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**SUMMARY and KEYWORDS**

## POWER AND CHEMICAL ENGINEERING

**A. B. Sulin, T. V. Ryabova, A. A. Nikitin**
Design characteristics of natural convection radiator with local heat load

The problem of optimized calculation of the geometric characteristics of a finned heat-exchange surface with a local heat source under conditions of natural convection is considered. The solution was obtained for the condition of the maximum specific volumetric heat transfer power. An engineering technique is proposed for taking into account the local nature of the application of heat load. The design characteristics are given as functions of temperature head, fin height and thickness of the radiator base.

**Keywords:** natural convection, finned radiator, local heat load, thermoelectric module.

**A. V. Zaitsev, A. A. Malyshev, K. F. Kouadio, O. S. Malinina, A. O. Lisovtsov**
Comprehensive two-phase flow calculation method with in-channel refrigerant boiling

In this paper, the authors deal with the processes occurring during boiling of two-phase flows in channels, which differ in many possible regimes, and their analytical description is possible only under strict restrictions within the given regime and the application of empirical data. An approach is proposed in which it is recommended to use a map of flow regimes (boiling) in coordinates Ж – lgFrm as an empirical component. The analysis of the process is carried out in the entire range of parameters — mass flow, temperature and pressure taking into account the change of flow regimes. The analytical dependencies presented form together a complete mathematical model, which is implemented in the form of a computer program.

**Keywords:** two-phase flows, in-channel boiling of refrigerants, true volumetric vapor content, flow regimes.

**O. S. Malinina, A. V. Baranenko**
Efficiency comparison of thermodynamic cycles of lithium bromide-water absorption refrigeration machines

The energy efficiency analysis of the actual thermodynamic cycles of lithium bromide-water absorption refrigeration machines (ABLRM) with single- and multi-stage processes of absorption and generation and with associated mass flow is carried out. The temperature influence analysis of the heating and cooling sources on the heat coefficient is performed. Parameters of external sources that allow implementation of these thermodynamic cycles are determined. Meanwhile, for cycles with two-stage absorption and generation processes, a heating source with temperature (20–24) °C lower in comparison with the basic single-stage cycle, and for a cycle with three-stage processes–lower by (27–30) °C is required. It has been established that with the accepted parameters of external sources, the actual coefficient of performance is within the limits: for a single-stage ABLRM) it is 0,68–0,74, for a two-stage ABLRM, it is 0,36–0,39 and for a three-stage ABLRM, it is 0,24–0,26.

**Keywords:** efficiency, actual thermodynamic cycle, lithium bromide-water absorption refrigeration machine (ABLRM), coupled mass flow, coefficient of performance.

**M. Mehrpooya, A. V. Zaitsev, A. O. Lisovtsov**
Application of new external cooling cycles in technological scheme of helium extraction and natural gas liquefaction

The paper presents the results of studying a combination of new technological solutions in the processes of natural gas liquefaction and helium extraction. The most common and effective way to ensure cooling capacity in the natural gas liquefaction process is to use a cascade cycle on mixed refrigerant (MFC) as

external cooling. The influence of introducing an absorption refrigeration unit on the technological process has been studied. To extract helium, the combined separation and rectification method is used. The purity of helium obtained is 50 % (in moles). The running conditions of operation and the corresponding technical characteristics of the devices are presented and described. The curves of the resulting characteristics of heat exchangers indicate the correctness of the thermohydraulic calculations performed. The relative value of energy costs for obtaining 1 kg of liquefied natural gas in a technological process using MFC is 0,265 kWh/kg of LNG introducing an absorption refrigeration unit into the cycle reduces the ratio presented to 0,1849 kWh/kg of LNG. In the process of extracting helium using an absorption refrigeration unit gives the result of 0,951 and 132,9 kW/kmol of helium respectively. When using an absorption refrigeration unit, the helium extraction rate and power consumption ratio are 0,951 and 132,9 kW/kmol of helium, respectively. Application of the exergic analysis methods to the processes under consideration shows that the greatest value of exergic losses relative to other devices is observed in compressors. A detailed economic analysis has been carried out. It shows that the cost of the product obtained in the normal MFC cycle and in the MFC cycle using an absorption refrigeration machine is $ 0,1939 and $ 0,2069 per kg of LNG, respectively. Finally, on the basis of such economic factors as the cost of electricity and the cost of the product, the efficiency of the new cycle was analyzed.

