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DEVELOPMENT OF A NEW METHODOLOGY FOR ACCEPTANCE TESTING OF REFRIGERATION APPLIANCES

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Abstract. Each manufactured refrigerator must be subject to acceptance testing to make sure every single unit complies with the heat and power characteristics prescribed by the state standard for each individual type of refrigerators (the types differ in the number of chambers, the number of compressors, etc.). The standard indicates only the parameters that the device must comply with, while the testing method is not regulated and is chosen by the manufacturer in accordance with the specifics of production or is developed by the manufacturer independently. The object of this work is the possibility of using a new technique for measuring the heat-and-power characteristics of the device. Based on the results of the comparative analysis with the existing methods, the differences of the new method are indicated, the advantages of its use are given in comparison with the existing and currently used control methods in Russia and other countries. Considering the comparative characteristics, such advantages of the new technique as saving production space, exclusion of the human factor, saving energy costs were found.

Keywords: refrigerator, thermal power characteristics, consumed electric power, acceptance test, test procedure

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РАЗРАБОТКА НОВОЙ МЕТОДИКИ ПРОВЕДЕНИЯ ПРИЁМО-СДАТОЧНЫХ ИСПЫТАНИЙ ХОЛОДИЛЬНЫХ ПРИБОРОВ

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Аннотация. Каждый холодильник, выпускаемый заводом, должен в обязательном порядке пройти приёмо-сдаточные испытания, по результатам которых можно судить о соответствии отдельно взятой единицы продукции теплоэнергетическим характеристикам, прописанным в стандарте для каждого типа холодильников (типы отличаются количеством камер, количеством компрессоров и т. д.). В стандарте указаны только параметры, которым должен соответствовать прибор, методика проверки не регламентирована и выбирается производителем в соответствии с особенностями производства или разрабатывается производителем самостоятельно. В статье изучена возможность применения новой методики измерения теплоэнергетических характеристик прибора. Описаны отличия новой методики, приведены преимущества её использования по сравнению с существующими и применяемыми на данный момент методиками контроля в России и других странах. При рассмотрении сравнительных характеристик отмечены такие преимущества новой методики, как экономия производственных площадей, нивелирование человеческого фактора, экономия затрат на электроэнергию.

Ключевые слова: холодильник, теплоэнергетические характеристики, потребляемая электрическая мощность, приёмо-сдаточные испытания, методика проведения испытаний

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Introduction

At the moment, in order to comply with the established standard IEC 62522-2013 [1], each refrigerating appliance must undergo acceptance tests for compliance with the standard of thermal power characteristics, which are also described in the standard IEC 62522-2013 [1]. The exact method of checking each device is not stated in the rules, so that each refrigerating appliances producer can choose one of the existing methods or develop its own new method. We will consider the possibility of replacing the existing method with a new one at the Krasnoyarsk Refrigerator Plant OAO KZH Biryusa [2, 3], describe all the disadvantages of the existing methodology and possible ways to make the new method more optimized and efficient [1]. We will also describe the most advanced existing ways acceptance testing.

Description of the methodology in use

Currently, an important point of acceptance is the need for a sufficiently long testing time. Each refrigerating appliance is tested for 40 min; all this time the refrigerating appliance must be connected to the power supply, after which the operator measures the temperature inside the refrigerating appliance with a pyrometer [4]. The existing system is programmed in such a way that at the time a person reads the temperature, there is already information about the energy consumption of this particular piece of equip-

ment in the system. The system also has the information about each refrigerating appliance model [5], the boundary permissible parameter values, which makes it possible to programmatically determine the correspondence of the thermal power parameters of the device cooling system to standard parameters, so that the machine decides whether the cooling device operates correctly [6]. If not, an operator can see a message with the description of a failure on the computer screen and a full list of parameters that refer to that exact one device [7, 8].

The system has the following disadvantages:

• The need for a sufficiently large production area where the refrigerating appliances are placed for acceptance testing by the existing method for the time of 40 min. It is impossible to reduce this amount of time without making changes to the methodology, because in a shorter period of time, the refrigerator compartment of the device will not have enough time to cool down to a temperature by which it will be possible to judge its serviceability [9]. Additional production space incurs extra maintenance expenses.

• Long time (40 min) when the refrigerating appliance needs to be connected to the power network [10]. During this time, the refrigerating appliance consumes electricity (additional expenses that potentially can be lowered).

