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The Influence of Refrigerants on Energy Indicators of Hermetic Compressors

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ABSTRACT

This work is devoted to determination of thermal energy indicators of hermetic compressor operating with R600a and R134a refrigerants. It has been mentioned that the operation efficiency and quality of refrigerating machines are mainly determined by technical-economic and operation properties of compressor. The main properties of hermetic refrigerator compressors, determining their technical level, are cooling factor, sound power level, and weight. Despite numerous experiments, up till now the main attention has been paid to analysis and reduction of bulk losses, and some scientific problems aimed at analysis of temperature field, bulk and energy indicators of hermetic compressors applying R600a and R134a refrigerants have not been studied in details. It has been demonstrated that development and solution to the issue of material processing were based on theoretical and experimental methods, including the method of system and structural analysis. The thermal energy indicators of hermetic compressors have been determined by means of adiabatic calorimetry. It has been experimentally determined that application of R600a refrigerant reduces temperature field of compressor by 20...22°C in comparison with R134a refrigerant. On the basis of experiments with hermetic compressor, it has been established that application of R600a refrigerant leads to decrease in consumed capacity by 85% in average, decrease in refrigeration capacity by 33%, increase in cooling factor by 27.6%.

Key words: hermetic compressor, refrigerant, thermal energy indicators.

1. INTRODUCTION

The operation efficiency and quality of household refrigerating machines are mainly determined by technical-economic and operation properties of compressor [1, 2]. Improvement of hermetic compressor as the most important and complicated element of household refrigerator attracted the main attention [3]. This is stipulated by the fact that the compressor indications determine reliability, life-time, the level of noise and vibrations of refrigerating machine [4, 5].

Numerous R&D projects are devoted to analysis and improvement of refrigerator hermetic compressors [5, 6, 7, 8, 9, 10].

With the increase in production and expansion of functional possibilities of household refrigerators, the improvement of hermetic compressor became especially important [11, 12].

The main properties of hermetic refrigerator compressors, determining their technical level, are cooling factor, sound power level, and weight [13-15].

The technical level of hermetic compressors is being improved mainly in four areas [16-19]:

- increase in cooling capacity per unit volume;
- decrease in consumed power per unit volume;
- decrease in sound power level;
- decrease in weight and dimensions per unit volume.

Despite numerous experiments, up till now the main attention has been paid to analysis and reduction of bulk losses, and some scientific problems aimed at analysis of temperature field, bulk and energy indicators of hermetic compressors applying R600a and R134a refrigerants have not been studied in details.

2. METHODS

The development and solution to the issue of material processing were based on theoretical and experimental methods, including the method of system and structural analysis.

The thermal energy indicators of hermetic compressors have been determined by means of adiabatic calorimetry.

