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Justification of the effective distribution of energy emitted by a film electric heater on stacked lumber

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Abstract. The research was carried out at the expense of the grant of the Russian Science Foundation No. 23-76-01090, https://rscf.ru/project/23-76-01090/. The article considers the issue of placing boards in a drying plant using infrared film electric heaters. Two options for placing one cubic meter of boards with a thickness of 25 mm and 50 mm are proposed for consideration. The boards are placed between shields with film electric heaters and are separated from each other by transverse gaskets, it is obvious that more gaskets are needed to accommodate boards with a thickness of 25, which means that the distance between the boards will be greater. Hence the hypothesis: an increase in the distance between the shields will lead to an increase in drying time and electrical energy costs. For a theoretical solution, the following is proposed – to present the piled stack in the form of a prism and, considering the known dimensional parameters of the skipped shield, according to a well-known formula, it is possible to obtain a dependence describing changes in the irradiation coefficient on the distance in the radiator-receiver system. The considered irradiance coefficient shows how much of the total radiation from the area of the "receiver" falls on the surface of the "receiver". As a result, an exponential dependence is obtained, according to which it can be determined that the irradiation coefficient for the placement of boards with a thickness of 25 mm is 8% less than for boards with a thickness of 50 mm, which ultimately will affect the duration of the drying process and the cost of electrical energy. Options are proposed to increase the drying efficiency by increasing the irradiation coefficient by reducing the distance between the panels with film electric heaters. In conclusion, in view of the result described in this article, the main directions for further research on improving the "radiator-receiver" system in relation to drying plants based on film electric heaters are given.

1 Introduction

Infrared installations for drying wood, based on a heating element of the film electric heater type, consist of several knocked-down shields (the number depends on the volume of loading), an automation unit and a power unit (or a combined single unit) [1-4].

A skipped shield made of slats with fixed film electric heaters can be in size (in meters):

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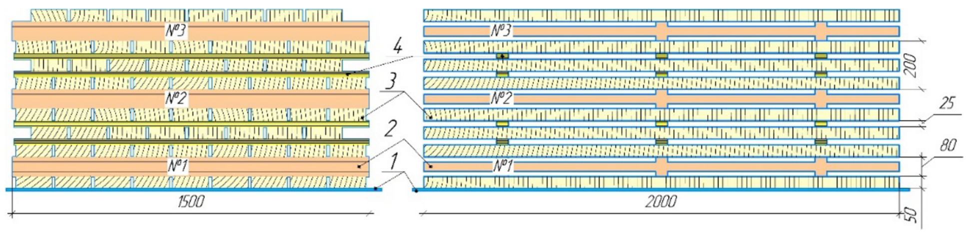
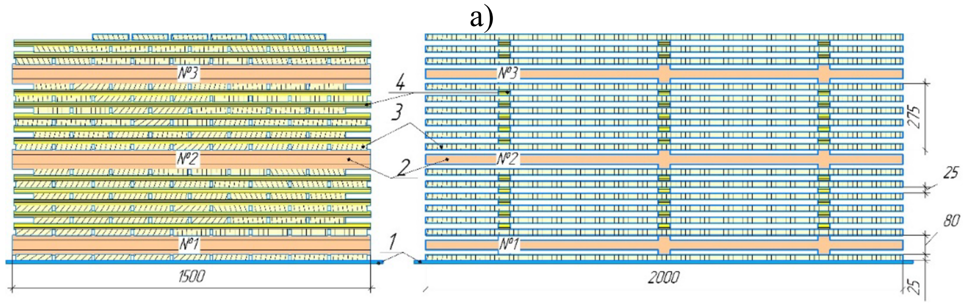
1.5x2.0, 2.0x3.0; 2.0x4.0; 2.0x6.0, etc. The pattern of the entire typical series of skipped shields is reduced to the size of the sawn boards, which can be in length (in meters): 2, 3, 4, 6.

The principle of laying boards with skipped shields is carried out according to the "sandwich" principle (Fig. 1). First of all, a heater with a reflective surface is laid, then a number of boards are laid, a shield with film electric heaters No. 1 is placed on them, then several rows of boards are laid through transverse gaskets (Fig. 1a 3 rows of boards with a thickness of 50 mm are laid; in Fig. 1b 6 rows of boards with a thickness of 25 mm are laid), shield No. 2 is laid on them and then everything is repeated n-number of times until the last shield on which an incomplete row of boards is laid on top. According to the technical reference literature for these types of dryers, it is recommended to form the number of rows of boards between the boards in such a way that the total thickness of all boards stacked in a row does not exceed 150 mm, excluding transverse gaskets (10-25 mm) [1-4]. The thickness of the dried boards varies from 16 to 50 mm, according to GOST 24454-80.



a)



b)

1 – insulation with a reflective surface; 2 – shield with film electric heaters; 3 – drying board; 4 – gasket between rows of boards.

