

*Обґрунтована необхідність пошуку рішень проблем ефективного використання енергетичних ресурсів під час процесів тепло- та масообміну, які широко застосовуються в харчовій і переробній промисловості та є дуже енергозатратними. Відзначено перспективність застосування індукованих процесів таких як ефект індукованого тепломасообміну, який характеризується високою енергоефективністю і екологічністю.*

*Проведено моделювання процесів сушіння та гідротермічної обробки вологої сировини з газонепроникними включеннями за її горизонтальної та вертикальної орієнтації. Встановлено, що характер даного ефекту за умов наявності газонепроникних включень в твердій фазі всередині термостата не відрізняється від характеру ефекту індукованого тепломасообміну за умов відсутності таких включень.*

*Доведено, що під час ефекту індукованого тепломасообміну особливості перетікання процесу будь-якого виділеного об'єму внутрішнього середовища термостата відбивається на характері його перетікання для інших виділених об'ємів. Відзначено, що дана ознака «штучності» та керованості даного ефекту робить можливим виконання визначених технологічних операцій з обробки різної сировини в одному апараті без її змішування.*

*Запропоновано технічне рішення апарата із застосуванням ефекту індукованого тепломасообміну для сушіння та гідротермічної обробки вологої сировини з використанням отриманих експериментальних результатів та встановлених теоретичних висновків. Продуктивність розробки за гідротермічною обробкою круп складає 18 кг/год, а енерговитрати –  $8,1 \cdot 10^6$  Дж на кг сушеної продукції. Кінцевою продукцією при цьому є швидковідновлювані каші, які не потребують варіння. Відзначено, що економічна привабливість застосування розробленого апарату з ефектом індукованого тепломасообміну для сушіння та гідротермічної обробки полягає у можливості зменшення енерговитрат на дані технологічні операції на 30 %*

*Ключові слова: ефект індукованого тепломасообміну, сушіння, гідротермічна обробка, кінетика температури, фазовий портрет*

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# DEVELOPMENT OF AN APPARATUS WITH INDUCED HEAT-AND-MASS TRANSFER FOR DRYING AND HYDROTHERMAL PROCESSING OF MOIST MATERIALS

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## 1. Introduction

Problems of efficient use of energy resources in current conditions of their shortage are extremely important issues today. This especially concerns the power-intensive heat-and-mass transfer processes widely used in the food and processing industries [1].

Studies in the line of improving the energy efficiency of the heat-and-mass transfer processes [2] show inexhaustibility and the possibility of further improvement of these processes by intensification [3], reduction of specific energy consumption [4], improvement of equipment and quality of products [5]. Potential opportunities for solving these problems determine the relevance of the studies conducted in this area.

## 2. Analysis of published data and problem statement

One of the urgent problems faced by the industry is the rational use of agricultural products and the reduction of their losses. Cereals are the most common agricultural products. In this regard, the grain processing industry is one of the leaders in the agro-industrial complex [6].

Cereals provide about 60 % of the body's daily protein needs and 40 % of caloric diet content. In this case, cereals make up 8 to 13 % of total grain consumption in the human diet [7]. Recently, semi-finished products of a high degree of readiness [8] which do not require cooking have become very popular. Grain is the stuff for them. Production of semi-finished products of a high degree of readiness from cereals significantly expands the range of dishes prepared from this raw material [9].

Most often, the following methods are used at the processing industry's enterprises for the production of semi-finished products of a high degree of readiness from grain.

Cereals are the raw material for one of the most common methods described in [10]. At the first stage, the grain is humidified and subjected to heat treatment in a temperature range of 110...145 °C. Next, the raw material is tempered and humidified with a decrease in temperature to 70...90 °C. After that, it is flattened to the thickness of flakes, dried, and subjected to forced cooling.

As described in [11], chopped oat kernels are used in other most common methods of production of high-grade semi-finished products. Chopped oat kernels are cleaned and moisturized. Next, they are subjected to hydrothermal treatment in a steaming machine of periodic action at a high steam pressure. After that, they are dried and simultaneously flattened in a roller dryer at a temperature of 150 °C, and the obtained product is cooled. The advantages of these methods include the relative simplicity of the technology of preparing final products. However, the high energy consumption is their disadvantage. The average energy consumption in the process according to these methods is 11...14 MJ/kg of dried products.

