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A DEVELOPMENT OF THE EXPERIMENTAL HEAT EXCHANGER FOR OBTAINING ENERGY FROM PHASE TRANSITION WATER-ICE

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ABSTRACT

In this article, the functional and technological scheme of experimental installation for receiving energy of phase transition water-ice is described. For assessment of initial requirements to the heat exchanger for receiving energy of phase transition water-ice and at its design pilot studies on heatphysical and electrophysical parameters of the heat carrier (salt solution of water) which were executed with use of electrophysical impact – an electromagnetic field of the 800 W super-high frequency, magnetron frequency 2450 MHz, and electro-hydro pressure by strength of 35-46 kV, electric capacity 0.2 microfarad are executed. Initial requirements to the heat exchanger are developed for receiving the energy of phase transition water-ice for heating of an agricultural object of 100 sq.m.

Disciplinary: Energy Sciences, Physics (Thermodynamics).

1. INTRODUCTION

The carried-out patent search showed the development of a design of the thermal pump and obtaining energy of phase transition water-ice – topical issues. Patent search in the VOIS website showed that now researches on the use of energy of phase transition water-ice are conducted, so, in Russia 258 patents on this subject are taken out. The European Patent Office specifies that the countries showing interest (in the percentage of the taken-out patents) that China is the highest 58% while Korea, UK, and Germany equally (Figure 1).

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This research objective is to develop initial requirements for the heat exchanger of experimental installation for obtaining energy of phase transition water-ice.

2. FUNCTIONAL AND TECHNOLOGICAL SCHEME OF THE EXPERIMENTAL EXAMPLE OF THE HEAT-EXCHANGING EQUIPMENT

The experimental example which excludes the need for difficult and expensive mounting of external underground or underwater heat-exchanging circuits is developed.

On the basis of an energy-saving system, the functional and technological scheme of experimental installation is developed for receiving energy of phase transition water-ice (Figure 2) (Vasiliev et al, 2018).

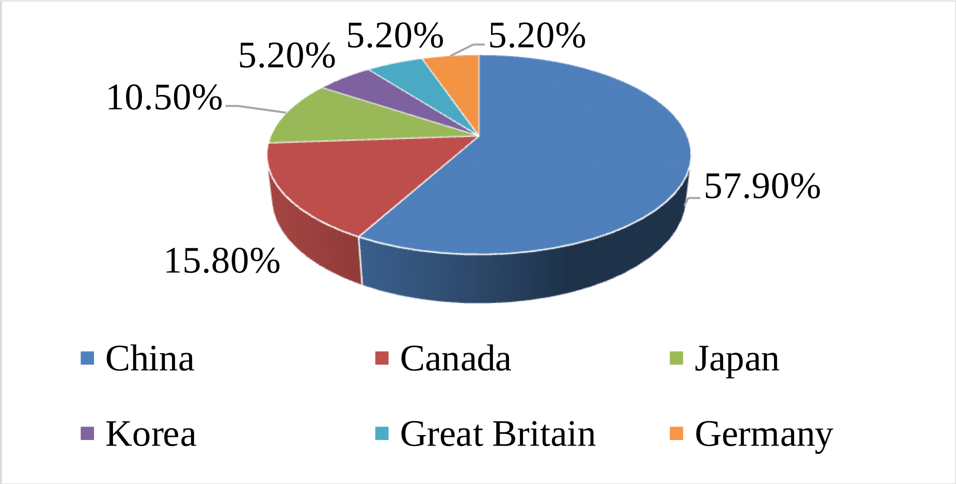

Figure 1. Distribution of the taken-out patents over the countries for use of energy of phase transition water-ice.

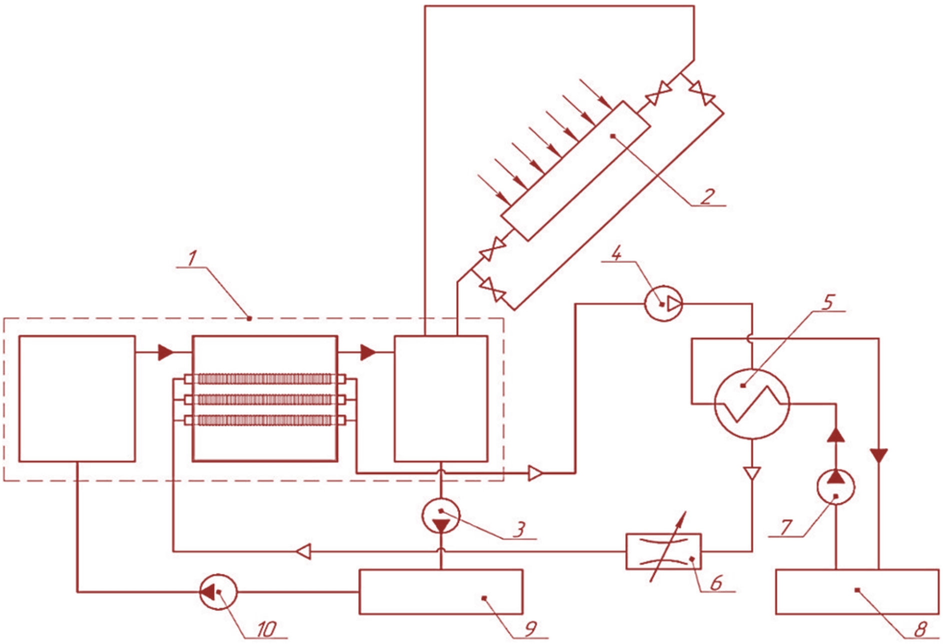

Figure 2: Functional and technological scheme of the heat-exchanging equipment: 1 – the heat exchanger with additional capacities for electrophysical processing of salt solution and for collecting ice, 2 – a solar collector, 3, 7, 10 – the circulation pump, 4 – the compressor, 5 – the condenser, 6 – the throttle gate, 8 – the consumer is warm, 9 – the consumer of cold.