Fig. 1. An example of the placement of dried boards on shields with film electric heaters.

Figure 1 shows two options for placing the same number of sawn boards by volume, namely 1 m^3 of boards 2000 mm long, 150 mm wide, 50 mm thick (Fig. 1a) and 25 mm thick (Fig. 1b). Based on the reference and technical literature [1-4], the specific power of the film electric heater is 360 W/m^2. With the overall dimensions of the skipped shield of 1.5x2.0 m (Fig. 1), its set power will be 1080 W. The specific power per 1 m^3 of stacked boards in both cases is 3240 W. Thus, the difference between piled stacks is the distance between the shield No. 1 and No. 2: for boards with a thickness of 50 mm, this distance is 200 mm; for boards with a thickness of 25 mm – 275 mm. In laying boards with a thickness of 25 mm, three more transverse gaskets were used, their thickness makes up the difference in distance between shields No. 1 and No. 2. Hence the hypothesis: an increase in the distance between the shields will lead to an increase in drying time and electrical energy costs.

The purpose of the study is to theoretically substantiate the dependence of the effective distribution of energy emitted by a film electric heater on stacked lumber.

2 Materials and Methods

It is known that infrared drying of materials refers to a technological process of photophysical action, in which optical radiation produces useful heating to remove moisture [5]. The density of the radiation flux and the spectral distribution of the flux energy are the main parameters of the geometry of the "emitter-receiver" system, that is, a system of two bodies involved in radiant heat exchange [5-8].

The formula describing the distribution of thermal energy in the form of electromagnetic waves has the form [8,9]:

$$Q_{\text{heat irr.}} = \mathrm{A_1 C} * [(\mathrm{T_1}/100)^4 - (\mathrm{T_2}/100)^4]\ \varphi \tag{1}$$

where A_1 is the surface area, T_1 is the absolute temperature, T_2 is the temperature of the covering surface, C is the emission coefficient of the gray body, φ is the irradiation coefficient of the surface with another surface.

In this formula, $Q_{\text{heat irr.}}$two coefficients have a significant impact on the final result: C is the emission coefficient, which depends on the degree of the body blackness and, if it tends to unity, then the thermal radiation indicators will be higher [9]; φ is the irradiation coefficient, showing what proportion of all radiation coming to site 1 is from the surface 2. φ is an exceptional feature characterizing the geometry of the radiating system, since it is determined by the geometric configuration of the walls and their situational plan in the design of drying plants [10-12].

To determine the irradiation coefficients of a surface by another surface and the area of mutual surfaces in typical cases of heat exchange by radiation for different locations, as well as the number and shape of bodies, there are already ready-derived formulas [9]. If we consider a piled stack of boards with shields from a film electric heater as a prism (Fig. 2), then the analytical formula will have the following form [9]:

$$\varphi_{m-p} = \frac{2}{ab\pi}\left[b\sqrt{a^2+h^2}arctg\frac{b}{\sqrt{a^2+h^2}} + a\sqrt{b^2+h^2}arctg\frac{a}{\sqrt{b^2+h^2}} - -bh\ arctg\frac{b}{h} - ah\ arctg\frac{a}{h} - \frac{h^2}{2}ln\frac{(h^2+a^2+b^2)h^2}{(a^2+h^2)(b^2+h^2)}\right] \tag{2}$$

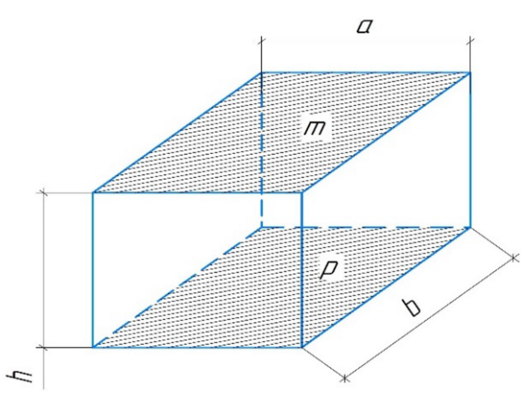


Fig. 2. Model of radiant heat transfer of a piled stack of boards with shields from a film electric heater.

