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Development Trends of Parametric Row of Compression Refrigerating Devices

Yurii BAIDAK

Odessa National academy of food technologies, 1/3 Dvoryanskaya str., Odessa, 65082, Ukraine,
Corresponding Author email: kozak_admin@ukr.net

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ABSTRACT: The main directions of compression refrigerating devices modern parametric row development and the most significant recent achievements which allow to improve energy efficiency and productivity of refrigeration machines, and those on which they will develop in the future, namely: improving of compression refrigerating device using environmentally friendly refrigerant; increasing of the volume and reducing the temperature in the freezer; searching of new insulation materials that promote the term of low temperature keeping in the refrigerating chamber in case of temporary loss of power supply; reduction of compression refrigerating device outer surface with unchanging useful volume of the chamber; creating conditions of uniform temperature distribution inside the useful volume of refrigerating chamber are summarized in the paper.

Introduction

Nowadays the main trends in the field of compression refrigerating devices parametric row development which allow to improve energy efficiency and productivity of refrigerating machines, and those on which they will develop in the future are the following:

improvement of compression refrigerating device using environmentally friendly refrigerant;

increasing of the volume and reducing the temperature in the freezer;

search of new insulation materials that promote the term of low temperature keeping in the refrigerating chamber in case of temporary loss of power supply;

reduction of compression refrigerating device outer surface with unchanging useful volume of the chamber; creating conditions of uniform temperature distribution inside the useful volume of refrigerating chamber;

Main Trends In The Field Of Compression Refrigerating Devices Parametric Row Development

Improvement of compression refrigerating device using environmentally friendly refrigerant

Recently, the leading international companies focused on production of domestic compression refrigerating devices where the freezer is made as a separate department with the 30 ... 40% of the total net volume of a chamber. Over the past 22 years efforts of compression refrigerating devices leading manufacturers, in accordance with the decisions of the World community have been aimed at the development of safe for the ozone layer refrigerants. The reason for this was implementation in production in the early 30-ies of household compression refrigerating devices charged with destroying the ozone layer refrigerant - Freon R12. In that time it significantly improved the specific electrical coefficient of refrigerating appliances, reduced power consumption of the units and thus contributed to the wide diversity of compression refrigerating devices, and their implementation into everyday life.

This situation led to the fact that only in the former CIS countries was accumulated more than 20,000 tons of hazardous to the ozone layer CFCs. However, in 1974, the US scientists have shown that chlorine monoxide molecule and chlorine atom, which are the part of Freon, are strong catalysts and facilitate the ozone layer destruction. The world community reacted to this statement by signing of the so-called Montreal Protocol on Substances. According to its recommendations some restrictions were put for the production and use of CFCs that deplete the ozone layer of the Earth. The Protocol was entered into force on 1 January 1989. He was joined by 127 States. In June 1990, at a conference in London it was decided to cease the use of all types of hazardous CFCs in industrialized countries by 2000. Those refrigerants which do not held chlorine atoms, namely hydrocarbons, fluoro-carbons and hydro fluoro-carbons – R23, R134a, R404a, R407a, R407v, R508v, R507, R600 have been considered as completely safe and suitable for production and usage, and therefore proposed for utilization in the modern compression refrigerating appliances.

To analyze the overall capacity of ozone layer depletion, the greenhouse effect, formed by the impact of refrigerant, the so-called total equivalent thermal effect is used, that is compatible direct effect from the direct penetration of refrigerant substances and indirect penetration of carbon dioxide into the atmosphere during the production of electrical energy necessary for the manufacture of the refrigerant and compression refrigerating device operation. In the developed countries, 20 ... 25% of electricity consumed for domestic purposes falls on compression refrigerating devices and therefore only 1...2% change of the energy performance of compression refrigerating device will significantly impact on global warming from carbon dioxide emissions into the atmosphere. For example, the impact on global warming potential of emissions into the atmosphere of dangerous to ozone layer refrigerant R134a is nearly 1300 times stronger than that of carbon dioxide CO2. That's why, the release of one charging (approximately 140g) of R134a from compression refrigerating device is equivalent to emission into the atmosphere of 182 kg of CO2. If in Europe during generation of 1 kWh of electricity 448 grams of CO2 are emitted into the atmosphere, the emissions of 182 kg of CO2 will correspond to 406 kWh, which is 15 ... 20 times more than the energy consumed by one compression refrigerating device for 15 ... 20 years of exploitation.

