Heat load Q_0 on HE is determined by the heat transfer surface area F_a and heat exchange intensity, which is characterised by the heat transfer coefficient k

$$k = Q_0/(F_a \cdot \theta). \quad (1)$$

Here θ is the average logarithmic temperature difference between air and refrigerant. Usually for HE of shipboard MRS θ is within the limits: for AC – 8...10 ºC, for ACC – 10...13 ºC [2, 4].

Increasing the heat transfer coefficient from the air to the outer surface of the HE by 30...40 % allows to increase the heat transfer coefficient k by the same amount [2]. As follows from expression (1), θ will decrease by 30...40 % with unchanged Q_0 and F_a. For simplification of calculations we take $\theta = 10$ ºC, and its reduction - 30 %. At unchanged air inlet temperatures t_{v1} and outlet t_{v2}, from HE and its flow rate G_v, this leads, as calculations show, to an increase in the boiling temperature t_0 and a decrease in the condensation temperature t_c by about 3 ºC. It is known from [4] that increase of t_0 by 1 ºC (at unchanged t_{v1}, t_{v2}, G_v) leads to increase of electric refrigeration coefficient ε_e by 3 %, and decrease of t_c by 1 ºC - to increase of ε_e by 1 %. Consequently, if t_0 increases and t_c decreases by 3 ºC, ε_e will increase by about 12 %. If Q_0 remains unchanged, the power consumed by the compressors will decrease by about the same amount (12 %) and, consequently, the fuel consumption associated with cold production will decrease by 12 %.

Conclusions. The use of HE having a unified tube-and-plate surface with a fin spacing of 4...6 mm allows reducing fuel consumption by shipboard MRS by about 12 % in comparison with the same surface having a fin spacing of 2.2 mm.

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DETERMINATION OF PARAMETERS AT TRANSIENT MODES (START-UP, SHUTDOWN) OF MARINE HERMETIC COMPRESSOR UNITS

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Abstract. Special studies have been carried out, which allow to determine the parameters and investigate the processes occurring during transient modes (start-up, stop) of hermetic compressor units (HCU) operating on refrigerant. Shipboard HCU were tested. The conducted experiments allowed us to determine the parameters, explain the physical essence of the processes occurring in the transient modes (start, stop) of the HCU, and reasonably select the initial conditions for calculation.

Keywords: hermetic compressor unit (HCU), transition operation of HCU, cylinder, piston, experiment.

Introduction. The start-up of a hermetic compressor unit (HCU) is an integral part of the cyclicoperation of the refrigeration machine of a ship's autonomous air conditioner and depends largely on the parameters preceding the start-up, i.e., the parameters that the HCU had after stopping. In [1], it was experimentally established that such parameters are the gas pressure in the cylinder and the position of the piston before start-up. However, these experiments were conducted in air, which does not allow making correct conclusions.

Aim. The purpose of this work is to determine the parameters and study the processes occurring during transient modes (start, stop) of HCU operating on refrigerant.

Main material. We have tested ship HCU: single-cylinder FGP-2,2 (cylinder diameter D_c = 42 mm, piston stroke S = 26 mm, cooling capacity Q_0 = 2,56 kW, electric motor - three-phase asynchronous with rotation frequency n = 25 s^{-1} at current frequency of 50 Hz) and two-cylinder (with V-shaped arrangement of cylinders) KFGV-14 (D_c = 42 mm, S = 26 mm, Q_0 = 16,3 kW, electric motor - three-phase asynchronous, n = 66,7 s^{-1} at current frequency of 400 Hz). Their starting conditions are heavier than those of HCU with a larger number and with a different arrangement of cylinders.

The HCU was tested on a calorimetric bench with oscillography of the processes occurring at stopping and starting. Stops were carried out at boiling temperatures t_0 about 5 ºC and condensation temperatures about 55 ºC, i.e., at the regime that preceded the HCU start-up at t_0 = 10 ºC and t_c = 50 ºC.