• The presence of a human factor when measuring the temperature in the refrigerator compartment of the device. The measurement is carried out by a person using a pyrometer. According to the methodology, the operator must measure the temperature at a certain point in the refrigerating chamber, which, due to human factors, cannot always be performed correctly [11]. There is a certain area in the back of the cooling chamber for the test temperature measurement, and a tester can accidently measure the temperature in a point outside of the needed area, so the result of the test will not be completely correct.

Description of an alternative existing technique

There is a progressive control methodology with a test time of approximately 9 min [12]. A certain device that measures thermal power characteristics of every cooling system should be placed in each refrigerating appliance tested. This method is often employed at Italian factories producing refrigerating appliances. Italian company Galileo provides devices that allow the testers to measure consumption parameters and the cost of one such device is approximately 400-450 euro. Considering the number of refrigerating appliances that can be simultaneously acceptance tested (approximately 150–170 devices), such a system is rather expensive. The method is used to determine the temperature in the refrigerating appliances indirectly (Fig. 1). In this case, the decrease in temperature inside the refrigerator and freezer compartment is

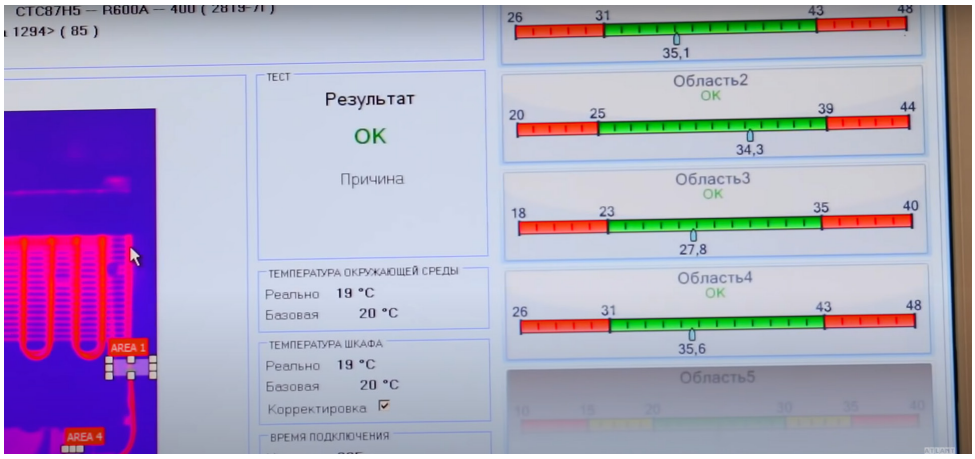


Fig. 1. Measuring the temperature in the refrigerating chamber by determining the temperature of the condenser

not measured, but with the help of a thermal imager, the temperature rise of the condenser is measured at certain points and moments of time.

For the refrigerating appliances of the same model, after a certain time interval, the temperature distribution on the condenser tube is believed to be repeated [13]. Thus, heating to 35–45° occur in the same places on the condenser of the same refrigerating appliances. In this case, the operator does not participate in the measurement of parameters [14], the decision on the compliance of the state of the refrigeration unit with the declared requirements is made by a computer without human intervention.

The main disadvantage (besides the high cost) of this method is the need to ensure the exact operating time of the compressor working before measuring the temperature with a thermal imager (with an increase of no more than 15–20 sec). In case of violation of the conveyor cycle, all refrigerating appliances from the conveyor of the testing station must be disconnected from the power grid, relocated to the storage [15], and kept at ambient temperature until the condenser and compressor have completely cooled down. Only after that, they can be reloaded onto the test conveyor and tested again.

Description of the new technique

The power consumed by the compressor during control tests of the refrigerator operability is determined by various factors, both external (inside temperature) and internal (boiling point of the refrigerant, compressor type). The main factors are:

- the amount of compressors in the cooling system;
- the volume of the refrigerating and freezing chambers;
- ambient temperature.

All processes related to temperature control in the refrigeration unit happen because of the operation of the compressor. In particular, the heat energy released by the condenser and absorbed by the evaporator is related to the electrical energy consumed by the compressor. In a long-term test, the relationship between the electrical power consumption of the compressor and the refrigeration processes are shown in Fig. 2, 3, where the power consumption is shown in blue, the temperature in the refrigerator compartment is shown in green and the temperature in the low-temperature compartment of the refrigerating appliance is lilac [16]. The Fig. show the result or the test of two two-compartment refrigerating appliances conducted by the authors at the local refrigerator factory [17, 18].

