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Comparative Characteristics of the Developed Electric Heat Exchanger Regulators to Obtain the Energy of Water-Ice Phase Transition

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Abstract

The authors have developed electric regulators: relay-pulse ones, with solid filler and electric heater, with solid filler and thermoelectric module, for a heat exchanger to obtain the energy of the water-ice phase transition.

Experimental studies were carried out, the static and dynamic characteristics of electrical controllers were determined to determine the most fast-acting regulator. They substantiated that after the use of the thermoelectric module, the regulator operation is ensured during potato storage heating and cooling. Moreover, when they change the 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 solid-filled electrical regulator and thermoelectric module is higher than of electrical regulator with solid-filled electrical controller and electric heater.

Keywords

Energy of Phase Transition Water-Ice, Heat Exchanger, Heat-Exchanging Equipment, Electrical Regulator, Electric Controller with Solid Filler and Thermoelectric Module, Heating of an Agricultural Object, Vegetable Storage

Introduction

Various energy-saving technologies using renewable energy sources [1, 2, 3, 4], electro-hydraulic effect [5], microwave technologies [6, 7, 8, 9] are used for agricultural facilities. The analysis of the literature data has shown the feasibility of water-ice phase transition energy use [10].

They developed the heat exchanger of the experimental unit, by which they maintain the necessary temperature parameters of the vegetable storage. They determined the theoretical parameters of the modernized electric regulators, which make it possible to maintain the required microclimate parameters of the vegetable storehouse through the distribution of the energy carrier to the condenser and to the additional evaporator of the heat exchanger.

Main Focus of the Chapter

They developed the modernized electric regulators: pulse-relay (Figure 1) [11], with solid filler and electric heater (Figure 2) [12], with solid filler and thermoelectric module (Figure 3) [13]. These regulators are developed for a heat exchanger to obtain ice water phase transition energy.

Figure 1 shows the working sample of a relay-pulse regulator, which is connected to SURI and PBR-3, tested at LLC "Slava Kartofelyu" agriculatural farm and at Cheboksary branch of "UniMilk Company".

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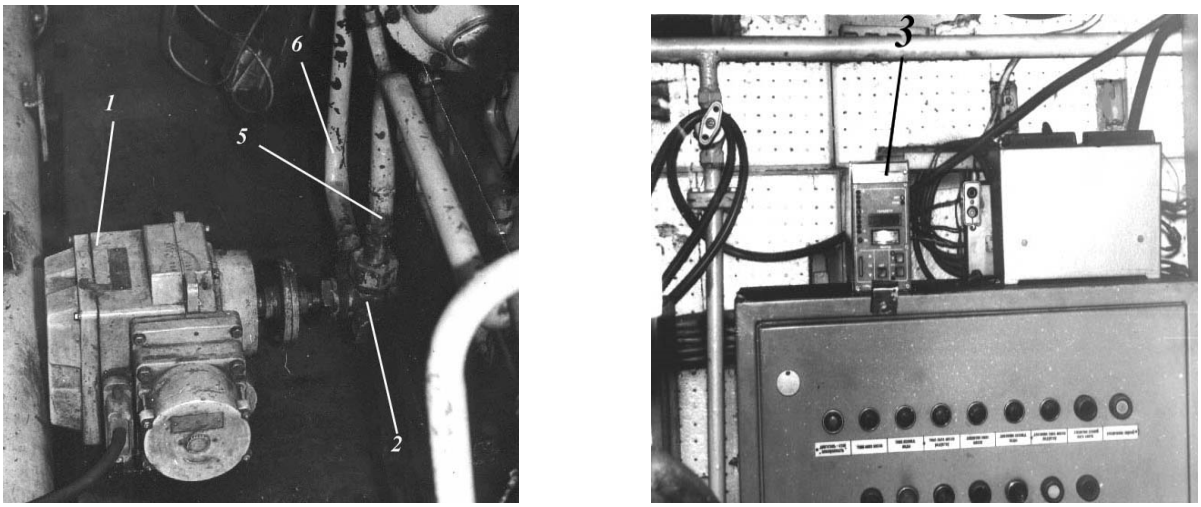

Figure 1: General View of the Relay-Pulse Regulator

(1: Actuator; 2: Regulatory Mechanism; 3: Electronic Control Unit ("SURI", PBR-3); 5, 6: Energy Carrier Channels from the Heat Pump to the Regulatory Body; to the Potato Storage; to the Heating Object, respectively)

Below they presented the sample of an electric regulator with a solid filler and an electric heater (EH) (Fig. 2).

