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ELECTRIC REGULATOR WITH SOLID FILLER AND THERMOELECTRIC HEAT EXCHANGER MODULE TO PRODUCE ENERGY OF WATER-ICE PHASE TRANSITION

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Abstract

The authors have developed electric regulators with solid filler and thermoelectric heat exchanger module to obtain the energy of the water-ice phase transition. They substantiated that the use of the thermoelectric module provides regulator operation for potato storage heating and cooling. At that, during the change of potato storage operating modes by changing the polarity of the thermoelectric module, the speed of the regulatory body is ensured. The heating efficiency of the electric regulator with solid filler and thermoelectric module is higher than the heating efficiency of the electric regulator with solid filler and electric heater.

Keywords

Energy of phase transition water-ice – Heat Exchange – Electrical regulator – Vegetable storage

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Introduction

It is necessary to maintain microclimate parameters in the storehouse for long-term storage of vegetables, which requires high energy costs. Currently, electro-hydraulic shock[1], microwave technology[2], renewable energy sources[3] and other energy-saving devices[4] are used to save energy at agricultural facilities.

They developed a heat exchanger of the experimental device, by which they maintain the necessary temperature parameters of the vegetable store. They determined the theoretical parameters for the modernized electric regulator with solid filler and a thermoelectric module, which allows to maintain the required microclimate parameters of the vegetable store through the distribution of the energy carrier to the condenser and to the additional evaporator of the heat exchanger.

Background

An electric regulator with solid filler and thermoelectric module (TM) can operate in heating and cooling modes. The controller allows heating of the solid filler from the thermoelectric module and the coolant. TM converts electric energy into heat due to elements of n- and p-types, on the junctions of which heat is released and absorbed (Peltier effect).

The amount of thermoelectric module heat is determined by the following formula[5]:

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[1] A. A. Belov, "Modeling the assessment of factors influencing the process of electro-hydraulic water treatment". VESTNIK NGIEI num 11 (2018): 103-112.

[2] A. V. Rodionova; M. S. Borovkov & M. A. Ershov, "Justification of the selected frequency of electromagnetic radiation in physical prophylaxis of harbols", NIVA POVOLZ num 1 (2012): 108-110; I. G. Ershova; M. V. Belova; D. V. Poruchikov & M. A. Ershov, "Heat treatment of fat-containing raw materials with energy of electromagnetic radiation", International research journal num 91 (2016): 38-40 y A. N. Vasiliev; D. A. Budnikov & A. A. Vasiliev, "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. Vol: 1 num 33 (2016): 12-17.

[3] A. Vasiliev; I. Ershova; A. Belov; V. Timofeev; V. Uhanova; A. Sokolov & A. Smirnov, (2018). Energy-saving system development based on heat pump", Amazonia Investiga. Vol: 7 num 17 (2018): 219-227;

[4] Patent 2599489 RF. Means for processing udder cows. G. A. Larionov, M. A. Ershov, O. N. Dmitrieva, N. I. Endierov, E. S. Yatrusheva, M. A. Sergeyeva. Application No. 2015135573; declare 08.21.2015; publ. 10.10.2016. Bul. No. 28; Patent 2280974 RF. The way to reduce the toxic effect of heavy metals on the roots of crops. P. M. Lukin, G. A. Larionov, N. A. Kirillov, M. A. Ershov, G. K. Wolves. No. 2005107853; declare 21.03.2005; publ. 10.08.2006, Bul. No. 22.; Patent 2283317 RF. Plant Growth Stimulator of Root Crops. P. M. Lukin, G. A. Larionov, N. A. Kirillov, M. A. Ershov. No. 2005107854; declare 21.03.2005; publ. 10.09.2006, Bul. No 25; Patent 2601119 RF. The method of obtaining funds for the treatment of udder cows / G.A. Larionov, M.A. Ershov, O.N. Dmitrieva, N.I. Endierov, E.S. Yatrusheva, M.A. Sergeyeva. Application No. 2015148102; declare 09.11.2015; publ. 10.27.2016. Bul. No 30; Patent 2615444 RF. Method for producing soft cheese. G. A. Larionov, L. A. Yavkina, N. I. Endierov, N. V. Shchiptsova, M. A. Ershov. Application No. 2015136349; declare 08.26.2015; publ. 04.04.2017. Bul. No. 10 y M. G. Terentyeva; R. N. Ivanova; G. A. Larionov; I. A. Alekseev & V. G. Semenov, "Phase Changes of Enzyme Activity in Hind Gut Tissues of Piglets", Advances in Engineering Research, Vol: 51 (2018): 723-730.

