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Stability of Heat and Energy Characteristics of Refrigerating Units as a Condition of Quality Increase of Agricultural Production Storage

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Abstract

This article provides information about the importance of stable thermal operating modes of refrigeration machines in the condition of changes in the thermal load on the compressor. We also consider the problem of the minimum energy consumption of refrigeration machines. These two parameters characterize the storage quality of agricultural products in refrigeration machines. It is shown that the temperature stability of the cooling chambers and the minimum energy consumption of the cooling process determine the refrigerator efficiency and, ultimately, the production cost. The article proposes continuous monitoring of the heat and energy indicators of refrigerators. These indicators are recorded and after the set period of operation, control and verification measurements of the control refrigeration machine's heat and energy indicators are performed. The convergence or divergence of these indicators is used to evaluate the stability of the cooling chambers' temperature regimes and the specific energy consumption. We also consider the influence of time on the performance of the compression refrigeration machine changes and methods of current technical condition diagnostics. If the deviations are insignificant, the program goes through the cycle to the beginning of monitoring and after a set period of time again automatically performs control measurements and evaluation of deviations. In the case of significant deviations, the decision-making subroutine is activated: either to operate the refrigerator further; perform its maintenance; suspend its operation; or replace it.

Keywords: refrigeration units, cooling, heat and power characteristics, management controller, storage quality of agricultural production

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1. Introduction

Modern international economic relations, tools of unfair competitiveness and sanctions have impact on the sphere of production and consumption of food products. Therefore,

the issues of import substitution and the development of domestic systems for the production and storage of agricultural products remain relevant. In this regard, the important task is to improve the quality of storage of agricultural production by ensuring the safe and efficient operation of an extensive network of refrigeration units used to cool various products during its production, storage, transportation and sale [1]. The “Energy Saving and Energy Efficiency Improvement” section of the Russian Federation State Program on Energy Efficiency and Energy Saving implies the assessment of the energy efficiency of various electricity consumers during operation. Obviously, these requirements are applied to refrigeration equipment, widely used in the production and storage of agricultural products [2]. Thus, the fishing industry of Russia, despite all the difficulties, is developing now - this is an economically, financially established fact. The fishermen of Russia reached the annual production of biological resources of 4 million tons and this despite the reduction in the number of fishing vessels due to their decommissioning and with a shortage of fish processing and refrigeration facilities. The import substitution of fish products is developing. Over the past five years, fish imports have declined by 17%. At the same time, the consumption of fish products by the population of the country increased. According to various assessments, currently it comprises 19-2 kg per year per capita, which is close to a rational diet of 22 kg. In order to eliminate the deficiencies in rising, modernizing and updating the fishery complex the government decided to allocate 9 billion rubles in the framework of the “fish” state program up to 2022. At the same time, the extraction of biological resources should increase to 4.5 million tons per year and the production of processed and canned fish and seafood should increase up to 4 million tons. It is necessary to store fish in cold.

Meat processing enterprises are energy-intensive industries. At the same time, about half of the energy consumed by enterprises is spent on the production of cold and the operation of cooling systems, and during summer period the proportion of electricity reaches 60% of the total consumption. In addition, enterprise cooling systems account for 25–35% of the consumed water [1].

The enterprises for the production of meat and dairy products, various food warehouses and trade facilities use domestic and imported refrigerators and relatively small power plants — small refrigeration units of the compression type, in which their specific energy consumption depends on the efficiency of heat removal from a condenser [1, 6].

The proposed design of a domestic refrigerator has the condenser with finning and it is fixed to the refrigerator so that it is able to make reciprocal movements and angular oscillatory movements in plane. In this embodiment, the upper part of the conditioning unit forcibly oscillates and the lower part connected to the sealed unit remains stationary.

The oscillatory movements of the tubing coil with respect to air create complex turbulent movements of the air flows around the fins and the condenser tube, which increases the intensity of heat exchange between the surrounding air and the surface of the condenser.

In order to ensure minimum energy consumption for the oscillation of condenser, the oscillation frequency of the pipeline close to the resonant frequency of the cantilever-fixed condenser is set, while the energy consumption of the electromagnetic vibrator is minimal. All this will allow creating an oscillatory process with low energy costs, as well as conducting intensive heat transfer of the condenser with the air. At the same time the small amplitude of the oscillation of the condenser will not be transmitted to the household refrigerator and cause its vibration. This method increases the effect of the heat exchange process on the surface of the condenser. In addition, the specific energy consumption of the compression refrigerator is reduced, which will lead to significant energy savings, increased reliability and safety of the refrigeration equipment when solving the multifunctional problem of product sales and storage. However, the reliability of such refrigeration technology is still understudied. For reliable operation of refrigeration equipment and minimal energy consumption for refrigeration while cooling products and raw materials, domestic cooling systems and methods for producing high-quality cold are needed. The authors mean stable temperature conditions for the operation of refrigeration units under conditions of changing thermal load on the compressor.

