

## **POWER AND CHEMICAL ENGINEERING**

**V. A. Pronin, A. V. Kovanov, E. A. Kalashnikova, V. A. Tsvetkov**

The prospect of using ozone-safe refrigerants with low global warming potential in scroll compressors.  
Part 1

The Montreal Protocol and the Kigali Amendment have determined the need and deadlines of the replacement of hydro fluorinated refrigerants. Substances of natural origin with a low global warming potential are becoming an alternative to hydrofluorocarbons that are being withdrawn from circulation. Such an alternative corrects the vector of development of refrigeration equipment and entails the need to adapt or create new models of equipment taking into account the excellent properties of new refrigerants. However, the consumer's choice is still based on the efficiency, cost and reliability of the equipment. Having studied the possibility of using new refrigerants, in the fields of using a scroll compressor, from the point of view of the operational properties of substances, we also noted some aspects of the influence of their thermodynamic and thermophysical properties on the working processes and design of compressor elements. Thus, we present a comparative analysis of the practical application and further prospects for the using of refrigerants in a scroll compressor, highlighting the current directions of studying this issue.

**Keywords:** scroll compressor, refrigerant properties, hydrofluorocarbons, flow rate, energy efficiency, fluid leaks.

**A. N. Fot, D. K. Melnikov**

Features of calculation of refrigerating machines with combined cooling of condensers taking into account climatic and economic factor

A method for calculating refrigerating machines with a condensation unit implementing water and air cooling methods is proposed taking into account the economic and climatic features of the calculated region. Since economic and climatic factors have different degrees of influence on the energy efficiency and efficiency of refrigerating machines over the entire range of changing temperatures of cooling media, the results of calculating refrigerating machines according to the proposed methodology allow making informed decisions about the layout of the condensation unit both at the design stage and at the stage of developing a program for managing the refrigeration unit throughout the year. A comparative analysis of refrigerating machines with combined cooling of condensers for the regions of Omsk and Berlin is carried out. The most significant influence of the climatic factor at low temperatures of the cooling air and the influence of the cost of cooling water at high air temperatures were revealed.

**Keywords:** combined cooling, condensation unit, water and air cooling, ecology, energy saving, mathematical model, refrigeration machine.

**A. R. Aliev**

Automation of technological process of filling chambers during pneumatic vacuum tests

The scheme and technology of the automated process of filling chambers with control gas are considered. Mathematical description of the functioning of filling system served as a basis for the development of design and analysis procedure of performance characteristics is constructed.

**Keywords:** tightness test, pneumatic vacuum tests, filling the chamber with gas, automatic filling mode, automation of the technological process.

**I. S. Busarov, S. S. Busarov, V. L. Yusha**

The effect of deformation of flow part of elastomeric elements of self-acting valves on characteristics of low-speed long-stroke compressor stages

The results of the study of the influence of changes in the area of the flow section in the seat of self-acting valves with elastomeric elements on the characteristics of low-speed compressor stages are presented. A method of experimental research of low-speed compressor stages with the possibility of obtaining instantaneous parameters of the gas state in the working chamber of the stage and its integral characteristics and an experimental stand for its implementation have been developed. The results of comparative experimental studies have confirmed the effectiveness of the valve design with a variable cross-sectional area of the seat in comparison with known designs — an increase in the feed coefficient and isothermal indicator efficiency is at least 10...15%.

**Keywords:** compressor low-speed stage, experimental research, work processes, self-acting valve, elastomeric seat.

**A. M. Kalashnikov, G. I. Chernov, V. L. Yusha**

Thermodynamic analysis of expansion process of screw expander in wet steam area

In this scientific work, the process of expansion of wet steam with different values of the inlet degree of dryness in a screw expander is considered. The study is carried out on the basis of the developed mathematical model, which includes both the basic thermodynamic equations and the process of heat exchange of the working substance with the environment in the process of expansion. During the study of the expansion process in the area of wet steam in a screw expander, a mathematical model of this process is developed. The mathematical model is verified by comparing the results obtained on its basis with the results obtained by other researchers on an identical object. It can be seen from the results obtained that at values of the initial degree of dryness greater than 0,01, the distributions of pressures and temperatures practically do not depend on its value. When the initial dryness values are less than 0,01, it begins to have a significant effect on the distribution of pressure and temperature over the angle of rotation of the main rotor of the screw expander.

**Keywords:** thermal energy, heat recovery, screw expander, expander, wet steam.

**I. D. Obukhov**

Optimization of waste heat recovery system for mobile compressor unit for compressing natural gas

This paper presents the methodology and results of optimization of the waste heat recovery system (WHRS) of a mobile compressor unit (MCU) designed to compress natural gas using a computer model in the MatLab with the CoolProp thermodynamic package. In the course of the study, a computer model of the WHRS is built, a criterion for the efficiency of recuperation is determined, an optimization problem is formulated and its solution is carried out. The boiling pressure and mass flow rate of the working fluid in the Rankine cycle are taken as the optimization parameters. With the optimal values of these parameters, the smallest value of the relative mass fuel consumption of the MCU is achieved, that is, the maximum recuperation efficiency is achieved.