Coldwater is used, for example, for cooling of milk after pasteurization as the consumer of cold (Vasilev & Tutunina, 2018).

3. PILOT STUDIES IN HEATPHYSICAL AND ELECTROPHYSICAL PARAMETERS OF THE HEAT CARRIER

The carried-out state-of-the-art review of the existing data of dependence of heat physical properties of the solutions which are exposed to electrophysical impacts allowed drawing the following conclusion. Heatphysical parameters heat carriers (freezing temperature, thermal diffusivity, solubility of salt, density) – water and salt solutions of various concentration and also electrophysical parameters (for example, specific conductivity), change at external electrophysical processing, for example, at influence of electric field (including electrofreezing), magnetic field (Chubik & Maslov, 1970; Vasilev & Tutunina, 2018; Dykstra, 1999).

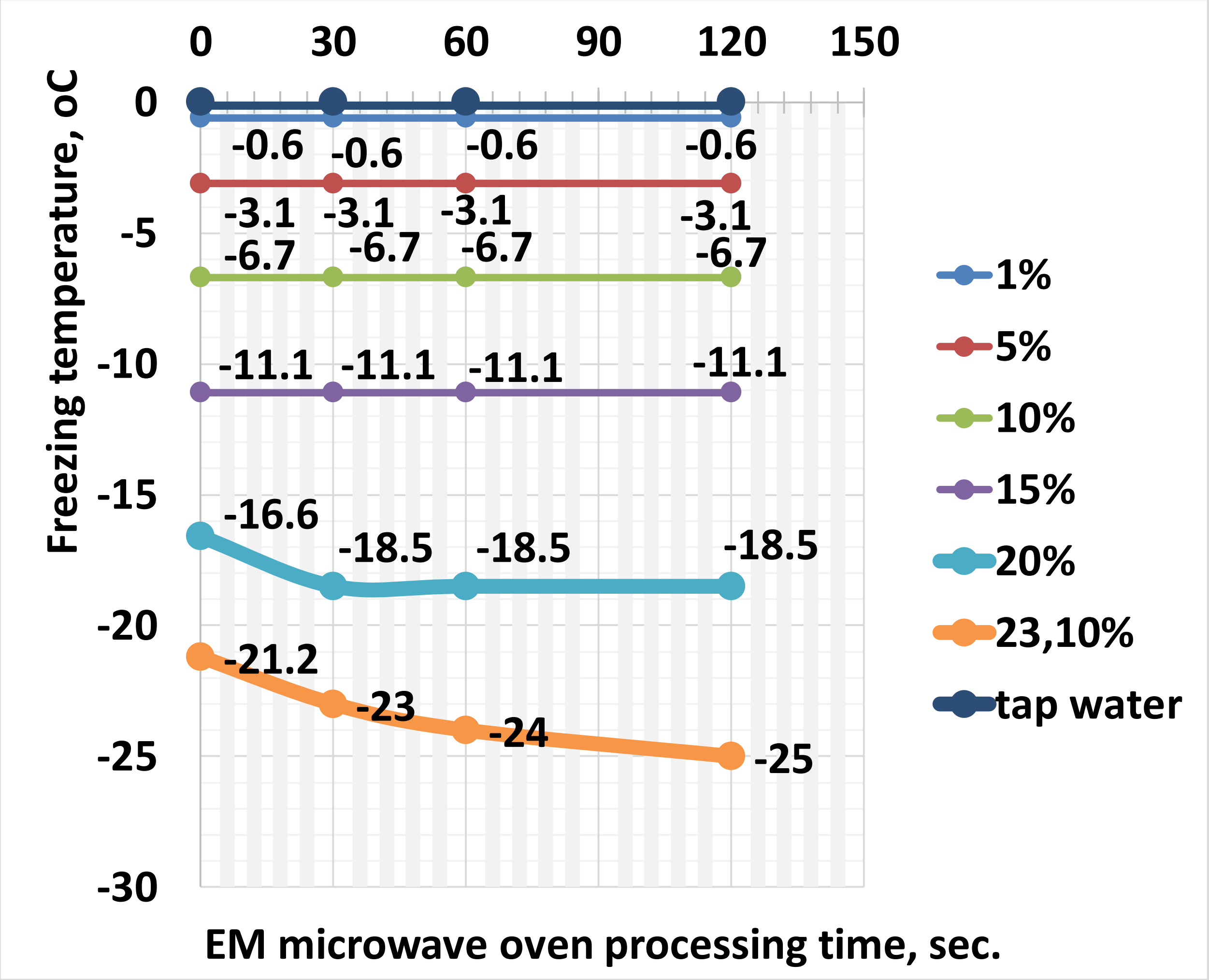

Figure 3: Definition of Tz solution when processing EMP microwave oven

3.1 INFLUENCE OF AN ELECTROMAGNETIC FIELD OF SUPER-HIGH FREQUENCY (VERY HIGH-FREQUENCY EMP)

At influence of EMP of a very high frequency 800 W (Mystery MMW-2315G microwave oven), with a frequency of magnetron of 2450 MHz, a processing time 30 with, 60 with, 120 with, on tap water and water solution of chloride of sodium concentration higher than 20% are observed solution freezing fall of temperature. The freezing temperature was determined by the refractometer (Vasiliev et al, 2016; Ershova et al, 2016). Fall of the temperature of freezing for solution concentration of 20%

*Corresponding author (I.Ershova). Tel: +7-9196538818. E-mail: eig85@yandex.ru happens to-16.6 to-18.5 ° C, for eutectic solution fall of temperature of freezing -21.2 to -25 ° C (Figure 3) concentration of 23.1%.