From the oscillogram of FGP-2.2 stopping, it followed that after the power supply was cut off, the shaft had time to make one revolution by inertia, and the gas in the cylinder was compressed to the condensation pressure. At the second revolution of the shaft, the piston, not reaching the TDC, was sharply braked and thrown back by gas pressure forces, the shaft acquired the opposite rotation, the piston was braked again, thrown back again, etc. until the complete stop near the BDC. At this point the gas pressure in the cylinder became approximately equal to the pressure on the intake side. The time of complete stopping, which was determined from the oscillograms from the moment of power supply interruption to the cessation of shaft angle marks, lasted about 0.45s.

After the power supply was cut off, the KHGV-14 shaft made about fourteen revolutions by inertia, each time compressing the gas in the cylinders to the condensation pressure, then braked sharply and immediately stopped. The pressure in the cylinder also dropped sharply and approximately equaled the pressure on the suction side. The compressor stop lasted about 0.55 s.

To determine the influence of the piston position at the moment of start-up on its duration, FGP-2.2 start-ups were carried out at reduced (0.85 nominal) mains voltage and piston positions corresponding to the angles 0, 135 and 225º (starting point from TDC) with oscillographic processes. The diametral clearance 2Δ between piston and cylinder was the same.

The oscillograms showed that the shortest start-up time (0.11 s) corresponded to the piston position at the shaft rotation angle φ = 0º, and the longest (0.25 s) corresponded to φ = 225°.

This phenomenon can be explained as follows.

In the first two cases (at φ = 0º and φ = 135º), the first start-up period occurs without load, and before compression begins, the inertial masses have time to accelerate to values sufficient to overcome the load peak. In the HCU, acceleration occurs in about one and a half turns, and the start-up times are not significantly different (0.11 and 0.16 s).

In the third case (φ = 225º), the force developed by the electric motor is used to accelerate the inertial masses and overcome the load during compression. When condensing pressure is reached in the cylinder, the HCU brakes, and after the cylinder gas passes through the 2Δ gap on the sleeve side, the HCU accelerates again and reaches the TDC. During the no-load movement of the BDC, the HCU gains sufficient speed to overcome the load peak and accelerates for two revolutions, with a significantly longer start-up time than in the first two cases (0.25 s).

Experiments to determine the most probable position of the piston after 100 stops of the HCU under load, i.e. before the subsequent start-up, allowed to establish the following.

The most probable position of the piston after stopping under load of single-cylinder FGP-2,2 is in the range of 180...225°, where the counteracting torque is practically equal to zero. Through the observation window in the housing it can be seen how the shaft of the HCU under load was retarded for a fraction of a second, and then under the action of pressure forces acting on the piston, moved to the opposite side and after oscillations the shaft (piston) stopped before the BDC.

Determining the most probable position of the piston after stopping the two-cylinder KFGV-14 engine proved to be quite difficult. Tests showed that after power failure the shaft had time to make about 14 revolutions by inertia, and then abruptly stopped practically in any position. However, multiple repetition of the experiments allowed us to establish a range of angles 100...130°, at which the HCU stops more often. For subsequent startup, this condition proved to be the most difficult, since the electric motor had to develop a torque sufficient to accelerate the inertial masses and overcome the resistance of the two cylinders in the series.

Conclusions. The conducted experiments allowed us to determine the parameters, explain the physical essence of the processes occurring in the transient modes (start, stop) of the HCU, and reasonably select the initial conditions for calculation.

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ENHASING THE FUEL EFFICIENCY OF GAS TURBINES IN SUBTROPICAL CLIMATIC CONDITIONS OF CHINA THROUGH INLET AIR COOLING

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Annotation. Enhancement of gas turbine (GT) efficiency by inlet air cooling, known as TIAC, in chillers using the heat of exhaust gas is one of the most attractive tendency in energetics. A sustainable operation of GT at stabilized low intake air temperature is impossible without determining rational design cooling capacity of the chiller and TIAC system as a whole to match current duties without overestimation. The most widespread absorption lithium-bromide chillers (ACh) of a simple cycle is unable to reduce the GT intake air temperature below 15 °C because the