In order to eliminate the harmful effects of the most widespread refrigerant R12 on the ozone layer, the alternative one-component R134a was developed which is almost seven times higher, but deemed safe for the ozone layer. Energy performance of R134a is lower than R12 according to the parameters of specific volume performance and refrigeration coefficient of refrigeration machine at boiling temperatures below minus 15 Celsius. Therefore, compression refrigerating devices, working at a refrigerant boiling temperature below minus 15°C, use compressor of higher performance or use the refrigerant with lower normal boiling point, e.g. the same R12 - in defiance of the Montreal Protocol (1987).

Unfortunately, the ideal refrigerant has not been synthesized up to now. If the refrigerant R134a does not destroy the ozone layer, its thermodynamic properties are far from perfect. They impact on energy efficiency and operational performance of compression refrigerating devices in the whole.

The most promising refrigerant today is a mixture of Freon R152 and R600a, the so-called synthesized C1. Its use in compression refrigerating devices has even allowed lowering daily electricity consumption of the compressor drive motor at the same performance of compression refrigerating devices by 5%. As for the energy efficiency of the mixture C1, the experimental tests performed on domestic refrigerator hermetic compressor showed that dependencies of its cooling capacity and refrigeration coefficient of the compression refrigerating devices in the range of CFCs boiling temperatures, specific to compression refrigerating device, meet the analog parameters of R12 which is dangerous for the ozone layer and especially of R134a - safe for the ozone.

Despite the difficulties in searching of a mixture of refrigerants that would fully meet all the requirements put forward for its use in compression refrigerating devices, only this complex area is considered the most promising and relevant in the field of energy efficiency increasing and modernization of existing compression refrigerating devices. Despite of some success in promoting friendly refrigerant the manufacture of artificial and sustainable solutions promotes environmental pollution and violation of international agreements.

Increasing of the volume and reducing the temperature in the freezer.

The impact of freezer compartment volume increasing at a constant storage capacity of compression refrigerating devices without increasing the productivity of the compressor unit certainly will lead to increase of the temperature in the freezer compartment and to its lowering in the refrigerating chamber. The duration of refrigerating machine exit in an orderly operation mode, the length of refrigeration cycles in it will be prolonged; electricity consumption for a comfortable operation mode will be higher.

As a major shortcoming of commonly recognized and implemented in the production by world compression refrigerating devices manufacturers can be considered the increasing the volume of the freezer compartment or a decreasing temperature in it, it is impossible to reach a uniform temperature distribution in the refrigerating chamber. The vertical temperature difference reaches (8...12)°C which is unacceptable in case of compression refrigerating devices utilization. The proportional temperature dependence in the refrigerating chamber and in the freezer compartment prevents compliance of existing requirements necessary for process temperature control in both storage capacity and at the same time with temporary extended storage products.

To eliminate the identified shortcoming with maintaining the optimal temperature mode in the refrigerating chambers, some manufacturers equip their refrigerating machine with two independent cooling circuits with independent temperature control. Independent regulation of temperature conditions in separate chambers is provided by two compressors and two temperature controllers, each of which has evaporator or with one compressor with two evaporators connected in parallel, which are equipped with servo solenoid valve and two steam temperature controllers, situated separately in their chambers. A significant advantage of the cooling system of such models is elimination of proportional temperatures dependency in chambers. Despite the fact that the additional compressor is significantly more expensive than solenoid valve itself, the increased cost of compression refrigerating device generally does not exceed 10% of the cost value. A significant drawback of compression refrigerating device with one compressor and solenoid valve in the construction of refrigerating machine, compared with the usual throttle - capillary tube, there is a limitation of the refrigeration process inside the chamber by the excess refrigerant pressure in the heat exchange condenser, formed by the compressor before its switching off and reducing of compression refrigerating device energy efficiency. To avoid this situation is possible due to the arrangement of refrigerant flow path passing through the valve. In general, at the same level of technology and manufacturing quality, combined refrigerator-freezers with two compressors are not only more expensive to manufacture, but are less reliable during operation.

Search of new insulation materials that promote the term of low temperature keeping in the refrigerating chamber in case of temporary loss of power supply

Among the specified areas of compression refrigerating devices parameters series, which are aimed on the improvement of their energy efficiency, the leading position sets the development and implementation of innovative manufacturing insulating materials with lower thermal conductivity. To eliminate the excess of heat flow to compression refrigerating device, usually the layer insulation surfaces of refrigeration cabinets are increased or insulation materials with lower thermal conductivity are used. Both directions significantly increase the cost value of compression refrigerating devices.