At the impact of EMP microwave oven on solution increase in ph of solution (Figure 4) is observed. Values defined by ph-meter. The maximum increase in ph happens for a 5% solution (to 5.7 to 6.5). ph of 20% solution increased from 6.2 to 6.4.

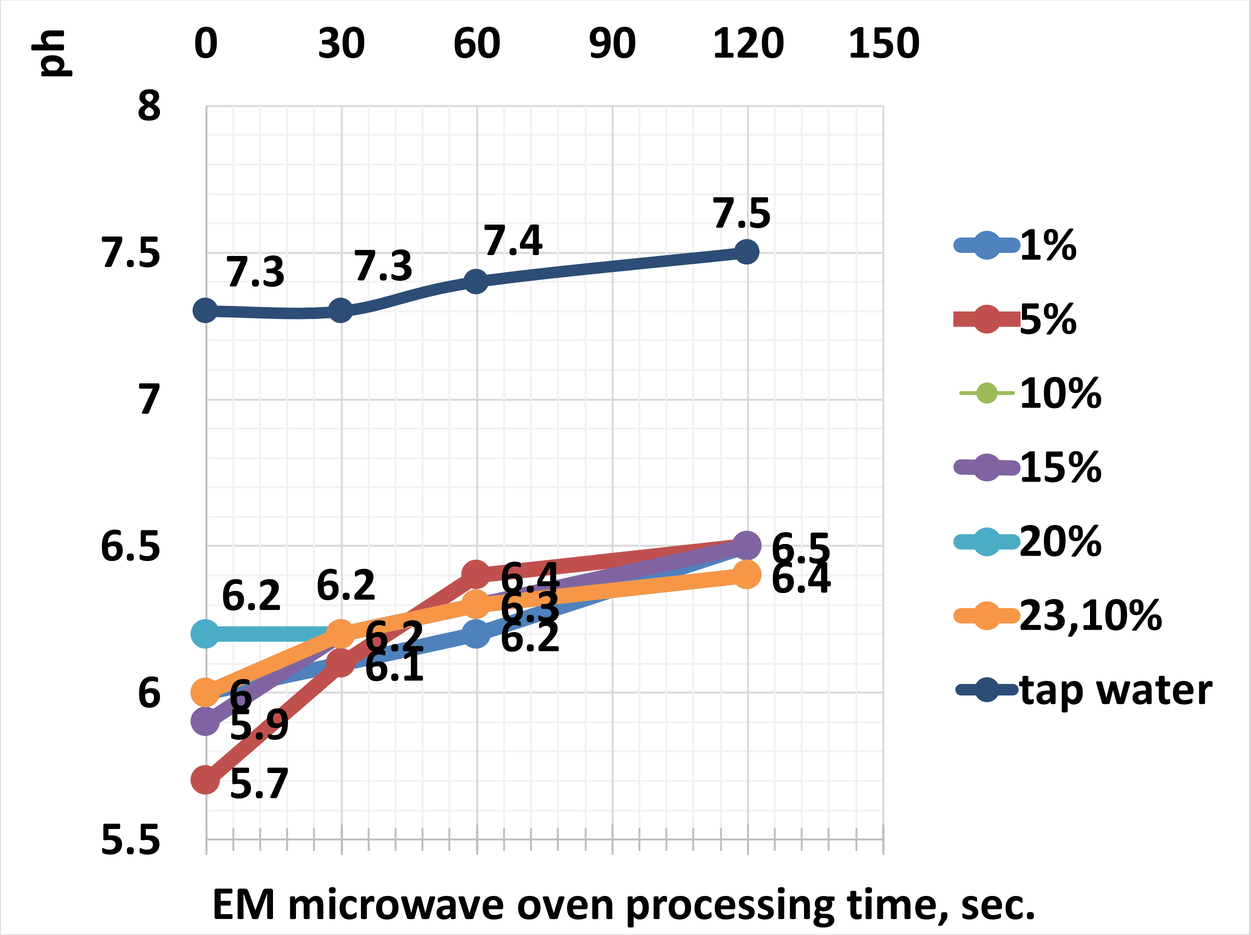

Figure 4: Definition of ph when processing EMP microwave oven.

The specific conductivity when processing EMP microwave oven of tap water and salt solutions was determined by the conductometer (Figure 5). The specific conductivity of 15% salt solution decreased from 1451 to 1262 micromho/cm.

The matrix of planning of an experiment on the optimization of the modes of regulation of electrophysical impact on the salt solution is made.

Using a technique of three-factorial active planning of an experiment of type 23 and the Statistic V5.0 program the following surfaces of responses and their two-dimensional sections in isolines are constructed: temperatures of freezing, acidity and specific conductivity of a salt solution (Figures 6, 7, 8) (Spirin & Lavrov, 2004).

