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JPRS L/10453

13 April 1982

USSR Report

ENGINEERING AND EQUIPMENT

(FOUO 3/82)



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NUCLEAR ENERGY

IMPROVING RELIABILITY AND ECONOMIC EFFICIENCY OF THERMAL AND NUCLEAR POWER PLANTS

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA I ORDENA OKTYABR'SKOY REVOLUTSII ENERGETI-CHESKOGO INSTITUTA, TEMATICHESKIY SBORNIK: POVYSHENIYE NADEZHNOСТИ I EKONOMICH-NOSTI TES I AES in Russian No 503, 1980 (signed to press 10 Feb 81) pp 2, 173-179

[Annotation and abstracts from collection of papers "Improving the Reliability and Economic Efficiency of Thermal and Nuclear Power Plants", edited by Doctor of Technical Sciences Professor N.G. Rassokhin, Moscow Power Engineering Institute, 500 copies, 179 pages]

[Text] In this collection are presented articles by associates of the departments of nuclear electric power plants, thermal power plants, engineering thermal physics, power plant steam generators, automated systems for controlling thermal processes and of the theoretical fundamentals of heat engineering relating to studying questions of the reliability and economic efficiency both of individual systems and of modern thermal and nuclear power plant units as a whole.

Included in this collection are the results of both experimental and theoretical research covering a broad range of questions relating to the technology, design and operation of thermal and nuclear power plants. Much attention is paid also to studying the reliability of individual nuclear power plant systems and to modeling dynamic processes originating in them under transient conditions.

This collection is intended for scientific and engineering and technical personnel working on problems of the design and operation of thermal and nuclear power plants.

UDC 621.311.22

USE OF CHELATES FOR CLEANING LOW-CAPACITY BOILERS AT OPERATING PARAMETERS

[Abstract of article by Rassokhin, N.G., Monakhov, A.S., Ryabova, L.V., Dik, V.P., Voronov, V.N. and Mayorov, M.F.]

[Text] Recommendations are given on the use of chelates (Trilon "B") for cleaning deposits from the inside heating surfaces of low-capacity boilers of the DKVr type, as the result of washing "in operation," i.e., without lowering operating parameters. Washing is achieved by dispensing into the boiler's feed water Trilon B

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in a quantity of 1.5 to 2 times the stoichiometric, for the purpose of combining with hardness and iron cations present in the feed water, as well as for dissolving previously formed deposits and converting them into a complex easily soluble form convenient for the removal of impurities with the blowdown, which is increased to 10 percent. The feasibility of performing a washing cycle "in operation" for low-capacity boilers is demonstrated.

UDC 621.311.25:621.039

QUESTIONS RELATING TO THE HEAT ENGINEERING RELIABILITY OF WATER-COOLED POWER REACTORS

[Abstract of article by Kabanov, L.P. and Reynsh, V.]

[Text] An analysis is made of a three-dimensional calculation scheme for estimating heat engineering reliability. The results are given of a calculation for reactors of the VVER-440 and VVER-1000 type.

UDC 621.311.25:621.039

ESTIMATION OF THE PERFORMANCE RELIABILITY OF THE SHELL OF A NUCLEAR POWER PLANT REACTOR

[Abstract of article by Kuznetsov, V.D. and Tsimmer, A.]

[Text] A procedure is presented for calculating the reliability of the shell of a nuclear power plant reactor by using the probabilistic approach. An attempt is made to take into account the existence of flaws in the shell's material and the dynamics of their development. The procedure makes it possible to take into account the influence of such factors as the nature of operation, features of effective loads and embrittlement of the material.

UDC 621.039.53

TWO-METAL CREVICE CORROSION OF STRUCTURAL STEEL UNDER CONDITIONS OF NEUTRAL WATER PARAMETERS WITH THE FEEDING OF OXYGEN

[Abstract of article by Tolstykh, A.N. and Lipanina, A.A.]

[Text] The results are given of a study of the two-metal crevice corrosion of steel specimens in a loop with the following parameters of the medium: pressure of 0.6 MPa, temperature of 428 K, traveling speed of medium (condensate) of 0.5 m/s. Oxygen content--0.1 to 0.4 mg/kg. The size of the gap in assemblies was not greater than 0.1 mm. Studies were made of specimens of grade 20 steel in combination with steel of grades OKh18N10T, AS-9 and EP-53 for 1500 h. It is demonstrated that the rate of corrosion of grade 20 steel reaches maximum values of 0.037 g/m²h in combination with grade AS-9 steel and minimum values of 0.025 g/m²h in contact with grade OKh18N10T steel. Pits up to 70 microns deep were present in grade 20 steel after testing, and there were no pits in the other materials tested.

UDC 621.311.25:621.039

USE OF RELIABILITY METHODS FOR A COMPARATIVE ANALYSIS OF NUCLEAR POWER PLANT SAFETY SYSTEMS

[Abstract of article by Kabanov, L.P. and Makarovskiy, P.L.]

[Text] A comparative analysis is made of the reliability of the emergency cooling systems of RBMK-1000 and SGHWR reactors by means of the Md0001 program, which analyzes reliability by means of the "failure tree" method.

UDC 621.039.53

STUDY OF THE CORROSION RESISTANCE OF PEARLITIC STEEL AS APPLIED TO THE OPERATING CONDITIONS OF THE CONDENSATE FEED SECTION OF STEAM POWER PLANTS

[Abstract of article by Tolstykh, A.N. and Ten, A.]

[Text] The results are given of a study of the corrosion resistance of pearlitic steel in an experimental loop at a temperature of 428 K with a rate of movement of the condensate of 5 m/s for 1500 h. It is demonstrated that under conditions of neutral water parameters with the feeding of 10 to 30 $\mu\text{g}/\text{kg}$ of oxygen the corrosion of grade 20 steel reaches 0.144 $\text{g}/\text{m}^2\text{h}$.

UDC 621.039.58

STABILITY OF A REACTOR OF THE POOL TYPE OPERATING UNDER CONDITIONS OF SURFACE BOILING

[Abstract of article by Ratnikov, Ye.F., Vlasov, V.I., Mokrushiy, S.A., Radchenko, R.V., Shagalov, A.G., Shtoyk, A.G. and Ismagilov, R.Sh.]

[Text] The hydrodynamic stability of the channels of an IVV-2 reactor is discussed. It is demonstrated that conditions are possible under which the reactor operates unstably. The appearance of instability in the core can result in the origin of heat stresses and the failure of fuel elements. It is demonstrated that for determining the region of stable operation of a reactor it is necessary to develop methods of fixing conditions for boiling of the heat transfer agent.

UDC 621.311.25:621.039

MODELING OF DYNAMIC PROCESSES IN A NUCLEAR POWER PLANT

[Abstract of article by Kuznetsov, V.D. and Romanov, Ye.V.]

[Text] The dynamics of a reactor are discussed, taking into account six groups of delayed neutrons and reactivity feedback. The results are given of the calculation of some accidental processes, in particular, with de-energizing of the main circulating pumps.

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UDC 621.311.25:621.039

EXPERIMENTAL STUDY OF THE MECHANISM FOR EJECTION OF THE WATER HEAT TRANSFER AGENT WITH TWO-WAY OUTFLOW

[Abstract of article by Dement'yev, B.A. and Al'-Bakhili]

[Text] The results are given of an experimental study of hydrodynamic processes in sudden ejection of the water heat transfer agent with two-way outflow from a high-pressure vessel, simulating the shell of a water-cooled reactor with intra-shell equipment. The mechanism for ejection of the boiling heat transfer agent and the influence of various factors on dewatering of the vessel are discussed.

UDC 621.311.25:621.039

DETERMINATION OF NONSTATIONARY RATE OF FLOW OF A BOILING HEAT TRANSFER AGENT

[Abstract of article by Dement'yev, B.A. and Al'-Bakhili]

[Text] The procedure and the results are given of a determination of the non-stationary rate of flow of a boiling heat transfer agent when it is ejected from a high-pressure vessel. An approximation equation which describes the nonstationary rate of flow is given.

UDC 621.039.526.53:669.24

INFLUENCE OF NICKEL ON THE CONVERSION FACTOR OF FAST REACTORS

[Abstract of article by Kalafati, D.D. and Groshkov, G.I.]

[Text] A study is made of the influence of nickel, contained in the construction materials of fast reactors, on the conversion factor for several heat transfer agents. It is demonstrated that the conversion factor is reduced considerably with an increase in nickel content. The conclusion is drawn that in selecting construction materials for fast reactors it is desirable to be oriented toward grades of steel and alloys with a low nickel content, especially for steam-cooled reactors.