There is also a method of obtaining flakes directly from grain [12]. The cleaned grain is immersed in boiling water. Next, the moistened raw material is dried to a certain humidity in a «fluidized bed» with air at a temperature of 100 °C. After that, the raw material is steamed under high steam pressure and re-dried in a «fluidized bed» with air at a temperature of 100 °C. The raw material treated in this way is flattened in plain rolls to obtain flakes dried to the final moisture content. This method disadvantage also consists in a high energy consumption. The average energy consumption in the process using this method is 14...16 MJ/kg of dried product.

Recently, a method of extrusion of raw materials has become quite widespread at enterprises producing semi-finished products of a high degree of readiness [13]. According to this method, grains are processed by heating and extrusion. The extruded product is then ground and mixed with ingredients highly sensitive to temperature. After that, the dry mixture is granulated to obtain wet granules which are finally dried. The advantage of this technology consists in the short time of preparation of the final product. High energy consumption is its disadvantage. The average energy consumption for the process according to this method is 13...16 MJ/kg of dried product.

Thus, each of the described methods includes the process of hydrothermal treatment. The main disadvantage is that energy consumption in this process is higher than that in grain production.

In addition, the end product of the above methods is flakes, powders, or swollen grains. The main disadvantage of such products is that after their recovery, porridges are far from the consistency of the porridges prepared in a traditional way, that is, cooked in water.

A method and apparatus working with the use of the effect of induced heat-and-mass transfer (InHMT) [14] is an option to overcome the above shortcomings, that is, reduce energy consumption and improve the product quality. A quick-recoverable porridge that does not require cooking is the final product of this method. Quick-recoverable porridges obtained by hydrothermal treatment of cereals by means of the InHMT feature high quality. Energy consumption by the apparatus using the InHMT for hydrothermal grain treatment

is  $8.1 \cdot 10^6$  J/kg of dried products. However, low productivity is its main disadvantage. It is impossible to raise its productivity in this design implementation because of an insufficient amount of experimental data on the features of the realization of the InHMT effect. All this suggests that it is appropriate to conduct studies on the nature of the InHMT effect in its various implementations. The obtained results will make it possible to expand the possibilities of using the InHMT apparatuses for hydrothermal treatment and drying not only grain but other moist materials as well.

### 3. The study objective and tasks

The study objective consists in increasing the power efficiency of food, chemical and pharmaceutical industries by applying the InHMT effect to perform manufacturing operations of drying and hydrothermal treatment of moist materials.

To achieve this objective, the following tasks were set:

- to model the processes of drying and hydrothermal treatment of moist raw materials with the use of gas-tight inserts in a horizontal orientation;
- to model the processes of drying and hydrothermal treatment of moist raw materials with the use of gas-tight inserts in a vertical orientation;
- using the study results, design a power-efficient apparatus of continuous action with the use of the InHMT effect to perform manufacturing operations of drying and hydrothermal treatment of moist raw materials.

### 4. The materials and methods used in modeling the InHMT effect

#### 4.1. The materials and equipment used in the experiment

To model the drying and hydrothermal treatment processes using the InHMT effect, the apparatus presented in Fig. 1 was used.