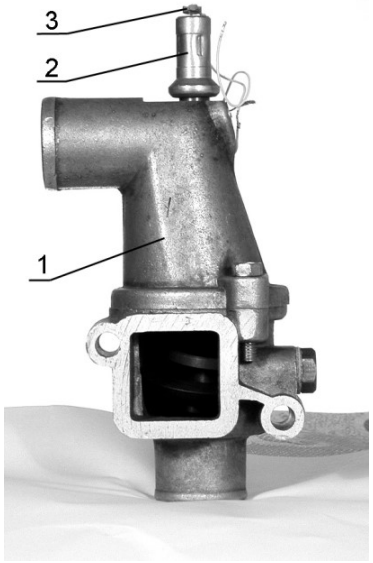

Figure 2 - Electric Regulator with Solid Filler and EH

[1: Housing, 2: Thermo-Power Sensor, 3: Electric Heater (Posistor)]

There is the sample of an electric controller with a thermoelectric module (TM) below [14, 15] (Fig. 2).

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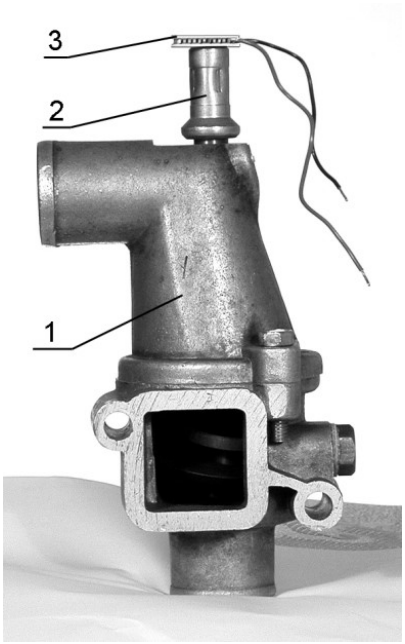

Figure 3 - Electric Regulator with TM
(1: Case, 2: Thermo-Power Sensor, 3: TM)

They studied the dependence of the rod displacement in various designs of actuators (with solid filler; with solid filler and electric heater; with solid filler and thermoelectric module) in the static mode (Fig. 4).

