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EFFECT OF COOLING HERMETIC COMPRESSOR ON NOISE REDUCTION IN A DOMESTIC REFRIGERATOR

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ARTICLE INFO	ABSTRACT
<p>Article history: Received: 2024-12-05 Received in revised form: 2024-12-05 Accepted: 2024-12-10 Available online:</p> <hr/> <p>Keywords: Positive displacement hermetic compressor; cooling system; refrigerating capacity; superheat; coefficient of performance; corrected sound power level.</p>	<p><i>In the household refrigerator compressor is the main source of noise and heat, and the isolation of sound from the compressor in the air increases the thermal stress of his work and a significant reduction of energy efficiency of the refrigerator. Installing sound insulation panel in front of the compressor housing to reduce the noise level. The cooling system compressor oil is widely used in foreign and domestic refrigerators, implements "tropical" operating temperature Options refrigeration units tested at optimal doses of freon and constant permeability of the capillary tube. Soundproofing compressor housing leads to some increase in temperature of the motor windings and optimization of dose refrigerant with soundproofed compressor housing will increase the value of these indicators. The results confirm the possibility of reducing the noise of the refrigerator, through the use of an optimized heat removal from the cylinder head of the compressor.</i></p>

Introduction

Vibroacoustic characteristics are an important indicator of the competitiveness of a household refrigerator as a representative of household appliances [2], and the hermetic refrigerant compressor has a decisive influence on their generation. Research into a hermetic compressor, which is a multi-level and multi-component airborne noise emitter, was implemented in the form of a set of technical solutions that make it possible to reduce the noise level of the compressor itself to 38-36 dBA [1]. Acoustic technical solutions for reducing noise levels are divided into: sound insulation, sound absorption and sound dampening.

Compressor technical level

A known sound-reflecting technical solution is described in the operating instructions for the ZIL-63 refrigerator [2]. In the lower part of the refrigerator cabinet there is a recess with a sealed compressor 1 placed in it and a metal shield 3 that partially covers the machine compartment, and the inner side of the shield is covered with sound-absorbing material.

Installing a soundproofing shield in front of the compressor casing allows you to reduce the noise level by $1.5 \div 2.5$ dBa. A graph for reducing the noise level across the spectrum with sound-absorbing shields is given in the book by I.V. Bolgov, A.I. Naberezhnykh. and others.

Installing a soundproofing shield in front of the compressor casing significantly increases the temperature level of compressor operation, which is clearly demonstrated by studying the temperature field with a thermal imager in Fig.1.

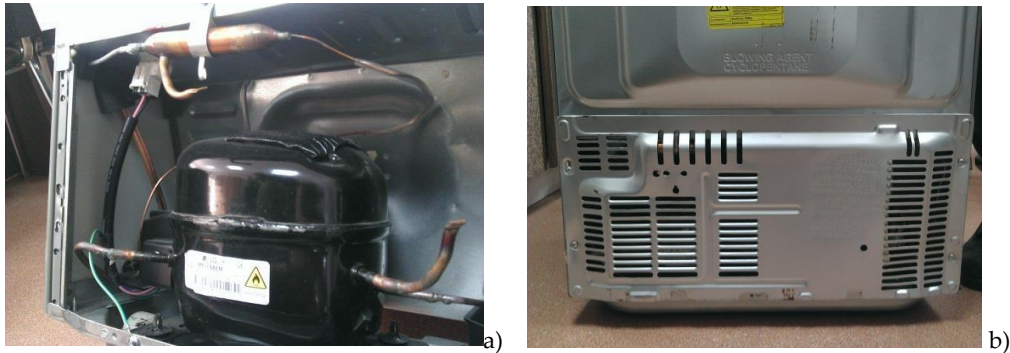


Figure 1. Study of LG refrigerator model GA-B409SLQ

a) image of a refrigerator without a shield; b) image of the soundproofing shield in front of the compressor casing

When a hermetic refrigeration compressor operates in a normalized temperature regime [4,5], the temperature of the working winding of the electric motor reaches 120 °C, the temperature of the suction vapor in the cylinder is $145 \div 155$ °C, and the temperature of the compressed vapor is $170 \div 190$ °C. It is obvious that the use of these compressors in refrigerators with sound and thermal insulation of the compressor, as well as in a tropical version without an additional cooling system, is not acceptable since the temperature of the electric motor windings exceeds 130 °C.