[5] L. P. Bulat & E. V. Buzin, Thermoelectric cooling devices: Method. directions for special students 070200 "Technique and physics of low temperatures". SPb.: SPbGuniPT. 2001).

$$Q_{г} = \alpha \cdot T_{г} \cdot I + 0{,}5 \cdot I^{2} \cdot R - k \cdot \Delta T \cdot \delta \text{ , Вт,} \tag{1}$$

and the heating coefficient –

$$k_{от} = \frac{Q_{Г}}{W} = \frac{\alpha \cdot T_{г} \cdot I + 0{,}5 \cdot I^{2} \cdot R - k \cdot \Delta T \cdot \delta}{\alpha \cdot \Delta T \cdot I + I^{2} \cdot R}, \tag{2}$$

where α is the coefficient of TM thermal emf, B/°C; $T_{г}$ − the temperature of the hot junction, °C;

I – the current strength, A; R – the resistance, Ohm; k − the thermal conductivity coefficient, W/(m·°C); ΔT – the temperature difference between the junctions, °C; W − the power consumption of the TM, W; δ – the ceramic plate thickness, m.

The coefficient ($k_{от}$) reaches its maximum at $I = \frac{\alpha \cdot \Delta T}{R \cdot (M - 1)}$, A, where $M = \sqrt{1 + z \cdot T_{г}}$ (universal characteristic of the thermocouple); z − thermoelectric efficiency, 1/°C.

The maximum value of heating coefficient:

$$k_{от} = \frac{T_{г}}{T_{г} - T_{x}} \cdot \frac{M - T_{x}/T_{г}}{M + 1}, \tag{3}$$

where $T_{г}$, $T_{х}$ − the temperature of hot and cold junctions, respectively, °C.

At $T_{г} = T_{х}$, $k_{от} = \infty$, and at $M = T_{х}/T_{г}$, $k_{от} = 0$.

Thus, in the temperature range of junctions from $T_{х} = T_{г}$ to $T_{х} = T_{г} \cdot M$ the heating coefficient TM ($k_{от}$) takes the values from ∞ to 0.

At $T_{х} = T_{г}/M$, $k_{от} = 1$, and at $T_{х} > T_{г}/M$, $k_{от} > 1$.

The heating coefficient can be expressed in terms of the heating coefficient, which depends on the current strength $\varepsilon = f(I)$ and the heat flux supplied from the external environment to the cold side of the thermoelectric module Q_{o} (W):

$$k_{от} = \frac{Q_{0} + W}{W} = \varepsilon + 1 . \tag{4}$$

The process of maintaining the temperature regime in the potato storage during an electric regulator application with solid filler and TM takes place as follows. In the heating mode, the solid filler expands due to the action of TM and the coolant. It acts on the stem opening the valve. At that, the necessary coolant flow is fed to the potato storage converter. The heat flow balance in the power sensor is the following one in this case:

$$Q = Q_{тм} + Q_{ж}, \quad W, \qquad (5)$$

where $Q_{тм}$ – the heat flux controlled by an electric regulator with solid filler and TM, W;

$Q_{ж}$ – the heat flux of the energy carrier circulating in the NPIE converter, W.

When the set temperature in the potato storage is reached, the heat pump and the electric regulator with TM stop[6], and the valve closes. In this case, to close the valve quickly, the TM switches to the cooling mode, so that the filler cools quickly. In the cooling mode, the solid filler expands under the influence of TM and, similarly, the regulator valve opens. In this case, the energy carrier with the temperature of -1 °C will prevent the valve from opening.

Then the heat flow balance in the power sensor is the following one:

$$Q = Q_{тм} – Q_{ж}, \text{Вт}. \qquad (6)$$

At that, power consumption is higher than in heating mode.

The choice of material for thermoelectric module elements. The efficiency of the TM, as well as the maximum decrease of temperature at the junctions, depend on the efficiency (quality factor) of the semiconductor substance z, which includes the electrical conductivity σ, the thermoelectric coefficient α and the thermal conductivity κ. These values are interrelated, since they depend on the concentration of free electrons or holes. The electrical conductivity σ is proportional to the number of carriers n, thermoEMF tends to zero with increasing n and increases with decreasing n.