Let us consider the graphs and try to find the connection between the obtained data on the consumption of the active electrical power of the compressor and the temperatures on the surface of the condenser

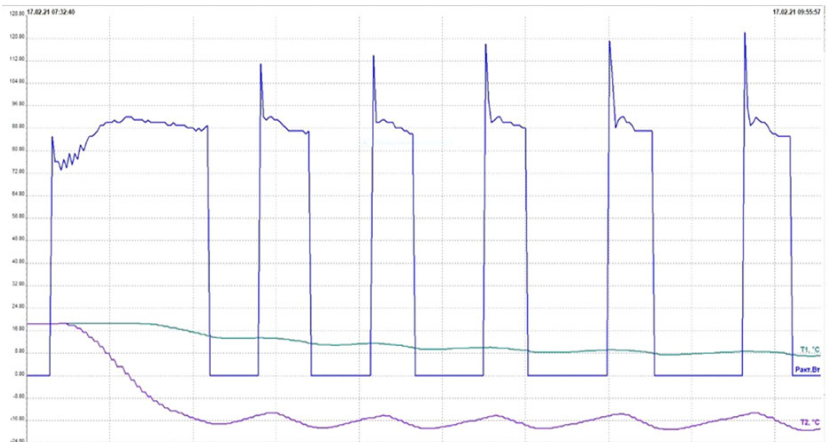


Fig. 2. Testing two-compartment refrigerating appliance No. 1

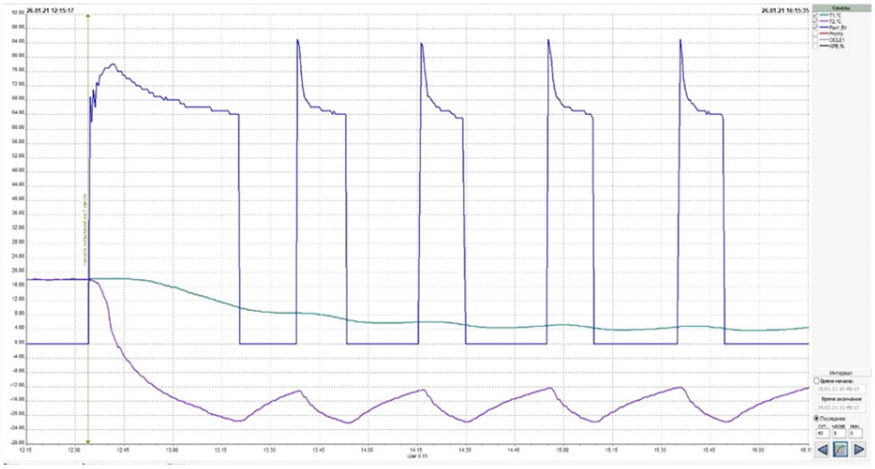


Fig. 3. Testing two-compartment refrigerating appliance No. 2

on the middle shelf of the refrigerating and freezing chambers of the refrigerating appliance. Temperature and electrical power consumed by the compressor is obtained using a power network parameter collection device: a module for measuring parameters of the electrical network "ME110" produced by OWEN and transmitting the received data to the "OwenCloud" cloud service using a PM01 GSM / GPRS modem in order to archive and subsequently analyze the data. In the cloud service, we can also store the data as long as we need, so that if any questions about any device arise, we would be able to find all the parameters of any refrigerating appliance in a very short time. At this point, we need to collect power supply parameters of refrigerating appliances of the same model. Fig. 4*a*,*b* shows graphs of the power consumption of refrigerators without deviations in the operation of the cooling system at ambient $T = 21^{\circ}$.

In the last two Figures, we note very similar power consumption graphs after the first start of the compressor.