UDC 621.311.22:639.025

SUPPLY OF HEAT FROM THE PRIMARY CIRCUIT OF WATER-COOLED POWER REACTORS FOR COVERING THE PEAK HEAT DEMAND OF A NUCLEAR HEAT AND POWER PLANT

[Abstract of article by Abramov, A.I., Il'chenko, A.G. and Kayekin, V.S.]

[Text] A scheme is presented for covering the peak heat demand of a nuclear heat and power plant with the heat of the primary circuit of a reactor. For a nuclear heat and power plant with a reactor of the water-cooled power reactor type, a procedure is given for determining the amount of adjusted expenditures for nuclear fuel taking into account the change in the heat rating of the reactor and the size of the reactivity margin while holding constant the values of the flow rate

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of the heat transfer agent, the length of the reactor's lifetime and the critical heat demand safety factor.

The results of technical and economic calculations are presented.

UDC 621.311.22:639.025

CHOICE OF SEPARATING PRESSURE FOR EXTRACTION TURBINES OPERATING ON SATURATED STEAM

[Abstract of article by Abramov, A.I., Tishin, S.G. and Il'chenko, A.G.]

[Text] The results are given of calculations for selecting the optimum value of the separating pressure in systems of nuclear heat and power plant steam turbine plants of the TK-450/500-65 type, with high attached condensation capacity.

It is demonstrated that the value of the separating pressure in systems of these plants can be selected to be the same as for nuclear power plant condensing turbines.

UDC 621.1:621.311.2

OPTIMIZATION OF DISTRIBUTION OF REGENERATIVE HEATING OF WATER IN A NUCLEAR POWER PLANT

[Abstract of article by Ryzhkin, V.Ya., Tsanev, S.V. and Sarvate, S.]

[Text] A procedure is discussed for making an analytical determination of the optimum distribution of the regenerative heating of the feed water of nuclear steam turbine plants operating on saturated steam. For the sake of comparison, the results are given of a determination of the optimum distribution of heating of water by means of alternative calculations.

UDC 621.311.25:621.039

AERODYNAMICS OF VENT TUBES

[Abstract of article by Gavrilov, Ye.I. and Yakunin, A.V.]

[Text] In a nuclear power plant radioactive gases are blown off from the equipment of the first circuit, pass through a special gas cleaning system, are thinned with ventilation air and are emitted in the atmosphere by means of vent tubes. Aerodynamic systems are suggested for vent tubes which make rarefaction possible over the entire height of the gas venting shaft.

UDC 621.311.25:621.039.681.332/333

SIMULATION ON SMALL COMPUTERS IN REAL TIME OF ELEMENTS AND SYSTEMS OF THE FIRST CIRCUIT OF A NUCLEAR POWER PLANT WITH VVER-440 UNITS

[Abstract of article by Plyutinskiy, V.I., Koloskov, Yu.V. and Gribanova, Z.K.]

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[Text] The use of the mode approach to simulating the operation of a nuclear power plant with VVER-440 units in creating simulators based on small computers is discussed.

The results are presented of calculations of the dynamic characteristics of various models of the VVER-440 reactor with various operating modes of the nuclear power plant and the use of a large integration step for differential equations.

UDC 621.039.524.44

MATHEMATICAL MODEL OF CIRCULATION DYNAMICS IN A LARGE SHELL-TYPE BOILING WATER REACTOR

[Abstract of article by Plyutinskiy, V.I. and Leppik, P.A.]

[Text] A linear mathematical spatially distributed model of the natural circulation loop in a large shell-type boiling water reactor is discussed. The conditions for interchannel and loopwide hydraulic stability are formulated.

UDC 621.176:536.248.2

PROCEDURE FOR A CHECK CALCULATION OF A CONDENSATION INJECTOR

[Abstract of article by Shpil'rayn, E.E., Sevast'yanov, A.P., An, I.V., Buturlinov, A.V., Grigoryan, A.B. and Solov'yev, A.A.]

[Text] A procedure is presented which is constructed on the basis of the experimental data described in the paper. An analysis is made of the structure of the flow and of the measured static pressure field, liquid phase velocity and acoustic characteristics of the stream. The conclusion is drawn that a structural transition exists from a steam drop flow to a foam bubble one. A system of 18 differential equations of conservation with corresponding closing relations is suggested for the laminar flow section. The systems of equations presented make it possible to calculate flow parameters in the injector's mixing chamber from assigned initial parameters and a known geometry.

UDC 621.176:536.248.2

CALCULATION OF THE COEFFICIENT OF VELOCITY OF THE MIXING CHAMBER OF A CONDENSATION INJECTOR WITH CENTRAL FEEDING OF SUPERHEATED STEAM

[Abstract of article by Shpil'rayn, E.E., Sevast'yanov, A.P., An, I.V. and Solov'yev, A.A.]

[Text] The parameters of the main effects determining the value of the coefficient of velocity of a mixing chamber, ϕ_{ks} , are discussed: the shock wave in the region of the exit section of nozzles and the shock wave at the center of the mixing chamber. Friction losses of the two-phase stream against the channel wall are calculated, taking into account the distribution of mixing losses (shock losses)

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over the length of the mixing chamber. On this basis a semiempirical relationship is obtained for calculating ϕ_{ks} , valid in general form for the class of injectors with the central feeding of superheated steam at supersonic velocity. Agreement with the experimental data is satisfactory.

UDC 621.039.578.001.5

STUDY OF THE CONVECTIVE HEAT EXCHANGE CRISIS IN PIPES AT LOW VELOCITIES OF THE STEAM-AND-WATER MIXTURE

[Abstract of article by Smirnov, O.K. and Afonin, V.K.]

[Text] The results are given of a regression analysis of data obtained on the convective heat exchange crisis boundary and convective heat exchange coefficients in the supercritical region with low velocities of the steam-and-water mixture in pipes. A comparison is made of data with a calculation according to the familiar empirical relationships.

UDC 621.039.514

PHYSICAL PREMISES FOR ACOUSTICAL DIAGNOSIS OF MODIFICATION OF FLOW CONDITIONS OF A TWO-PHASE MEDIUM

[Abstract of article by Proskuryakov, K.N.]

[Text] The results are given of a theoretical and calculation study of the dependence of acoustic vibrations in a two-phase flow on flow conditions.

It is demonstrated that an increase in the acoustical capacity of the heat transfer agent results in the appearance of a negative component of acoustic resistance and is conducive to the amplification of vibrations.

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CONSTRUCTION OF NUCLEAR AND ORGANIC-FUEL-FIRED POWER PLANTS

Moscow STROITEL'STVO TEPLOVYKH ELEKTROSTANTSIY NA YADERNOM I ORGANICHESKOM TOPLIVE in Russian No 180, 1980 (signed to press 12 Aug 80) pp 2, 132-133

[Annotation and table of contents from book "Construction of Nuclear and Organic-Fuel-Fired Power Plants", edited by Professor Doctor of Technical Sciences V.B. Dubrovskiy and Assistant Professor Candidate of Technical Sciences N.Ya. Turchin, Moscow Order of the Red Banner of Labor Engineering-Construction Institute imeni V.V. Kuybyshev, 1000 copies, 134 pages]

[Text] Articles are published here, representing the results of research on the protection, strength and economic characteristics of construction designs of nuclear and thermal power plants, and articles devoted to studying the aftereffects of chemical, mechanical and structural changes taking place in a number of construction materials in the work process, and to study of the technical and economic indices of the construction of thermal and nuclear power plants.

Intended for scientific personnel and engineers specializing in various areas of the planning and construction of power plants, as well as for students enrolled in the course "Construction of Thermal and Nuclear Power Plants."

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RESEARCH AND DEVELOPMENT OF MATERIALS FOR NUCLEAR FUSION REACTORS

Moscow ISSLEDOVANIYE I RAZRABOTKA MATERIALOV DLYA REAKTOROV TERMOYADERNOGO SINTEZA in Russian 1981 pp 2, 172-183

[Annotation and abstracts from collection of articles "Research and Development of Materials for Nuclear Fusion Reactors", edited by Academician N.V. Ageyev, Izdatel'stvo "Nauka", 183 pages]

[Text] At the present time one of the most important tasks facing our country's scientists and engineers is the creation of a new energy base based on the utilization of thermonuclear power engineering.

The creation in the very near future of demonstration and industrial nuclear fusion reactors with magnetic and inertial plasma confinement has already now become a reality. However, in order to solve these problems it is necessary to create and study many classes of construction materials able to function under the very severe conditions of thermonuclear reactors.

The present collection is made up of original articles on fundamental problems of solid-state radiation physics as applied to problems of creating materials for nuclear fusion reactors, developing construction materials, etc. Individual sections of the collection are devoted to studying the bulk and surface radiation properties of various metallic and other materials; also included are original articles on materials-science problems relating to pulsed thermonuclear reactors.

This edition is intended for a wide range of researchers and practical workers working on scientific and engineering problems of controlled nuclear fusion.