The following methods of cooling hermetic compressors have found their application in household refrigerators:

- sucked in refrigerant vapors;
- heat removal from the surface of the casing by external blowing with a fan;
- heat removal from the casing by cooling the oil with liquid refrigerants from the precondenser or a heat pipe.

Cooling of the hermetic compressor housing is achieved by forced circulation in the engine compartment, which is sucked in by a fan through the right side of the front grille (Fig.1 b) and thrown out of the compartment into the room through the left side of the grille.

The oil cooling system in the compressor has become widespread in foreign and domestic refrigerators, realizing a “tropical” temperature operating mode. In them, cooling is achieved by evaporation of liquid refrigerant coming from the precondenser into a coil, which is located in the oil bath of the compressor casing.

Calorimetric studies carried out by the Mazeikiai Compressor Plant and the Russian State University of Tourism and Service (formerly MIT) [5] show that compressors with mass production of the “S-KO – OS” series with cooling of the oil bath with liquid refrigerant from the precondenser, which can increase the cooling capacity by $3 \div 4.5\%$, the efficiency coefficient

(COP) by 3 ÷ 4%, and the power consumption remains practically constant. The temperature of the electric motor winding decreases by 15 ÷ 20 °C depending on the area of the precapacitor. These indicators are not highly effective and require further improvement and search for a constructive solution [3].

The technical problem is to develop and study the efficiency of a compressor cooling system, which makes it possible to enhance the sound insulation of the compressor.

A system has been developed for cooling the compressor head with liquid refrigerant from the precondenser [6], shown in Fig.3. A study of this system shows that the process of cooling the compressor elements from the precondenser is carried out with liquid refrigerant in the so-called calorimetric mode [4] in nominal parameters and provides: an increase in cooling capacity and efficiency coefficient, respectively, by 9 ÷ 16% and 15 ÷ 20%; reduce the temperature of the electric motor winding by 21 ÷ 25%; remove the thermal energy of the compression work through the pre-condenser into the environment at a temperature of 60°C.