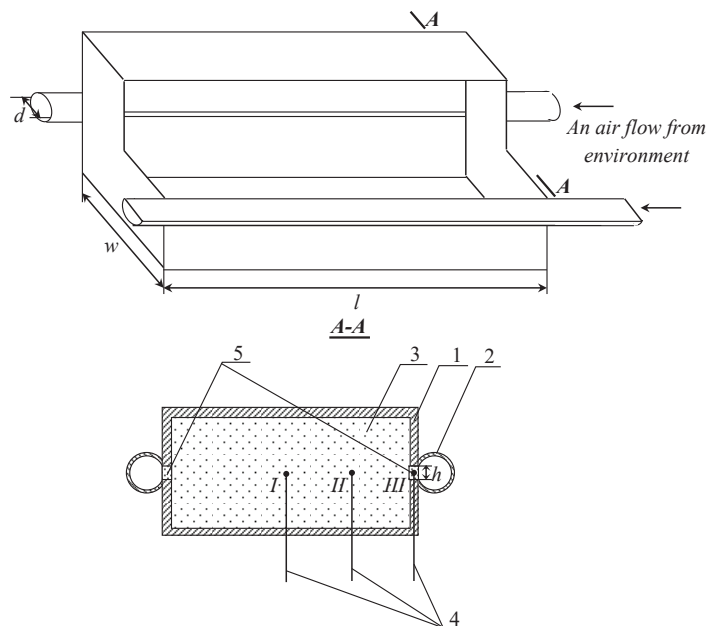


Fig. 1. Sketch diagram of the apparatus for modeling the drying and hydrothermal treatment processes using the InHMT effect; dimensions in mm:  $l = 100$ ;  $w = 20$ ;  $d = 10$ ;  $h = 1$

The notation used in Fig. 1:

- 1 – thermostat;
- 2 – tubes through which air is blown from the environment;
- 3 – moist material consisting of gaseous, liquid, and solid phases;
- 4 – thermocouples;
- 5 – shutters.

Synthetic felt was used in modeling as a moist material (3) inside the thermostat. Layout and dimensions of the felt pieces are given as they were immediately before the experiment described in what follows. The shutter was made of synthetic felt of a chosen thickness. The fluctuation of the gaseous medium in the shutter space was provided by a flow of air blown through the tubes (2). The tubes were fixed on the thermostat surface along the shutters. Thermostating was provided by conductive heat supply from the heating surface to the outer surface of the thermostat.

**4. 2. The procedures used in modeling the InHMT effect**

The nature of the InHMT effect was studied at atmospheric pressure and thermostat temperature of 60...70 °C. The signals from thermocouples were recorded using analog-to-digital and digital-to-analog converters from DCON Utility Co., USA.

The implementation of the InHMT effect was described in detail in [15]. The «start» of the InHMT effect could be judged on proceeding from the nature of temperature kinetics in various points inside the thermostat based on the recorded signals from the thermocouples (Fig. 2).

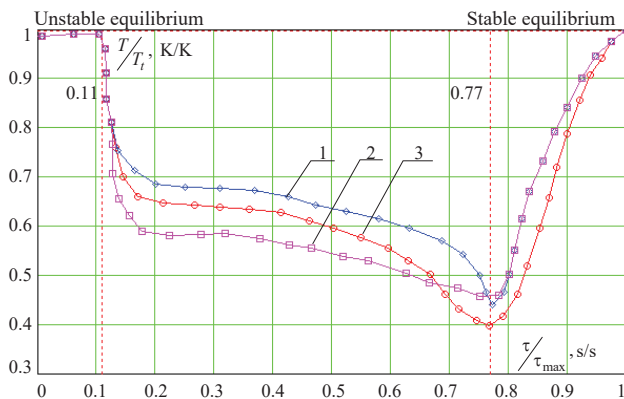


Fig. 2. Kinetics of the body temperature read from thermocouples during the InHMT effect: 1 – I; 2 – II; 3 – III

A drop in the body temperature corresponding to the «start» of the InHMT effect is shown by the first dotted line of the thermogram (Fig. 2). After removal of the liquid phase inside the thermostat (the second dotted line is the minimum of temperature kinetics), the body temperature begins to regain the thermostat temperature. The InHMT effect ends when the mass of liquid in the thermostat becomes zero. This means that the system has reached equilibrium.