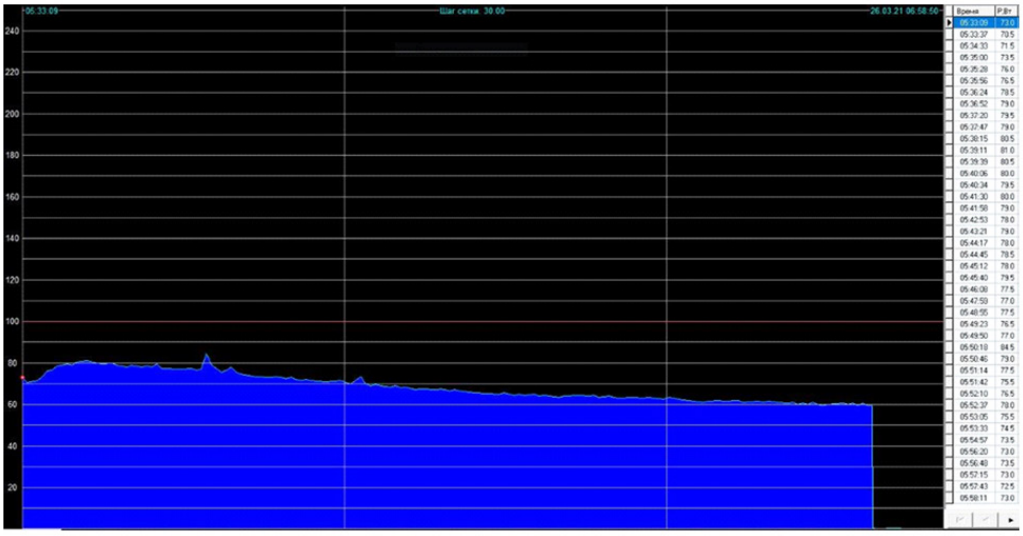
According to the graphs [19–21], we see how the active power consumed by the compressor changes in time for refrigerating appliances that meet the requirements of the standard [1] IEC 62522-2013. Fig. 5*a*,*b* shows the measurement of the same parameter only for refrigerating appliances with defects in the cooling system, so we can clearly observe the difference in the electrical power consumption of the compressor of a refrigerating appliance with a defective refrigeration unit.

The graphs obtained from refrigerating appliances that meet the requirements of the standard [1] IEC 62522-2013 show the repeatability of the dependence of the parameters over time with a small spread of no more than 7–10 % in the electrical power of the compressor. Any deviation of the compressor power consumption graph is necessarily associated with changes in the temperature graphs in the refrigerating appliance and low-temperature compartments of the refrigeration unit. We can conclude that according to the graph of the electric power of the compressor one can judge about the parameters of the refrigeration unit. Thus, having collected a certain amount of statistical data, it seems possible to create a new method for determining the compliance of the heat and power parameters of refrigerating appliances with the norm, automatically determining the correct operation of the refrigerator cooling system, according to the power consumption graph.

The advantages of the new technique in comparison with the existing ones

- Reduced time for acceptance tests. According to the new method, the time spent on one product unit is 6–10 min, which is at least 4 times less than that of the existing method.
- At least 4 times less energy costs, because each refrigerating appliance will be connected to the electrical network for a much shorter time.

a)



b)

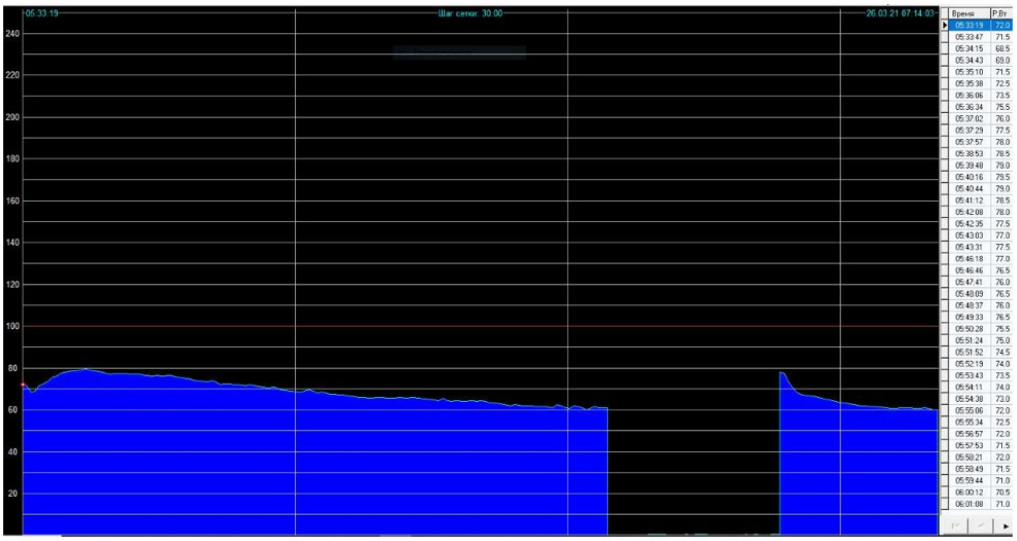
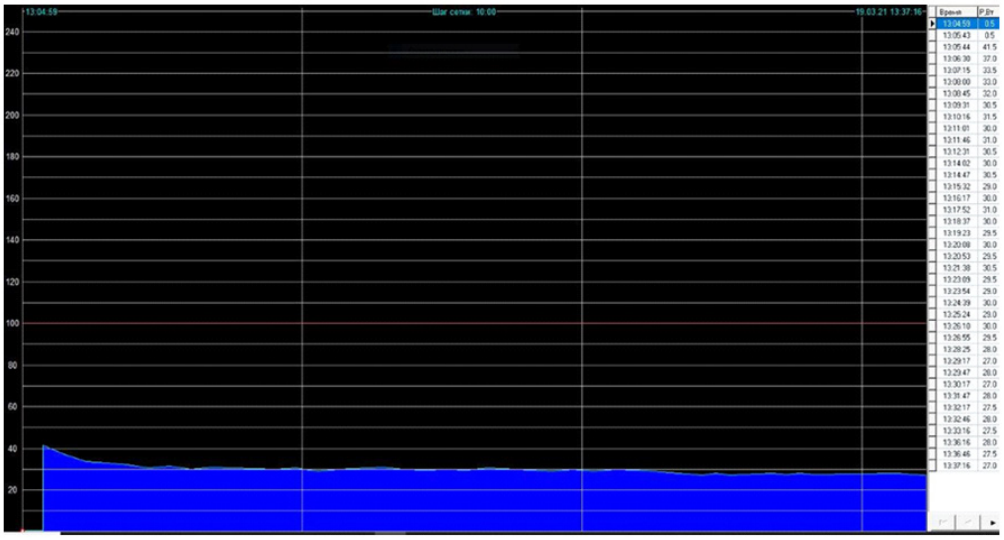