UDC 539.12.04.:621.039.616

STUDY OF THE INFLUENCE OF ALLOYING ON THE RADIATION RESISTANCE OF MOLYBDENUM

[Abstract of article by Kalin, B.A., Skorov, D.M. and Yakushin, V.L.]

[Text] A study is made of the cathode sputtering and blistering of grade MChVP vacuum-melted molybdenum and alloys TsM10VD, TsM6 and Mo - 0.6 to 2.4 percent by weight V - 0.03 percent by weight C when exposed to helium ions. Sputtering was carried out in a low-pressure helium glow discharge and blistering was studied under exposure to a monoenergetic ion beam with energy of 20 keV at a temperature

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of 330 K with a dose of $5 \cdot 10^{17}$ ions/cm². It is demonstrated that alloying molybdenum with slight additions of vanadium, boron, aluminum and carbon does not result in considerable changes in the erosion coefficients of alloys and in blister-formation parameters as compared with pure molybdenum. Increasing the content of vanadium in the Mo-V-C system results in some reduction of the alloy's sputtering coefficient.

UDC 621.039.532.21

RADIATION ALTERATION OF PROPERTIES OF GRAPHITE CONSTRUCTION MATERIALS IN THE RANGE OF 70-950 °C TO FLUENCE OF $2.5 \cdot 10^{22}$ n/cm²

[Abstract of article by Virgil'yev, Yu.S. and Kostikov, V.I.]

[Text] Data are given on radiation alteration of the physical properties (dimensional stability, heat conduction, strength, creep, etc.) of construction graphite for a wide temperature and neutron fluence range. The influence of several technological factors in the production of graphite on radiation resistance is discussed.

It is suggested that the data presented can be used for a preliminary estimate of the working capacity of graphite under conditions of a fusion reactor. It is furthermore noted that selection of the optimum working temperature in addition to selection of the grade of graphite will make it possible to reduce radiation disturbance of its properties and at the same time to extend the period for the functioning of graphite in a fusion reactor.

UDC 620.172.251.2

PROCEDURE FOR STUDYING CREEP OF MATERIALS IN THE PROCESS OF THERMAL CYCLING

[Abstract of article by Skorov, D.M., Kalin, B.A. and Fedotov, V.T.]

[Text] As applied to proposed temperature-time parameters of the operation of fusion reactors, a procedure is suggested for studying creep with the temperature changing in cycles, making it possible to conduct tests under temperature conditions controlled with high precision and to compare anisothermic tests with results obtained at constant temperatures. A description is given of a high-vacuum unit, of a model of special design heated by the direct passing of electric current through it, and of the flowchart of the program for calculating on a computer anisothermic creep curves, and the results of a study of niobium alloy ELN1 are given.

UDC 621.039.634

PROBLEMS OF CONSTRUCTION MATERIALS FOR THE FIRST WALL OF A FUSION REACTOR ASSOCIATED WITH VOLUMETRIC RADIATION EFFECTS

[Abstract of article by Kazakov, V.A. and Shamardin, V.K.]

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[Text] A review of the published data has established definite progress both in determination of the probable working parameters of the first wall in fusion reactors of various designs and in understanding of the features of radiation effects which will take place in fusion reactors. The most complicated problems involve volumetric radiation damage. They are similar to a great extent to those discovered and studied in sufficient detail in materials used in fission reactors.

A whole series of experimental studies indicate the possibility of a more drastic manifestation of some already known problems, such as, for example, high-temperature radiation embrittlement and swelling of nickel-containing steel and alloys under conditions of the use of the first wall of a fusion reactor. These radiation effects are intensified on account of the high concentrations of helium formed in the majority of elements on account of nuclear reactions caused by neutrons with energy of 14 MeV. The possibility is indicated of realistic technological and design solutions to a whole series of difficulties in the selection and recommendation of materials for the first generation of fusion reactors.

The complexity of materials science problems associated with volumetric radiation effects and the diversity of ways of solving them necessitate a comprehensive approach for the purpose of finding the most economical and safe variants of designs for the blanket of a fusion reactor.

UDC 533.924:539.12.17

STUDY OF PROCESSES OF SUBLIMATION OF SOME CONSTRUCTION MATERIALS

[Abstract of article by Fedichkin, G.M., Bondarenko, G.G. and Shmykov, A.A.]

[Text] By the method of microweighing under high vacuum, measurements are made of the rates of sublimation of grade EP838 and 316 steel, the "Nimonik" alloy (50 percent gamma phase) and a beta-titanium alloy over a wide temperature range. Kinetic mechanisms are obtained for processes of the sublimation of volatile components from the alloys studied. It is established that processes of the sublimation of volatile components of these alloys are limited by diffusion of these components toward the sublimation surface. Individual activation energies are calculated. It is demonstrated that the manganese in EP-838 steel ($E_a = 45.7$ kcal/mole) is sublimated at the highest rate at working temperatures, resulting in the appearance of impermissible ferromagnetic regions on the surface of the material. Based on the results obtained, an estimate is made of the contribution of sublimation processes to the total erosion of construction materials.

UDC 539.12.04:621.039.616

INFLUENCE OF INTENSITY OF ION FLUX ON RADIATION EROSION OF MATERIALS

[Abstract of article by Kalin, B.A., Pol'skiy, V.I. and Skorov, D.M.]

[Text] An analysis is made of the influence of the intensity of a beam of light ions on the heating-up temperature of an irradiated target and its radiation destruction as applied to fusion reactors. Heating-up temperatures are calculated from a fourth-order heat balance equation for various cases of heat removal of

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the target. An estimate is also made of the possible migration of bubbles of introduced gas from the depth to the surface of the target. The calculations presented demonstrate that erosion of the surface on account of the gas bubble migration mechanism depends substantially on heating up of the target and results in the appearance of an etched relief in the form of a spongy or acicular structure of the surface of the irradiated target.

UDC 539.12.04:621.039.616

STUDY OF MASS TRANSFER MECHANISMS IN A 'COVERING - GAP - FIRST WALL' SYSTEM AS APPLIED TO FUSION REACTORS

[Abstract of article by Kirilin, N.M., Shulov, V.A., Skorov, D.M., Yevstyukhin, A.I. and Kalin, B.A.]

[Text] A thermodynamic and kinetic analysis is made of the an alloy-covering system with the presence between them of a gap filled with a mixture of active gases (hydrogen, oxygen, etc.) with pressure of 10^{-12} to 10^{-6} atm.

Elements with an atomic number of less than 14 and their compounds are discussed as shielding materials, and alloys based on vanadium, molybdenum and niobium and stainless steels as materials for the first wall. It is demonstrated that alloying high-melting metals with Ti and Si (for niobium) suppresses the mass transfer of atoms of alloys to the covering over the 800-1200 °C temperature range. From the viewpoint of mass transfer, of the shielding materials considered preference is to be given to compounds based on aluminum.

UDC 533.924:539.12.17

DEPENDENCE OF RADIATION EROSION OF OKh16N15M2B STAINLESS STEEL ON THE DOSE IN IRRADIATION WITH HELIUM IONS WITH ENERGY OF 20 keV

[Abstract of article by Kalin, B.A., Kirilin, N.M., Skorov, D.M. and Chernov, I.I.]

[Text] A study is made of the radiation erosion of OKh16N15M2B stainless steel in the austenitized and 20-percent cold-strained states when irradiated with helium ions with energy of 20 keV at 200 °C over the dose range of $(10 \text{ to } 500) \cdot 10^{21}$ ions/m². It is demonstrated that in the dose range studied the maximum erosion coefficient was on the order of 0.5 at/ion when irradiating with a dose of $1 \cdot 10^{22}$ ion/m² and was reduced with an increase in the ion dose. With irradiation doses higher than $2 \cdot 10^{23}$ ions/m² the total erosion coefficient practically equals the steel's sputtering ratio. The influence of pretreatment on erosion of the material is reduced with an increase in dose and is practically lacking with high irradiation doses of $(4 \text{ to } 6) \cdot 10^{22}$ ions/m².

UDC 669.27:537.534.9

FIELD-ION AND ELECTRON MICROSCOPE STUDY OF THE SURFACE OF TUNGSTEN IRRADIATED WITH HELIUM IONS

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[Abstract of article by Dranova, Zh.I., Mikhaylovskiy, I.M., Pivovar, L.I. and Tostolutskaya, G.D.]

[Text] By the methods of electron and field-ion microscopy studies were made of changes in the structure and microrelief of the surface of tungsten under the effect of irradiation with helium ions. A study was made by means of an electron microscope of the influence on blistering of the original structure of the material formed as the result of rolling and recrystallization annealing.