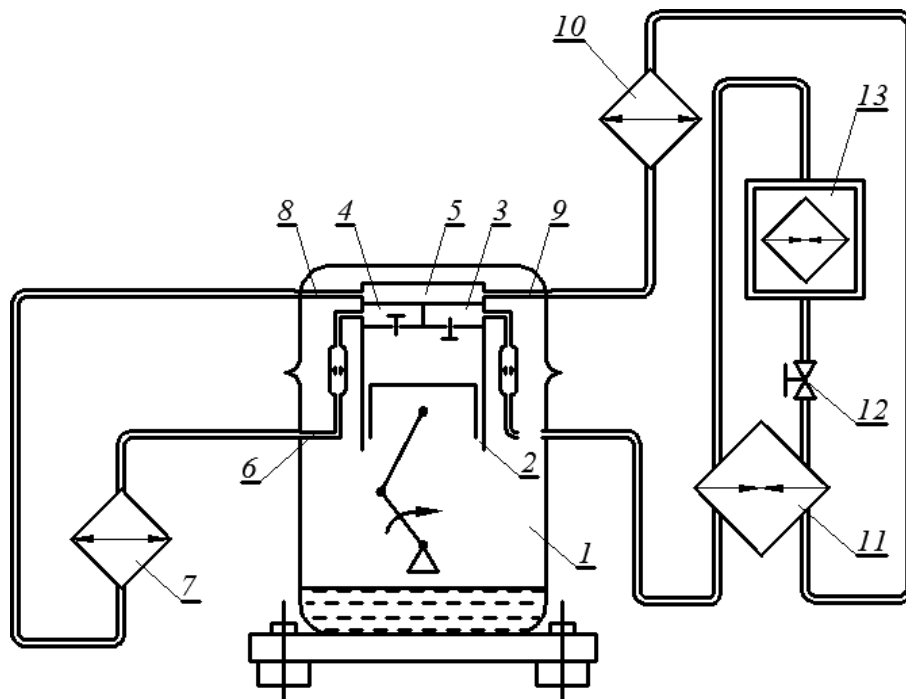


Figure 2. Cooling system of the compressor head with liquid refrigerant:
 1 – GKKh; 2 – cylinder; 3 – suction chamber; 4 – discharge chamber; 5 – cylinder head; 6 – coil for removing refrigerant vapors from the compressor (discharge coil); 7 – precondenser; 8 – coil for introducing liquid refrigerant into the cylinder head; 9 – coil for removing refrigerant vapors from the cylinder; 10 – condenser of the refrigeration unit; 11 – regenerative heat exchanger; 12 – capillary tube; 13 – evaporator

The object of the study is a hermetic compressor S-KO120N5 (Fig.3) produced by the Baranovich Machine Tool Plant (Belarus), with a cooling capacity of 123 W, included in the Atlant refrigeration unit with a pre-condenser, from which liquid refrigerant is supplied through a flexible coil into a sealed cavity mounted on the head cylinder block, where the coolant boils under condensation pressure, intensively cooling the compressor parts (Fig.3).

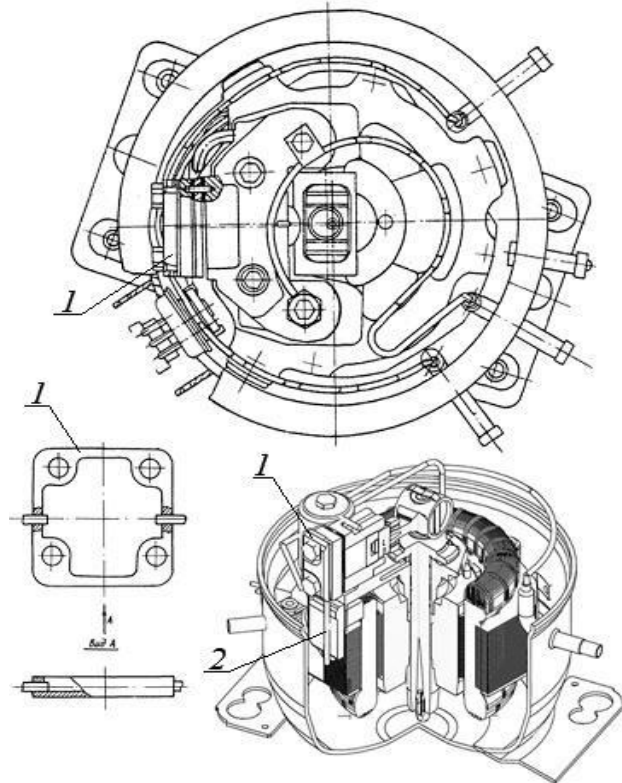


Figure 3. Hermetic piston-type compressor for household refrigeration equipment with cylinder head cooling
 1 – cylinder head; 2 - coil for removing refrigerant vapors from the cylinder

The cylinder cooling head is structurally an element with a milled part to limit the lift of the discharge valve. An installed partition separates the suction and discharge cavities. Coolant for cooling the cylinder head is supplied through flexible steel coils.

Compressors with a cooled cylinder head and a soundproofed outer surface of the compressor casing were subjected to standardized [3,6] tests on a calorimetric stand.

Two modifications of the refrigeration unit were tested in the calorimetric cycle, presented in Fig.4.

