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Electronic-Physical Model Determining the Thermal Conductivity of the Walls of the Device for Rapid Determination of Germination Energy and Germination of Vegetable Seeds

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ABSTRACT The article analyzes data on the creation of an electronic-physical model designed to determine the thermal conductivity of walls made of various bulk or solid materials used in the agricultural sector and construction. At the end of 2023 and the beginning of 2024, during abnormally cold winter days observed in the Republic of Uzbekistan, accidents were observed at many construction sites and in heating networks. In response to this, by decision of the government, practical work was carried out to cover the outer part (facade) of buildings with a special basalt material. The article analyzes studies of one-dimensional heat transfer in a composite cylinder, carried out in a steady-state mode with constant thermal conductivity of the material. In these studies, heat conduction equations were investigated using the results of heat transfer simulation developed using the Ansys software. The electronic-physical model proposed in the article allows you to quickly and accurately measure the thermal and temperature diffusivity of walls made of various materials. Using temperature sensors, it will be possible to intelligently control the electronic-physical model. The article contains detailed engineering calculations and illustrative materials. Internet data were analyzed and specific conclusions were made. The work provided prerequisites for creating an intelligent system for measuring the temperature and thermal conductivity of walls made of various bulk materials.

I. INTRODUCTION

The heat equation is solved and the boundary and initial conditions are specified to obtain the results of the heat transfer simulation developed using Ansys 2023 software. The dimensions, temperatures and convective heat transfer coefficients are entered into Ansys 2023 to obtain the results. This software is used by engineers in all areas of physics, structural modeling, vibration, fluid dynamics, heat transfer and electromagnetic interactions. This study mainly focuses on how the temperature and heat flux change in a composite cylinder [1]. The process of heat transfer through a building wall is complex and dynamic and is carried out by conduction, convection and radiation [2]. For example, during the day, solar radiation hits the outer surface of a wall, some of which is released into the environment and some of which is absorbed and conducted through the material. The inner surface of the wall then exchanges heat with the room air and other surfaces through convection and radiation. These heat transfer methods regulate the indoor air temperature and therefore affect the thermal comfort state. The rate and direction of heat transfer through the building envelope depend on several parameters, including solar radiation, indoor temperature, outdoor temperature, thermal properties of the material, and exposed surface area. The thermal properties of the material that affect the rate of heat transfer are density, thermal conductivity, heat capacity, thermal resistance, U-value, and surface characteristics [2,3]. Besides the thermophysical properties, material thickness affects the heat storage capacity of the wall as well [4,5]. In addition, the orientation of the wall can affect heat gain and loss through the wall and this should be taken into account when designing an energy efficient building envelope [6,7].

II. SIGNIFICANCE OF THE SYSTEM

Many studies are being conducted worldwide to develop new scientific and technical foundations for resource-saving technologies and devices to improve the quality of agricultural seeds. In particular, in this area, research and development work on the creation of improved energy-saving electrical technologies for electrical processing and germination of onion seeds, the development of equipment for their implementation and the substantiation of their parameters are relevant.

III. LITERATURE SURVEY

Research into technological processes of germination of seeds of agricultural crops in an electric field, development and improvement of electrical technologies implementing them were conducted abroad by A.I. Belenkov, A.E. Kozrev, V.I. Khainovsky, Ch.S. Litvinov, V.A. Borisov, T.A. Dvoryashina, S.Kh. Pratik, A. Morillo-Coronado, M. Hozain, L. Kubis, Ya.Ya. Bay, T. Rotcharoen, Forugh Molamofrad, F. Efendi, Barbara Jagos, A. Vujicicka, I. Khatun, R. Hossen, V.M. Ivanov, A.P. Tibirkov, M. Abdelkader, A.N. Dulsky, P.A. Berbert, M.B. Khorynsky and others.

