Conference Paper

Improvement of Structural and Technological Parameters of the Innovative Type Climate Chamber

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Abstract

While studying the influence of the parameters, characterizing heat removal from the working medium of the chamber, on operational characteristics of the experimental installation, the values of the amperage supplied to the thermoelectric module were being varied from 1.4 to 4.2 A, as well as the degree of chamber adiabaticity was being altered by changing the number of extruded polystyrene foam plates 20 mm thick in the build-up chamber cover from one to 3. The dynamics of the working medium temperature change depending on the amperage supplied to the thermoelectric module is illustrated by graph dependencies. As a result of data processing by constructing the second order orthogonal central composition plan the adequate regression equation was received for the cooling process and the thermo stating of the climate chamber working medium and the conclusion on a rational number of the chamber cover plates (which equals 3) was made. It was found out that upon increasing the amperage supplied to the thermoelectric module and using a three-plate cover the experimental chamber working medium temperature is varied from - 2°C to 11°C, this can be applied for cooling and thermo stating various objects including biological raw materials of both animal and plant origin as well as non-food objects.

Keywords: thermoelectric module, chamber working medium temperature, degree of chamber adiabaticity.

1. Introduction

Nowadays there are a great number of various manufacturers' climate chambers having different metrological and technical specifications. Several types of chambers may be distinguished, which create certain conditions depending on the purpose: a chamber of heat, a chamber of cold, a chamber of moisture, combined chambers, a chamber of rain and dust, high temperature chambers, shock freezing chamber, test chambers for special purpose.

At present people pay great attention to problems of food security, to implementation of the processes of modernization, diversification and globalization of eating behavior; at the same time an intensive growth in the refrigeration equipment market is in progress [1--4]. These trends can underlie the idea of implementing an energy-efficient way of storing food products, i.e. the use of climate chambers with required technical characteristics [5] for this purpose.

The use of traditional compressor circuits in climate chambers is energy-consuming. Reducing the cost of service can be reached by using Peltier cooling modules. The main advantage of thermoelectric cooling is cooling to temperatures well below the ambient temperature combined with unique small dimensions of the thermoelectric elements [6--8]. The most essential advantages of constructing cooling systems and thermal stabilization with the use of thermoelectric elements [7--9] are:

- lack of moving wearing parts, lack of vibration and noise;
- average time of trouble-free running hours is at least 200000 hours (time between failures);
- high cooling capacity per one unit of weight and volume -- up to 150W/gr and 100 W/cm^3;
- possibility of smooth and high- precision regulation of cooling capacity and temperature;
- low inertia, fast transition from cooling to heating mode;
- lack of working liquids and gases;
- practically unlimited service life;
- arbitrary orientation in space and in the gravity field;
- resistance to dynamic and static overloads;
- environmental cleanliness.

On the basis of the foregoing, it was decided to formulate the main areas of scientific work as follows:

- study of the degree of influence of the amperage supplied to the thermoelectric modules on the intensity of the cooling processes of the experimental climate chamber working medium;
- study of the degree of influence of the climate chamber system adiabaticity level on the intensity of the working medium cooling processes;

- development of optimal design and technological parameters of the experimental climate chamber;
- formulation of recommendations for the experimental climate chamber operation.

2. Methods and Equipment

2.1. Methods

The objects of the study in this work are the experimental installation of an innovative type [10] climate chamber and the climate chamber working medium which was obtained by removing heat from air moisture using thermoelectric modules on Peltier elements. The analytic and experimental researches were sequentially carried out and as a result, the design parameters of the innovative type climate chamber and working medium rational options of the chamber were scientifically substantiated.

In order to develop a technology for obtaining the climate chamber working medium it is necessary to determine the modes of its production close to the optimal ones, and respectively the chamber design, at which the working medium will be characterized by the properties providing the possibility of using the climate chamber according to its intended purpose.

The experimental installation that is the innovative type climate chamber consists of the following modules:

- a chamber with useful volume of 21dm^3 , carrying a build-up cover of varied thickness depending on the number of the plates used;
- a cooling module, composed of thermoelectric modules [6--8], aluminum radiators (total heat transfer surface is 0.592 m^2) and two fans with 88 m^3/hour capacity to intensify heat and cool removal from the top and bottom sides respectively;
- a DC source with two regulated outlets, which provides possibility for varying the parameters of amperage and voltage supplied to the cooling module.