The thermal conductivity k depends on the thermal conductivity of the crystal lattice $κ_p$, which is practically independent of n, and the electronic thermal conductivity $κ_e$ proportional to n. The effectiveness of metals and metal alloys is low due to the low coefficient of thermoEMF, and due to the very low electrical conductivity in dielectrics. As compared to metals and dielectrics, the efficiency of semiconductors is much higher, which explains their widespread use in TM nowadays.

The effectiveness of materials also depends on temperature. TM consists of two branches: negative (n-type) and positive (p-type). Since the material with electron permeability has a negative emf and the material with hole conductivity has a positive emf, a higher thermal emf can be obtained. With emf increase, z increases. Currently, low-temperature thermoelectric materials are used for thermoelectric modules, the starting materials of which are bismuth, antimony, selenium, and tellurium[7].

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[6] Patent 2285872, F25B30 / 02. Heat pump. I. V. Moskalenko, A. M. Kostin; publ. 10/20/2006, Bul. No. 29.

[7] A. V. Baranenko, "Thermoelectric Effect. Efficiency of application of thermoelectric cooling". Kholodilshchik.ru num 2 (2006).

The maximum efficiency z for these materials at room temperature is the following: $2{,}6\cdot10^{-3}$ °C^{-1} for *n* type, $2{,}6\cdot10^{-1}$ °C^{-1} – for *p* type. At present, Bi_2Te_3 is rarely used, since Bi_2Te_3-Be_2Se_3 and Bi_2Te_3-Sb_2Te_3 solid solutions created on its basis have higher z values.

These materials were first obtained and studied in our country, and the production of alloys TVEH-1 and TVEH-2 was mastered on their basis for the branches with electronic conductivity and TVDH-1 and TVDH-2 for the branches with hole conductivity[8]. Solid solutions of Bi-Se are used in the temperature range below 250 K. The maximum value of $z = 6 \cdot 10^{-3}$ °C^{-1} is obtained at T≈80-90 K.

In order to replace mechanical inertial regulators with high-speed ones, the electric regulator was modernized and a regulator with a solid filler and a thermoelectric module was developed.

Main focus of the chapter

The development of an electric regulator with solid filler and thermoelectric module. Using the works of the Russian academician A.F. Ioffe and his colleagues, semiconductor alloys were synthesized, which made it possible to use the Peltier effect in practice and begin serial production of thermoelectric cooling devices for widespread use in various sectors of the national economy[9].

A new design of the electric regulator allows the use of an electric actuator in the form of a thermoelectric element located outside the case of the regulatory body. In addition to the above-mentioned elements, the electric regulator contains a thermoelectric module and energy carrier pipes (Figure 1).

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[8] A. I. Chernov & Moe Zoe, “Experimental determination of the basic parameters of the operation of a thermoelectric liquid cooler”. Journal of the University of Water Communications. St. Petersburg: St. Petersburg State University of Water Communications num 4 (2011): 28-34 y G. L. Shegal & M. P. Korotkov, Electric actuators in control systems (Moscú: Energy. 1968).

[9] V. N. Timofeev, The Use of Thermoelectric Coolers in ICE Cooling Systems (Cheboksary: Chuvash. state University. 1998); K. D. Timoshenkov, Temperature sensors with solid filler (Moscú: 1975) y P. Shostakovsky, “Modern solutions of thermoelectric cooling for electronic, medical, industrial and household appliances”, Components and technologies num 1 (2010): 102-109.

