the radiation energy is absorbed in the volume of the gas molecules. In this case, only the energy of photons corresponding to the vapor-air molecule is absorbed in certain wavelength ranges of gas absorption. Photons with a different energy pass through gas molecules without being absorbed [11].

The change in the internal energy of the steam-air mixture (photon energy) is determined by the following formula:

$$\Delta U = \frac{5}{2} \cdot (P_2 - P_1) \cdot V \quad (1)$$

Where P_2 is the partial pressure of the air-steam mixture after exposure to sunlight, kPa; P_1 is the partial pressure of the air-steam mixture before exposure to sunlight, kPa; V is the volume of the drying chamber, m^3.

Based on this formula and the above preliminary data, the change in the internal energy (energy flow) of the steam-air mixture in the drying chamber of the drying unit without an additional transparent cover was 9.3 W. In the modernized solar dryer (solar dryer with an additional transparent cover), the energy flow of the steam-air mixture increased by another 5.7 W.

Five main features, factors and requirements that have a direct negative impact on the technical and economic indicators of solar dryers for drying grapes were identified. To reduce these disadvantages, it was recommended to use a heat pipe system in solar dryers.

When using an additional transparent lid on a solar dryer, the internal energy of the vapor-air mixture increases and, according to our calculations, is equal to an average of 15W.

If in the proposed solar drying device the surface area of the flat collector of the heat pipe is 0.7 m^2, then the power of the solar radiation incident on it is assumed to be 262 W, then a power of 9.3 W is used to lift the vapor-air mass in the drying chamber into the chimney, for example, the indicator is 3% of efficiency (productivity).

If an additional transparent cover is installed in the drying cabinet chamber of the drying device being created, near the installation site of the chimney, then the efficiency of the device will increase by 5.73%, i.e. by 2.7% compared to the prototype.

CONCLUSION

As a heat exchange device capable of transferring large heat capacities at low temperature gradients, the mode of using a heat tube in the solar collector of an indirect solar dryer has been established, and the principle of operation of the dryer has been established.

In the volume under the chimney parts of the chamber of the drying device cabinet, where the steam-air mixture is collected, an additional lid with a transparent surface is installed (only in the sunny period of the day), at which the temperature pressure force (temperature pressure) increases to 10°C, such a process increases the drying efficiency, that is, a reduction in the drying process in the apparatus by 1.5-2 days.

REFERENCES

1. M. M. Mirzaev, *Viticulture of the foothill zone of Uzbekistan* (FAN Publishing House 1980), p. 236.
2. J. Jumaev, S. Ibragimov and Sh. Mirzaev, Modeling of the process of solar drying of grapes in indirect type installations with natural air convection, Journal of Physics: Conference Series, **2573**, 012043 (2023).
3. D. R. Pangavhane and R. L. Sawhney, Review of research and development work on solar dryers for grape drying, Energy Conversion and Management, **43**, 45–61 (2002).
4. P. N. Sarasavadia, R. L. Sawhney, D. R. Pangavhane and S. P. Singh, Drying behaviour of brined onion slices. Journal of Food Engineering, **40**, 219–226 (1999).
5. J. Jumayev, J. Kodirov and Sh. Mirzayev, Simulation of natural convection in a solar collector. Journal of Physics: Conference Series, **2573**, 012024 (2023).
6. K. S. Jairaj, S. P. Singh and K. Srikant, A review of solar dryers developed for grape drying, Solar Energy, **83**, 1698-1712 (2009).
7. Sh. Mirzaev, J. Kodirov and S. I. Khamraev, Method for determining the sizes of structural elements and semi-empirical formula of thermal characteristics of solar dryers, IOP Conf. Series: Earth and Environmental Science, 1070, 012021 (2022).
8. Almatykilem, URL: https://almatykilem.kz/article/view/types-towels/
9. V. B. Eliseev and D. I. Sergeev, What is a heat pipe? Energy, 136 (1971).

10. L. A. Aliyarova, U. H. Ibragimov and S. I. Khamraev, Investigation of hydrodynamic processes in tubes of a combined solar collector, AIP Conference Proceedings **2612**, 030018 (2023). https://doi.org/10.1063/5.0124758
11. M. A. Mikheev and I. M. Mikheeva, Fundamentals of heat transfer. Publishing house "Energy", Publ. 2nd, 182-193 (1977).
12. S. I. Khamraev, Study of the combined solar heating system of residential houses, BIO Web of Conferences, **71**, 02017 (2023). https://doi.org/10.1051/bioconf/20237102017 CIBTA-II-2023
13. G. N. Uzakov, V. L. Charvinski, U. Kh. Ibragimov, S. I. Khamraev and B. I. Kamolov, Mathematical Modeling of the Combined Heat Supply System of a Solar House. Energetika, Proc. CIS Higher Educ. Inst. and Power Eng. Assoc, **65**(**5**), 412–421 (2022). https://doi.org/10. 21122/1029-7448-2022-65-5-412-421
14. S. Khuzhakulov, Z. Pardaev and S. Khamraev, Thermal conditions of systems for solar thermal regeneration of adsorbents, IPICSE 2020, IOP Conf. Series: Materials Science and Engineering, **1030**, 012166 (2021). doi:10.1088/1757-899X/1030/1/012166