To analyze the nature of the InHMT effect, the method of phase portrait described in detail in [16] was used. For greater clarity, the phase portrait of the InHMT effect was given in only two generalized coordinates. The first generalized coordinate is temperature  $T$  of the moist material in the internal medium of the thermostat normalized to the thermostat temperature  $T_{thermostat}$ . The second generalized coordinate is the function  $\Psi(T, w_{evapor})$ . It is equal to the ratio of the energy absorbed by the internal medium of the thermostat to the

energy dissipated by this medium in evaporation. The coordinate  $\Psi(T, w_{evapor})$  was chosen dimensionless in order to obtain a convenient scale to identify the nature of the system behavior and special points of the phase portrait during the InHMT.

In the phase portrait of the InHMT effect, the condition  $dT < 0$  was satisfied during the system evolution between the points of dynamic and stable equilibrium. This means that there was a so-called heat deficit inside the thermostat [15]. It was caused by the fact that energy dissipation in the phase transition of the liquid of the first kind occurred at a higher rate than the heat supply from the thermostat walls. Self-implementation of the dissipative structures occurred in the moist raw material inside the thermostat. In a case of the InHMT occurrence, the temperature increase changed its sign again only if there was a case of an amount of the liquid phase insufficient for further self-implementation of the dissipative structures. This means that the liquid phase in the thermostat has disappeared. At the same time, there was a local minimum of temperature on the way to establishing the thermostat temperature in the system. The example of constructing a phase portrait for the InHMT effect was given as a result of modeling the processes of drying and hydrothermal treatment of moist raw materials with the use of gas-tight inserts.

**5. The results obtained in modeling the InHMT effect in its various implementations**

**5. 1. Modeling the effect of InHMT of a moist raw material with the use of gas-tight inserts in a horizontal orientation**

Modeling of the InHMT effect for raw material with the use of gas-tight inserts was performed in the thermostat shown in Fig. 1. The area of the thermostat walls enveloping its internal volume was  $7.5 \cdot 10^3 \text{ mm}^2$  and the area of the outer surface of the shutters was  $1.9 \cdot 10^2 \text{ mm}^2$ . The ratio between the areas was 40:1. Three rectangular layers of moist material measuring  $95 \times 5 \times 22 \text{ mm}$  were arranged parallel to the heating surfaces as shown in Fig. 3.

Interfaces between the layers of the raw material were artificially provided using a vapor-tight material. To this end, aluminum foil in a form of rectangular  $95 \times 22 \text{ mm}$  sheets was used. The foil thickness was 0.02 mm.

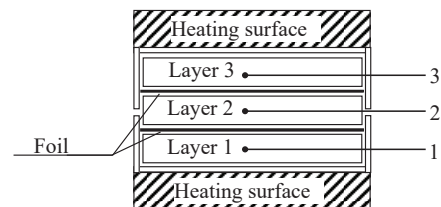


Fig. 3. The layout of thermocouples and sheets of aluminum foil between layers of the moist material in modeling the InHMT in horizontal orientation of the raw material with gas-tight inserts: 1, 2, 3 – thermocouples in respective layers of the moist material

Obviously, penetration of gas or liquid between the layers is only possible through the gaps between the inner surface of the thermostat walls enveloping its internal space and edges of the foil sheets. One layer of the raw material (layer II) is in contact with the environment through the gaps in the ther-

mostat walls. Functions of the shutter are performed by the part of this raw material layer directly adjacent to the gap.

Fig. 4 shows the temperature kinetics of the moist material layers during the InHMT effect according to this experimental implementation.

Temperature kinetics for different layers of the moist material is typical for the InHMT effect. When the material is heated, local temperature attains a maximum value corresponding to the bifurcation point. Then the temperature drops with time and gains the local minimum. At the last conditional stage, the material is heated to the thermostat temperature. The local temperature minimum corresponds to attainment by the model raw material the hygroscopic state corresponding to the final period of the process of heat-and-mass transfer in the thermostat.

As can be seen from Fig. 4, it is layer 2 that attains the local temperature minimum corresponding to the hygroscopic state of the material first. At the same time, a sharp change in the angle of layers 1 and 3 inclination to the axis of the InHMT duration takes place for their temperature kinetics. After a 0.1 fraction of the total process duration, the temperature kinetics of layers 1 and 2 also reach their local minima, that is, these layers reach the hygroscopic state as well. Next, the internal medium is heated to the thermostat temperature. Based on the results of the experiment, it can be seen that different layers have reached an equilibrium moisture content with a difference in duration equal to 10 % of the total duration of the heat-and-mass transfer process even though a vapor-proof barrier was inserted between them.