Research in this direction in Uzbekistan was conducted by A. Mukhammadiev, A. Yusubaliev, O. Zh. Primov, H. Egamov, I. Kimsanov, M. O. Kholdorov, A. M. Denmukhammadiev, Zh. M. Kurbonov, Sh. Zh. Yusupov, Sh. M. Muzaffarov and other scientists. The results of these studies are used to a certain extent in agricultural production. However, research on the disinfection and germination of onion seeds by treating them with electric current has not been conducted, given the unique physical and mechanical properties of the seeds. Intelligent systems related to plant health detection in general have also been proposed and many scientific papers have been published on them [8,9,10].

IV. METHODOLOGY

An analysis of the work [11] shows that the section “Heat Transfer in the Stationary Thermal Measurement Method” describes in detail the theoretical calculations for the stationary thermal measurement method. It is also noted here that the transfer of thermal energy occurs simultaneously by conduction, convection and radiation, and that all three types of heat transfer are of interest for measurements. In the general case, in a linear system, the heat transfer process is usually written based on Newton’s law in the form [11]

$$Q = \alpha \cdot F \cdot \Delta t \cdot \tau \tag{1}$$

where Q - heat given (or received) by the body to the environment, J

F - heat exchange surface, m^2;

Δt - the driving force of the heat transfer process, which is the temperature difference between the body and the environment, deg;

τ - duration of the process, sec;

α - heat transfer coefficient, $\frac{W}{m^2}$ deg.

In formula (1) it is meant that it does not reflect the real dependence of heat flow on temperature, physical properties and dimensions of the body and environment, but is a kind of formal technique, with the help of which all the difficulties of calculating heat transfer are transferred to determining the value of the coefficient α, which depends to a lesser extent on F and Δt than Q [11].

Therefore, the coefficient α is the summary heat transfer coefficient:

$$\alpha = \alpha_t + \alpha_k + \alpha_l \tag{2}$$

where α_t, α_k and α_l are heat transfer coefficients by conduction, convection and radiation, respectively.

Heat transfer by thermal conduction takes place when there is a temperature gradient in the body, which is a physical factor that entirely determines the conditions for the occurrence of a heat flow.

The relationship between the amount of heat Q transferred through the surface F during time τ and the temperature gradient $\frac{\partial t}{\partial l}\, l$ is the basis of the Fourier law, the mathematical expression of which, taking into account the direction of the gradient (toward a higher temperature), has the form [11]

$$Q = -\lambda \frac{\partial t}{\partial l} \cdot F \cdot \tau \tag{3}$$

The coefficient of proportionality λ characterizes the body's ability to transfer thermal energy and is called the coefficient of thermal conductivity $(\frac{J}{m} \cdot deg \cdot sec)$.

In the process of thermal measurements, it is necessary to know the finite values of temperature differences, distances along the normal to the isothermal surface, and time intervals. Therefore, for the total amount of heat transferred through a flat wall during the time τ, the following expression is true:

$$Q = \frac{\lambda}{l} \cdot F \cdot (t_1 - t_2) \cdot \tau \tag{4}$$

Here l - wall thickness - the distance between the sections of the body, in which the temperatures t_1 and t_2 are measured, m;

F - wall area through which the heat flux passes, m^2;

τ - time for which the heat flux is measured, sec.

Next value

$$q = \frac{Q}{F\tau} = \frac{\lambda}{l}(t_1 - t_2) \tag{5}$$

is called the specific heat flux or heat flux density. The ratio $\frac{\lambda}{l}$, by analogy with formula (1), can be called the heat transfer coefficient α_t by heat conduction.

When a solid body comes into thermal contact with a flow of liquid or gas, when a temperature difference arises between the body and the medium, a heat transfer process called convective heat exchange occurs. In this type of heat transfer, thermal energy is transferred by moving the material particles of the medium. In addition, convection can be accompanied by thermal conductivity [12].