As to the design, the mixing chamber is a rectangular casing made up of eight layer plates mounted on a metal frame: an aluminium foil layer of 0.5 mm, a high pressure foam layer laminated with metallized lavsan film of 3 mm, a silicone sealant layer of 3mm, ceramic insulation of 15 mm, an extruded polystyrene foam plate of 20 mm,a ceramic insulation of 15 mm, a silicone sealant layer of 3 mm, an aluminium foil layer of 0.5 mm. The total ratio of the chamber wall heat transfer is 0.002W/(mK).

The installation has a build-up cover with a technological opening provided for mounting the cooling module.

The general view of the installation is shown in Figure 1, the following elements are indicated by the positions: 1- a temperature sensor, that indicates the temperature on the outer side of a chamber wall; 2 -- a build-up chamber cover (3 plates); 3 -- an outer radiator of the cooling unit (module); 4 -- an outer fan of the cooling unit (module); 5 -- a DC source; 6 -- a thermo hygrometer IVA; 7 -- a four channel automatic temperature recorder; 8 -- a temperature sensor fixing the air temperature in the laboratory.

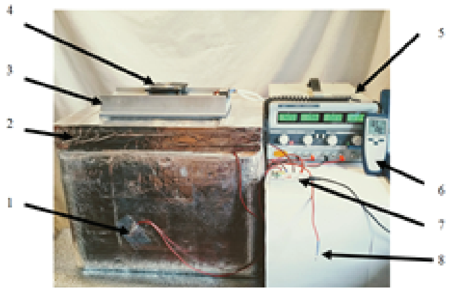

Figure 1: General view of the experimental installation.

The amperage and voltage supplied to the thermoelectric modules (TEM) were varied from 1.4 to 4.2 A and from 6.6 to 19.8 V, during the experiment the parameters of amperage and voltage supplied to the fans were fixed at the level of 0.23 A and 23.4 V respectively.

The chamber working medium temperature was measured by the four channel automatic temperature recorder, comprising temperature sensors MF52AT 10 k OM ntc-thermistor-resistor tolerance G; thermo hygrometer IVA-6A-KP-D meeting the requirements of TC (technical conditions) 4311-011-77511225-2010 and duly verified, the number in the RF State Register is CI 46434-1.

3. Results

The research of the influence of the parameters characterizing heat removal from the chamber working medium on the installation operation specifications while using the thermoelectric modules (TEM) were carried out according to the plan below.

In the course of studying the influence of the parameters characterizing heat removal from the chamber working medium on the installation operation specifications the values of the amperage supplied to the TEM were varied on the one hand as well as the chamber adiabaticity by changing the plate's number of the build-up chamber cover on the other.

When carrying out the experimental researches the cooling unit assembled of thermoelectric modules TV-127-1.4-2.0 [6--9, 11, 12], radiators with extended heat transfer surface, fans for effective removal of heat generated from the hot side of the TEM and for exciting the forced convection mode in the chamber gas medium to intensify the cooling process.

When conducting the series of the experiments in question for changing the value of the amperage supplied to the thermoelectric module, a DC source with varied amperage and voltage was used.

Depending on the chosen conditions of the experiment the climate chamber working medium parameters were being varied.

In the first series of the experiments the amperage supplied to the TEM was varied from 4.2 to 1.4 A and at fixed degree of the system adiabaticity the chamber cover with one extruded polystyrene foam plate 20 mm thick was used.

The dynamics of the working medium temperature change depending on the amperage supplied to the thermoelectric module is illustrated by the graph dependencies shown in Figure 2.

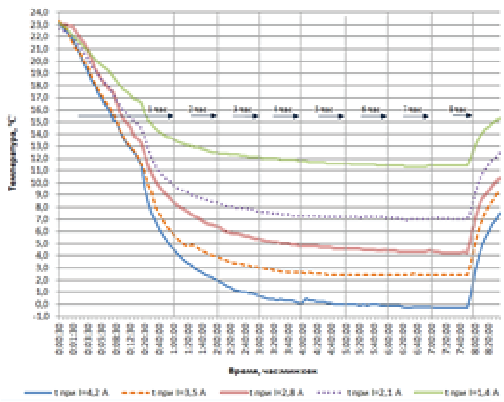

Figure 2: Dynamics of the chamber working medium temperature change when varying the amperage supplied to the TEM.

In the second series of the experiments the amperage supplied to the TEM was varied from 4.2 to 1.4 A at fixed degree of the system adiabaticity the chamber cover with two extruded polystyrene foam plates 20 mm thick was used.