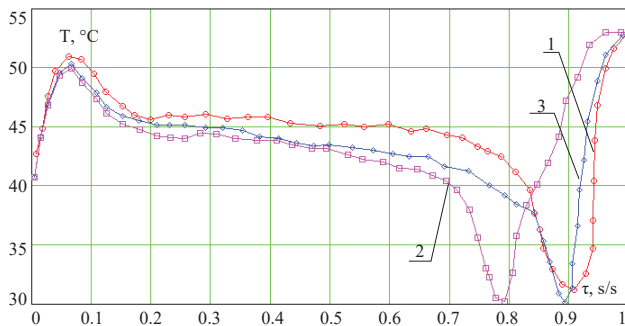


Fig. 4. Temperature kinetics of the wet material layers during modeling of the InHMT effect in horizontal orientation of the raw material with gas-tight inserts: 1 – layer 1; 2 – layer 2; 3 – layer 3

The obtained data confirm the phenomenological hypothesis of the InHMT effect and prove that the interface «environment-internal medium of the thermostat» is within the space of the shutter and the gaseous medium inside the thermostat is continuous.

### 5.2. Modeling the InHMT of wet raw material with gas-tight inserts in a vertical orientation

The InHMT effect was modeled for a horizontal orientation of the wet raw material with gas-tight barrier inserts between its layers. A total of five layers were arranged between which rectangular foil sheets were placed as shown in Fig. 5.

The phase portraits of the InHMT effect obtained for three layers are shown in Fig. 6. The phase portraits were constructed for only three layers since it was proved in the study of this effect [15] that there was a plane symmetry of the InHMT in the heat-and-mass exchange module in a form

of parallelepiped under the same external conditions on its walls with shutters. That is, obviously, the phase portraits of the InHMT effect for layers 1 and 5 coincide. The same applies to layers 2 and 4.

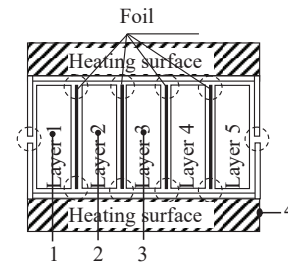


Fig. 5. The layout of thermocouples and sheets of aluminum foil between layers of moist material in modeling the InHMT effect in a vertical orientation of raw materials with gas-tight inserts: 1, 2, 3, 4 – thermocouples

In such implementation of the structure of internal medium in the thermostat, that is, phase portraits of the InHMT effect have certain features with such arrangement of layers of moist material and elements of a vapor-tight material (Fig. 6). The main difference between the above phase portraits and phase portraits for other realizations of the InHMT effect [16] consists in the presence of two loops with a section of the phase path in the negative region of the plane with coordinates  $k_{\Psi} \cdot \Psi(T, w)$  and  $T/T_{\text{thermostat}}$ .

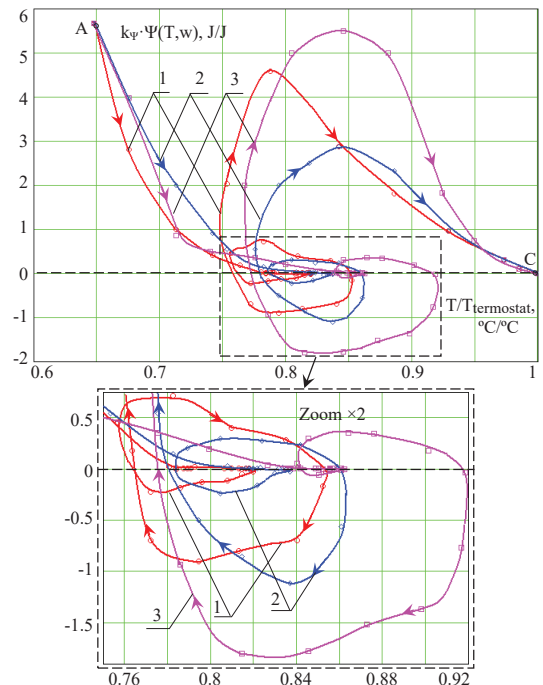


Fig. 6. Phase portraits of the InHMT effect in the vertical orientation of the raw material with gas-tight inserts: 1 – layer 1 and layer 5; 2 – layer 2 and layer 4; 3 – layer 3 (from Fig. 7)