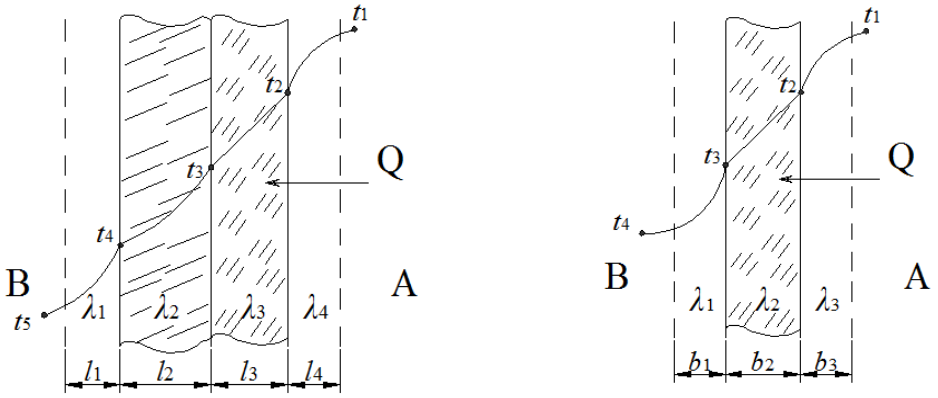
Let us consider the similarity and difference of these processes on the examples of heat conduction through a three-layer wall (Fig. 1, a) and heat transfer through a flat wall, washed by flows from both sides (Fig. 1, (b)). For each layer (Fig. 1, (a)), one can write an equation for the temperature difference using formula (5).

The result will be:

$$t_1 - t_4 = \left(\frac{l_1}{\lambda_1 F} + \frac{l_2}{\lambda_2 F} + \frac{l_3}{\lambda_3 F}\right)\frac{Q}{\tau} \tag{6}$$

The brackets contain the sum of the thermal resistances of the individual layers.

In convective exchange, the wall separates two media A and B (Figure 1 (b)). In this case, we do not know the temperatures on the wall surfaces. We only know the temperatures of the bulk of the liquids on both sides of the wall (t_1 and t_4). In addition to the bulk of the liquid or core, boundary layers are also formed when liquids flow near the wall. The concept of "boundary layer thickness" is quite arbitrary, since there is no sharp transition from the boundary layer to the flow outside the layer. The following boundary layers are distinguished: hydrodynamic and thermal [12].



a) b)

Figure 1. Heat transfer schemes: *a*) — through a multi-layer flat wall;
b) — a flat wall washed by streams on both sides [10].

That is, the entire change in gas (air) temperature (Figure 1, (*b*)) is concentrated in a relatively thin layer. The depth of the boundary layer depends on many factors.

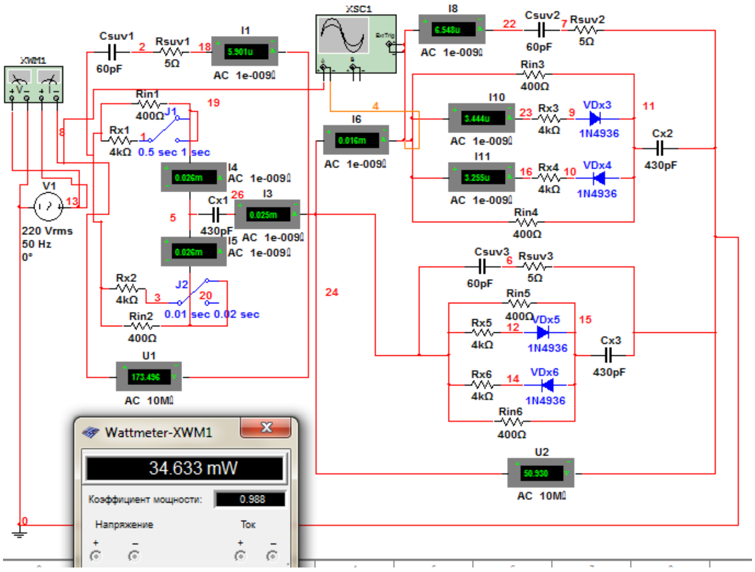


Figure 2. Circuit diagram of a sector-shaped physical model implemented in NI Multisim 10.