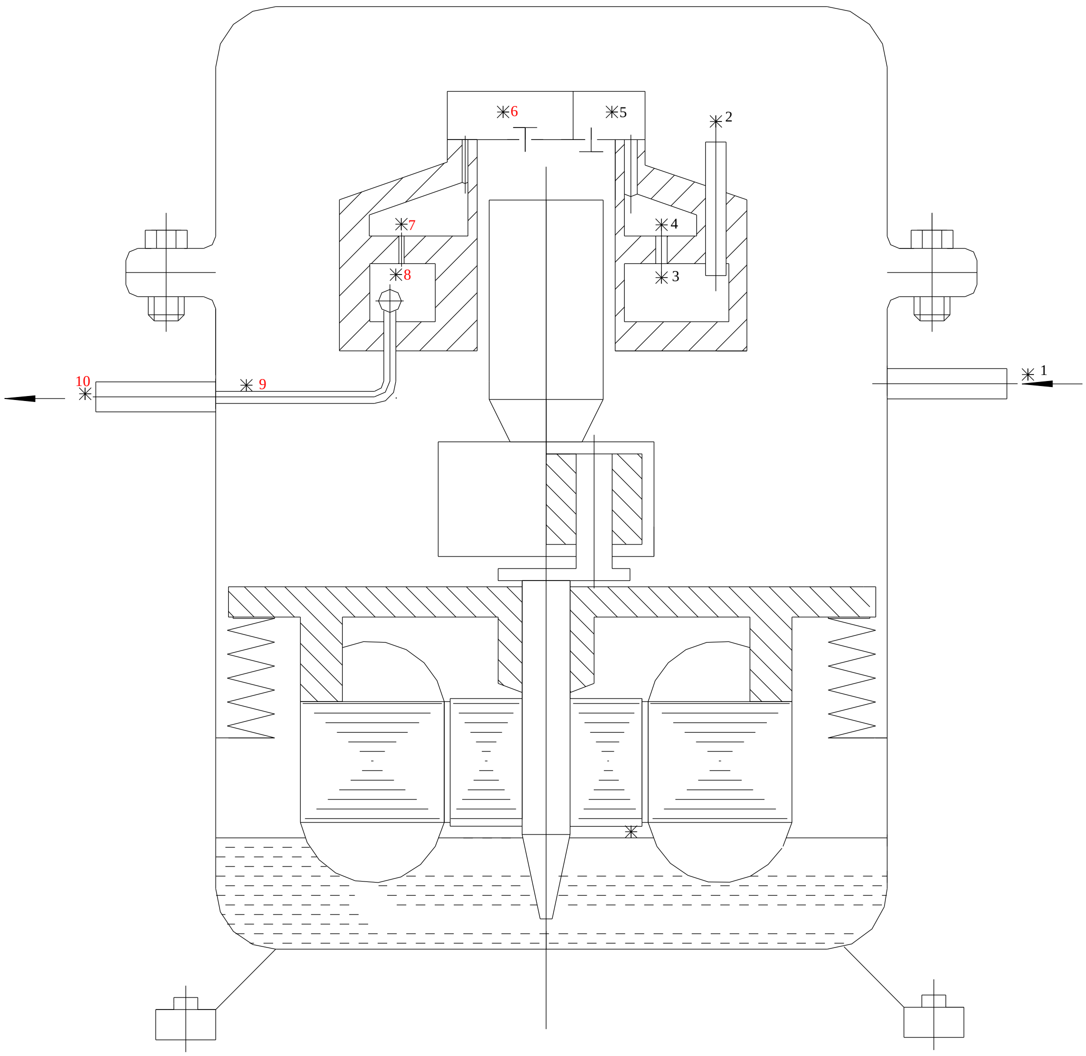
3. RESULTS AND DISCUSSION

Operation of hermetic refrigerator compressor is stipulated by peculiar conditions developed in closed cycle of refrigerator. Compressor carries out compressing and forcing of refrigerant vapors in wide pressure range of condensation and boiling, which are determined by the required temperature limits of cooling cycle and thermophysical properties of applied working medium.

For maximum approximation of experimental conditions to actual operation, accurate measurement of minor flow rates of refrigerant and determination of properties of hermetic compressors, specialized testing methods were developed on the basis of adiabatic calorimetry; these methods are successfully applied [14, 15].

The main thermal energy properties of the compressors were determined in accordance with the recommendations [14, 15].

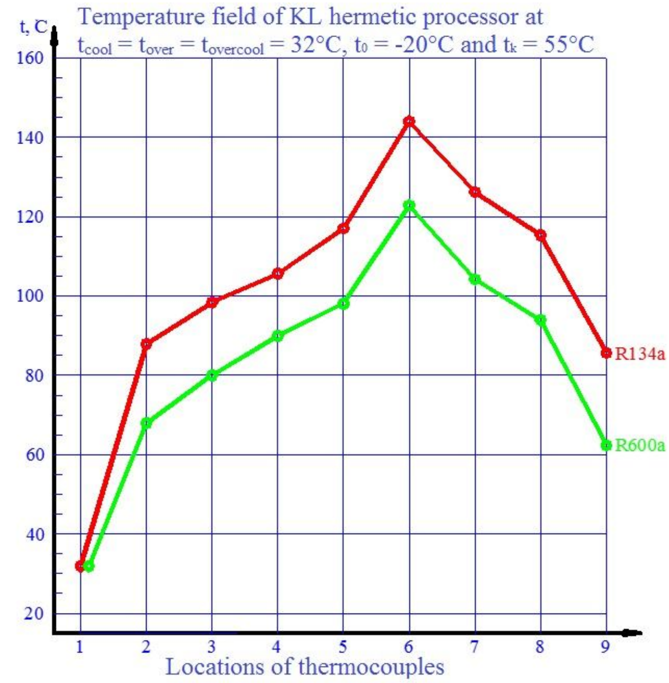
The influence of the applied refrigerant on temperature field of hermetic compressors (Figure 1) was determined experimentally.



✳1 refrigerant temperature near the inlet to compressor suction pipe
✳2 refrigerant temperature near the inlet to suction pipe
✳3 refrigerant temperature in the first silencer at suction side
✳4 refrigerant temperature in the second silencer at suction side
✳5 refrigerant temperature in the suction space
✳6 refrigerant temperature in the injection space
✳7 refrigerant temperature in the first silencer at the injection side
✳8 refrigerant temperature in the second silencer at the injection side
✳9 refrigerant temperature in the injection pipe at the outlet from casing
✳10 refrigerant temperature behind the compressor injection pipe

Figure 1: Schematic view of compressor indicating locations of thermocouples

The experimental results of the piston compressor are illustrated in Figure 2.