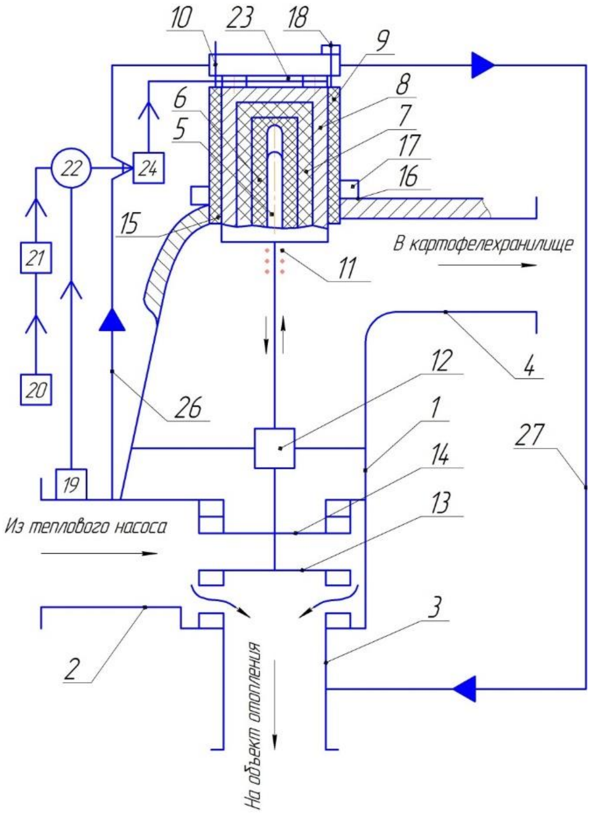

Figure 1
Electrical regulator with TM: 1 - case; 2, 3, 4, 26, 27 - nozzles; 5 - extended stem; 6 - rubber sleeve; 7 - solid filler; 8 - brass container; 9 - heat-insulating cylinder; 10 - heat exchanger; 11 - spring; 12 - guide sleeve; 13 - additional valve; 14 - main valve; 15 - sealing ring; 16 - sealing gasket; 17, 18 - fixing screws; 19, 20 - temperature and load sensors; 21 - setter; 22 - comparison unit; 23 - TM; 24 - control unit

Peltier and Thomson thermoelectric phenomena are used as an active control action by thermal conditions, the energy (thermal) effect of which is most pronounced in semiconductor materials[10] (Patent 31637, 2003). The use of these reversible phenomena to solve the problems of thermal control of an energy carrier is justified by the following reasons:

- the ability to stabilize the filler temperature at various values (levels) of temperature due to reverse control of the heat flux during the change of the electric current direction and strength through semiconductor elements;
- the ability to maintain the temperature in the working zone of the regulator below the ambient temperature, which cannot be obtained in electric heating regulators.
- During operation of the potato storage, especially at high ambient temperatures, the thermoelectric module is reversed in the control unit. Then the hot junctions become cold and the cold junctions become hot, thus the filler is heated and, accordingly, under the action of the spring, the stem moves and the valve closes, the valve opens and the coolant flow enters the potato storage through the pipe.

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[10] Patent 31637, IPC F 25B21 / 02. A device for controlling the temperature of milk during its transportation. V. N. Timofeev, G. E. Chekmarev, N. A. Galkina, etc.; publ. 08.20.2003.

At that, part of the energy carrier flow is directed to the heat exchanger from the nozzle, where heat is exchanged between the energy carrier and cold junctions of the thermoelectric module, which then enters the consumer object.

When the set temperature has been set, the operation of the regulator is stabilized, the energy supply to the potato storage is cut off. To accelerate valve closure, the control unit reverses (the hot side of the TM becomes cold). Thus, the temperature of the filler rapidly decreases and returns to its original position[11].

During operation of the potato storage in winter, when the air temperature drops below a predetermined value, the TM is switched on, and the regulator, similarly to operation in the cooling mode, starts supplying the energy carrier flow to the potato storage, in this case, the coolant.

During operation of the potato storage at low ambient temperatures after the “reverse” in the control unit, the “hot” junctions of the thermoelectric element heat the heat exchanger, which, through the joint heat exchange with the thermoelectric module and the heat carrier, heats the solid filler through the cylinder. In this case, rapid heating of the solid filler occurs.

Thus, the thermoelectric module in the electric regulator increases the speed of its operation, and the solid filler begins to cool due to the reverse to close the valve.

In this case, cold junctions are heated, and hot junctions are cooled, and the thermoelectric module operates in the heat pump mode. That is, the thermoelectric module can also be considered as a regular recuperative heat exchanger, in which Joule heat is released in the wall volume, and the Peltier effect appears on the surface.

Effective parameters and operating modes of the regulator with thermoelectric module (TM)

The analytical determination of the static and dynamic characteristics of SART with an electric regulator with a solid filler and a thermoelectric module is associated with complex calculations[12]. In this regard, in this work, an experimental study was conducted with an electric regulator sample with a solid filler and TM. At that they determined the following: 1) the valve opening time; 2) the optimal parameters of the thermoelectric module (TM).

Determination of the regulator valve opening time

The thermoelectric module TOM 8-127 was mounted to the sensitive element of the regulator with a solid filler (Fig. 2) in such a way that the “cold” junction interacts with convective heat exchange with the solid filler, and the “hot” junction interacts with the coolant. The solid filler (paraffin) is placed in the cylinder 4, where, depending on the

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[11] V. P. Babin, Thermoelectric modules quality testing by a manufacturer. V. P. Babin, S. M. Gorodetskiy. Proc. XIV Int. Conf. on Thermoelectrics. St. Petersburg, Russia. June 27– 30, 1995. 338-339.