Expression (2) and the corresponding model (Fig. 2) clearly show the relationship between a, b, h parameters. Solving this dependence will help to find the optimal ratio in which the coefficient φ will tend to 1. Knowing the values of a and b, the article considers 1500 mm and 2000 mm, respectively, it is possible to obtain a visual dependence that ultimately shows the most rational distance between the shields in which the boards can be placed.

3 Results and Discussion

Using the Mathcad software product, the function φ (h) is obtained by expression (2) (Fig. 3). It follows from the resulting graph that with increasing values of the parameter h, the irradiance coefficient decreases exponentially. Thus, when drying boards of 25 mm (Fig. 1b), the coefficient φ will be less than when drying boards of 50 mm (Fig. 1a), this means that the distribution of thermal energy in the form of electromagnetic waves will also be less. The difference in the coefficient φ for placing boards of 25 mm and 50 mm is 0.08, in percentage terms it is 8%. The difference is not significant, but in the time frame of the entire wood drying process, which can range from 5 to 30 days, this difference can significantly affect the drying time, the cost of electrical energy, the uniformity of the moisture content of the entire piled stack, as a result, the quality of the final dry product.

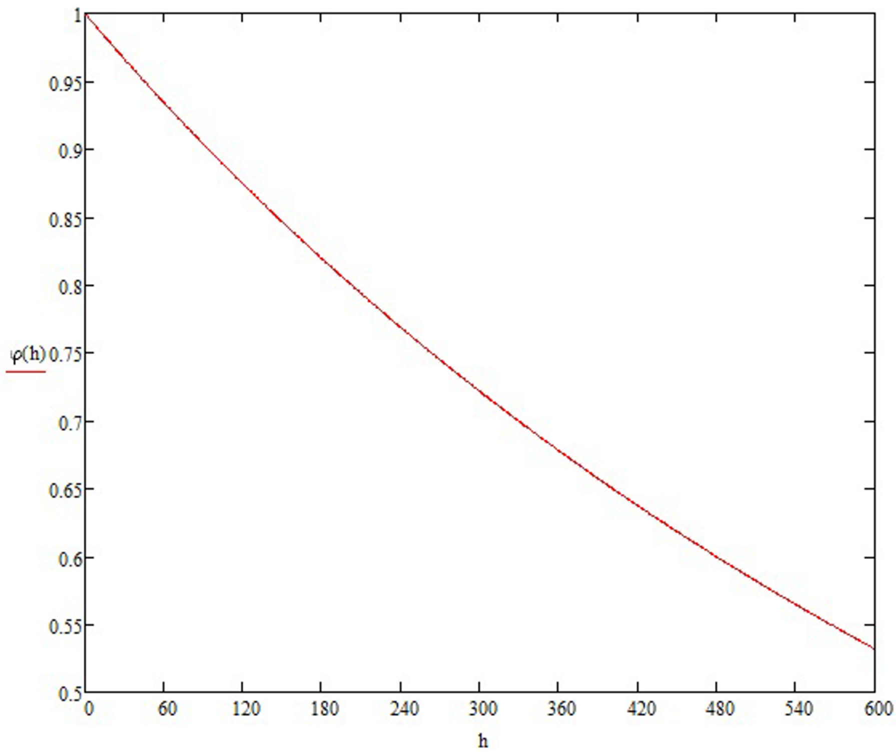


Fig. 3. Dependence of the irradiance coefficient φ on the parameter h.

One of the options for increasing the drying efficiency is to reduce the thickness of the transverse gaskets, which will numerically increase the coefficient φ, but it is important to consider the conditions under which the piled stack will be placed. For example, if it is placed in a chamber from which moisture is removed by means of supply and exhaust ventilation, it is important to consider the mass transfer processes occurring according to the laws of convection directly in the stack. If the piled stack is placed in a vacuum chamber, then in addition to a numerical increase in the coefficient φ, the useful volume occupied by the lumber for drying will also increase.

The second option to increase the drying efficiency is to reduce the number of stacked rows of boards, which will also numerically increase the coefficient φ. Nevertheless, in this case, the specific capacity per unit volume of wood will increase. The advantage of this option should be considered the intensification of the drying process, including faster access to peak values set by the automatic control system. The disadvantages include, firstly, this will lead to an increase in the cost of the entire installation structure due to an increase in the number of actuators, each of which must be equipped with an output cable and connector; switching devices, etc.; secondly, additional shields will take up space, respectively, the balance of the loaded volume of boards to the total volume and the volume occupied by the technological the equipment will be changed for the worse (for chambers based on the principle of moisture removal by convection, this is not significant, but it is significant for vacuum chambers, where compactness is very important, since this will subsequently affect the cost of the entire chamber structure and the performance of the vacuum pump); thirdly, it is not always an increase in exposure (for example, an increase in power) the drying object has a beneficial effect on the quality of the final product, especially when it comes to a biological object [13-17].