1- inlet to compressor casing
2- near suction pipe
3- in the first silencer at the suction side
4- in the second silencer at the suction side
5- in the suction space
6- min temperature in the cylinder during suction
7- max temperature in the cylinder during compression
8- in the first silencer at the injection side
9- in the second silencer at the injection side
10- injection pipe in the casing
11- injection pipe behind the casing

Figure 2: Temperature field of hermetic compressor at $t_{cool}=t_{over} = t_{overcool} = 32°C$, $t_0 = –20°C$ and $t_k =55°C$

The experiments were carried out using calorimetry test rig allowing to determine the bulk capacity of compressor by two independent methods: on the basis of thermal balance of condenser and thermal balance of calorimeter [14, 15]. In the first case, mass flow rate and temperature of cooling water are recorded at inlet and outlet from condenser, the temperature of refrigerant at inlet and outlet from condenser is determined; and in the second case, the power to electric heater of calorimeter, the pressure and temperature of refrigerant at inlet and outlet are measured. In the bottom part of calorimeter filled with refrigerant, the electric heater is installed. The vapor generated during boiling is condensed on outer surface of vaporizer. During testing the heater power is adjusted so that the pressure of secondary refrigerant is constant, that is, the amount of generated cold is equal to the amount of supplied heat.

Comparative experiments with the hermetic compressor have demonstrated that application of R600a refrigerant reduces the temperature field of compressor by 20...22°C in average in comparison with R134a refrigerant (Figure 2).

The experiments with KL compressors were carried out in accordance with the procedure described in section 6.2.

The influence of the applied refrigerants on thermal energy properties indications of compressor was determined by measurements of power consumed by compressor, cooling capacity of compressor, mass flow rate of refrigerant.

The experiments were carried out at two temperatures of condensation: $t_k = 45ºC$ and $t_k = 55ºC$ for two refrigerants: R600a and R134a.

The results of comparisons of compressor with various refrigerants are illustrated in Figures. 3–8.

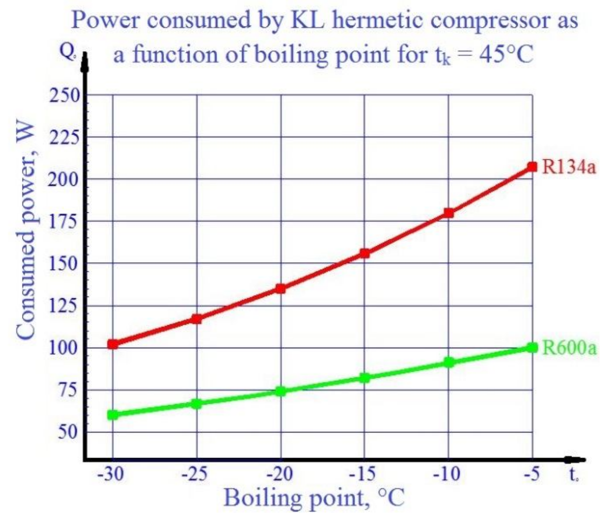


Figure 3: Power consumed by hermetic compressor as a function of boiling point for $t_k = 45°C$

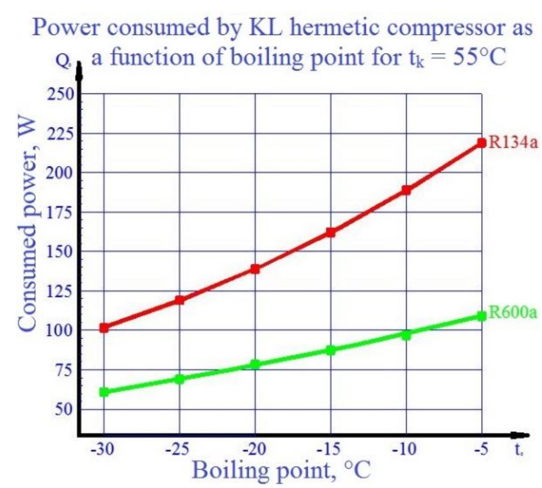


Figure 4: Power consumed by hermetic compressor as a function of boiling point for $t_k = 55°C$