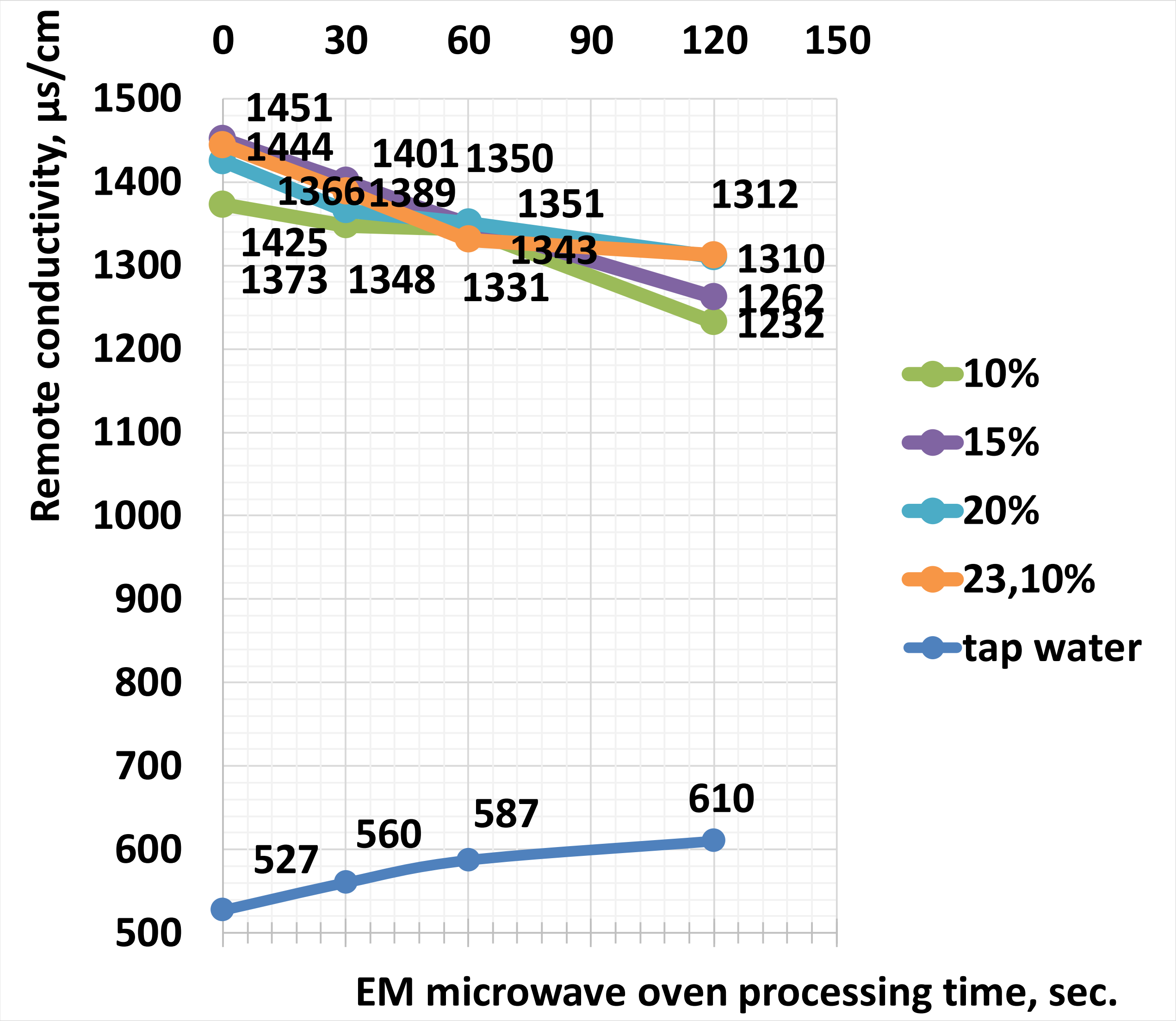

Figure 5: Determination of specific conductivity when processing EMP microwave oven.

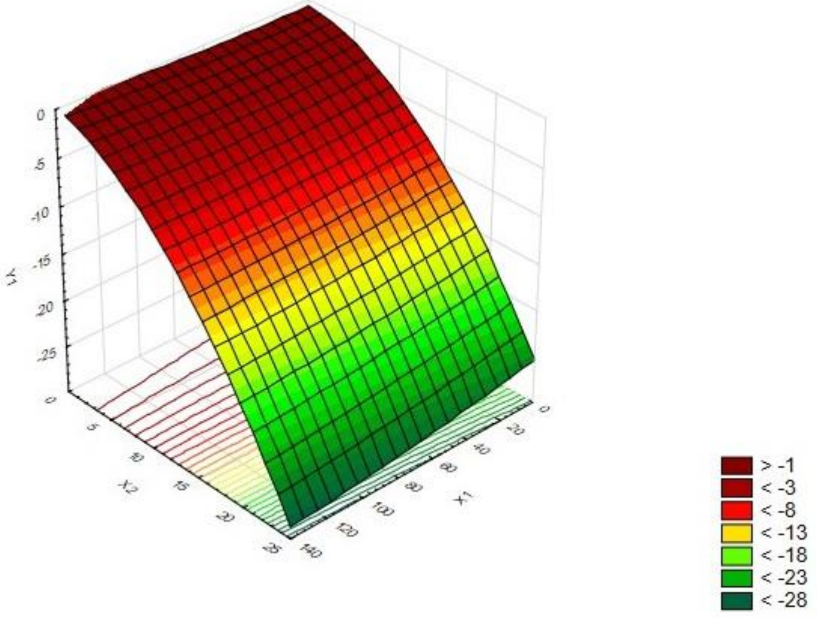

Figure 6: Two-dimensional sections in isolines and a surface of a response of three-factorial model of the temperature of freezing of solution depending on the processing time of EMP microwave oven and concentration of solution

Empirical expression of the model of freezing temperature of solution depending on the processing time of EMP microwave oven and concentration of a solution:

$$t_з = -0.6693-0.0018\cdot\tau-0.1037\cdot c+6.5789\cdot10^{-5}\cdot\tau^2-0.0013\cdot\tau\cdot c-0.0353\cdot c^2 \quad (1).$$