For such implementation of the structure of the internal medium in the thermostat, the system is divided into subsystems. The role of shutters in this study was performed by the parts of moist material adjacent to the gap between the vapor-tight parts of the thermostat (indicated by circles in Fig. 5). That is, at the boundary between the internal medium of



the thermostat and the environment, the role of vapor-tight inserts is performed by walls of the heat-and-mass transfer module which envelope internal space of the thermostat with a gap provided in their surface. In the internal medium, the inner surface of the thermostat walls and the sheets of aluminum foil form such vapor-tight barriers. Slits between the foil sheets and the thermostat walls function as gaps.

**6. Discussion of the results obtained in modeling the InHMT effect in its various implementations**

The phenomenological hypothesis of the InHMT effect was proved by modeling the processes of drying and hydrothermal treatment of moist raw material with gas-tight inserts in a horizontal orientation by means of the InHMT. Namely, its theses are as follows:

- the interface «environment-internal medium of the thermostat» is within the shutter space;
  - the gaseous medium inside the thermostat is continuous.
- The following is meant by the above.

The internal space of the thermostat (in which the InHMT effect takes place) is enveloped by its inner walls made of a vapor-tight material having a high thermal conductivity. The inner walls of the thermostat are the surfaces through which heat exchange with its internal medium is realized, that is, they are heat-exchange surfaces. The internal medium of the thermostat is contacting with the environment through the shutters provided in the inner walls of the thermostat. The required condition for the thermostat design is that the heat exchange areas must be at least an order of magnitude larger than the outer area of the thermostat shutters [15]. The thermostat is technically implemented as a heat-and-mass transfer module. The determined heat capacity of this module walls (in accordance with the conditions necessary for the implementation of the InHMT effect) is provided either by the heat capacity of the environment in which the module is installed or by the heating surfaces contacting with the module walls.

It is obvious from these requirements that the shutter volume is the mass transfer interface «environment-internal medium of the thermostat». The gaseous medium inside the thermostat is considered to be continuous at the partial pressure of the liquid vapor.

In this case, dimensions, design of internal space of the thermostat, methods, and the degree of filling with the raw material are the parameters that determine initial requirements for designing the devices using the InHMT effect.

By modeling the processes of drying and hydrothermal treatment of moist raw materials with gas-tight inserts in a vertical orientation by means of the InHMT, the following was established. The thermostat with layers of moist material and sheets of aluminum foil placed inside it (Fig. 5) can be considered to be in-series and in-parallel connected conventional thermostats. The conventional equivalent diagram of such a connection of thermostats is shown in Fig. 7.

The occurrence of fluctuations in volume concentration of water molecules of the internal thermostat continuous gas medium in a shutter at the interface «environment-internal medium of the thermostat» causes fluctuations in the concentration of water molecules of the continuous gas medium inside the thermostat. Accordingly, fluctuations also take place in shutters at the interface between conditional thermostats. Based on this, the «start», «breakdown», «running» or «end» of the InHMT effect in any of the conditional ther-

mostats will affect the nature of the heat-and-mass transfer throughout the entire system. This statement is clearly confirmed by the phase portraits shown in Fig. 6.