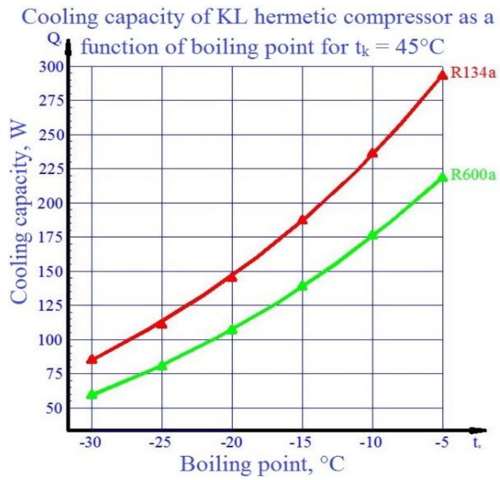


Figure 5: Cooling capacity of hermetic compressor as a function of boiling point for t_k = 45°C

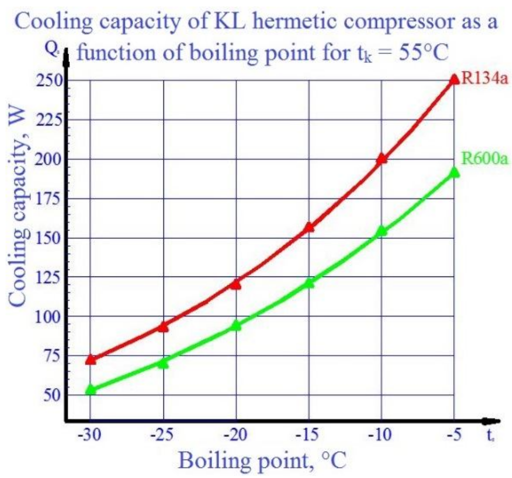


Figure 6: Cooling capacity of hermetic compressor as a function of boiling point for t_k = 55°C

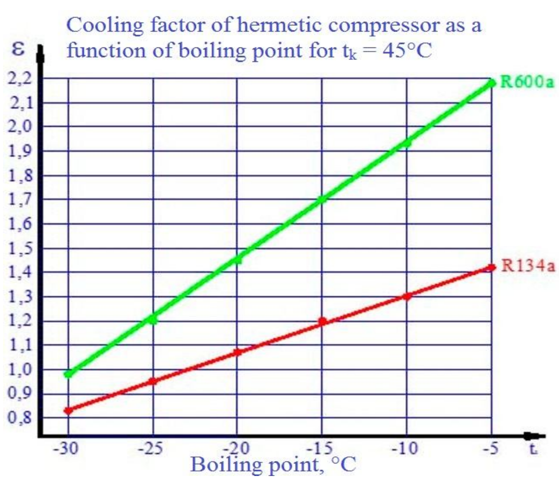


Figure 7: Cooling factor of hermetic compressor as a function of boiling point for t_k = 45°C

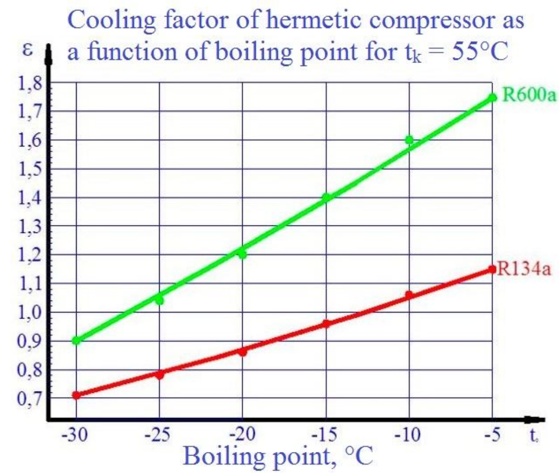


Figure 8: Cooling factor of hermetic compressor as a function of boiling point for t_k = 55°C

Comparative analysis of the results illustrated in Figs. 3–8 has demonstrated that the cooling factor for R600a refrigerant is higher than that for R134a by 26.3...27.6%.

The performed studies confirm the theoretical conclusions that the R600a refrigerant is superior to the R134a refrigerant under predefined constrained experimental conditions.

4. CONCLUSION

The analyzed trends of development of hermetic compressors for household refrigerators have demonstrated that they are aimed at improvement of technical level upon application of ozone-safe refrigerants R600a and R134a.

Comparative analysis of experimental results of hermetic compressor has confirmed theoretical conclusions and has revealed that application of R600a refrigerant reduces temperature field of compressor by 20...22°C in comparison with R134a refrigerant.

Analysis of hermetic compressor has revealed that application of R600a refrigerant leads to decrease in consumed capacity by 85% in average, decrease in refrigeration capacity by 33%, increase in cooling factor by 27.6%.

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