Comparison of structures formed on the surface of tungsten as the result of irradiation at room temperature and as the result of irradiation with subsequent annealing demonstrated that no substantial difference was observed in the nature of scouring. Measurements were made of the thickness of the scoured layer as a function of the ion energy and a comparison was made of the thickness of covers with calculated values of the mean free paths of helium ions in tungsten.

By means of a field-ion microscope a study was made of the atomic topography of single crystals of tungsten irradiated with helium ions with energy of 0.1 to 3.0 keV over the dose range of 10^{11} to 10^{17} cm^{-2} . It was established that with an irradiation dose of 10^{11} to 10^{12} cm^{-2} the change in microtopography as the result of the radiation effect is two orders of magnitude greater than the form-alteration effect caused by erosion. Early stages of blister formation were observed with doses of 10^{16} cm^{-2} and higher; the blisters measured 10^2 to 10^3 Å. A study was made of the microstructure of irradiated tungsten by means of the method of field-controlled layer-by-layer sublimation.

UDC 533.924:539.12.17

MAGNETO-OPTICAL STUDY OF ISOLATION OF THE FERROMAGNETIC PHASE ON THE SURFACE OF SOME CONSTRUCTION MATERIALS FOR FUSION REACTORS

[Abstract of article by Krinchik, G.S., Nikitin, L.V., Bondarenko, G.G. and Fedichkin, G.M.]

[Text] By the magneto-optical method a study is made of isolation of the ferromagnetic phase on the surface of chrome-manganese austenitic steel after various kinds of heat treatment. The ferromagnetic phase was not detected on the original samples which had been electropolished, but after vacuum annealing the appearance of a ferromagnetic alpha phase was observed caused by the sublimation of austenitized components. Quantitative characteristics of the selective sublimation of these components are given, obtained by the method of microweighing under high vacuum. For the purpose of studying the kinetics of the alpha phase formation process taking place, temperature measurements were made with a specially created magneto-optical apparatus making it possible to study surface magnetic characteristics under conditions of high vacuum and high temperatures. A comparative analysis is made of processes taking place in materials of various compositions and the possibility is indicated of the appearance of a thin ferromagnetic layer in the course of utilization of the first wall of a reactor.

UDC 662.747:546.11:533.9:537.525

INTERACTION OF CARBON (GRAPHITE AND DIAMOND) COATINGS WITH THE HYDROGEN PLASMA OF A GLOW DISCHARGE

[Abstract of article by Fedoseyev, D.V., Deryagin, B.V., Tolmachev, Yu.N., Bukhovets, V.L., Varnin, V.P. and Teremetskaya, I.G.]

[Text] It has been proven that the application of a coating of an acetylene-hydrogen plasma to char substantially reduces the rate of gasification of the char in a hydrogen plasma. The dependence of the rate of gasification of a carbon coating in a hydrogen plasma on the temperature has a 550-900 °C section in which the reaction rate is reduced with an increase in temperature. The depth of penetration of the reaction into a layer of diamond powder coated with graphite does not exceed 1 mm with a particle size of 100 to 125 microns, which is associated with the rapid recombination of hydrogen atoms in the powder layer. In the interaction of polycrystalline graphite with a hydrogen plasma the amorphous component is gasified first, whereas graphite crystals are gasified at a considerably slower rate.

UDC 539.9.082:533.924

BLISTERING IN VANADIUM WITH SUCCESSIVE IRRADIATION WITH HYDROGEN AND HELIUM IONS

[Abstract of article by Guseva, M.I., Zykova, N.M., Ionova, Ye.S., Koltynin, V.M., Krasulin, Yu.L., Kurakina, T.S., Nedospasov, A.V. and Rozina, I.A.]

[Text] A study is made of the influence of preliminary and later implantation of H⁺ ions on helium blistering in monocrystalline vanadium. The considerable influence of irradiation with hydrogen ions on erosion of the surface has been proven and the introduction of hydrogen causes embrittlement of the surface of vanadium, resulting in the opening of blisters along the outline of shells.

UDC 621.032.573

MATERIALS SCIENCE QUESTIONS IN THE PROBLEM OF PULSED FUSION REACTORS

[Abstract of article by Gryaznov, G.M., Yevtikhin, V.A., Kosukhin, A.Ya., Zanevina, O.A., Mosin, A.P. and Gurov, A.D.]

[Text] Factors of the effect of a thermonuclear microexplosion on materials of the first wall are discussed in condensed form. Key trends of studies relating to the theoretical and experimental investigation of materials are indicated.

UDC 533.924:539.12.17

STUDY OF THE PROCESS OF BLISTERING OF ALUMINUM AND STAINLESS STEEL IN IRRADIATION WITH HELIUM IONS

[Abstract of article by Bondarenko, G.G. and Vasil'yevskiy, V.V.]

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[Text] An electron microscope study is made of erosion of the surface of polycrystalline aluminum and stainless steel of austenitic class EP-838 under the effect of helium ions with energy of 10, 20 and 175 keV. The materials were irradiated in the "Vezuviy" [Vesuvius] heavy ion accelerator, as well as directly in the column of an EF2-Z6 field-emission microscope by means of a special attachment.

A study is made of the influence of postradiation annealing on the nature of form modification and scouring of the surface of EP-838 steel. It has been proven that increasing the temperature of the irradiated sample to 1200 °C results in an approximately sevenfold increase in the surface erosion coefficient.

A study is made of the influence of particle energy and the irradiation dose on the nature of radiation damage to the surface in polycrystalline aluminum. It is demonstrated that with low energies of helium ions (5 to 10 keV) the dominant process is physical erosion of the irradiated surface, and with increased energies (20 to 30 keV) the blistering effect. In the $5 \cdot 10^{17}$ to $1.7 \cdot 10^{18}$ ions/cm² range increasing the irradiation dose results in an increase in the surface erosion coefficient by more than an order of magnitude.

UDC 620. 19

MATERIALS SCIENCE QUESTIONS RELATING TO CREATION OF LIQUID METAL SYSTEMS FOR PULSED FUSION REACTORS

[Abstract of article by Gryaznov, G.M., Kosukhin, A.Ya., Koloskov, D.M., Loseva, N.V. and Yevtikhin, V.A.]

[Text] Possible corrosion processes in a construction material - lithium system are discussed. The influence of various factors responsible for the penetrability of an alkali metal and corrosion is demonstrated.

A determination is made of the necessary conditions and technological requirements, confirmed by full-scale circuit tests, making possible the reliable working capacity of materials of liquid metal systems with lithium.

An analysis is made of working conditions for materials of the blanket zone of a pulsed fusion reactor. The possible influence of factors of the microexplosion of a D-T target on the materials of the first wall and blanket zone is demonstrated. The key trends of studies relating to materials science research are delineated.

UDC 539.12.04:621.039.616

STUDY OF RADIATION EROSION OF MATERIALS IN CYCLIC IRRADIATION WITH IONS

[Abstract of article by Begrambekov, L.B., Kalin, B.A., Korshunov, S.N., Skorov, D.M., Skulanov, S.B., Tel'kovskiy, V.G. and Yakushin, V.L.]

[Text] A study is made of the radiation blistering of grade MChVP molybdenum and grade VEL-2 vanadium when irradiated with helium ions with energy of 20 keV

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in a dose of $2 \cdot 10^{18}$ ions/cm² over a wide range of angles of incidence of ions and with a cyclic mode of irradiation. Simulation of the range of angles of incidence of ions is accomplished by evenly turning the target in the process of irradiation around an axis perpendicular to the incident ion beam. It is demonstrated that the irradiation of materials over a wide range of angles of incidence of ions results in reduction of the erosion coefficients of the materials because of the breaking of blisters and changes in blister formation parameters.

UDC 539.234

PASSING OF BEAMS OF HIGH-ENERGY ELECTRONS THROUGH A GRAPHITE FOIL

[Abstract of article by Fedoseyev, D.V., Vnukov, S.P. and Statenkova, Ye.V.]

[Text] Graphite foil--a material produced as the result of the pyrolysis of methane and acetylene--is vacuum tight and thermally stable and therefore can be recommended for the windows of high-energy electron accelerators.

A calculation presented of the passing of a fairly powerful beam of relativistic electrons (approximately 2 MeV) through graphite foil has demonstrated that it can transmit pulses of up to $3 \cdot 10^9$ J/m².

UDC 539.121.72

HIGH-INTENSITY NEUTRON GENERATORS

[Abstract of article by Tel'kovskiy, V.G.]

[Text] Methods of producing intense (greater than 10^{13} n/4 π) neutron flux with energy on the order of 14 MeV are discussed. Circuits of neutron generators with these parameters developed in our country and abroad are analyzed, utilizing the reaction for the fusion of deuterium and tritium ("solid state" and "gas" targets) and the reaction for fusion of lithium-7 and deuterium.