[12] I. P. Suslov, Basics of the theory of reliability of statistical indicators I. P. Suslov (Novosibirsk: Science, 1979).

temperature and paraffin volume expansion, the piston with the rod connected to the regulator valves reciprocates. TOM 8-127 thermoelectric module is installed in the lower part of the cylinder. It is connected through a control unit to the temperature sensors 12 and load sensors 13. Depending on the load of the hot junction, TOM 8-127 can be switched on in the heating and cooling modes. At that, TOM 8-127 cold junction makes heat exchange with the energy carrier in tank A. The upgraded actuator (UA) consists of TM 10, solid filler 9, piston 2, and rod 3.

When the load is increased, the TOM 8-127 hot junctions are heated by the convective heat exchange through the cylinder wall 4, the solid filler is heated, the cold junctions are cooled by the coolant (using a fan in the prototype), and when the load is reduced, the operation of TOM 8-127 is performed in reversed order i.e. solid filler is cooled.

Hot water with the temperature of 85 ^{0}C is connected to the regulator with a solid filler (Fig. 2) and TM was turned on at the same time.

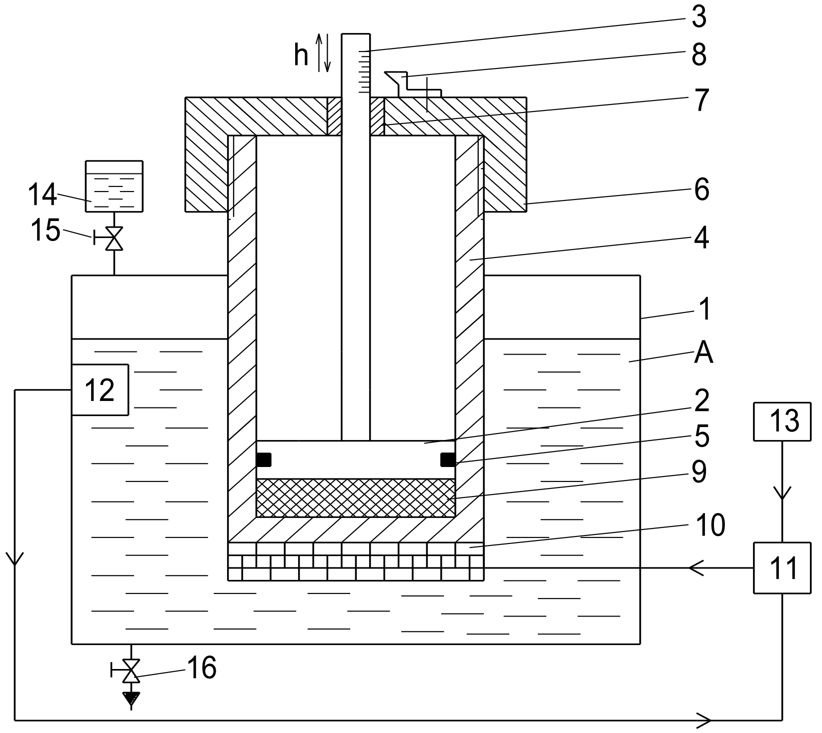
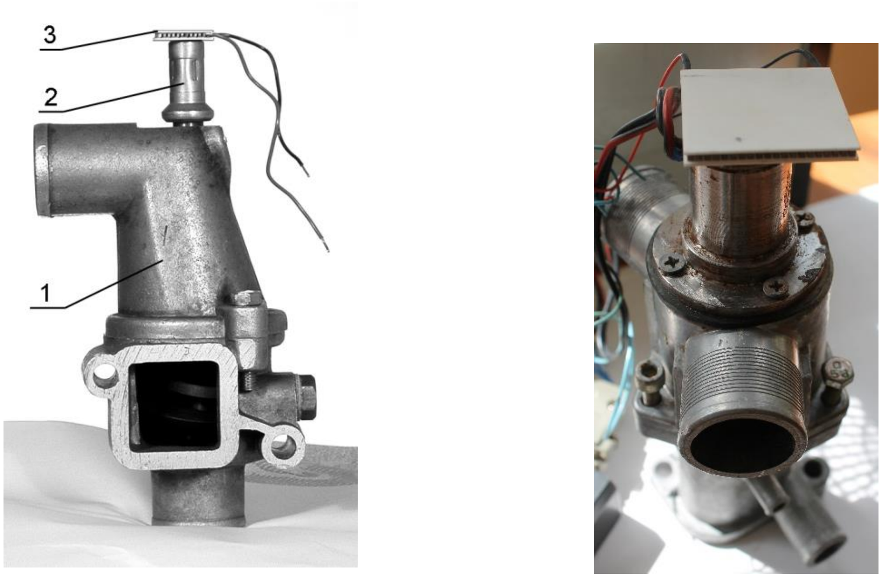


