Generation of test method boundaries for refrigeration technology

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Abstract. When manufacturing refrigeration appliances, it makes sense to minimize the number of defective products. This can be achieved in several ways. Since the causes of marriage are great, only those that are determined by a person and are not unambiguous should be considered. One of the possible reasons for its decrease is the accurate determination of the numerical values of the parameters of a suitable refrigerator. A deviation from the values obtained in this way will form a suitability range for each temperature. The task is facilitated by the presence of two numerical parameters for suitability: temperature and power. Consequently, if the power is at the level of the working standard refrigerator, and the temperature gained over a certain time is higher than it should be, then the refrigerator can be unambiguously recognized as defective. This article discusses the possibility of an automated calculation of the boundaries of the parameters of the acceptance test methods (ATM). They are carried out before the release of the finished product to the consumer. The calculation is based on real production statistics. The test data forms parameterized point clouds for power and temperature. Classifying points in the cloud will make the boundary calculations more accurate. This will lead to a decrease in the human factor when deciding on suitability. Consequently, the accuracy of determining the defective product will increase.

1. Introduction

According to GOST 16317-87, acceptance tests (ATM) must be subjected to each manufactured refrigeration device (refrigerator), for compliance with the reference sample. The sequence of testing is indicated in the normative and technical documentation (NTD) for a refrigeration appliance of a particular model. Temperature and energy parameters (TPE) are checked according to the method developed by the manufacturer [1].

In this work, the manufacturer is "Krasnoyarsk Refrigerator Plant "Biryusa". The development of PSI techniques is carried out in the laboratory based on experimental data. The obtained PSI methods set the permissible limits in which the temperature and energy parameters of the refrigerating device, obtained at the PSI station, should be located.

Manufacturing technology of refrigeration devices "KZH" Biryusa" provides that after assembly of the device it is connected to the power supply. Further along the conveyor, it moves for a predetermined time, during which it manages to enter the operating mode and lower the internal temperature of the...
chamber. The initial temperature level from which the device is started is in most cases equal to the ambient room temperature. The exception is the warm body of the device, when it was recently foamed. During the tests, the refrigerating appliance is cooled to the level set by the tester on the temperature controller. Both an electronic unit and a mechanical temperature switch with a bellows pressure sensor can act as a regulator.

At the exit from the PSI station, the device is disconnected from the power supply and checked according to two parameters: the power of the last shutdown and the internal temperature of the chamber, to which the cooling system had time. If these parameters are within the specified method, then the product goes further along the conveyor. It is staffed, packed and sent to the warehouse. Otherwise, if the value of one of the parameters is outside the permissible limits of the technique, the product is removed from the conveyor and sent either for retesting or to a repair site.

Modern computer-aided design systems have a multi-module structure and can work autonomously, however, the automation efficiency will be noticeably higher if the data generated in one of the systems is available in other systems, since the decisions made in them will become more reasonable. To achieve the proper level of interaction between industrial automated systems, it is required to create a single information space not only at individual enterprises, but also, more importantly, within the framework of the merger of enterprises.

A single information space is provided through the unification of the form, content and lists of names of entities, attributes and relations in the considered subject area, which are the basis for a unified electronic description of a product in the CALS space.

The world leaders among the manufacturers of ERP (Enterprise Resource Planning) software are the R3 SAP, Oracle Applications, Omega Production systems. Among the Russian automated control systems there are the Parus, Galaktika, Flagman, Compass systems, etc.

All of these systems have a subsystem "Production" or "Production management", which are used to maintain product data, planning and operational management of production processes, but none of them has a module that solves the issues of testing [2].

The proposed program is designed to facilitate the laboratory's work in drawing up and adjusting the boundaries of the method. The idea is to programmatically set optimal boundaries based on statistics data. It is assumed that the program will be more accurate in adjusting and setting the tolerance limits than a human.

2. Data sampling
There is a database of statistics collected over several years. It stores data about models that have already been tested. When choosing the B-649 model and the period for September 2020, the program will display on the graph a two-dimensional point cloud shown in figure 1. The abscissa shows the power of the last shutdown, and the ordinate shows the ambient temperature at which the power value was obtained.