In the case of neutron generators with a solid-state target (ions of deuterium irradiate a metal target saturated with tritium), design solutions for neutron generators are discussed, as well as the physics of processes taking place on the irradiated surface (including questions relating to confining the tritium in the target).

In the case of a gas target (ions of deuterium bombard a supersonic stream of tritium), processes of heat transfer from the reaction zone, the problem of the entry of a powerful ion beam into a dense gas target and possible design solutions for neutron generators are discussed.

Possibilities of the creation and the features of neutron generators with a lithium target are discussed and the possible circuit of a neutron generator is given.

Based on an analysis of the results, directions of further study required for the creation of high-intensity neutron generators are pointed out.

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UDC 533.2

PROCESSES OF DEFECT FORMATION AND DIFFUSION IN MOLYBDENUM UNDER CONDITIONS OF IRRADIATION WITH LOW-ENERGY IONS OF HYDROGEN, DEUTERIUM AND HELIUM

[Abstract of article by Zakharov, A.P.]

[Text] By means of electron microscope methods, structural changes are traced in surface layers of molybdenum irradiated with low-energy hydrogen ions. In studying processes of the penetration of hydrogen through a metal under conditions of the plasma of a glow discharge, the effect of the radiation-accelerated diffusion of hydrogen has been discovered, caused by the formation of an internal interstitial atom - hydrogen atom dynamic complex with a dissociation energy of approximately 2 eV. New possibilities for studying the distribution of light implanted ions are offered by the method of layer-by-layer analysis by means of erosion with argon ions. Because of its application it has been possible to fix the position of ions in the lattice of a metal with various irradiation temperatures and to reveal the phenomenon of the redistribution of helium found in vacancies as the result of reaction with SAM-N complexes.

UDC 681.32:548.4

INFLUENCE ON HARDENING OF THE ALIGNMENT OF RADIATION DEFECTS IN THE SUPERLATTICE

[Abstract of article by Ibragimov, Sh.Sh., Kirsanov, V.V. and Tyupkina, O.G.]

[Text] By means of a modified Formen-Meykin model the particular case of the distribution of radiation defects in front of a moving dislocation is discussed, namely, their ordered arrangement (the so-called superlattice of defects). Since defects in experimentally observed superlattices are nonuniform in size, it is to be expected that in interaction with a moving dislocation they will behave differently. Within the framework of the model used an attempt is made to take this effect into account, by introducing two sizes of point obstacles and distributing them randomly over points of the superlattice.

UDC 620.193.6:539.219.3

RESULTS OF STUDYING THE PROPERTIES OF NICKEL-FREE STAINLESS STEEL UNDER CONDITIONS CHARACTERISTIC OF A FUSION REACTOR

[Abstract of article by Barannikova, G.A., Vaulin, L.N., Gol'tsov, V.A., Guseva, M.I., Latyshev, V.V., Prokof'yev, Yu.G., Saksaganskiy, G.L., Sotnichenko, A.L. and Fefelov, P.A.]

[Text] The results are presented of studies of the properties of chrome-manganese steel O6Kh17G17DAMB (AS9) and O6Kh17G15NAB (AS43) performed in connection with studying the possibility of using these steels in designs of fusion reactors. In particular, experimental data are presented on the change in the mechanical characteristics of these steels in the temperature range of 20 to 700 °C after being irradiated with fast neutrons (dose of $8 \cdot 10^{20}$ n/cm², irradiation

temperature of 650 °C) and on a study of short-time fatigue in the 20-600 °C temperature range under vacuum and in hydrogen.

Data are also presented on the erosion resistance of the steels studied when irradiated with hydrogen and helium ions and on their gas diffusion and magnetic characteristics.

UDC 539.9.082:533.924

PROBLEMS RELATING TO THE FIRST WALL OF FUSION REACTORS

[Abstract of article by Guseva, M.I., Martynenko, Yu.V. and Pleshivtsev, N.V.]

[Text] Major processes on the surface of the first wall of a thermonuclear reactor--a tokamak--are discussed. A calculation is made of the rate of erosion of the wall of a T-20 tokamak under the effect of bombarding ions (atoms), D^+ , T^+ and He^+ . It is demonstrated that the main physical process responsible for erosion of the surface of the first wall is erosion of the wall's material by D^+ , T^+ and He^+ ions. Ways of protecting the first wall from erosion are discussed.

UDC 539.9.082:533.924

STUDY OF EROSION OF THE SURFACE OF CHROME-NICKEL ALLOYS IN BOMBARDMENT WITH HELIUM AND HYDROGEN IONS

[Abstract of article by Busharov, N.P., Gusev, V.M., Guseva, M.I., Ionova, Ye.S., Mansurova, A.N., Chelnokov, O.I., Afrikanov, I.N., Morozov, V.N. and Fefelov, P.A.]

[Text] Studies are made of radiation damage to the surface of Fe-Cr-Ni alloys in bombardment with ions with energy of 40 keV at various temperatures. At T_{irr} [region] = 200 °C scouring of layers is observed and the erosion rate reaches approximately 1 at/ion, and at 500 °C blisters form on the surface. Maximum erosion of the surface takes place at T_{irr} about 39% of melting point." Erosion coefficients of these alloys are measured for ions with energy of 10 keV.

UDC 621.791.85:669.018.8

ROLE OF RADIATION-STIMULATED PHASE TRANSFORMATIONS IN CHANGING OF THE PROPERTIES OF FUSION REACTOR MATERIALS

[Abstract of article by Bystrov, L.N., Ivanov, L.I., Ustinovshchikov, V.M. and Tsepelev, A.B.]

[Text] The question of the influence of radiation-stimulated structural phase transformations on the mechanical properties of fusion reactor construction materials is discussed. A study is made of grades 316 and EP838 stainless steel. A study is made of the kinetics of a change in the electrical resistance of 316 steel under the effect of electron irradiation with energy of 2.3 MeV in the temperature range of 100-400 °C and the possible mechanism for changes observed in electrical resistance is discussed. By the active tension method and a study of creep a measurement is made of the mechanical characteristics of 316 and

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EP838 steel irradiated with electrons in the austenitized and cold-strained states. The conclusion is drawn that there is the possibility of the considerable influence of radiation-stimulated diffusion processes on changing of the properties of austenitic stainless steel in the process of operation of a fusion reactor.

UDC 533.924:539.12.17

STUDY OF RADIATION EROSION OF NIOBIUM ALLOYS

[Abstract of article by Kalin, B.A., Skorov, D.M. and Shishkin, G.N.]

[Text] An electron microscope study is made of failure in ion bombardment of the surface of alloys of the system Nb-Zr-C having undergone tests for 1-percent creep in Li. Irradiation was with helium ions with energy of 15 keV over the dose range of $(0.5 \text{ to } 10) \cdot 10^{18}$ ions/cm² at 700 °C with a beam current of 0.4 mA/cm². It is demonstrated that the process of blister formation takes place with doses of $(5 \text{ to } 10) \cdot 10^{17}$ ions/cm² and practically does not depend on the technological characteristics of the alloy. With an increase in the dose to $5 \cdot 10^{18}$ ions/cm² and more radiation erosion is determined basically by sputtering. The alloys tested prior to irradiation for an extended period under a load in lithium tend toward local erosion with the formation of craters measuring 200-700 Å.

UDC 620.17:537.534

COMBINATION OF EXPERIMENTAL APPARATUS FOR STUDYING RADIATION-VACUUM AND PHYSICO-MECHANICAL CHARACTERISTICS OF FUSION REACTOR CONSTRUCTION MATERIALS

[Abstract of article by Karasev, B.G., Komarov, V.L., Prokof'yev, Yu.G., Saksaganskiy, G.L., Serebrennikov, D.V., Spirchenko, Yu.V. and Fefelov, P.A.]

[Text] A brief description is given of the designs and technical characteristics of experimentation stands for studying erosion resistance of the surface, water tightness at high temperatures and the mechanical characteristics under conditions of static and cyclic straining, of construction materials which are promising for use in fusion reactors.

The SVICH stand has a hydrogen ion source with energy from 20 to 80 keV, current density of the beam at the target of 0.01 to 0.1 A/cm² and background pressure in the measuring chamber of $1 \cdot 10^{-10}$ mm Hg.

The MKI stand has been created for irradiating materials with ion beams with a mass spectrum from 1 to 40. The ion energy is 0.1 to 20 keV, the beam current is a maximum of 5 mA and the background pressure in the target chamber is $1 \cdot 10^{-10}$ mm Hg. The possibility is provided of irradiating the target simultaneously with two ion beams of different types.

The TYeST and LUCH stands are designed for studying the water tightness of materials at high temperatures, including by taking into account nonequilibrium conditions and the stressed-strained state of the material.