**Keywords:** helium recovery, liquefied natural gas, refrigeration cycle, thermal integration of processes, energy efficiency, exergy analysis.

**O. Yu. Manikhin, V. V. Shalay**
Process equipment analysis integrated gas treatment unit for diethylene glycol absorbent change to triethylene glycol

Based on the calculated data obtained by using the software complex of modeling of technological processes for preparation of hydrocarbon raw materials of the domestic development «GIBBS», the article confirmed the advantage of triethylene glycol relative to diethylene glycol in terms of reduction of dew point temperature of dried gas in changing thermobaric conditions of operation of technological equipment of the complex gas treatment plant. The design parameters are confirmed by experimental data obtained during operation of the natural gas drying system at the facilities of Gazprom dobycha Noyabrsk LLC, where triethylene glycol is used as an absorbent.

**Keywords:** booster compressor station, gas absorption drying, diethylene glycol, triethylene glycol, dew point temperature, process modeling.

**A. D. Vanyashov, A. V. Krupnikov**
Applying «compressor-network» analysis method for the system with reciprocating compressor and recirculating line

The subject of research is an opposed reciprocating compressor (RC) providing gas injection into the underground gas storage. Issues concerning implementation of compressor start-up conditions to recirculating line have been considered. As a tool, the compressor-network analysis method is used, which consists in determining the system operating points through matching characteristics of the reciprocating compressor and the network, for which in this case the recirculating line with the control valve is considered. Recommendations have been received to sel ect a control valve type for the reciprocating compressor operating in both single-stage and two-stage modes.

**Keywords:** reciprocating compressor, underground gas storage, control valve, recirculating line.

**D. S. Titov, S. S. Busarov, I. P. Aistov, K. A. Vansovich**
Analysis of piston seals efficiency in silent pump units using analysis of deformed state of compression chamber cylindrical part

The article discusses the application of various types of seals in piston pump with low-speed long-stroke units. The calculated values of the deformations of the cylindrical part of the working chamber and the current value of the actual clearances for various cylinder-piston seals are determined. Based on the established restrictions on the minimum value of the feed coefficient, an analysis is made of the working

process of the pump piston stage of a long-stroke unit and recommendations are developed on the use of the considered types of seals.

**Keywords:** low-speed long-stroke stage, piston pump unit, piston unit balancing, cylinder deformation, clearance.

**A. V. Burakov, A. A. Levikhin, A. V. Pobelyanskiy, A. S. Perminov**
Adaptation of 3D printing technology and topological optimization methods for creating low flow rate turbochargers

The article describes the vast experience of the Compressor holding company in creating compressor equipment for various industries. Existing methods for the development and manufacture of turbochargers are demonstrated using an example of a non-standard refrigeration
compressor designed to operate on gaseous refrigerant R704. The data on the additive technologies mastered by leading foreign companies in the field of aviation and rocket science are analyzed for the manufacture of parts and assembly units using 3D printing with metal materials. The experience of applying topological optimization methods in aircraft and rocket science is considered. The conclusion is drawn on the applicability of topological optimization methods for creating turbocompressor elements together with 3D printing technology. A method is proposed for creating non-standard low-consumption turbochargers providing a reduction in material consumption and an increase in the strength of parts and assemblies, including the stages of design calculation, preliminary calculation, building a 3D model, phased topological optimization, verification of loads, verification of technology, manufacturing using 3D printing, 3D scanning to confirm compliance of the printed part specified geometric properties, verification of the part for compliance with mechanical properties.

**Keywords:** turbocharger, 3D printing, 3D scanning, load optimization, design calculation.

**L. G. M. De Luca, E. Silva, C. J. Deschamps**
Assessment of simplifying hypotheses adopted for valve leakage modeling / trans. from Engl. M. A. Fedorova

The reed-type valves employed in refrigeration compressors must provide adequate sealing when closed to avoid leakage of gas between the compression chamber and the suction and discharge chambers. Recent studies show that valve leakage can considerably affect the performance of the small reciprocating compressors used for domestic refrigeration. The present paper reports an investigation on the adequacy of simplifying the hypothesis adopted in the simulation models of valve leakage. The results indicate that the transient effects related to both the valve deflection and fluid flow are negligible. Also, the ideal gas formulation was found suitable in some operating conditions found in domestic refrigeration. On the other hand, leakage was found to be overpredicted by almost 20 % when the reed valve geometry was simplified to a circular plate in order to reduce the computational processing cost.