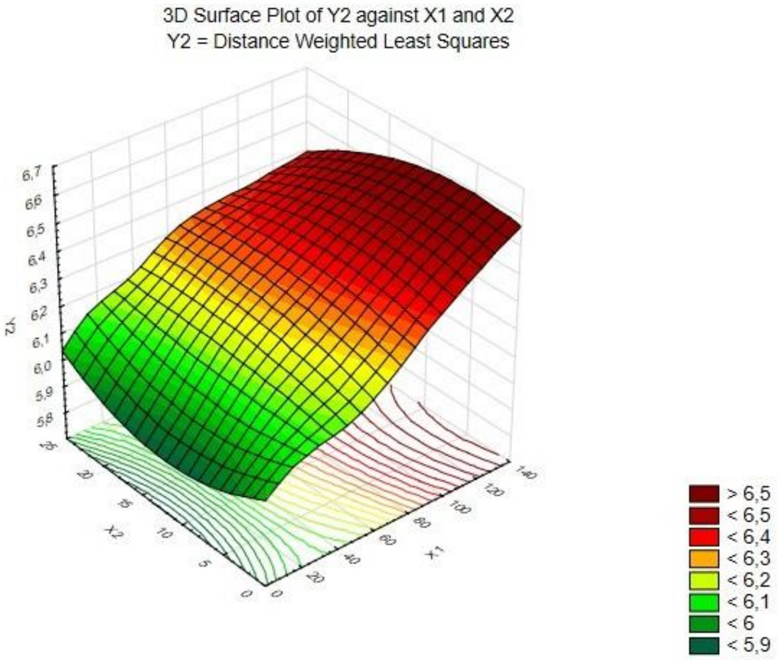

Figure 7: Two-dimensional sections in isolines and a surface of a response of three-factorial model of acidity of solution depending on the processing time of EMP microwave oven and concentration of a solution

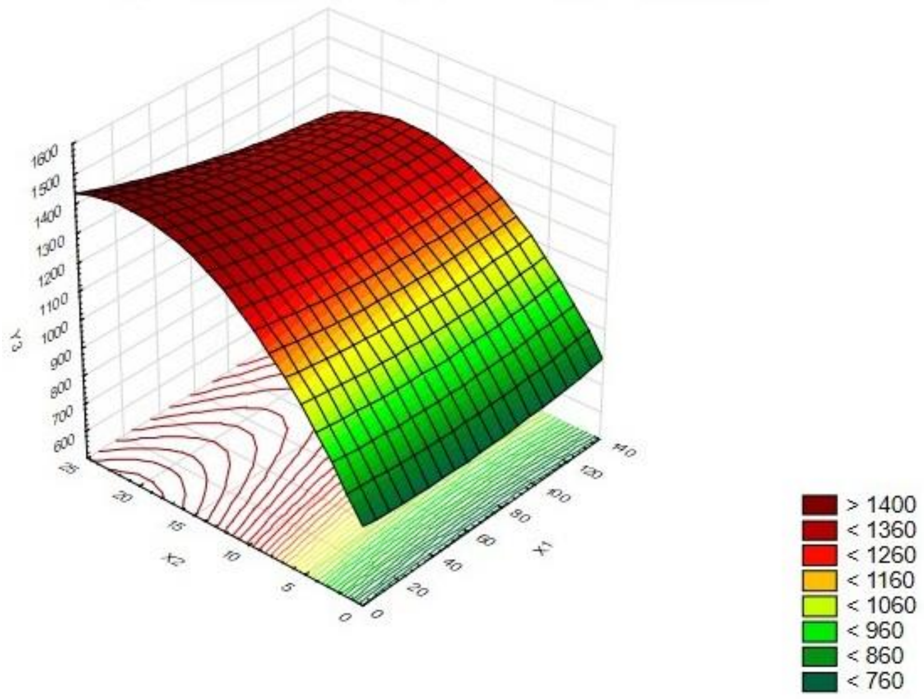

Figure 8: Two-dimensional sections in isolines and a surface of a response of three-factorial model of specific conductivity of solution depending on the processing time of EMP microwave oven and concentration of a solution

Empirical expression of the model of specific conductivity of solution depending on the processing time of EMP microwave oven and concentration of a solution:

$$\sigma = 778.8615-0.7394\cdot\tau+68.1052\cdot c+0.0062\cdot\tau^2-0.0643\cdot\tau\cdot c-1.6739\cdot c^2 \quad (2).$$

3.2 INFLUENCE ELECTROHYDRO-(EH) PRESSURE

The matrix of planning of an experiment on optimization of the modes of regulation of impact of EMP microwave oven on the salt solution is made (Belov, 2018).

Using a technique of three-factorial active planning of an experiment of type 23 and the Statistic V5.0 program the following surfaces of responses and their two-dimensional sections in isolines are constructed: temperatures of freezing, acidity and specific conductivity of a salt solution (Figures 9, 10, 11) (Spirin & Lavrov, 2004).