The dynamics of the working medium temperature change depending on the amperage supplied to the thermoelectric module is illustrated by the graph dependencies shown in Figure 3.

In the third series of the experiments the amperage supplied to the TEM was varied from 4.2 to 1.4 A at fixed degree of the system adiabaticity the chamber cover with three extruded polystyrene foam plates 20 mm thick was used.

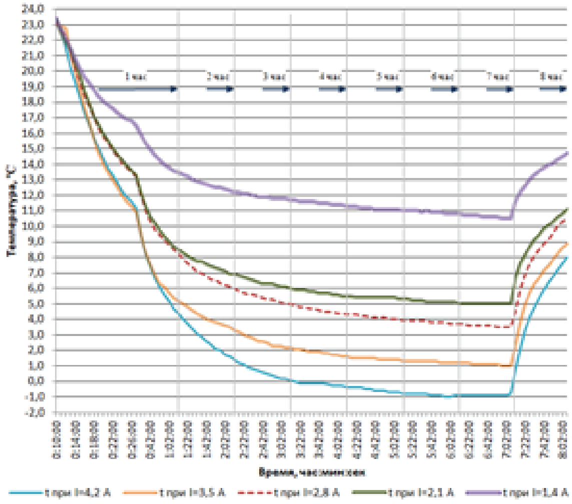

Figure 3: Dynamics of the chamber working medium temperature change when varying the amperage supplied to the TEM.

The dynamics of the working medium temperature change as well as the change of the chamber surface temperatures depending on the amperage supplied to the thermoelectric module is illustrated by the graph dependencies shown in Figure 4.

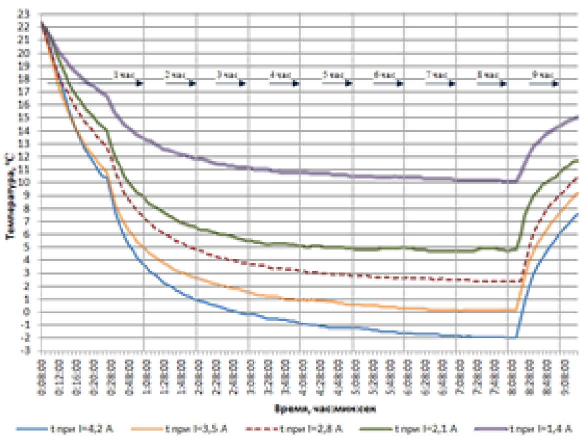

Figure 4: Dynamics of the chamber working medium temperature change when varying the amperage supplied to the TEM.

4. Discussion

The analysis of the research results illustrated by the above graphical dependences allows making the conclusion) that an increase in the system adiabaticity degree and allowed achieving a lower temperature of the chamber working medium at a constant amperage supplied to the TEM.

The dependence of the chamber working medium temperature on the influencing factors can be expressed by the function:

$$Y = f(n, I) \tag{1}$$

where *n* -- the number of the chamber build-up cover plates; *I* -- the amperage supplied to the thermoelectric modules, A.

The mathematical modeling of the cooling process and climate chamber working medium thermo stating with varying the adiabaticity degree of the chamber thermodynamic system and cooling capacity when using the thermoelectric method of cooling, was conducted as follows.

The determination of the rational parameters of the cooling process and of the climate chamber working medium thermo stating in the first case was performed by constructing the second order orthogonal central composition plan. A method like this one allows making up a response function in the form of a full quadratic polynomial, with the number of influencing factors n = 2. A full quadratic polynomial has the following view [13, 14]:

$$Y = B_0 + B_1 X_1 + B_2 X_2 + B_{12} X_1 X_2 + B_{11} {X_1}^2 + B_{22} {X_2}^2 \tag{2}$$

As the influencing factors the following parameters were taken: X_1 -- the plate number of the chamber prefabricated cover; X_2 -- the amperage supplied to Peltier elements, I, A. The factor space area was limited by the following values of the influencing factors: for X_1 -- from 1 to 3, step 1, for X_2 -- from 1.4 to 4.2 A, step 1.4 A

The number of experiments is $2^2+2\cdot x^2+1=9$. In order to minimize possible mistakes each experiment was carried out at least 3 times. The deviation was not more than 5 %.