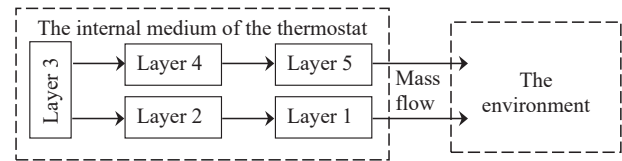


Fig. 7. Equivalent block diagram of the interior of the thermostat from Fig. 5

In the given phase portraits of the InHMT effect for each layer of moist material (for a conditional thermostat), there are two loops with a section of the phase path in the second quarter of the phase plane. The phase path in this part of the phase plane has a negative sign in the coordinate  $k_v \cdot \Psi(T, w)$ . This section of the phase path (in the negative plane) corresponds to the InHMT effect. It should be assumed that the first loop occurs through the «start», «running» and «end» of the InHMT effect obviously in layers 1 and 5. The shutters of these layers of moist material are located at the interface «environment-internal medium of the thermostat». The second loop occurs due to running of the InHMT effect in internal conditional thermostats, that is, in layers 2, 3 and 4.

Thus, there is a split of the phase portrait of the InHMT effect in this dynamic system under the conditions of experiment implementation, namely:

- for the given implementation of the structure of internal medium of the thermostat (in-series connection of conditional thermostats);
- for the given properties of the material from which the shutter and layers of the model raw materials are made;
- for the given energy of the airflow moving relative to the shutters.

The presence of a two-level split (absence of a three-level split) under the condition of three in-series connected conventional thermostats is explained as follows. According to the phenomenological hypothesis of the InHMT effect [15], the mass flow in the space of shutters is «induced» by a temporal  $\left(\frac{\partial x_{ind}}{\partial \tau}\right)$  and spatial  $\left(\frac{\partial \langle n_{ind} \rangle}{\partial x_{ind}}\right)$  fluctuations, the limit

values of which are determined by the energy of activation of the InHMT effect. During the sequential transition between conditional thermostats, the power of fluctuations decreases due to the dissipation of their values in the thermostat space. Obviously, if the volume of temporal and spatial fluctuations relative to the limit values (required for «start» and «running» of the InHMT effect) reduces in the next shutter, the InHMT effect in this next conditional thermostat will not «start». Accordingly, the «start» of the InHMT in this next shutter is only possible if the conditions necessary for its implementation are fulfilled.

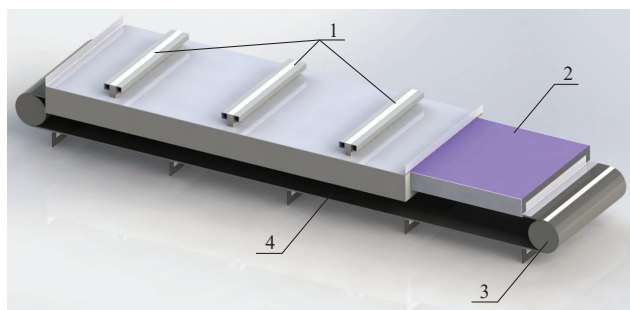
If the system moves in one of the evolution ways under the constant external influence on it, then the following is possible. Necessary conditions for «starting» or «re-starting» of the InHMT effect in the next conditional thermostat from the in-series connected set start to be fulfilled due to the reduction of dissipation of power fluctuation in the previous conditional thermostats. The dissipation of temporal and spatial fluctuations can be reduced by reducing the amount of liquid phase for which phase transition of the first kind is

possible under these conditions. It is this path of the system evolution that is shown in the phase portrait shown in Fig. 6.

Another way to «start» the InHMT effect in a conventional thermostat from an in-series connected set consists in a change of external influence on the system so that the necessary requirements begin to be met. One of the ways consists in increasing the flow of environmental air moving relative to the outer surface of the shutter. However, the increase in the flow energy can violate the necessary requirements for the shutter properties. In addition, this also entails additional energy consumption. Thus, during any external influence on the system, the necessary conditions for its implementation must be met in order to realize the InHMT effect.

The nature of the InHMT effect in this study is the same for all individual volumes of the internal space of the thermostat and the special points for them must be synchronous. The obtained data prove that there is a «directionality» of the nature of the heat-and-mass transfer process when the InHMT effect is running. The «directionality» means that peculiarities of the flow of any selected volume of the internal medium of the thermostat affect the nature of its flow for other allocated volumes. Such behavior is characteristic only of a continuous medium. It should be noted that the presence of «directionality» of the heat-and-mass transfer process is another sign of «artificiality» and controllability of the InHMT effect. This property expands the potential use of this method in practice. It is possible to use this feature of the InHMT effect to perform manufacturing operations in processing various raw materials in one device without their mixing.