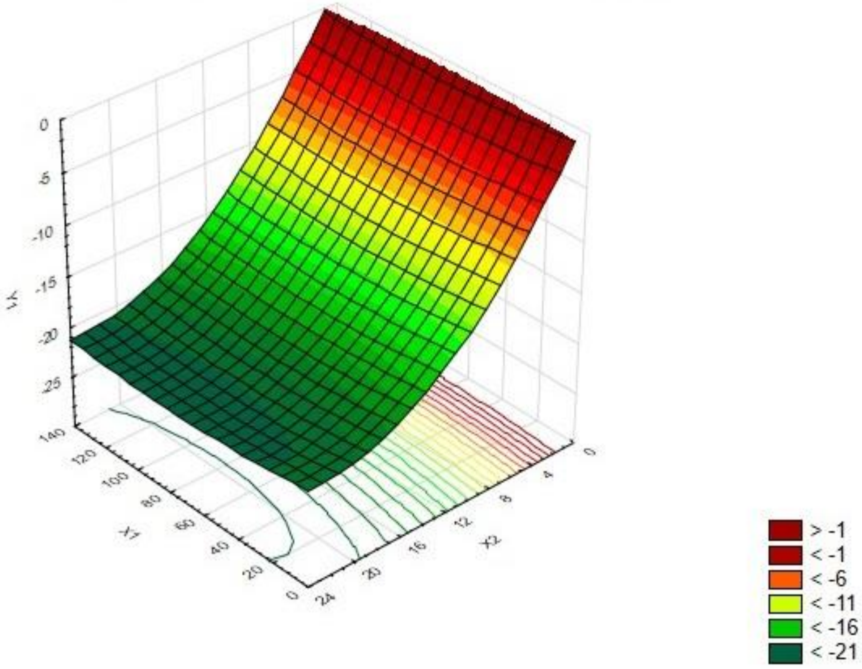

Figure 9: Two-dimensional sections in isolines and a surface of a response of three-factorial model of the freezing temperature of solution depending on the number of categories (EH pressure) and concentration of a solution.

Empirical expression of the model of freezing temperature of solution depending on the number of categories (EH pressure) and concentration of solution:

$$t_{з} = 2.4317-0.0236\cdot n-1.9994\cdot c+0.0002\cdot n^2-0.0002\cdot n\cdot c+0.0435\cdot c^2 \quad (3)$$

Empirical expression of model of acidity of solution depending on the number of categories (EH pressure) and concentration of a solution:

$$ph = 7.2486+0.0028\cdot n-0.0391\cdot c-3.0053\cdot 10^{-18}\cdot c^2+0.0004\cdot n\cdot c-0.0009\cdot c^2 \quad (4)$$

Empirical expression of the model of specific conductivity of solution depending on the number of categories (EH pressure) and concentration of solution:

$$\sigma = 446.3868+0.0242\cdot n+96.8422\cdot c+3.655\cdot 10^{-5}\cdot c^2-0.0715\cdot n\cdot c-2.2771\cdot c^2 \quad (5)$$

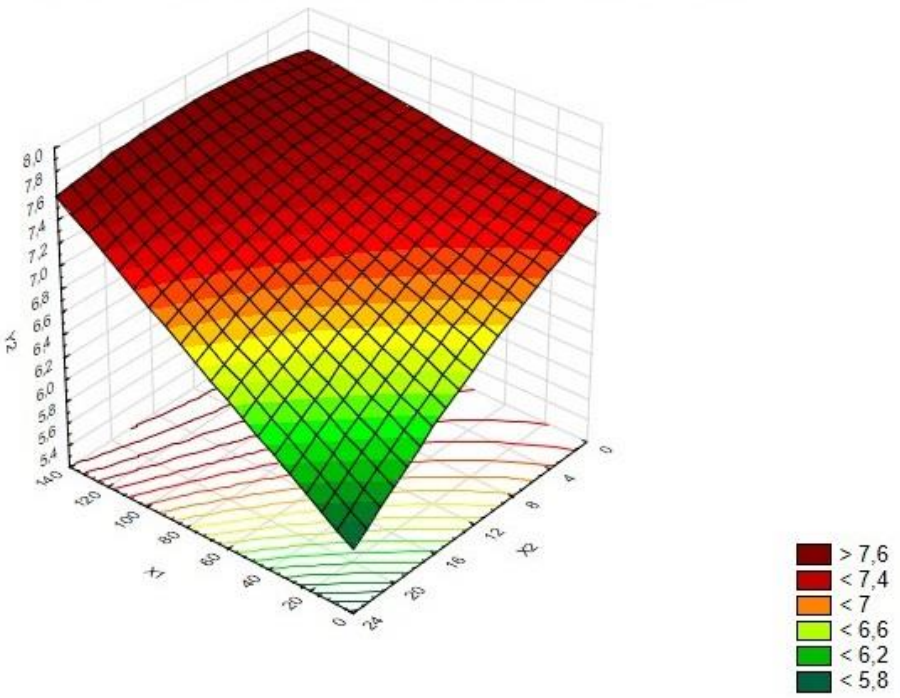

Figure 10: Two-dimensional sections in isolines and a surface of a response of three-factorial model of acidity of solution depending on the number of categories (EH pressure) and concentration of the solution.