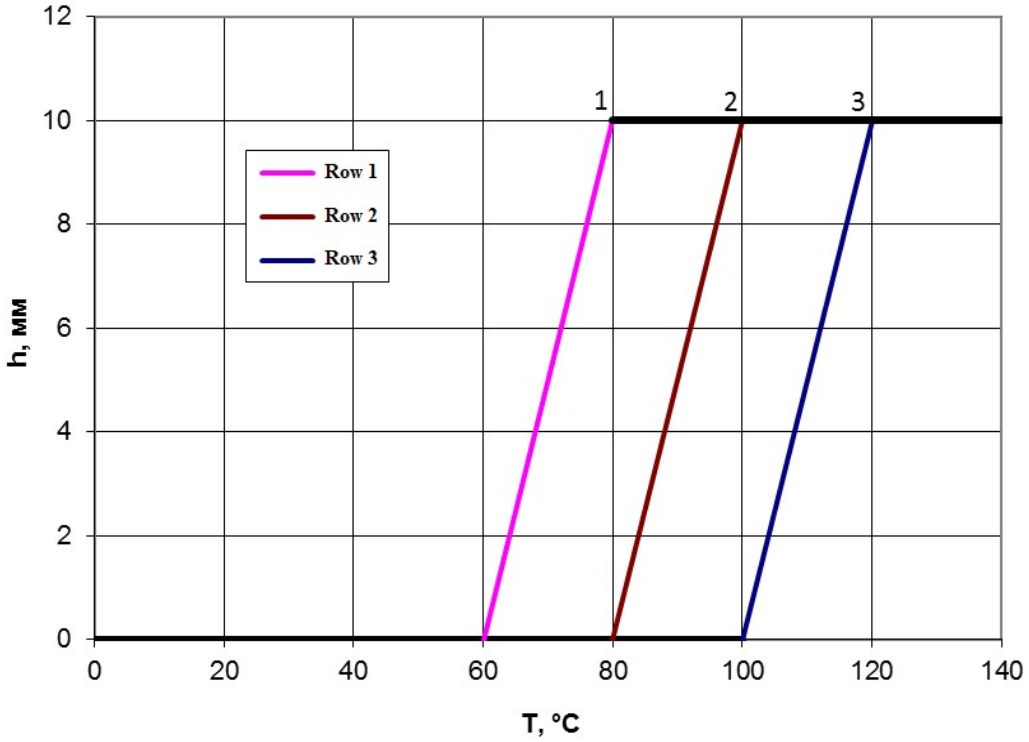

Figure 4: Static Characteristics of Electrical Regulators:
(1: with solid filler and EH; 2: with solid filler; 3: with solid filler and TM)

The study results of the static characteristics of electrical regulators show that the use of heating elements: an electric heater (EH), a thermoelectric module (TM) (graph 1,3) allows you to shift the temperature operation mode in relation to a regulator containing only solid filler (the 2nd graph).