**Keywords:** reciprocating refrigeration compressor, valve, overflow, mathematical model, numerical experiment, verification.
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**3. ^ahin, H. Kerpi33i, A. Ya. Karabay, K. Karahan**
Investigation of Discharge Flow and Force Coefficients in Hermetic Reciprocating Compressors / trans. from Engl. M. A. Fedorova

Low energy consuming products are eternal target of all household appliance manufacturers. To acquire desired energy index, high efficiency variable capacity compressors have started to be used widely on refrigerators. Reed valves and valve plate designs are the most critical issues in the development of reciprocating compressors in terms of coefficient of performance (COP). The stiffness of the reed valves and the port geometries play an important role on reducing the losses at various speeds and operating conditions. In the last decade, Fluid-Structure Interaction (FSI) method has started to be used in order to investigate valve dynamics. Because of the complexity and high computational cost of FSI method,

system simulation tools are still preferred for faster and simpler solutions. In-house developed simulation tool uses flow and force coefficients to calculate valve dynamics and mass flow rate. Those are calculated with the Computational Fluid Dynamics (CFD) analyses with respect to the valve lift. In the present study, flow and force coefficients at different piston positions were investigated. Piston pin which is used to reduce dead volume was also considered as a parameter. CFD calculations were established for steady state conditions at different valve positions with Ansys Fluent. The calculated flow and force coefficients were implemented into the simulation tool and the effect of piston position was presented in terms of COP, cooling capacity and compared with the experimental results.

**Keywords:** reciprocating refrigeration compressor, valves, pressure coefficient, flow coefficient, CFD analysis, simulation model, experiment, verification.
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**I. S. Busarov, V. L. Yusha, S. S. Busarov**
Experimental determination of rebound coefficient of valve plate with elastomeric elements in piston low-speed compressor stage

Experimental studies of dynamics of the locking element of self-acting valve with elastomeric elements of slow-moving long-stroke stages makes it possible for the first time to obtain a diagram of motion of the valve plate for the compressor units under consideration. The main principal result of the dynamic analysis of the valve is the absence of rebounds from the seat and the lift limiter during motion of the locking element. The data obtained in the future can be used to develop and verify the methodology for calculating such valves.

**Keywords:** slow-speed long-stroke stage, self-acting valves, valve motion diagram, experimental studies.

**AVIATION AND ROCKET-SPACE ENGINEERING**

**A. B. Yakovlev**
Development of vortex compressed air drying devices for ground launch complex systems

The possibility of using the vortex effect for drying compressed air used in various industrial installations including systems for thermostating ground launch complexes is shown. A mathematical model of the process of reducing the moisture content is presented and a method for calculating the optimal geometric dimensions of the vortex drying device is created. The results presented in this paper allow us to increase the efficiency of production processes that use compressed air as a working fluid.

**Keywords:** launch complex, pneumatic system, Ranque effect, vortex flow, moisture content, mechanical drying.

**V. N. Klimov, D. Ya. Dudev, V. Ya. Sigaylo, N. I. Klimov**
Determination of temperature mode of rotary bearings of gas turbine engine with air and fuel lubrication system

The article is devoted to the problem of choosing the optimal parameters of the air-fuel mixture in gas turbine engines (GTE) with the air-fuel lubrication system. Currently, determining the optimal parameters of the air-fuel mixture is significantly complicated by the inability to calculate the temperature mode of the bearings. The main specific characteristics of the gas turbine engine significantly depend on the amount of air and fuel taken fr om the flow part and the fuel line of the engine. Therefore, determining the dependence of the bearing temperature on their operating conditions (parameters of the air-fuel mixture and operating modes) is an urgent task. The purpose of this work is to develop a method for determining the temperature of a bearing that is lubricated and cooled by an air-fuel mixture. The paper analyzes the thermal state of bearings installed in the rotor supports of a gas turbine engine with an air-fuel lubrication system. On the basis of the test results of hybrid ball radial thrust bearings 45-126205РЯ the dependences of the friction moment and the coefficient of convective heat transfer on the parameters of the air-fuel mixture and operating modes are determined. A method for calculating the temperature of a

bearing that is lubricated and cooled by an air-fuel mixture has been developed. The use of the obtained results in the design of promising short-life gas turbine engines with air-fuel lubrication system will lead to improved engine performance and will contribute to expanding the scope of its application.

**Keywords:** gas turbine engine, air-fuel mixture, lubrication system, method, bearing temperature.