This is the brief list of materials that are used refrigeration engineering nowadays:

Staple fiber, artificial mineral felt with heat conductivity of mineral felt, but biologically and water-resistant;

Mineral or mineral wool felts treated with solutions of synthetic resins and having a thermal conductivity at 25 ° C;

Polystyrene as a white solid foam with a uniform closed porous structure and thermal conductivity, which is used by direct filling of refrigeration chambers. Moisture resistance of Styrofoam is almost 100%. It retains all the positive qualities of fiber, is also well processed and withstands mechanical loads in compression;

Polyurethane foam-309M is the most common and effective insulating material for the formation of foam in which Halocarbon R11, or safe for the ozone layer mixtures - R141b, R134a and cyclopentane are used. This material has low thermal conductivity and is applied by direct filling piers of refrigerating chambers;

Vacuum panels;

Pentane and others.

Development and introduction of highly efficient thermal insulation materials have a significant impact on the cost of compression refrigerating device and its energy efficiency. The most successful solution to this issue has been gained in Japan. The thickest Polyurethane foam with the lowest thermal conductivity was developed there. Its application in compression refrigerating device chamber with useful volume 250 ... 350 dm3 allowed the manufacturer, within existing size, to reduce the thickness of insulation from 56 mm to 34 mm and thus to increase the useful volume of the chamber on 32%. Some manufacturers apply powder thermal insulator. Its substratum is composed of perlite powder which is inflicted on the kraft - paper for further sealing and vacuum processing. The outer material is like cardboard with aluminum foil which is inflicted on its surface. The effectiveness of the thermal insulator is twice higher than foam and can reduce the thickness of the freezer cabinet insulation from 62 mm to 40 mm. However, too high cost value allows its utilization for thermal insulation of refrigerating chambers of refrigerators with volume up to 300 dm^3.

Summarizing the above-mentioned facts, we can conclude that achievement of compression refrigerating devices high energy efficiency through the introduction of new insulation materials as a whole comes down to lowering of heat inflow to its useful volume by means of:

augmentation of the chamber or some of its walls insulation thickness;

improvement of the used polyurethane foam insulation quality;

providing of high-quality polyurethane foam insulation filling of the whole space between the inner chamber and refrigerating device housing.

These measures are significantly limited in use because increasing of insulation thickness leads either to a decrease in net volume, or to increase of its external surface with a reverse increase of heat inflow from the environment. As for improving the insulation thermal properties, with its simultaneous price reduction, it has not happened for nearly 50 years after the invention of polyurethane. The quality of the filling process of insulated interior space in the housing of refrigerating appliance cabinets depends only on the perfection of technological process.

Hence, the measures applied by producers are limited with the cost of refrigeration devices and slow process of inherent drawbacks improvement and so should be solved together with the restriction of the outer surface area of the chambers with the environment temperature.

Reduction of compression refrigerating device outer surface with unchanging useful volume of the chamber

Proceeding from the destination of heat isolated surface of compression refrigerating device to prevent the penetration of heat from the environment to its useful volume, it is desirable to have the minimal one. The manufacturers of compression refrigerating devices have always paid much attention to the improvement of their external surface. The leading Swedish company "Electrolux" for the first time introduced the forced air cooling of compressor and the entire surface of the compact heat exchange condenser, which were positioned at the bottom of the refrigerator. The exchange of heat flows - cooling and flowing hot was provided through the front decorative panel. Energy saving resulting from implementation of innovations was about 8%. Similar studies held in Ukraine showed that the effective reduction of energy consumption by household compression refrigerating device was possible by forced cooling of only the last third part of heat exchange capacitor coils beginning from the compressor, where the refrigerant is in a liquid state and its rate is negligible compared with the current refrigerant vapor. The estimated energy savings on the 15% level is determined by reduction ratio of compressor operation time. However, undesirable dependence of obtained efficiency from the ambient temperature and separately for each model of compression refrigerating device which was determined by developers, did not allow generalizing the method application.

Creating conditions of uniform temperature distribution inside the useful volume of refrigerating chamber