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Experimental studies were carried out with an electric regulator sample, the installation diagram using the example of the regulator with solid filler and TM is shown in Figure 5. In this case, the following were determined: 1) the opening time of the regulator valve; 2) regulator operation modes. Based on the results of the studies, the dynamic characteristics of electrical regulators are developed.

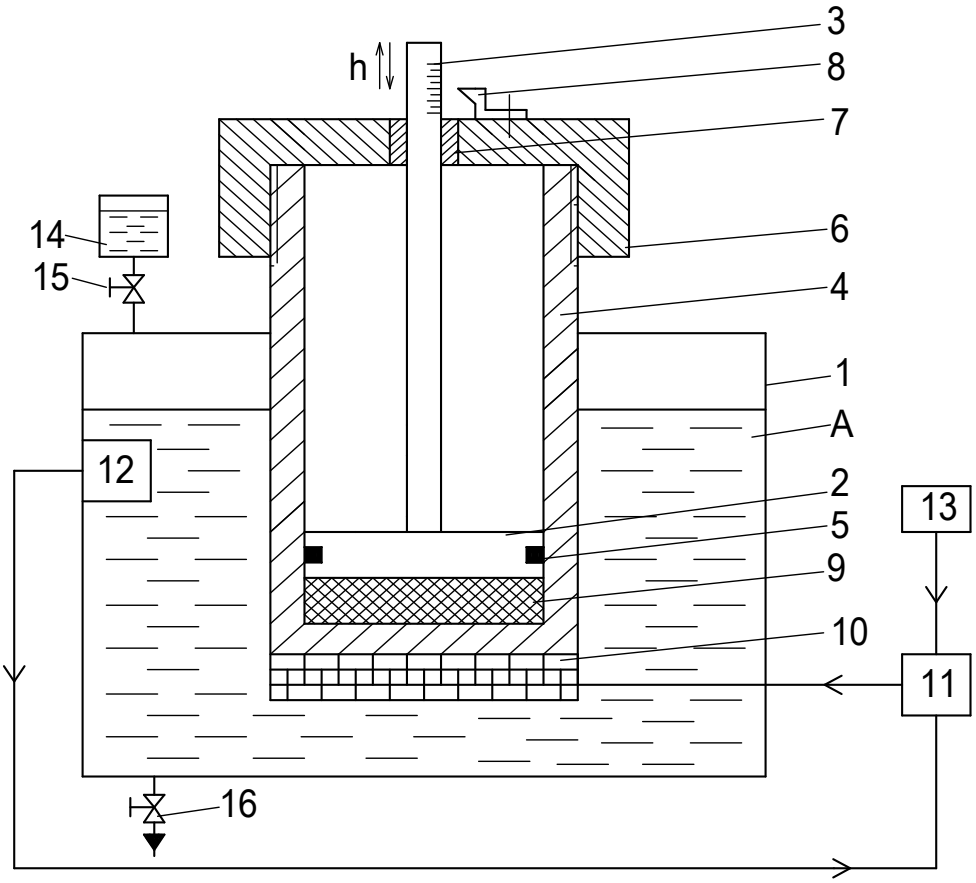
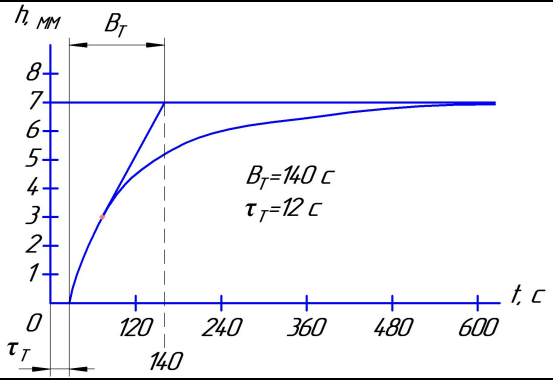