As a result of data processing, the following regression equation for the cooling process and the climate chamber working medium thermo stating was obtained:

$$Y = 23,307 - 1,840 \cdot X_1 - 8,597 \cdot X_2 + 0,280 \cdot X_1 \cdot X_2 + 0,860 \cdot {X_1}^2 - 0,079 \cdot {X_2}^2 \tag{3}$$

The regression equation adequacy was checked by means of the Fisher criterion using a program of scientific and engineering calculations ``Datafit Ver. 8.2''. The numerical values of the regression coefficients were tested for significance by comparing the calculated and table values of t - Student criterion considering the accepted level of significance of α = 0.05. The calculated value of the Fisher criterion F= 120.43; the determination coefficient is R^2 = 0.985. The comparison of the Fisher criterion calculated value with the tabular one allows making a conclusion on the model adequacy and static significance of the regression coefficient (equation).

The response surface of the factor space is shown in Figure 5. The possible deviations are marked by dots on the graph.

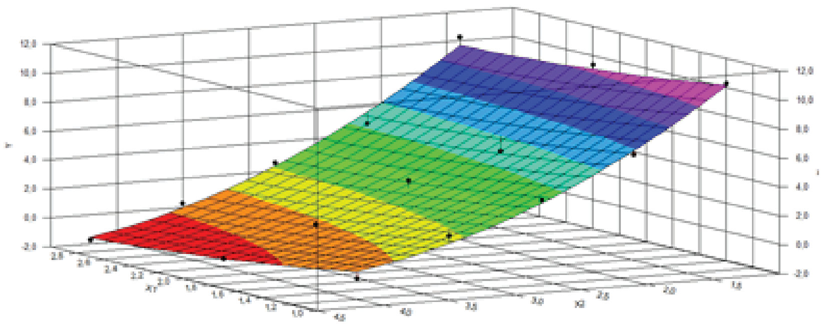

Figure 5: Factor space response surface for the cooling process of the climate chamber working medium.

Thus, the rational parameters of the working medium cooling process are experimentally determined. The data are given in Table 1.

TABLE 1: Rational parameters of the climate chamber working medium cooling process.

Object	The amperage supplied to TEM	The number of the chamber build-up cover plates
Climate chamber working medium	In the range of 4.2 to 1.4 A depending on the temperature modes of storing objects to be cooled	3

In the course of the experimental study the data were obtained, based on which we can conclude that the designed climate chamber being designed depending on the level of the amperage supplied to the TEM can maintain the working medium temperature in the range of -2°C to +11°C, that is why the options of its application are rather variable.

The chamber being designed can be used for cooling and thermo stating various objects including biological raw materials of both animal and plant origin as the temperature conditions of many food products storage correspond to the temperature range from -2°C to +11°C in accordance with Sanitary Rules and Regulations 2.3.2.1324-03 ``Hygienic requirements for shelf life and storage conditions of food products''.

The climate chamber can also be used for storing any non-food objects requiring the temperature maintenance in the given range.

It is possible to get closer to solving the problem of ensuring a guaranteed and sustainable supply of safe and quality food to population continuing the study aimed at searching for optimal physical influence on the climate chamber working medium with the purpose of its cooling and thermo stating at a preset level. In particular, in the course of the further work, an ultrasonic generator of water aerosol is supposed to be integrated into the installation design as the chamber working medium moisturizing unit, the average value of mass-median aerodynamic particle diameter of an aerosol particle being 4 mkm [15].

5. Conclusion

In the given work the methods of heat removal from the climate chamber working medium have been considered, the rational (within technical possibilities of the used experimental equipment) chamber operation modes for intensification of the cooling and thermo stating processes are identified. As a result of the research conducted it is possible to make the following conclusion:

1. The structural and technological parameters of the experimental climate chamber have been determined. They are: dimensions, the effective combination of heat insulation materials, providing the acceptable degree of the climate chamber system adiabaticity. The chamber operation temperature range from -2°C to +11°C has been fixed.

2. It was found out that increasing the amperage supplied to the TEM of the climate chamber cooling system up to 4.2 lowers down the chamber working medium temperature to -2°C.

3. It has been found out that in case of using the thermoelectric modules for cooling the working medium the increase of the system adiabaticity degree allows obtaining lower temperatures of the medium at the constant amperage.

4. The rational modes of the chamber working medium cooling were offered: the amperage supplied to the TEM must be from 1.4 to 4.2A depending on the purpose of the climate chamber application, the plate number of the build-up cover must be 3.

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