Fig. 4. Graph of the power consumption of the refrigerating appliance:
a – power consumed by refrigerating appliance;
b – power consumed by refrigerating appliance of the same model

- Less production area required for testing.
- Elimination of the human factor as all of the measurements are automatic.
- Any deviation of the test time towards its increase does not cancel the result (that was stated as a negative point in the method of the condenser's temperature measurement by the thermal imager).
- Permissible deviation of the supply voltage within 10 %.
- Easy way of obtaining reference values for each newly released model of refrigerating appliances. It is enough to determine the limits of the spread of the controlled power values by initially testing 20–30 new specimens on a test conveyor (previously tested in a steady state in heat chambers).

a)



b)

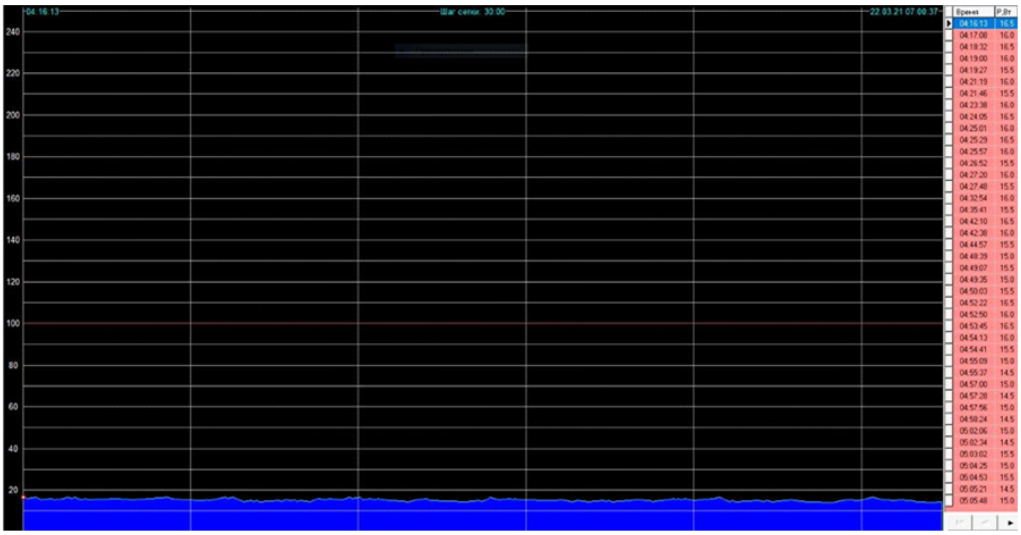


Fig. 5. Graph of the power consumption of the refrigerating appliance:
a – with a defective refrigeration unit;
b – by another refrigerating appliance with a defective refrigeration unit

Conclusion

Based on the results of the experiments presented above, it is possible to draw an unambiguous conclusion about the usefulness and effectiveness of introducing a new methodology for conducting acceptance tests. The authors intend to develop this idea further by accumulating statistical information on the control of electrical power of two models of refrigerating appliances during acceptance tests. In addition, it is planned to determine the dependence of the compressor power on the ambient temperature, supply voltage, initial temperature of the internal cabinet of the refrigerator, as well as with the main defects of the refrigeration unit.

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