2. Research Task

Refrigeration units (RU) during operation, as a rule, are not monitored in terms of “specific energy consumption” [3], and in cooling chambers the temperature is not always stable with a changing heat load on the cooling system. At the same time it is known that compression refrigerators during operation are exposed to various internal and external operational factors [4] that affect the stability indicators of the cooling system, including changes in heat and energy indicators, in particular, daily energy consumption increases and temperatures in chambers can exceed values specified in the technical documentation. The temperature regime during storage of products is also affected by the factor of opening doors to chambers [5].

A large fleet of operating RU determines the appropriateness of monitoring their technical condition during operation, including the use of a programmable controller for this purpose [6].

During the operation of RU, an individual user does not have the ability to quickly detect changes in the operational parameters of his refrigerator, which may deteriorate after a certain period of operation. At the same time, temporary processes in the cooling system, including the cooling chamber, compressor, refrigerant, lead to deviations of the performance of the refrigeration unit and can lead to significant changes and sometimes to the run-out of refrigerator state [7].

Refrigeration units unlike technological machines are constantly connected to the power line and constantly consume electricity during the operation of the compressor. It is obvious that the technical condition of such machine is characterized by specific energy consumption and the accuracy of the maintained temperatures in the refrigerator chambers [8].

3. Problem Solution

Increased energy consumption, unstable temperature modes in cooling chambers that do not correspond to the temperature conditions specified in the technical documentation, accelerated wear of friction units in the compressor and a significant decrease in the service life can be eliminated by monitoring the technical condition of the RU as a whole and its individual subsystems during operation. Control systems for throttling process, operation of the condenser drive and compressor operation under the management of the controller can neutralize the influence of a number of operational factors and ensure optimal functioning of a refrigerator. As a result, its daily energy consumption can be kept to a minimum. This will ensure the quality of storage of products while reducing the cost of producing cold, and, consequently, reducing the cost of agricultural products.

It is known that during the operation of refrigeration units for cooling products or in technological lines of food production, the methods for their technical diagnostics are applied, which can be studied using the patent documents of the Foundation of Federal Institute for Industrial Property.

The analysis of the studied methods and methods for the assessment of the technical condition of refrigeration units using literature sources and FIPS foundation revealed several specific approaches to the solution of the diagnostic problems of these machines. In this paper, the authors consider the most characteristic ones. For example, in the work [9] a method for the operational assessment of the heat and energy performance of a refrigeration unit during its operation is described. The purpose of the research is to ensure the stability of the heat and energy performance of a refrigeration unit.

There is also the method for the assessment of the current state of the refrigeration unit to ensure the stability of the heat and power performance of its operation [10], in which the technical condition of the refrigerator is determined by the assessment of the change in the coefficient of run time of the compressor. There is claim for an invention of the “Bosch und Siemens Hausgeräte” company, which describes a diagnostic method for a refrigeration unit based on the measurement of several temperatures in the subsystems of a refrigeration unit [11]. In this method, after the measurements, the obtained indicators are compared to the standard (passport) values of these indicators. According to the results of the comparison, it is possible to make a conclusion about the technical condition of the refrigeration unit.

There is also a known method for the determination of heat and energy performance of a RU during its use, in which the temperature conditions in chambers are measured at different heat loads and the specific (average daily) power consumption at the beginning of operation at certain intervals of the RU’s operation time is determined. For example, the interval may be one year or another period of time. Measurements, calculations and comparisons in this method are performed by the program managed by the controller. The details of the method are described in the source [12]. The methods for the assessment of the energy efficiency of a working refrigerator and the stability of its temperature conditions, studied by patent sources and publications, are based on the obligatory participation of a person in the process of assessment.

The existing methods do not provide an automatic process for the determination of the performance of a refrigerator and systematic monitoring of its operation. The authors developed a method for systematic monitoring of temperature characteristics and specific energy consumption. This method provides minimal human participation in the monitoring process. For this, the refrigerator is equipped with a module for the measurement of current characteristics on the basis of a programmable controller with software control of the monitoring process and measurement subprograms for processing the received information. This monitoring system allows simultaneous monitoring of several refrigeration units at one storage facility of products. The authors developed a method and algorithm in order to ensure the stability of heat and power characteristics of RU using automated microcontroller-based software control, presented in Figure 1

The algorithm includes the following stages:

1. Heat and energy indicators of RU are measured before the start of operation, which are taken as the basic values in the subsequent control program in order to compare the subsequent values of the measurement results with the basic ones, after the set period of operation.

2. The record (registration) of these indicators is performed and upon the expiration of the specified period of operation, control verification measurements of heat and power parameters of the controlled refrigeration unit are performed.

3. According to the convergence or difference of these indicators the authors assess the stability of temperature conditions in cooling chambers and specific energy consumption, their change, or reveal the transcendental values. The set period between the basic and control measurements depends on the type of a RU, its service life (run time) and the variability of the conditions of use.