The issue of creating conditions of uniform temperature distribution inside the useful volume of refrigerating chamber arose with the appearance of a great number of offers for compression refrigerating devices on the market and consumers demand. The applied today and widely widespread today compression refrigerating devices with increased comfort and artificially generated climate system "no frost" has partly solved the problem. In the refrigerating chamber the cooling is formed by forced division of cold air flows through an artificial system of branching air channels located at different levels along the height in the refrigerating chamber of compression refrigerating device. Evaporator of refrigerating chamber is allocated into a separate heat exchange volume seized in size of about 20 dm^3 from the useful volume of refrigerating chamber. The ice slurry, created by the moist air on the surface of the evaporator after switching off the compressor is melting and given out until its next switching on. This solution maintains the high estimated efficiency of refrigerating machine. But the resulting improvement of temperature distribution along the height of the chamber, however, revealed a number of significant shortcomings of defined system, including the most important – it is the intensive evaporation of temporary storage products during the system operation and additional power consumption during fan evaporator operation. Despite the advantages and shortcomings of "no frost", compression refrigerating devices producers stabilized the temperature drop along the height of refrigeration chamber within ± 2°C. For development and improvement of the "no frost" system effectiveness it was proposed to set the evaporator with fan at the angle in the freezer and the advanced branching system of air channels was designed to enhance the efficiency of the heat flux flows by natural convection. As an alternative solution to the "no frost" artificial climate system can be seen the placing in the freezer of low-power fan, which increases the natural convection of air, moving its layers until restoration of embedded temperature differences along the height. The latter can be done by the scheme of balance resistive bridge. Unlike the "no frost", evaporator of refrigeration chamber is in the useful volume of compression refrigerating device, is covered with ice-slurry and periodically requires melting mode by deactivating of its refrigerating machine that affects its estimated effectiveness.

Analyzing the main directions of compression refrigerating devices modern parametric row development we can determine that direct measures to ensure equal distribution of temperature field in the cabinets (without the use of additional devices) were not invented.

Recently, more attention is paid to the use of frequency converters for powering the electric motor drive of hermetic compressor of refrigerating machine, despite of its cost, which is equal to or even greater than the cost of compression refrigerating device *(*Buzelin, *et.al.)*. Frequency converters allow carrying out deeper regulation speed of asynchronous electric motor, which proportionally affects the performance of the compressor and allows you to get a uniform temperature distribution along height of refrigeration chamber. This possibility, as the specialists conclude, in case of the application of the relevant law and regulation circuit of motor operation, depending on cooling temperature and while ensuring a balance between heat flow that flows into the useful volume of refrigeration chamber and heat flow, which is taken out by refrigerant, hypothetically allows to set such performance of the compressor (lower than estimated), in which the on/off compressor engine modes will be eliminated. Experimental tests given in *(*Buzelin, *et.al.)* indicate that in this way it is impossible to implement continuous operation of the compressor motor and vice versa, the frequency of its on/ off is increased because of reducing the temperature differential in the effective volume of chambers and this is the most undesirable phenomenon in the refrigerating machine compressor (dynamic overload).

Unfortunately, deep compressor performance regulation in a sealed refrigerating machine towards its reduction without control valve (capillary tube) for refrigerant supply is associated with fall of its pressure in refrigerating machine, and, as a consequence, the fall of refrigerant condensation temperature in the evaporator, that negatively reflects on temperatures in the refrigeration chamber. The increased of compressor productivity by electric motor rpm increase, is conversely associated with the increase of refrigerant pressure in refrigerating machine, and, as a consequence, by increase of its condensation temperature in the evaporator and also by violation of temperature control in compression refrigerating device chambers.

Conclusion

Further reduction in energy consumption, which should be at 3.1% annually, is associated with the implementation of these comprehensive measures:

Improvement of compression system (using ram intake, reduced hydrodynamic resistance, the use of rotary compressors only);

Modernization of the heat exchange condenser;

Increase of condensation evaporators surfaces.

Correct choice of motor-compressor aggregates according to the required amount of cold for a particular model of refrigerating device;

Selection of motor compressor with the least mechanical, electrical and thermodynamic losses that are characterized by high values of the coefficient cooling capacity;

Providing regular temperature control of the electric motor of the compressor, and so on.

References

Beyond A.2007. dynamic new labeling scheme is necessary for promoting continuous improvement of the energy performance of home appliances // CECED Position Paper. – P. 4.

Experimental development of an intelligent refrigeration system / L. O. S. Buzelin, S. C. Amico, J. V. C. Vargas, J. A. R. Parise. – International Journal of Refrigeration 28(2005) p.165 – 175

UNE-EN 28187/A1:2003 Household refrigerating appliances. Regriferator-freezers. Characteristics and test methods. Amendment 1: Special compartments for the preservation of highly perishable foodstuffs. (ISO 8187:1991/AM1997)

UNEP. Montreal Protocol on Substances That Deplete The Ozone Layer. Final Act: date 16 September 1987. – 6 p.

UNEP. Montreal Protocol on Substances That Deplete The Ozone Layer. As adjusted and amended by the second meeting of the parties: London, 1990.