![Figure 1. Cloud of points of values of power (Upper plot) and temperature (Lower plot). a - high power, b - low power, c - high temperature.](image-url)
Borders, with a shaded area inside, indicate the boundaries of the area specified by the technique. In figure 1, you can see that a significant number of points are depicted that are outside the area. This designation of those models that were recognized as a marriage, or sent for re-testing [3].

It should be noted that for correct calculations, it is necessary to remove data from the sample that will negatively affect further calculations. These include the data recognized as marriage.

Marriage can be recognized by the following indicators (classification):

- The temperature inside the refrigerator compartment is too high or coincides with the ambient temperature, due to the compressor not starting or undercharging [4]. In figure 1(c) and figure 2, the measured temperature is 21 °C;
- The power value is too high (figure 1(a)), this is caused by a jammed compressor or a high dose of refrigerant;
- The power value is too low. This is due to underfilling, leakage, or the compressor did not start, in which case the power will be zero (figure 1(b)) [5];
- For a more detailed understanding of the suitability, it is necessary to consider the graph, which depicts the cycle of the sample refrigerator (figure 3).

![Figure 2. High temperature inside the refrigerator after testing.](image)

![Figure 3. The cycle of the B-649 refrigerator at an ambient temperature of 25.](image)

Power is plotted on the vertical axis of the graph; time is plotted on the horizontal axis. The horizontal solid line is drawn at 88 W, which corresponds to the first cycle trip power. As you can see from the graph, the shutdown power of the refrigerator can be higher if the device is turned off before the end of
the operating cycle. But if the power is lower than the drawn line, then this may indicate an insufficient amount of freon. Therefore, such cases of power reduction should be given higher priority than increased power.

In addition to filtering data, it is necessary to take into account the effect of seasonal temperatures on the sample and the methodology as a whole. As the ambient temperature rises, the temperature limits increase. The power channel accordingly also moves up the vertical axis (figure 1).

The range of values changes depending on this limit. The figure shows that many points go beyond the boundaries. These values cannot be discarded from the sample during program calculation, since they signal that boundaries may be revised at a given location. The channel width can thus change significantly.

3. Software-generated boundaries

To create boundaries programmatically, it is necessary to take into account the seasonal influence of temperatures, the continuity of the sample, and the invariability of the design of the model used for the measurements. Failure to comply with the above affects the accuracy of the calculations [6].

To begin with, 2020 was chosen and the period from July to December. Model B-649. After that, based on the selected cloud of power points, the SIP boundaries were drawn. Then the noise was removed from the sample and the boundaries were recalculated. The results are shown in the graphs in Figure 4.

When creating boundaries on the basis of a sample, we obtain two boundaries that form a channel of suitable values for the ATM.

![Figure 4. Centerline-based power boundaries.](image-url)
The top graph shows that the boundaries are more displaced downward, which is why more boundary values enter the channel. This is due to the noise that lies below the main point cloud. Especially many points lie on the horizontal axis. These are zero power values that are caused by not starting the parting. The percentage of filtered noise in this case is 4.8% or 840 items. This amount of noise noticeably shifts the border down and should not be reflected in the created methods. The points that, because of this, fall within the usability limits, can be the power values of refrigerators with an unfilled refrigerant or a broken socket (P = 0 W).

Too little Halon will cause the refrigerator to run longer in order to lower the internal temperature to the target temperature. Consequently, the parking time decreases or does not change, which in any case leads to an increase in the working time ratio (WTR). Hence, we can conclude that the power consumption of the device also increases. Thus, low power should be considered a marriage. The boundary that separates the scrap points from the points suitable for release on the graph should be calculated as accurately as possible [7].

As you can see in the upper graph of figure 3: the lower border of the channel cuts off the models that are not included in the channel. While there is a margin at the upper border.

4. Conclusion

The ultimate goal of the created program is to minimize false rejects and accurately identify truly unusable models, by discarding from a sample of refrigerators whose values do not correspond to the methodology. The programmatically created boundaries for each type of marriage are designed to solve this problem.

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