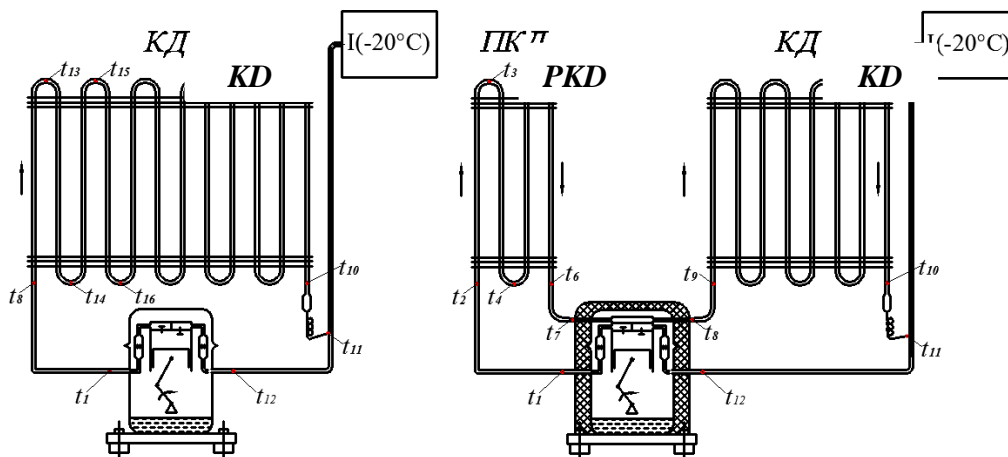


Figure 4. Modifications of the studied refrigeration unit circuits

a) option 1 serial refrigeration unit without a cooling system (condenser area $F_{cd} = 0.776 \text{ m}^2$); b) option 2, the refrigeration unit includes a compressor with a cooling head (pre-condenser with an area of $F_{cd} = 0.26 \text{ m}^2$ and a condenser with an area of $F_{cd} = 0.52 \text{ m}^2$). I – evaporator, KD - condenser, PKD - pre-condenser.

The sound insulation of the compressor casing in the refrigeration unit was made in the form of a technological cap, Fig.3, made of polyurethane foam with a wall thickness of 20 ÷ 30 mm, which covered the compressor mounted on a polyurethane foam stand 50 mm thick. In the cap for the pipes connecting the compressor to the condenser and precondenser, a window measuring 190 × 170 mm was cut out. The outer diameter of the cap is 280 mm, height 260 mm.

The refrigeration unit made according to option 2 was tested twice: with and without soundproofing of the compressor casing at an ambient temperature of 32 °C and 43 °C. The results are presented in Fig.4a.

Test results

The main results of calorimetric testing of a compressor with sound insulation and without sound insulation of the compressor casing (Fig.4) are presented in Fig.5. Analysis of the results of calorimetry of a compressor with sound insulation and without sound insulation of the compressor casing allows us to draw the following conclusions:

- a) the use of a cooling system with liquid refrigerant from the pre-condenser of the cylinder head ensures that the compressor casing is isolated from the environment with sound-insulating material, practically without disturbing its temperature regime and loss of cooling capacity.
- b) the introduction of sound insulation will reduce the noise level by an amount determined by the thickness and effectiveness of the soundproofing material.

The results of testing refrigeration units (options 1 and 2) in the calorimetric cycle are presented in Fig.5a.

In Fig.5 shows a graph of changes in the temperature field of the pre-condenser and condenser of the refrigeration unit in calorimetry mode with a device for cooling the cylinder block with sound insulation and without sound insulation of the compressor casing at an ambient temperature of 32 °C and 43 °C.