The TsIKL stand has been created for studying the influence on materials of static and cyclic mechanical loads at various temperatures over the range of -260 to 1000 °C. Investigation of the behavior of materials with variation in strain forces and temperatures of samples according to a specific program is provided for.

UDC 539.9.082:533.924

INFLUENCE OF ORIENTATION ON EROSION OF MONOCRYSTALLINE VANADIUM UNDER BOMBARDMENT WITH HELIUM IONS

[Abstract of article by Guseva, M.I., Zykova, N.M., Ionova, Ye.S., Koltygin, V.M., Krasulin, Yu.L., Kurakina, T.S., Nedospasov, A.V. and Rozina, I.A.]

[Text] Studies are made of radiation damage to the surface of monocrystalline vanadium under bombardment with He⁺ ions with energy of 10 and 40 keV. It is demonstrated that with a dose of 0.5 curies/cm² in the case of irradiation with He⁺ ions with energy of 10 keV, on a {100}, {111} and {110} surface blisters are formed with undamaged shells, whereas after implantation with 40-keV He⁺ ions, other conditions being equal, on these planes multilayer scouring is observed, and strong anisotropy of blistering and flaking occurs.

UDC 621.039.553

PROSPECTS FOR USING ALPHA ALLOYS OF TITANIUM AS A CONSTRUCTION MATERIAL FOR THE FIRST WALL OF THE LOW-TEMPERATURE DISCHARGE CHAMBER OF A FUSION REACTOR

[Abstract of article by Al'tovskiy, I.V., Gorynin, I.V., Kozhevnikov, O.A., Lemke, N.G., Odintsov, N.B., Odintsov, V.N., Parshin, A.M., Privol'neva, A.S., Syschikov, V.I., Ushkov, S.S., Fefelov, P.A., Chechulin, B.B., Yakovleva, T.A. and Yaroshevich, V.D.]

[Text] The results are presented of a study of grade VT1-0 technically pure titanium and of the alpha alloy PT-7M in the original state and after neutron irradiation with fluence up to $2 \cdot 10^{21}$ n/cm² ($E \geq 0.85$ meV). It is demonstrated that the alloys studied possess high radiation resistance and preserve their ductile properties at a sufficient level both under short-term and extended testing. The conclusion is drawn that in terms of combination of physicomechanical properties low-alloy alpha alloys of titanium satisfy the requirements imposed on construction materials for discharge chambers of fusion reactors and are promising for use in these structures.

UDC 533.924.:539.12.17

HIGH-NICKEL ALLOYS OF THE CHS-42 AND CHS-43 TYPE AS MATERIALS FOR THE FIRST WALL OF FUSION REACTORS

[Abstract of article by Bannykh, O.A., Gorynin, I.V., Ibragimov, Sh.Sh., Ivanov, A.I., Kozhevnikov, O.A., Lapin, A.N., Lopatina, O.A., Makhlin, N.A., Parshin, A.M., Pen'kov, G.A. and Yaroshevich, V.D.]

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[Text] Questions are discussed relating to using high-nickel alloys of the ChS-42 and ChS-43 type as construction materials for the first wall of a fusion reactor over a broad temperature range. Data are presented on the radiation resistance of these alloys, obtained on the basis of both reactor and simulation tests. These data confirm that in terms of their radiation resistance and also their combination of key physicomachanical properties alloys of the ChS-42 and ChS-43 type surpass a number of well-known domestic and foreign steels of the austenitic class.

UDC 548.539

INFLUENCE OF FORMATION OF MOBILE INTERNAL POINT DEFECT - IMPURITY ATOM COMPLEXES ON DIFFUSION FLOWS OF DEFECTS TO DISLOCATIONS AND PORES

[Abstract of article by Vershok, B.A. and Gorbатов, G.Z.]

[Text] A study is made of the influence of the formation of mobile binary internal point defect (STD) - impurity atom complexes on diffusion flow of STD's toward dislocations and pores, as well as on the origin of superequilibrium segregations of an impurity in sinks. On the basis of solving stationary equations of diffusion around a straight-line edge dislocation and spherical pore, simple analytical expressions are obtained for diffusion flows of each type of defect and segregations of an impurity in sinks. The formation of complexes results in a change in elastic interaction and the effectiveness of the absorption of STD's by dislocations. This can result in a substantial change in vacancy swelling with the addition of an impurity.

UDC 539.16.04

STUDY OF BLISTERING IN SINGLE CRYSTALS OF ZIRCONIUM OXIDE STABILIZED WITH YTTRIUM OXIDE

[Abstract of article by Akishin, A.I., Malov, M.M., Pokhil, G.P., Ryazantsev, A.D., Solov'yev, G.G., Tulinov, A.F. and Chumanov, V.Ya.]

[Text] A study is made of crystals of zirconium oxide irradiated with protons with energy of 100 keV right up to the appearance of blisters. By the back-scattering method a determination is made of the profiles of defects at the early stages of the origin of blistering. At the same time, at the early stages of defect formation a study was made of the change in the optical properties of zirconium oxide. The data obtained indicate that the mechanism for the formation of blisters in zirconium oxide in irradiation with protons is associated with the development of mechanical stresses in the irradiated zone rather than with the growth of gas pores.

UDC 548.77:620.174

ANISOTROPY OF BRITTLE FAILURE OF ROLLED MOLYBDENUM ALLOYS AND THEIR WELDED JOINTS

[Abstract of article by Yevstyukhin, A.I., Perlovich, Yu.A., Baskov, A.F., Semenov, V.V., Nerodenko, M.M. and Polishchuk, Ye.P.]

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[Text] A study is made of the influence of structural factors on the anisotropy of brittle failure of a number of widely used rolled alloys based on molybdenum (TsM-2a, UM-6, TsM-8, TsM-10 and VM-5) and of their welded joints. The temperature of brittle failure was determined in bending tests of samples cut from a sheet at various angles to the rolling direction. In changing from one alloy to another their metallographic and crystallographic textures vary substantially, which makes it possible to isolate their contributions to the anisotropy of brittle failure observed. In analyzing mechanisms of the influence of texture on the anisotropy of brittle failure, the form and size of structural elements, primarily the orientation of shear boundaries and planes, were taken into account.

The principal nature of the anisotropy of brittle failure is determined by the metallographic texture, and when it is weakened by the crystallographic texture. The nature of the anisotropy of brittle failure of welded joints is similar to that observed for welded sheets of molybdenum alloys.

UDC 621.039.573

MATERIALS SCIENCE PROBLEMS IN THERMONUCLEAR POWER GENERATION

[Abstract of article by Ivanov, L.I.]

[Text] On the general level key problems in selecting materials for the first wall of a fusion reactor are discussed. The promise of creating porous protective coatings on elements with low Z is indicated. For the purpose of improving the radiation resistance of metal materials for the first wall, it is recommended that alloying elements be chosen with small nuclear cross sections for nuclear reactions with fusion neutrons resulting in the formation of helium.

In this connection the promise of using manganese austenitic steel as a material for the first wall is indicated. Attention is turned to the performance of specific kinds of mechanical treatment of industrial metal materials for improving their radiation resistance.

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TURBINE AND ENGINE DESIGN

TURBODYNAMOS

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA I ORDENA OKIYABR'SKOY REVOLYUTSII ENERGETICHESKOGO INSTITUTA, TEMATICHESKIY SBORNIK: TURBOMASHINY in Russian No 504, 1980 (signed to press 18 Mar 81) pp 2, 140-147

[Annotation and abstracts from collection of papers "Turbodynamos", edited by Doctor of Technical Sciences Professor A.Ye. Zaryankin, Moscow Power Engineering Institute, 300 copies, 147 pages]

[Text] Studies by the Steam and Gas Turbines Faculty performed from 1977 to 1978 are presented in this collection.

A considerable portion of the material presented covers questions relating to the gas dynamical improvement of various elements of the flow section of steam and saturated steam turbines, questions relating to the experimental investigation of turbines and questions relating to improving the reliability of turbine plants. A number of articles are devoted to automatic control, experimentation stands and improvement of procedures for designing turbodynamos.

This collection is of interest to engineering and technical and scientific personnel and graduate students at scientific research and educational institutes working on problems of improving turbodynamos, as well as to engineering and technical personnel of all turbine-building plants.

UDC 62-135:533.6.011

INFLUENCE OF THE SHAPE OF THE TRAILING EDGE OF A SECTION ON THE MAGNITUDE OF LIP LOSSES

[Abstract of article by Deych, M.Ye., Lazarev, L.Ya. and Zhegalin, A.S.]

[Text] Experimental data are presented on traversing of the outlet field of the stream of a plane vane cascade placed in a wind tunnel of the open type.

It is demonstrated that by adding cutouts to the trailing edge of the section of a turbine blade the plane flow in the wake of the lip is transformed into 3-dimensional flow consisting of individual three-dimensional wakes interacting with one another.