Figure 5: The Scheme of of the Electric Regulator Experimental Unit

(1: Unit Capacity Housing; 2: Piston; 3: Rod; 4: Cylinder; 5: Sealing Ring; 6: Cover; 7: Guide Bush; 8: Pointer; 9: Solid Filler; 10: TM; 11: Control Unit; 12:Temperature Sensor; 13: Load Sensor; 14: Supply Tank, 15, 16: Valves; A - Installation Tank)

The analysis of the dynamic characteristics of electric regulators is shown on Figure 6.

Name	Heating mode (valve opening). Bath water temperature (T_{bath}) 85ºC	
Solid filler regulator (industrial thermostat [16])		
	Heating mode (valve opening). Bath water temperature (T_{bath}) 85ºC	Cooling mode (valve closure). Bath water temperature (T_{bath}) 4ºC

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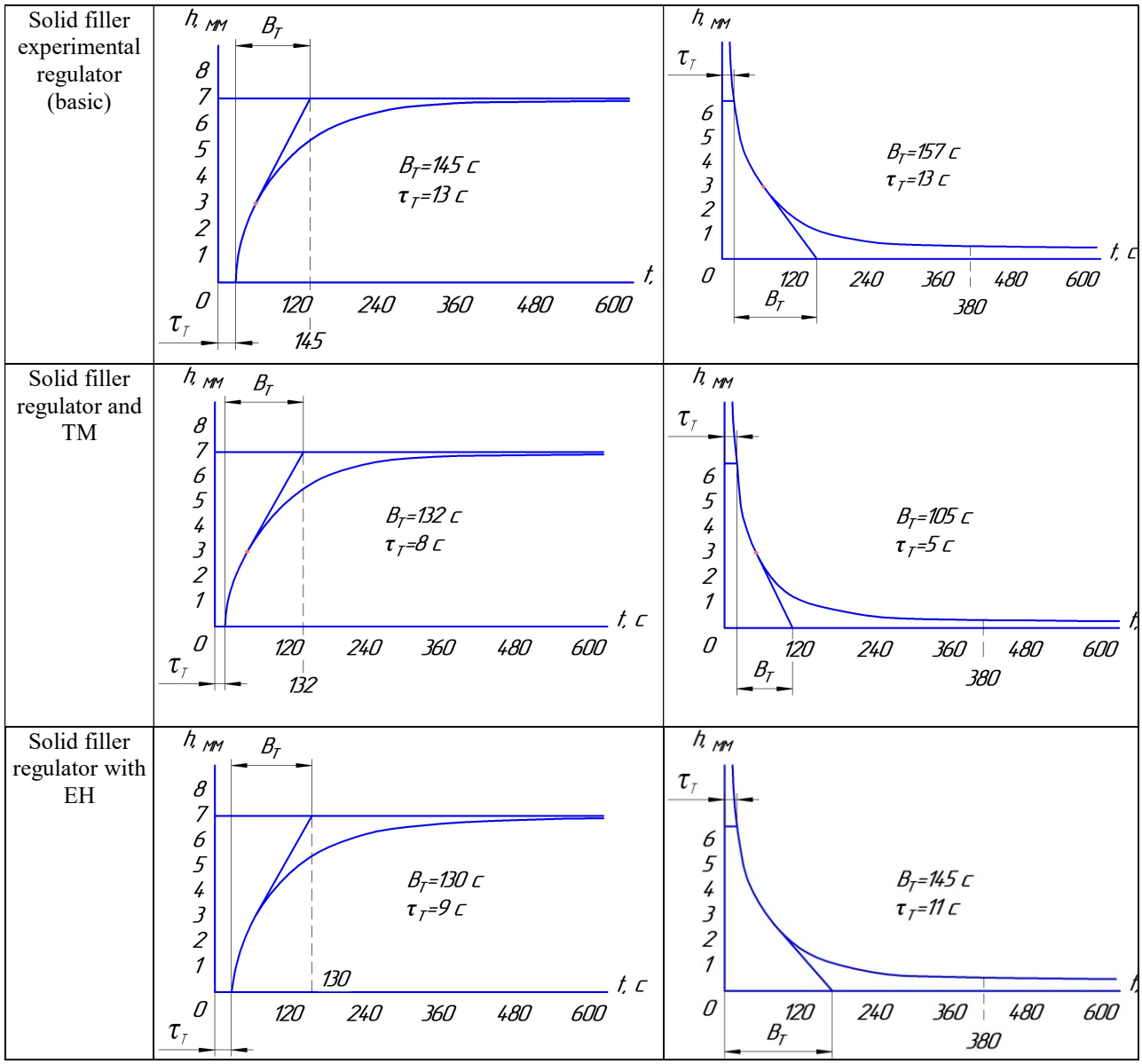

Figure 6: The Analysis of Electrical Regulator Dynamic Characteristics: $B_т$ – Time Constant, s; $\tau_т$ – Delay Time, s

Thus, the electric and thermoelectric heating elements with speed, can maintain the temperature of the potato storage air effectively. Besides, the location of an electric heater and a thermoelectric module outside the energy medium provides the ease of electric regulator installation, operation and repair [17].

The developed electric regulators are intended for use in a heat exchanger design to obtain the energy of the water-ice phase transition.

Conclusion

1. Upgraded electric regulators allow to maintain the microclimate of the vegetable storehouse through the distribution of an energy carrier to a condenser and to an additional evaporator of a heat exchanger.
2. The static characteristics of the upgraded electrical regulators determined the working temperature of the solid filler: the minimum (50-60 °C) - with an electric heater, and the maximum (70-80 °C) - with a thermoelectric module.
3. Using the dynamic characteristics of the modernized regulators their performance was compared. In the heating mode, the delay time of regulator valve opening with a thermoelectric module makes 8 seconds, with an electric heater - 9 seconds, of industrial thermostat (basic) - 12 seconds, of the regulator without a heating element - 13 seconds. In cooling mode, the closing time of the regulator valve closure with the thermoelectric module makes 5 s., of the regulator without a heating element - 13 s., of the regulator with an electric heater - 11 s.
4. The heating efficiency of a solid-filled electrical regulator and a thermoelectric module is higher than the solid-filled electrical regulator with electric heater.

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Conflict of Interest

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

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