Figure 2
Regulator experimental device scheme with solid filler and TM: 1 - device capacity hosing; 2 - piston; 3 - rod; 4 - cylinder; 5 - sealing ring; 6 - cover; 7 - guide bush; 8 - pointer; 9 - solid filler; 10 - TM TOM 8-127; 11 - control unit; 12 - temperature sensor; 13 - load sensor; 14 - supply tank, 15, 16 - valves; A - installation tank

The electric regulator with TM is shown on Figure 3.



a

b

Figure 3
Electric regulator with TM: a - side view: 1 - case, 2 - thermo-power sensor, 3 - TM, b - front view

Thus, the “hot” and the “cold” side of the thermoelectric module provide effective parameters of the heat pump electric controller for the SART of the potato storage air.

Maintaining the temperature regime of the potato storage through deviation of the energy carrier temperature and the disturbing effect is an effective way, i.e., it is possible to neutralize the undesirable effect of the disturbance on the controlled temperature. This explains the efficiency of the modernized regulator with solid filler and thermoelectric module.

An experimental sevice was assembled to substantiate the optimal parameters of the TOM 8-127 thermoelectric module (Fig. 4).

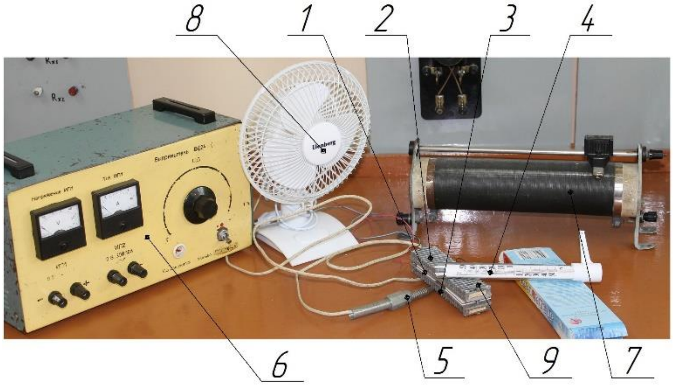


Figure 4
Experimental device to justify the optimal parameters of TM: 1 - TM TOM 8-127; 2 - hot junction heat exchanger; 3 - cold junction heat exchanger; 4 - alcohol thermometer ("hot" junction heat exchanger 2); 5 - temperature sensor TXK-0379-01 ("cold" junction heat exchanger 3); 6 - rectifier B-24; 7 - slider rheostat RP-100; 8 - fan; 9 – fixing screws.

The experimental procedure is the following one. Using the rectifier 6, we set the required value of the DC voltage. Heat was removed from the hot heat exchanger using the fan 8. TM 1 was installed between the heat exchangers of hot 2 and cold junction 4, providing tight contact between them due to fixing screws 9.

1st test. By changing the current strength, the voltage was recorded using the voltmeter on VP-24 rectifier. Based on the data obtained, the current-voltage characteristic of the thermoelectric module is designed (graph 1, Fig. 5). 2nd test. In the process of changing the current strength, theey recorded the temperature of the cold junction heat exchanger using the temperature sensor 5 TXK-0379-01. Based on the data obtained, they developed the graph of the “cold” junction temperature dependence on the current strength.

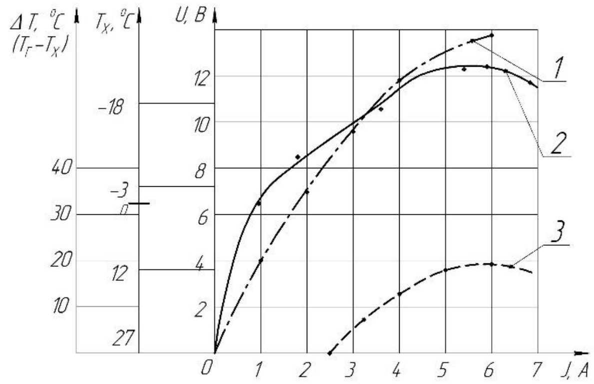


Figure 5
TM characteristics: 1 - voltage dependence on current strength; 2 - the dependence of the “cold” junction temperature on the current strength; 3 - the dependence of the temperature difference on the TM junctions on the current strength