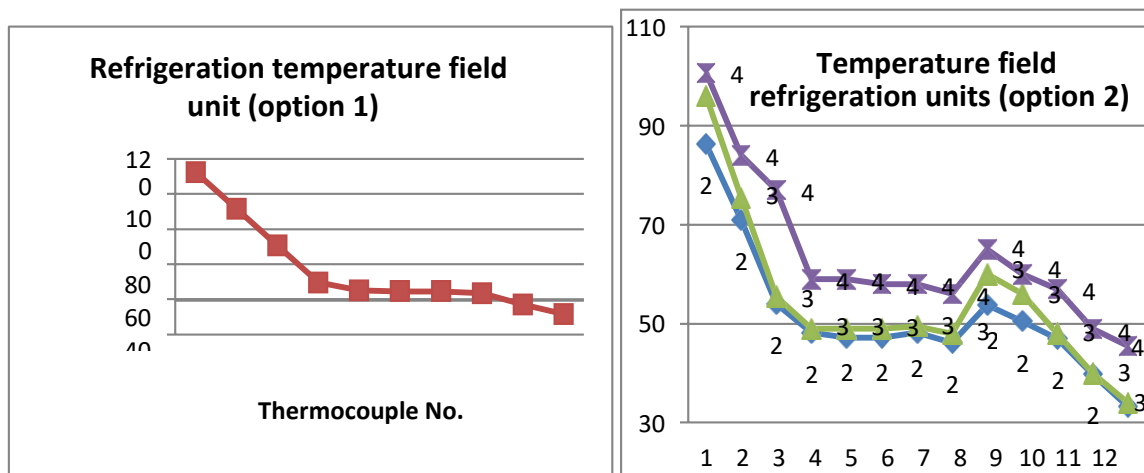


Figure 5. Results of the study of the temperature field of the refrigeration unit

(1-1) - the nature of the change in the temperature of the refrigerant in the condenser (option 1) at an ambient temperature of 32 °C without sound insulation of the compressor casing.

(2-2) and (3-3) – the nature of the change in the refrigerant temperature in the precondenser, cooling head and condenser (option 2) at an ambient temperature of 32 °C without sound insulation of the compressor casing (2-2) and with sound insulation of the compressor casing (3-3).

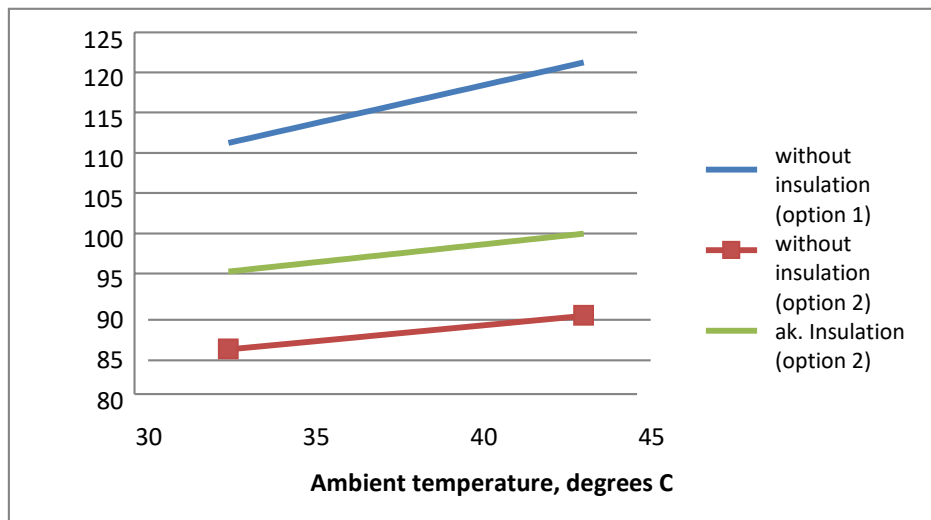


Figure 6. Dependence of ambient temperature on compressor winding temperature

Variants of refrigeration units were tested at optimal doses of refrigerant and a constant flow rate of the capillary tube of 6.2 ± 0.2 l/min. The optimal dose of refrigerant was selected for each option based on the ambient temperature of 32 °C and 43 °C without compressor casing insulation. When installing sound insulation of the casing and compressor, the dose of refrigerant was not adjusted, but remained the same, as when testing a refrigeration unit without sound insulation of the compressor casing.

Analysis of the research results shows that at temperatures of 32 °C and 43 °C, both with and without sound insulation of the compressor casing, there is an increase Q_0 , Ke , decrease in the temperature of the working winding with an increase in the area of the precapacitor.

Sound insulation of the compressor casing leads to a slight decrease in Q_0 , Ke , and an increase in the temperature of the operating winding of the electric motor. It is likely that optimizing the refrigerant dose during soundproofing of the compressor casing will increase the value of these indicators.