4. The results of measurements of characteristics are recorded, the specific energy consumption and the range of temperature fluctuations in refrigerator chambers are calculated, and then operations of comparison and control subprograms to ensure identical measurement conditions are performed. In order to implement the algorithm, a programmable controller is used, which supplies the cooling chamber.

5. If the deviations are insignificant, the program proceeds to the beginning of monitoring and after a set period of time again it automatically performs control measurements and the assessment of deviations. In case of significant deviations, the decision-making subprogram is activated: to operate a RU further, or to carry out its maintenance, or to suspend its operation or replace it. This description provides an abbreviated algorithm.

4. Conclusion

1. The authors developed a method to improve the quality of storage of agricultural products ensuring the stability of heat and power characteristics of refrigerators;

2. The stability of heat and power characteristics of refrigeration units is ensured by continuous monitoring of changes in the performance of RU;

3. The automatic detection of critical deviations in the operation of RU is provided;

4. The accuracy of the determination of temperature indicators and specific energy consumption of RU is ensured, taking into account heat load, including the ambient temperature, the load of the chambers with products and their heat capacity;

5. The authors developed a controller operation algorithm in order to ensure the stability of heat and power characteristics of refrigeration units.

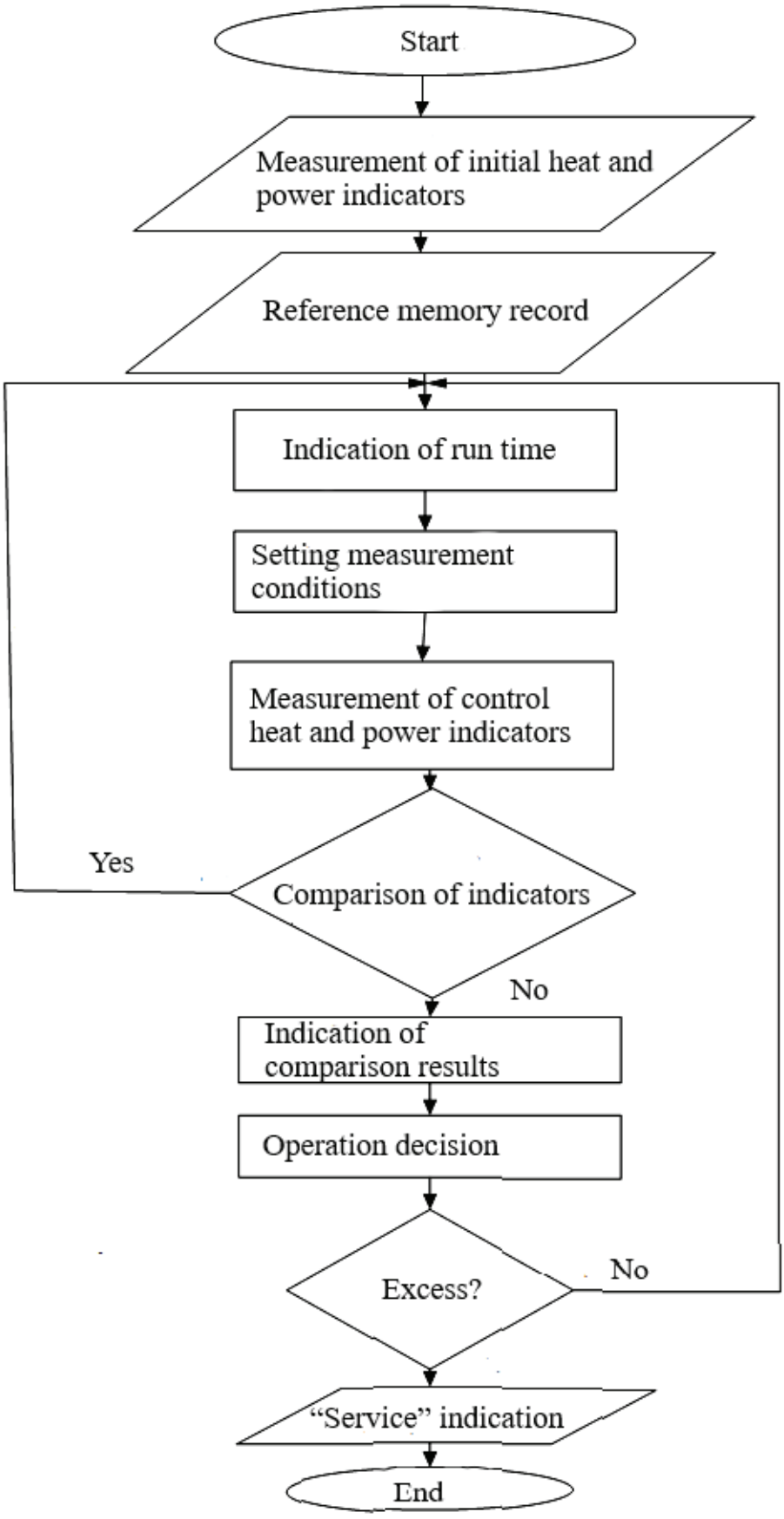

Figure 1: Algorithm of controller operation

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