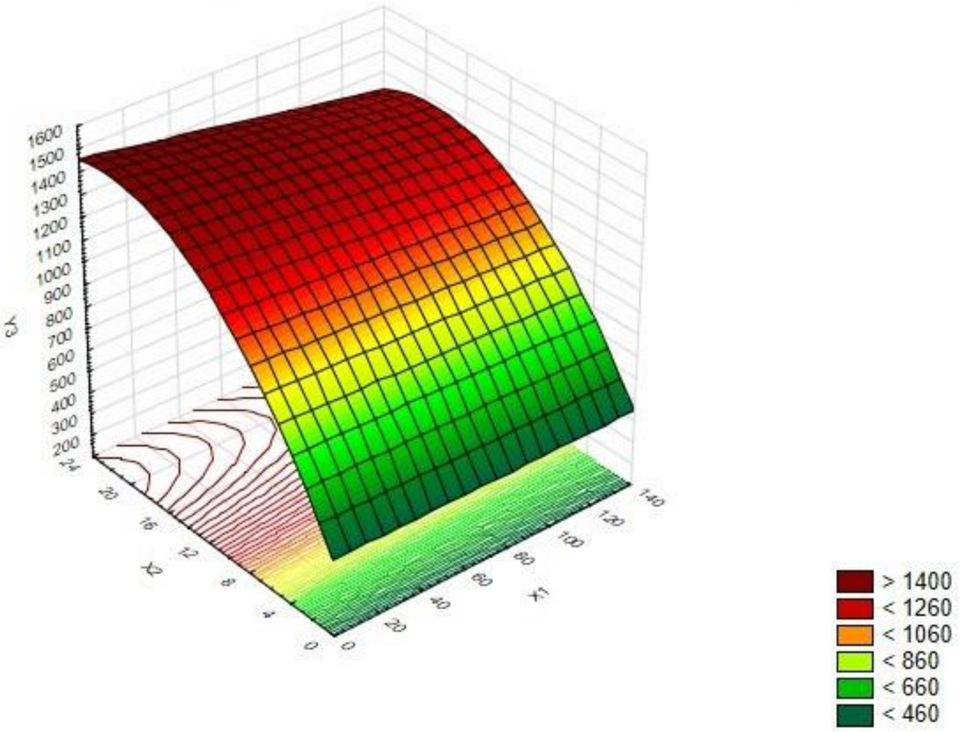

Figure 11: Two-dimensional sections in isolines and a surface of a response of three-factorial model of specific conductivity of solution depending on the number of categories (EH pressure) and concentration of the solution.

4. THE SCHEME OF THE HEAT EXCHANGER OF EXPERIMENTAL INSTALLATION FOR OBTAINING ENERGY OF PHASE TRANSITION WATER-ICE

We apply as the heat carrier in a tank the 4th salt solution concentration of 20% which freezing temperature is -16.6°C. After processing of EMP of a very high frequency (the Mystery MMW-2315G microwave oven, magnetron frequency 2450MHz, rated power 800 W) salt solution which freezing temperature will be -18.5°C comes to the heat exchanger tank #2 (Figure 12).

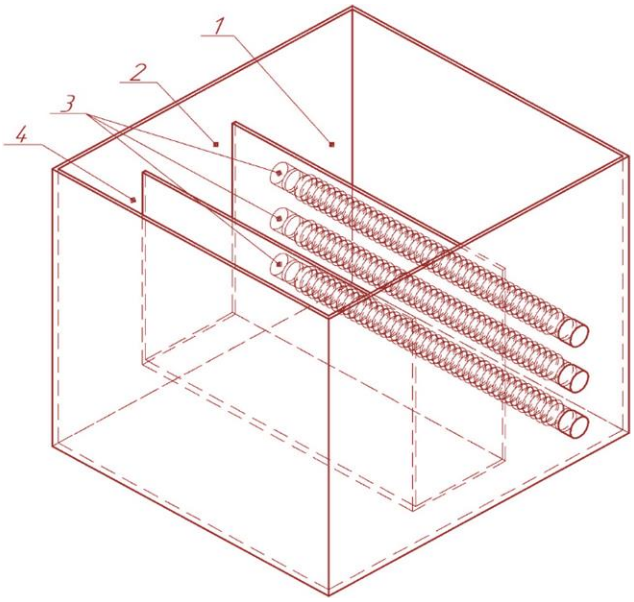

Figure 12: The scheme of the heat exchanger of experimental installation for obtaining energy of phase transition water-ice: 1 – a tank for collecting ice, 2 – a heat exchanger tank, 3 – a corrugated hose (silicone tubes) in which freon circulates, 4 – a tank for electrophysical processing of salt solution (the field microwave oven reducing water freezing temperature).

5. INITIAL REQUIREMENTS TO THE HEAT EXCHANGER OF EXPERIMENTAL INSTALLATION FOR OBTAINING ENERGY FROM PHASE TRANSITION WATER-ICE

The initial requirements to the heat exchanger of experimental installation for receiving the energy of phase transition water-ice allowing to execute preparation of sketches and to make an experimental example are set.

By the estimation, it is established that for heating of an agricultural object of 100 sq.m the power of heat power equipment will be 12.8 kW, in day 306 kW/h.

The required volume of ice: 3602.8 l of ice.

The volume of ice production of the heat exchanger is 150.1 l ice/hour.

Tank volume for collecting ice will be 2 m^3, heat exchanger tank volume with silicone tubes of 3 x 2 m^3, tank volume for electrophysical processing of solution is 1 m^3, the total amount of a tank of the heat exchanger 5 m^3.

Processing of EMP of a very high frequency happens in a tank 4, at the same time, the consumption of salt solution in processing makes 3 m^3/hour (50 l/min.), the outer diameter of a pipe 32 mm, pipe wall thickness 1.1 mm.

Power supply voltage 220 V, 50 Hz of alternating current with use in a distribution network of the safety plug not below 16 And or the time cutout of the same face value. Maximum power consumption: 1200 W. Magnetron frequency: 2450 MHz. Rated power: 800 W.

The length of a silicone tube with a diameter of 30 mm for implementation of the process of formation of ice on predesigns will make 1.5 m.

In silicone pipes coolant (R410a freon) boils at a temperature of -25 °C (with a pressure of 2.35 bar), and on their surface ice freezes on, its expense makes 2 m^3/hour.

The maximum thickness of ice should not exceed 3.5 cm.

5.1 MAIN MODES: HEATING, HEATING/HOT WATER, COOLING

The thickness of the isolation of the walls of the heat exchanger is 150 mm. Isolation material – expanded polystyrene of 35 kg/m^3. The coefficient of heat conductivity of material of isolation is 0.02 W/(m•K).