**Keywords:** recuperation, Rankine cycle, mobile compressor unit, optimization, natural gas.

**A. S. Khrekin, I. V. Baranov, A. A. Nikitin**

The analysis of cascade refrigeration machine cycles efficiency using carbon dioxide

The paper analyzes and proves the feasibility of improving the energy performance of low-temperature refrigeration machines operating on R744 using cascade design with R134a, R1234yf and R717 as refrigerants based on data the scientific study of two-stage schemes analysis. At present, it is given the existing environmental prohibitions and the growing interest in the creation of low-temperature refrigeration machines operating on carbon dioxide (R744) in two-stage and cascade schemes, the presented research supplements the scientific literature on justifying the use of each of them.

**Keywords:** cascade refrigeration system, global warming potential, upper cascade, transcritical cycle, conventional refrigerants, ozone-depleting potential, carbon dioxide, cooling capacity, natural refrigerant, refrigeration unit.

**Y. S. Hu, H. J. Wei, B. Yu, O. X. Yang, J. Wang, J. Wu**

Research on the Vapor Injection of Two-stage Rotary Compressor / trans. from Engl. M. A. Fedorova

In order to understand the vapor injection flow characteristics of two-stage rotary compressor in the course of compression, a mathematical model based on mass conservation equation, energy equation and thermodynamic identity was established and proved by P-V diagram testing results. Some useful conclusions about pressure in the intermediate chamber and mass flow of vapor injection in the course of compression were also given out. The results show that, gas backflow between the intermediate chamber and the vapor injection channel is an important deflection of two-stage rotary compressor which can be solved by the application of injection valve in vapor injection channel. The injection valve can obviously reduce the gas backflow and the power loss in the course of compression while increasing the pressure fluctuation in the intermediate chamber. Experiments show that the COP of two-stage rotary compressor with the injection valve increased by over 2% in ASHRAE/T working condition.

**Keywords:** refrigeration machine, rotary compressor, steam injection, mathematical model, experiment, verification.

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## AVIATION AND ROCKET-SPACE ENGINEERING

**V. N. Blinov, V. V. Kositsin, A. I. Lukyanchik, P. V. Stepen, P. S. Yachmenev**

Research on reliability of pulsed electrothermal propulsion system of nanosatellite

In the paper have been discussed nanosatellite propulsion system normalization actual themes, as well their acknowledgement by the testing results. To secure needed survival probability  $P \geq 0,995$ , the propulsion system bottlenecks normalized values are defined. The results of propulsion system fatigue test and reliability evaluation also have been presented. The realized count of propulsion system pulse mode switching is 15700. The actual value testing propulsion system survival probability is  $P=0,9979$ . That confirms the ability of nanosatellite propulsion system demanded reliability.

**Keywords:** nanosatellite, resistojet, propulsion system, reliability, survival probability.

**V. I. Kuznetsov, V. V. Makarov**

Uniformity of working processes of jet and vortex ejectors, vortex tube and Hartmann–Sprenger pipe

Based on the previously considered physical and mathematical models of jet and vortex ejectors, vortex tube and Hartmann–Sprenger tube, it makes a conclusion about the identity of the processes of exchange of work and heat in these devices. The influence of viscosity, tangential stresses, and the gradient of linear and angular velocities on the transfer of kinetic energy from a high-pressure to a low-pressure gas is shown. The difference of thermodynamic temperatures for heat exchange of high-pressure and low-pressure gases is taken into account.

**Keywords:** jet and vortex ejector, vortex tube, Hartmann–Sprenger tube, work exchange, heat exchange, viscosity, tangential stress.

**V. I. Trushlyakov, V. A. Urbansky, A. N. Pavlenko, V. E. Zhukov, E. Yu. Sukhorukova**

Experimental studies of unsteady processes of cryogenic liquid evaporation in rocket tank model

The program and the methodology of the experiment and the results of the experiment have been developed. The experimental bench and metrological support have been created, liquid nitrogen (LN) has been considered as a model liquid. A database of heat and mass exchange process parameters (pressure, temperature) under the modes of tank inflation with helium gas up to 2 atm., given external thermal loading, pressure relief after reaching 4 atm. up to 1 atm. The technique of processing the results of pressure and temperature measurements with the assumptions and limitations is given.

**Keywords:** liquid nitrogen, conductive heating, evaporation, boiling, volumetric boiling, pressurization, helium gas, mass evaporation rate.