C_{water} – electrical capacity of water, $\varepsilon = 81$, R_{water} – electrical resistance of water;

C_x – electrical capacity of an onion cell, $\varepsilon = 2{,}3$, R_x – electrical resistance of the cell (shell); R_{ri} – resistance to infection, $R_{ri} = \frac{R_x}{10}$ It is assumed that;

VD_{x1}, VD_{x2} – "conditional" diode (semiconductor) effect in a cell.

The active power parameter obtained in a single sector-shaped physical model is calculated by multiplying it by 6 for a part of the cylinder, and by 4 for the entire cylinder tank. Calculations obtained from some engineering and experimental results are presented in the following tables and correlation graphs.

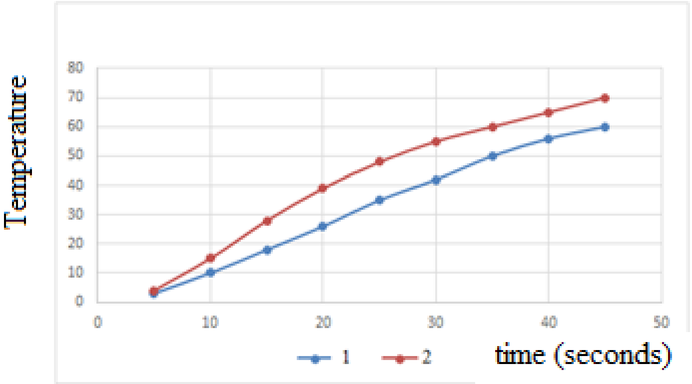
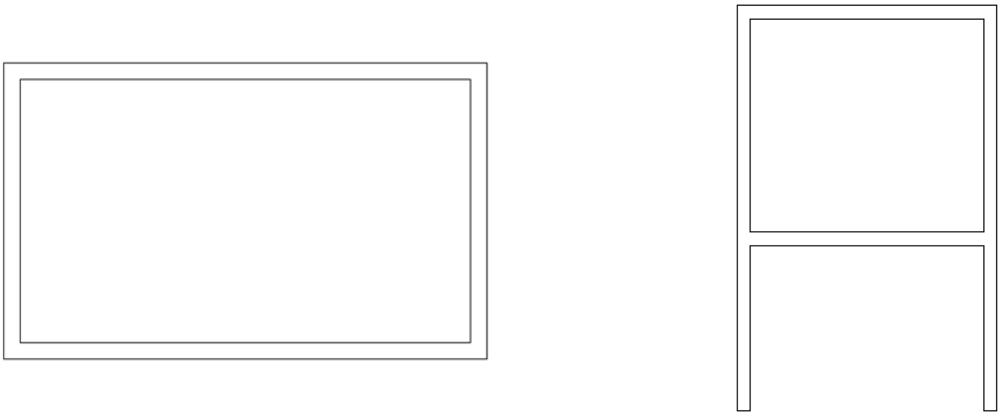


Figure 3. Graph of the dependence of the time of electrical treatment of onion seeds on temperature

V. EXPERIMENTAL RESULTS

Using known methods (table values), we calculate the heat loss of the chamber over the same area.

Let's calculate the heat balance in a chamber surrounded on all sides by room temperature (the linear dimensions of the chamber are shown in Figure 4 below).



a) *b)*

Figure 4. Camera location (diagram): *a*) front view and *b*) side view.

Camera location: dimensions and area – 0.5 m x 0.75 m (0.375 m²); ceiling height compared to a steel floor – 0.5 m; number of external walls – 4; material and thickness of the outer walls - organic transparent glass 0.5 sm thick; number of windows – 4, two with glass (height – 0.43 m, width – 0.43 m); the floor is made of a metal sheet 0.2 sm thick; at the bottom of the floor, above and on the outer surfaces of the windows there is a lower chamber - it is surrounded by room air, the room temperature is on average 18.5 °C. We carry out engineering calculations based on this temperature indicator.