Given the maximum possible hot junction temperature of 74 °C, they developed the following formula to determine the heat output of TM:

$$Q_{\text{г}} = I^2\left(0{,}5\cdot R - 1{,}5\cdot k\cdot\delta\right) + I\left(74\cdot\alpha - 18{,}26\cdot k\cdot\delta\right) + 36\cdot k\cdot\delta. \qquad (6)$$

3rd test. Changing the current strength, we recorded the temperature difference between the heat exchangers of the “cold” and “hot” junctions using the temperature sensor 5 TXK-0379-01. Based on the data obtained, they developed the graph of TM junction temperature difference dependence on the current strength (Fig. 6).

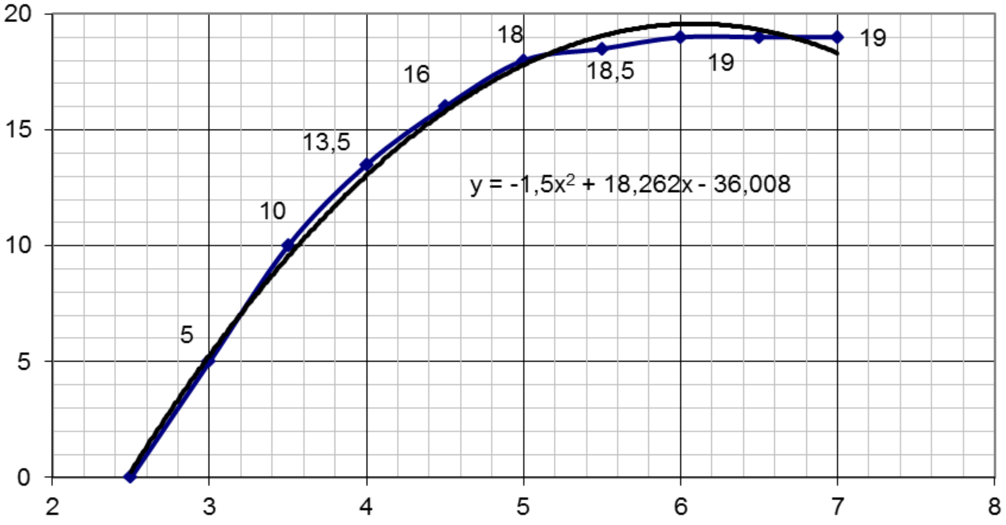


Figure 6
The dependence of TM junction temperature difference on the current

The electric regulator, as well as its spare parts, must be of high quality and durable[13].

Conclusión

Upgraded solid-filled electrical regulators and a thermoelectric module make it possible to maintain microclimate parameters of the vegetable storehouse through the distribution of the energy carrier to the condenser and to the additional evaporator of the heat pump.

They substantiated that the result of the thermoelectric module use is the controller operation provision for potato storage heating and cooling. Moreover, when you change the potato storage operating modes by changing the polarity of the thermoelectric module, the speed of the regulatory body is ensured.

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[13] A. S. Dorokhov, “Efficiency assessment of the quality of agricultural machinery and spare parts”, Bulletin of the Federal State Educational Institution of Higher Professional Education Moscow State Agroengineering University named after V. P. Goryachkina num 1 (2015): 31-35.

They studied the dependences of the voltage and the temperature of the “cold” junction; the dependences of the temperature difference on the current strength junctions of the thermoelectric module of the solid-filled electrical controller. Maintaining the temperature difference at the junctions of the thermoelectric module within 12-20 °C, supporting the working temperature of the solid filler, is possible at the voltage of 3-14 V and the current strength of 4-6 A, which ensures the regulator speed during the transition from cooling to heating mode and back due to polarity changes.

Conflict of interest

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

References

Babin, V. P. Thermoelectric modules quality testing by a manufacturer. V. P. Babin, S. M. Gorodetskiy. Proc. XIV Int. Conf. on Thermoelectrics. St. Petersburg, Russia. June 27– 30, 1995. 338-339.

Baranenko, A. V. “Thermoelectric Effect. Efficiency of application of thermoelectric cooling”. Kholodilshchik.ru num 2 (2006).

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

Belova, M. V.; Novikova G. V.; Ershova I. G.; Ershov M. A. & O. V. Mikhailova. “Innovations in Technologies of Agricultural Raw Materials Processing”. ARPN Journal of Engineering and Applied Sciences Tomo 11 (2006): 1269-1277.