4 Conclusion

Further research will be aimed at continuing to identify the relationships between the design and technological parameters of the drying plant using film electric heaters, as well as with the parameters of the drying object (spectral characteristics and electrophysical properties of different types of wood), which will allow to obtain optimal drying modes, including in a discharged environment, allowing to increase the efficiency of using electric energy for dewatering lumber.

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References

1. V.N. Levinskiy, Comparative experiment on the use of a film electric heater for drying wood in vacuum conditions, In the Collection: BIO Web of Conferences. International Scientific and Practical Conference «Methods for Synthesis of New Biologically Active Substances and Their Application in Various Industries of the World Economy – 2023» (MSNBAS2023) (Les Ulis, 2024) 05025.
2. V.N. Levinsky, M.V. Filatov, Scientific and technical Bulletin: Technical systems in agriculture, **2(18),** 20-26 (2023).
3. V.M. Popov, V.N. Levinsky, V.A. Afonkina, On the issue of infrared drying of wood, In the collection: Current trends in agroengineering sciences and innovative technologies in agriculture. Materials of the International Scientific and Practical Conference of the Institute of Agroengineering (Chelyabinsk, 2021) 242-251.
4. Infrared drying of wood UKLS [Electronic resource] Access mode: https://www.tmelekt.ru
5. V.N. Karpov, S.A. Rakutko, *Energy saving in optical electrical technologies of the agroindustrial complex, Applied theory and private techniques* (St. Petersburg: SPbSAU, 2009) 100.
6. V.D. Ochirov, I.V. Altukhov, S.M. Bykova, M.A. Blokhnin, Interaction analysis of the electrotechnological system «emitter-material» in the process of heating and drying of

food plant raw materials, In the Collection: IOP Conference Series: Earth and Environmental Science. III International Scientific Conference: AGRITECH-III-2020: Agribusiness, Environmental Engineering and Biotechnologies. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations, 62006 (2022).

7. V. Popov, V. Afonkina, V. Levinskiy, E. Zudin, E. Krivosheeva, Designing the infrared drying machines of cylindrical type with an active reflector, In the Collection: IOP Conference Series: Earth and Environmental Science. 12th International Scientific Conference on Agricultural Machinery Industry, INTERAGROMASH 2019 012008 (2019).
8. V.M. Popov, V.A. Afonkina, V.N. Levinsky, Bulletin of the Bashkir State Agrarian University, **3(47),** 84-88 (2019).
9. A. Machkashi, L. Banhidi, *Radiant heating, Trans. from hung. V.M. Belyaeva* (Moscow, Stroyizdat, 1985) 464.
10. V.M. Popov, V.A. Afonkina, E.I. Shukshina, A.V. Gorbatko, Electrotechnical systems and complexes, **20,** 343-348 (2012).
11. V.M. Popov, V.A. Afonkina, Izvestiya St. Petersburg State Agrarian University, **32,** 238-241 (2013).
12. V.M. Popov, V.A. Afonkina, A.I. Baranova, Chemistry and Technology of Fuels and Oils, **2,** 503 (2017).
13. V.N. Levinskiy, *Spectral analysis of various types of wood as the basis of low-temperature drying technology in vacuum conditions*, In the Collection: BIO Web of Conferences. International Scientific and Practical Conference «Methods for Synthesis of New Biologically Active Substances and Their Application in Various Industries of the World Economy – 2023» (MSNBAS2023) (Les Ulis, 2024) 05026.
14. V.A. Afonkina, Polythematic network electronic scientific journal of Kuban State Agrarian University, **194,** 12-19 (2023).
15. V.G. Zakhakhatnov, P.V. Kashin, G.D. Kokovin, Agroindustrial Complex of Russia, **25(2),** 400-404 (2018).
16. Sh.G. Zaripov, V.A. Kornienko, News of higher educational institutions. Forest journal, **4(376),** 134-146 (2020).
17. D.I. Deyanov, A.A. Kosarin, S.A. Moiseev, G.N. Kuryshov, Lesnoy Vestnik. Forestry Bulletin, **27(3),** 143-149 (2023). https://doi.org/10.18698/2542-1468-2023-3-143-149