Using the obtained experimental results and theoretical conclusions to them, a technical solution for the apparatus with the application of the InHMT to drying and hydrothermal treatment of moist raw materials was elaborated. The general view of the working structural unit of the device is presented in Fig. 8. The structural unit means an autonomous part of the apparatus in which drying or hydrothermal treatment of moist raw materials is carried out. The productivity of the device can be varied by changing the number of such structural units that have a certain overall size, certain productivity, and energy consumption for processing.



**Fig. 8. General view of the working structural unit of the apparatus using the InHMT effect for drying and hydrothermal treatment of moist raw materials:**  
1 – shutters; 2 – moist raw material; 3 – horizontal conveyor; 4 – heating surface

The principle of operation of the device is as follows. Moist raw material 2 is drawn by a horizontal conveyor 3 through a rectangular shaft. In the upper part of the shaft, there are shutters 1 along which air is blown at a certain speed. Heat is supplied to the raw material from the heating surface 4 through the lower part of the shaft. The speed of the conveyor

belt is determined by the type and moisture content in the raw material to be dried or hydrothermally treated, temperature, and quality requirements for the final product. The productivity of the given working structural unit in hydrothermal processing of cereals makes 18 kg/h and the energy consumption is  $8.1 \cdot 10^6$  J/kg of dried product. The final product is a quick-recoverable porridge that does not require cooking.

It is necessary to note the versatility of the developed device using the InHMT effect. It lies in the possibility of using a single device to perform both drying operations and hydrothermal treatment of moist raw materials. The economic attractiveness of using the developed device with the InHMT effect for drying and hydrothermal treatment consists in the ability to reduce energy consumption for these manufacturing operations by 30 %.

The study limitation consists in the lack of experimental data on the nature of the InHMT effect in the presence of solid, liquid, and gas phases inside the thermostat with gaps between phases. Prospects for further studies in this area include modeling of the InHMT effect in the presence of gaps between phases the volume of which is proportional to the internal volume of the thermostat. Prospects for further applied studies include an adaptation of the developed apparatus to various types of raw materials subject to hydrothermal treatment or drying in production.

## 7. Conclusions

1. It was proved by modeling of the processes of drying and hydrothermal treatment by means of InHMT of moist raw materials with gas-tight inserts in a horizontal orientation that the interface «medium-internal medium of the thermostat» is in the space of the shutter. It was proved that the gaseous medium inside the thermostat is continuous during the InHMT effect. It was established that the nature of this effect in the presence of gas-tight inserts in the solid phase inside the thermostat does not differ from the nature of the InHMT effect in the absence of such inserts.

2. The presence of splitting of the phase portrait of the InHMT effect in the dynamic system under given conditions of its implementation was established by modeling the processes of drying and hydrothermal treatment of moist raw materials with gas-tight inserts in a vertical orientation by means of the InHMT. It was proved that during the running of the InHMT effect, peculiarities of the flow of any volume of the internal thermostat medium affect the nature of this flow for other volumes. It was noted that this feature of «artificiality» and controllability of the InHMT effect makes it possible to perform certain manufacturing operations for processing different raw materials in one device without mixing them.

3. A technical solution on an apparatus with the application of the InHMT effect to drying and hydrothermal processing of damp raw materials was elaborated based on the obtained experimental results and the established theoretical conclusions. It was established by calculations and experimental studies that productivity of hydrothermal treatment of cereals is 18 kg/h and the energy consumption is  $8.1 \cdot 10^6$  J/kg of dried products. The final product is a quick-recoverable porridge that does not require cooking. The economic attractiveness of using the developed device with the InHMT effect for drying and hydrothermal treatment consists in the ability to reduce energy consumption for these manufacturing operations by 30 %.

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