Bulat, L. P. & Buzin E. V. Thermoelectric cooling devices: Method. directions for special students 070200 “Technique and physics of low temperatures”. SPb.: SPbGuniPT. 2001.

Chernov A. I. & Zoe, Moe. “Experimental determination of the basic parameters of the operation of a thermoelectric liquid cooler”. Journal of the University of Water Communications. St. Petersburg: St. Petersburg State University of Water Communications num 4 (2011): 28-34.

Dorokhov, A. S. “Efficiency assessment of the quality of agricultural machinery and spare parts” Bulletin of the Federal State Educational Institution of Higher Professional Education Moscow State Agroengineering University named after V. P. Goryachkina num 1 (2015): 31-35.

Ershova, I. G.; Belova, M. V.; Poruchikov, D. V. & Ershov, M. A. “Heat treatment of fat-containing raw materials with energy of electromagnetic radiation”. International research journal num 91 (2016): 38-40.

Patent 2599489 RF. Means for processing udder cows. G. A. Larionov, M. A. Ershov, O. N. Dmitrieva, N. I. Endierov, E. S. Yatrusheva, M. A. Sergeyeva. Application No. 2015135573; declare 08.21.2015; publ. 10.10.2016. Bul. No. 28.

Patent 2280974 RF. The way to reduce the toxic effect of heavy metals on the roots of crops. P. M. Lukin, G. A. Larionov, N. A. Kirillov, M. A. Ershov, G. K. Wolves. No. 2005107853; declare 21.03.2005; publ. 10.08.2006, Bul. No. 22.

Patent 2283317 RF. Plant Growth Stimulator of Root Crops. P. M. Lukin, G. A. Larionov, N. A. Kirillov, M. A. Ershov. No. 2005107854; declare 21.03.2005; publ. 10.09.2006, Bul. No 25.

Patent 2601119 RF. The method of obtaining funds for the treatment of udder cows / G.A. Larionov, M.A. Ershov, O.N. Dmitrieva, N.I. Endierov, E.S. Yatrusheva, M.A. Sergeyeva. Application No. 2015148102; declare 09.11.2015; publ. 10.27.2016. Bul. No 30.

Patent 2615444 RF. Method for producing soft cheese. G. A. Larionov, L. A. Yavkina, N. I. Endierov, N. V. Shchiptsova, M. A. Ershov. Application No. 2015136349; declare 08.26.2015; publ. 04.04.2017. Bul. No. 10.

Patent 31637, IPC F 25B21 / 02. A device for controlling the temperature of milk during its transportation. V. N. Timofeev, G. E. Chekmarev, N. A. Galkina, etc.; publ. 08.20.2003.

Patent 2285872, F25B30 / 02. Heat pump. I. V. Moskalenko, A. M. Kostin; publ. 10/20/2006, Bul. No. 29.

Rodionova, A. V., Borovkov M. S. & Ershov M. A. “Justification of the selected frequency of electromagnetic radiation in physical prophylaxis of harbols”. NIVA POVOLZ num 1 (2012): 108-110.

Shegal, G. L. & Korotkov M. P. Electric actuators in control systems. Moscú: Energy. 1968.

Shostakovsky, P. “Modern solutions of thermoelectric cooling for electronic, medical, industrial and household appliances”. Components and technologies num 1 (2010): 102-109.

Suslov, I. P. Basics of the theory of reliability of statistical indicators I. P. Suslov. Novosibirsk: Science. 1979.

Terentyeva, M. G.; Ivanova, R. N.; Larionov, G. A.; Alekseev, I. A. & Semenov, V. G. “Phase Changes of Enzyme Activity in Hind Gut Tissues of Piglets”. Advances in Engineering Research, Vol: 51 (2018): 723-730.

Timofeev, V. N. The Use of Thermoelectric Coolers in ICE Cooling Systems. Cheboksary: Chuvash. state University. 1998.

Timoshenkov, K. D. Temperature sensors with solid filler. Moscú: 1975.

Vasiliev, A. N.; Budnikov, D. A. & Vasiliev, A. A. “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. Vol: 1 num 33 (2016): 12-17.

Vasiliev, A.; Ershova, I.; Belov, A.; Timofeev, V.; Uhanova, V.; Sokolov, A. & Smirnov, A. (2018). Energy-saving system development based on heat pump”. Amazonia Investiga. Vol: 7 num 17 (2018): 219-227.

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