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UDC 621.165.53.001.5

INFLUENCE OF RELATIVE HEIGHT OF A BLADE ON SEPARATION OF THE STREAM AND LOSSES
IN AN ACTIVE SUPERSONIC BLADING

[Abstract of article by Mikesh, I.]

[Text] Physical aspects of the interaction of primary and secondary flows in supersonic active bladings with separation of the stream along the profile are discussed.

It is demonstrated that with low relative heights of the blading secondary flows are conducive to reduction of the zone of separation along the profile and to the reduction of secondary losses.

UDC 621.165.001

RESULTS OF INVESTIGATION OF A MODIFIED RADIAL-AXIAL STAGE

[Abstract of article by Demin, Yu.V., Ignat'yevskiy, Ye.A. and Frolov, V.V.]

[Text] Experimental dependences are presented, of the internal relative efficiency and degree of reactivity of a radial-axial stage without radial blades on the ratio of the total pressure in front of the stage to the pressure behind the stage and on the velocity ratio with a constant Reynolds number.

UDC 621.165.6.019

INFLUENCE OF PRODUCTION PROCESS DEVIATIONS ON ECONOMIC EFFICIENCY OF STEAM
TURBINE BLADINGS

[Abstract of article by Abramov, V.I. and Khali', A.B.]

[Text] The results are presented of an experimental study of the influence of production errors in the manufacture of guide vanes and blades for turbines on profile energy losses.

Recommendations are given on selecting the manufacturing precision for blades with various chords.

UDC 621.165.533.6

SOME ASPECTS OF A STATISTICAL DESCRIPTION OF TURBULENCE

[Abstract of article by Zaryankin, A.Ye. and Baranovskiy, B.V.]

[Text] On the theoretical plane the possibility of constructing a closed statistical theory of turbulence is discussed.

It is demonstrated that the hypothesis used at the present time, regarding the independence of uniform statistical criteria, cannot serve as a basis for

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closing equations of turbulence, and that a correct solution to this problem is on the whole problematic.

UDC 621.532

ESTIMATION OF THE ZONE OF SEPARATION-FREE FLOW IN A DIFFUSER USING VARIOUS FLOW SEPARATION CRITERIA

[Abstract of article by Gribin, V.G. and Denisov, V.N.]

[Text] The possibility is discussed of using various criteria for separation of a turbulent boundary layer for estimating the zone of separation-free flow in a diffuser channel. Comparison of the results obtained with experimental data has demonstrated the possibility of using the criterion suggested by L.G. Loytsyanskiy for calculations of this sort.

UDC 621.165.51-146.24

REDESIGNING OF CONTROL VALVES ON TYPE PT-60 AND R-50 LMZ TURBINES

[Abstract of article by Zaryankin, A.Ye. and Tolkachev, B.P.]

[Text] Design modifications of the control valves of PT-60 and R-50 turbines are presented, which are conducive to improving the reliability and economic efficiency of the steam admission elements of these turbines.

The possible savings from this redesigning is indicated.

UDC 625.165.6.019.3003.31

SELECTION OF OPTIMUM PRINCIPLES FOR THE VARIATION OF FLOW SECTIONS OF DIFFUSER CHANNELS

[Abstract of article by Kasilov, V.F.]

[Text] A principle for profiling a diffuser channel on the condition of the pre-separation state of the turbulent boundary layer over its length is discussed. An expression is derived for calculating the instantaneous degree of expansion of the diffuser.

Calculation and experimental data on the geometrical and aerodynamic characteristics of pre-separation diffusers are presented.

UDC 621.165.6.019

THEORETICAL ESTIMATE OF AERODYNAMIC CHARACTERISTICS OF AXIRADIAL DIFFUSERS

[Abstract of article by Tyufyakov, I.I.]

[Text] A procedure is presented for calculating losses in axiradial diffusers, based on the calculation of boundary layer characteristics.

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Diagrams are presented which make it possible to estimate the order of losses in diffusers with various outlines of the flow section.

UDC 621.165.6.019

SOME ASPECTS OF FLOW IN CONICAL DIFFUSERS

[Abstract of article by Tarvat, A.Kh.]

[Text] The question of experimentally estimating the characteristics of diffusers is discussed. It is demonstrated that even in an axisymmetric channel the symmetry of the flow is broken and that this fact can have a substantial effect on the accuracy of an experimental estimate of losses.

UDC 621.165.6.019

STUDY OF PLANE DIFFUSERS WITH JOINED BOUNDARY LAYERS IN THEIR INLET

[Abstract of article by Sherstyuk, A.N. and Bronovets, I.P.]

[Text] The results are given of studies of a large series of plane diffusers with joined boundary layers in their inlet. The data obtained makes it possible to estimate the order of magnitude of losses in plane diffusers with various geometrical proportions.

UDC 621.165.001.5

INFLUENCE OF FAN SHAPE OF A STAGE ON OPERATION OF THE 'LAST STAGE - OUTLET CONNECTION' COMBINATION

[Abstract of article by Rodionova, L.K.]

[Text] Based on a theoretical and calculation analysis, a study is made of the influence of the fan shape of a stage on the operation of the "last stage - outlet connection" combination over a wide range of variation of operating modes. The analysis has demonstrated that increasing the degree of fanning of a stage causes worsening of the restoration of pressure in the outlet connection and the mutual influence of the stage and this connection is intensified.

UDC 621.165.013

STUDY OF MOISTURE COAGULATOR

[Abstract of article by Filippov, G.A., Povarov, O.A., Nikol'skiy, A.I. and Semenyuk, A.V.]

[Text] The results are given of experimental studies of a special mechanical coagulator which is designed to increase the effectiveness of moisture removal in different kinds of separators. Tests were made in an experimental turbine utilizing finely divided wet steam with a modal drop size of $d_k^m = 0.3 \mu\text{m}$.

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UDC 621.165-185.3;533.6.0015

SOME RESULTS OF A NUMERICAL STUDY OF TRANSONIC FLOW IN CHANNELS BY THE 'LARGE PARTICLE' METHOD

[Abstract of article by Mayorskiy, Ye.V., Aparkin, F.M., Garagulya, B.A. and Kulikov, V.D.]

[Text] The results of a numerical study of flow in channels by the nonstationary "large particle" method are discussed.

Calculated and experimental distributions of flow parameters are presented.

The possibility of using this numerical method for calculating flow around turbine bladings is demonstrated.

UDC 621.165-253.5.001.57

CALCULATION OF DYNAMIC STRESSES IN TURBINE BLADES TAKING INTO ACCOUNT THE FORCE EFFECT PHASE SHIFT RELATIVE TO HEIGHT

[Abstract of article by Samoylovich, G.S. and Antipin, A.V.]

[Text] A method is discussed for calculating dynamic stresses in the vibration of blades with nonsimultaneity of the force effect of disturbing forces relative to height. Experimental phase shift angles are presented. A confirmation of the procedure is carried out and calculation results are presented.

UDC 621.165:529/574.6.001.5.

ESTIMATING THE MAGNITUDE OF RESONANCE DYNAMIC STRESSES IN THE BLADES OF A COMPRESSOR

[Abstract of article by Samoylovich, G.S., Nitusov, V.V., Strekopytov, A.S., Pis'min, I.N., Opilat, V.G. and Kravtsov, Yu.A.]

[Text] A method is discussed for final adjustment of the blading of a compressor in relation to the level of dynamic stresses in real time. It is suggested that in addition to the usual aerodynamic measurements in testing measurements of the peripheral inhomogeneity of the flow behind the guiding apparatus be provided for.

The results of a study of velocity nonuniformity and the values of calculated aerodynamic forces are presented, and an estimate is made of the level of stresses in the heel of a full-scale blade.

UDC 621.165:681.3

MATHEMATICAL MODELING OF RANDOM DISTURBANCES IN THE CONTROL SYSTEM OF A POWER TURBINE

[Abstract of article by Kalashnikov, A.A.]

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[Text] Based on a Poisson random process a model is proposed for deviations in the rate of rotation of the rotor of a turbogenerator set operating in a power system. The parameters of the model are selected by comparing calculated autocorrelation functions of the random process with experimental data. The influence of the nature of the flow of autocorrelation functions on the results of studying the turbine control system is demonstrated.

UDC 621.165

EXPERIMENTAL DYNAMIC CHARACTERISTICS OF THE OVPT-500 TURBOPUMP UNIT

[Abstract of article by Khizantsyan, M.S.]

[Text] Experimental dynamic characteristics of a turbopump unit are presented in the form of acceleration curves and an approximation of them by channel.

UDC 621.65/18.001.4

ANALYTICAL DESCRIPTION OF THE FIELD OF CHARACTERISTICS OF A CENTRIFUGAL PUMP

[Abstract of article by Vertelin, S.N.]