At influence of EMP of a very high frequency (magnetron frequency 2450 MHz, rated power – 800 W, duration of 120 pages) on sodium chloride solution concentration higher than 20% of 50 ml (height of liquid of 3 cm, diameter of a glass 4 cm) are observed solution freezing fall of temperature by concentration of 20% from-16.6 to-18.5 ° C, for eutectic solution fall of temperature of freezing from-21.2 to -25 ° C happens concentration of 23.1%. At the impact of EMP of a very high frequency on mains water, its freezing temperature did not change.

At the influence of EMP microwave oven increase in ph of the solution is observed, the maximum increase in ph. happens for 5% solution – to 5.7-6.5, the specific conductivity of 15% solution decreased from 1451 to 1262 micromho/sec.

The concentration of salt in tap water after processing increased from 0.263 to 0.306 mg/l.

5.2 EH-INFLUENCE

When processing by EH-influence (tension of 35 kV, electric capacity 0.2 мкФ, distance of an air gap of 10 mm, between electrodes of 10 mm, a form of electrodes "edge plane", 1000 categories) tap water of 2.5 l at 20 ° C temperature of freezing did not change (0 ° C). At impact on 20% solution is observed fall of temperature of freezing from-16.6 to -19 ° C. When processing by EH-impact (tension of 46 kV) on 23.1% solution temperature of freezing did not change.

When processing by EH-influence (tension of 45 kV) of ph of 20% solution increased from 6.2 to 7.8, and ph of 23.1% solution increased from 6 to 7.2.

When processing by EH-influence (tension of 35 kV) ph of tap water increased from 7.3 to 7.7.

When processing by EH-influence (tension of 45 kV) the specific conductivity of 20% solution decreased from 1425 to 1223 micromho/see.

When processing by EH-influence (tension of 46 kV) the specific conductivity of 23.1% solution decreased from 1444 to 1298 micromho/see.

When processing by EH-influence (tension of 35 kV) of tap water at 20 ° C, its specific conductivity increased from 0.527 to 0.550 micromho/see.

When processing by EH-influence (tension of 35 kV) of concentration of salt in tap water increased from 0.263 to 0.275 mg/l.

When processing by EH-influence (tension of 45 kV) concentration of salt of 20% solution decreased from 0.710 to 0.611 mg/l, and solution from 0.721 to 0.650 mg/l.

6. CONCLUSION

The functional and technological scheme of an experimental sample of the heat-exchanging equipment is developed. The heat exchanger with additional tanks for electrophysical water treatment and for collecting ice is provided in this scheme. Processing by electrophysical impact happens to the purpose of the fall of freezing temperature of the heat carrier that is confirmed experimentally. 2) Pilot studies on heat physical (freezing temperature, ph) and electrophysical (specific conductivity) to heat carrier parameters (water and salt solution of chloride of sodium of different concentrations) are conducted, at electrophysical impact (the influence MO, EH fields).

The scheme of the heat exchanger of experimental installation for obtaining energy of phase transition water-ice contains a heat exchanger tank, a tank for collecting ice, a corrugated hose in which coolant, a tank for electrophysical processing of the heat carrier circulates (EMP microwave oven lowering temperature of freezing of the heat carrier – water-salt solution).

For heating of an agricultural object of 100 sq.m, the power of the heat power equipment will be 12.8 kW in a day (306 kW/h). The required volume of ice will be 3602.8 l of ice, the volume of production of ice of the heat exchanger 150.1 ice/hour. Tank volume for collecting ice will be 2 m^3, a heat exchanger tank with silicone tubes 2 m^3, a tank for electrophysical water treatment – 1 m^3, the total amount of a tank of the heat exchanger 5 m^3. The length of a silicone tube with a diameter of 30 mm for implementation of the process of formation of ice will be 1.5 m. In silicone pipes coolant (R410a freon) boils at a temperature of -25°C, and on their surface ice freezes on, its expense makes 2 m^3/hour. The maximum thickness of the ice is 3.5 cm.

7. AVAILABILITY OF DATA AND MATERIAL

All the used and generated data in this study are already presented in this article.

8. CONFLICT OF INTEREST

The authors confirm that the provided data do not contain a conflict of interest.

9. REFERENCES

Belov, A., A. (2018). Modeling the assessment of factors influencing the process of electro-hydraulic water treatment. *VESTNIK NGIEI*, *11*, 103-112.

Chubik, I. A., & Maslov, A. M. (1970). Handbook on the thermophysical characteristics of food products and semi-finished products. *M: Food industry.-184 p*.

Dykstra, C. E. (1999). External electric field effects on the water trimer. *Chemical Physics Letters*, *299*(2), 132-136.

Ershova, I. G., Belova, M. V., Poruchikov, D. V., & Ershov, M. A. (2016). Heat treatment of fat-containing raw materials with energy of electromagnetic radiation. *Международный научно-исследовательский журнал*, (9-2), 38-40.

Spirin, N. A. & Lavrov, V. V. (2004). Methods of planning and processing of the results of the engineering experiment. *Ekaterinburg: GOU VPO UGTU-UPI*, 357 p.

Vasilev, A. N., & Tutunina, E. V. (2018). The Results of a preliminary experimental verification of the utilization of low temperature heat transfer fluids in the heat pumps work. *Bulletin of agricultural science of the don*, *3*(43), 62-67.

Vasiliev, A. N., Budnikov, D. A., Vasiliev, A. A. (2016). Modeling the process of heating the grain in the microwave field of a universal electrical module with various algorithms of electrical equipment. *Bulletin of Agrarian Science Don*, *1*(33), 12-17.

Vasiliev, A. N., Ershov, I. G., Belov, A. A., Timofeev, V. N., Uhanova, V. Y., Sokolov, A. V., & Smirnov, A. A. (2018). Energy-saving system development based on heat pump. *Revista Amazonia Investiga*, *7*(17), 219-227.

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