From the presented dependencies it follows that the sound insulation of the compressor casing is acceptable when operating the refrigeration unit at temperatures not exceeding 32 °C. For temperatures of 43 °C, operation of refrigeration units is possible (recommended pre-condenser area $F_{pkd} = 0.64$ m²).

In Fig.7 shows comparative results of the adjusted sound power level of MXM-268 refrigerators in the 1/3 octave frequency range with a cylinder head cooling system and sound insulation and without sound insulation of the compressor casing.

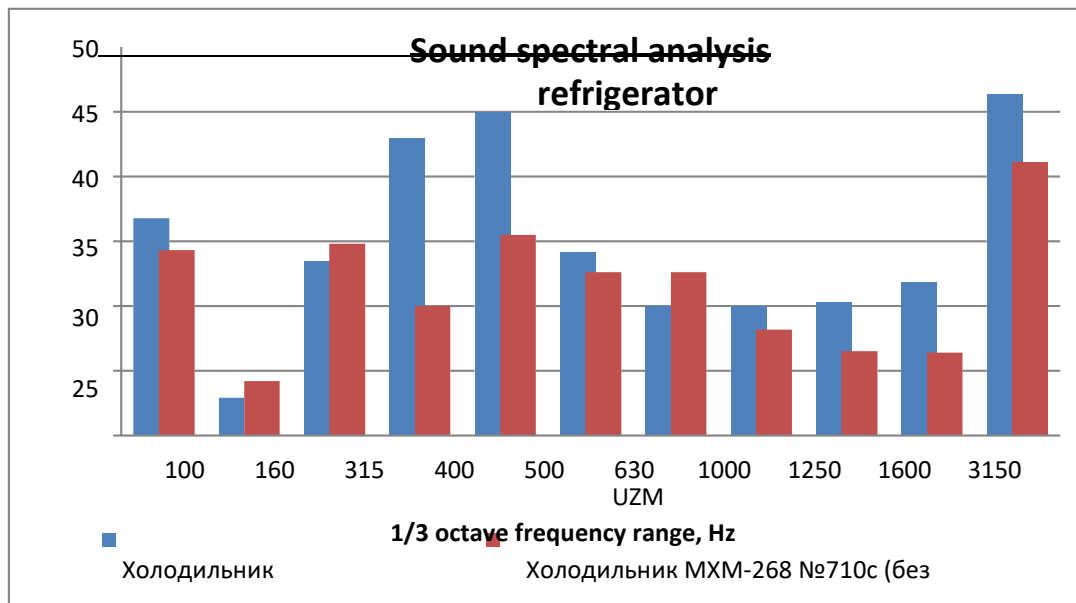


Figure 7. Comparative analysis of the adjusted sound power level of refrigerators in the 1/3 octave frequency range

Conclusion

1. Calorimetric tests of a compressor with a cooling system with liquid refrigerant from the cylinder head pre-condenser showed that the values of cooling capacity, power consumption and temperature of the electric motor windings make it possible to soundproof the compressor casing with insulating material.
2. The cooling capacity and refrigeration coefficient of a compressor with cylinder head cooling and a soundproof casing is higher than that of a compressor without a cooling system by 1 and 10%, respectively, and the operating winding temperature and sound power level are lower by 17% and 11%, respectively.
3. The temperature of the compressor operating winding with cylinder head cooling and soundproof casing does not exceed 100 °C at Tamb., WHO. = 32 °C and 105 °C.
4. The adjusted sound power level of a household refrigerator LG model GA-B409SLQA with a soundproof shield in front of the compressor (Fig.1.b), determined according to GOST 30163.0-95, was 47.56 dBA. Based on the presented results, it can be assumed that the use of heat removal from the compressor cylinder head [5], where recommendations for process control can be used [6], will increase the sound insulating and sound reflecting ability of the plate and thereby reduce the noise level of the refrigerator and increase its energy efficiency.

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