The temperature required for seed germination inside the chamber is $20 - 22$ °C. First, let's calculate the areas of heat transfer surfaces.

Window area F_1 (glass surfaces) (Swindow):

$$F_1 = 2 \cdot [43 \cdot 43 \cdot 10^{-4}] + 2 \cdot [68 \cdot 43 \cdot 10^{-4}] = 0.9546\, m^2.$$

The area of the external walls of the two-layer part of the chamber, excluding windows, is equal to F_2 (Swalls):

$$F_2 = 0.0651 + 0.0826 = 0.1477\, m^2.$$

Floor surface of chamber F_3 (floor):

$$F_3 = 75 \cdot 50 \cdot 10^{-4} = 0.375\, m^2.$$

Ceiling area F_4 (Sceiling):

$$F_4 = 75 \cdot 50 \cdot 10^{-4} = 0.375\, m^2.$$

The area of the internal parts and shelves is not taken into account, since they have the same temperature on both sides and heat does not escape through them. Based on the results obtained above, we calculate the heat loss Q of each surface:

Thermal conductivity (λ) for walls made of carbon steel (2 and 4 mm): $\lambda_1 = 45\, \frac{\mathrm{W}}{\mathrm{m \cdot K}}$, for plexiglass: $\lambda_2 = 0{,}19\, \frac{\mathrm{W}}{\mathrm{m \cdot K}}$.

Heat loss from glass surfaces

$$Q_{windows} = \tau \cdot \Delta t \cdot \frac{\lambda_2 \cdot F_1}{l_2} = 120\, s \cdot 3.5\, K \cdot \frac{0.19\, \frac{W}{m \cdot K} \cdot 0.9546\, m^2}{0.5 \cdot 10^{-2} m} = 15235.4\, Joul$$

Heat loss of two - layer external walls

$$t_1 - t_3 = (\frac{l_1}{\lambda_1 \cdot F} + \frac{l_2}{\lambda_2 \cdot F}) \cdot \frac{Q}{\tau}$$

$$Q_{wall} = \tau \cdot \Delta t \cdot \frac{1}{\left(\frac{l_1}{\lambda_1 \cdot F_2} + \frac{l_2}{\lambda_2 \cdot F_2}\right)} = 120\, s \cdot 3.5\, K \cdot \frac{1}{\left(\frac{0.4 \cdot 10^{-2} m}{45\, \frac{W}{m \cdot K} \cdot 0.1477\, m^2} + \frac{0.5 \cdot 10^{-2} m}{0.19 \frac{W}{m \cdot K} \cdot 0.1477\, m^2}\right)} = 23.57\, Joul$$

We assume that heat loss on the floor surface of the chamber is zero:

$$Q_{floor} = 0$$

Due to convective action, the hot air in the chamber predominantly rises upward. Therefore, we do not take into account heat loss from the floor.

Heat loss in the ceiling area

$$Q_{ceiling} = \tau \cdot \Delta t \cdot \frac{\lambda_2 \cdot F_4}{l_2} = 120\ s \cdot 3.5\ K \cdot \frac{0.19 \frac{W}{m \cdot K} \cdot 0.375\ m^2}{0.5 \cdot 10^{-2} m} = 5985\ Joul$$

In total, the total heat loss of the chamber is:

$$Q_{total} = Q_{windows} + Q_{wall} + Q_{floor} + Q_{ceiling} = 15235.4 + 23.57 + 0 + 5985 = 21243.93\ Joul$$

VI. CONCLUSION AND FUTURE WORK

The studies on the calculation of thermal conductivity of walls in closed rooms are analyzed. In particular, the work presents engineering calculations of heat loss of a small-volume chamber for the prompt determination of germination and energy of germination of vegetable seeds in the initial vegetation of plants. In a small chamber, the temperature necessary for seed germination cannot be achieved immediately. Specific engineering calculations showed that with two-position regulation of the closed chamber load in the initial energy consumption area, losses are within 9,4-10 %. Since additional electrical energy is required to heat the chamber itself.

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