[Text] Linearized equations are obtained by means of which from the known rate of rotation of the pump's shaft and system head curve it is possible to determine with a degree of precision sufficient for practical calculations the pump's output and head, the power required by it and the torque on its shaft.

UDC 621.515.12.001.5

USE OF TURBODYNAMOS IN A SYSTEM FOR THE LOW-TEMPERATURE PROCESSING OF NATURAL GAS

[Abstract of article by Sokolov, A.I. and Chizhov, V.V.]

[Text] An analysis is made of possible layouts for the structural design of turbo-separators for the low-temperature processing of natural gas. Several structural layouts are suggested for the flow section of turbines with organization of the separation of the liquid phase from the gas stream. Justification is given for the most appropriate variant of the flow section of a turbo-separator.

UDC 621.165.752.0015

EXPERIMENTAL APPARATUS FOR STUDYING AERODYNAMIC FORCES IN A MODEL OF A TURBO-DYNAMO SEAL

[Abstract of article by Kiselev, L.Ye.]

[Text] A description is given of an experimental apparatus consisting of a ring-shaped chamber with a radial nozzle unit from which a twisted flow of air enters labyrinth seals formed by a stationary shroud and a disk turned by an electric motor. The measurement system makes it possible to measure aerodynamic forces both directly by the weighing method and by measuring the distribution of pressure in the chambers of the seals over their circumference.

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UDC 621.438-529

USE OF AUTOMATED DIGITAL MEASURING SYSTEMS IN AERODYNAMIC STUDIES

[Abstract of article by Kazintsev, F.V. and Konyayeva, N.P.]

[Text] A brief description is given of two measuring systems used in aerodynamic studies. Comparisons are made with the industrially produced K-734, K-484 and M-6000 systems.

UDC 621.438-529

AUTOMATIC SYSTEM FOR LOGGING DATA IN AN AERODYNAMIC EXPERIMENT

[Abstract of article by Golovin, V.A. and Fedyakin, V.V.]

[Text] A description is given of an automatic system, constructed with standard V2-23, F5033K and EUM-23D instruments, for recording the difference in total Pitot pressures in relation to the spacing of a plane blade cascade. The system's operation is controlled by means of a control unit which moves a probe along by steps, sets the time delay and issues instructions to print out coordinates, the pressure difference and angles. After passing along the cascade step by step the probe returns to its starting position.

UDC 532.62(045)

STUDY OF PRIMARY ELECTRICAL TRANSDUCERS FOR MEASURING THE THICKNESS OF A LIQUID FILM WHICH TUNE OUT THE INFLUENCE OF CONDUCTIVITY

[Abstract of article by Fedorov, A.S. and Diktov, N.V.]

[Text] Electrical transducers are suggested whose output voltage changes 20 percent when going from tap water to condensate.

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NAVIGATION AND GUIDANCE SYSTEMS

UDC 62-50

MAN AS ELEMENT OF FOLLOW-UP SYSTEM

Moscow CHELOVEK KAK ZVENO SLEDYASHCHEY SISTEMY in Russian 1981 (signed to press 22 Jun 81) pp 2-5

[Annotation and table of contents from book "Man as an Element of a Follow-Up System", by Iosif Yevseyevich Tsibulevskiy, Izdatel'stvo "Nauka", 6700 copies, 288 pages]

[Text] Beginning from the time of the Second World War the dynamic characteristics of man as part of a follow-up system have been studied extensively. From numerous domestic and foreign studies scattered throughout periodicals on engineering and psychology, in this book reliable and, practically speaking, valuable data needed by developers and investigators of man-machine systems have been singled out, critically evaluated and generalized. Methods of improving the efficiency of the actions of a human being performing a follow-up operation are discussed.

This monograph is intended for scientific personnel and engineers involved in designing, testing and studying man-machine systems, as well as for students and graduate students studying ergonomics and engineering psychology.

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FLUID MECHANICS

UDC 532.526

INFLUENCE OF SMALL AMOUNTS OF POLYMER ADDITIVES INTRODUCED INTO STREAM ON HYDRODYNAMIC CHARACTERISTICS OF FLAT AIRFOILS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 81 (manuscript received 30 Apr 80) pp 35-41

[Article by V.V. Droblenkov and G.I. Kanevskiy]

[Text] This article considers the undetached flow of weak homogeneous polymer solutions past flat airfoils. To solve the problem, the stream is divided into two regions by the interface between the boundary layer and wake: the zone of potential flow and that of viscous liquid flow (i.e., the boundary layer and wake, whose characteristics are continuously contiguous at the interface).

After the stream is divided into two components, the problem is solved by successive approximation, taking into account the interaction of the two regions. The influence of the zone of potential flow on that of viscous flow is incorporated through the pressure distribution at the interface of the boundary layer and wake. That of the viscous flow component is taken into account by introducing an additional eddy whose strength equals the vorticity integral over the entire viscous region and additional velocities at the wake-boundary layer interface that deform the streamlines in the potential flow region and bring them into conformity with the flow pattern in a real liquid.

The results yielded by calculation of hydrodynamic characteristics for a Zhukovskiy-type airfoil are compared with experimental data. The influence of introduction of small amounts of polymer additives into the stream on the distributed and integrated flow characteristics for a number of Reynolds numbers is analyzed for a modified NACA66 profile.

The boundary-layer parameters for the upper and lower surfaces of an airfoil are calculated separately, using the integral-relationship method [1], which takes into account the laminar, transitional, and turbulent flow zones in the layer. The presence of small amounts of polymer additives in the stream is taken into consideration by using the Meyer correlation for the longitudinal velocity component u in the

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turbulent boundary layer at an airfoil [2]:

$$(1.1) \quad \frac{u}{v^*} = \frac{1}{\kappa} \ln \frac{y_1 v^*}{\nu} + \frac{\Pi}{\kappa} \left(1 - \cos \frac{\pi y_1}{\delta} \right) + B_0 + \Delta B$$

$$\Delta B = 0, \quad v^* < v_0^*, \quad \Delta B = \beta \ln \frac{v^*}{v_0^*}, \quad v^* \geq v_0^*$$

Here y_1 is the coordinate perpendicular to the surface around which the stream flows, v^* is the dynamic velocity, $\kappa = 0.4$ and $B_0 = 5.2$ are the turbulence constants, Π is the Cowles parameter, δ is the thickness of the boundary layer, β is a parameter that takes into account the properties of the dissolved polymer and its concentration in the solution, and v_0^* is the dynamic velocity corresponding to the point at which the Thoms effect develops.

The characteristics of the turbulent wake beyond the airfoil are determined separately for its upper and lower portions, using the integral method [3]. The axis of the wake is assumed to be the zero-deflection streamline in an ideal liquid for a predetermined velocity circulation around the airfoil. The distributions of the longitudinal flow-speed component u and the tangential stresses τ in the wake are approximated by the relationships

$$(1.2) \quad \frac{u}{U_\delta} = 1 - \left(1 - \frac{U_m}{U_\delta} \right) \left[(1-\gamma) \exp\left(-\frac{k^2 y_1^2}{\delta^2}\right) + \frac{\gamma}{2} \left(1 + \cos \frac{\pi y_1}{\delta} \right) \right]$$

$$(1.3) \quad \frac{\tau}{\rho U_\delta^2} = 2\kappa_1 \left(1 - \frac{U_m}{U_\delta} \right)^2 (1-\gamma) k^2 \frac{y_1}{\delta} \exp\left(-\frac{k^2 y_1^2}{\delta^2}\right)$$

Here U_δ is the longitudinal flow-speed component at the outer boundary of the wake, U_m is the flow speed at the wake axis, k and γ are wake parameters that vary along the length of the wake, ρ is the density of the liquid, and κ_1 is the turbulent viscosity coefficient, which also varies along the length of the wake.

Assuming the influence of small amounts of polymer additives to consist solely in reorganization of turbulent exchange in the immediate vicinity of the surface around which the stream flows and to have no direct action on the free turbulence, we proceed on the premise that the entire influence of the additives on flow characteristics in the wake is taken into account in the changes in the initial data employed for its calculation. The initial parameter values for the upper and lower portions of the wake are determined from the continuity condition for the thickness δ , the displacement distance δ^* , the momentum-loss distance δ^{**} , and the maximum tangential stresses for the transition from the boundary layer to the wake.

In order to determine the position of the interface between the viscous and non-viscous flow zones, the thickness of the boundary layer (wake) is laid off along perpendiculars to the airfoil surface or wake axis. The resultant boundary is smoothed by fitting to cubic parabolas in the immediate vicinity of the trailing edge of the airfoil.

The characteristics of the potential flow component are calculated by using the theory of conformal mapping. A profile of the desired shape is laid out on the physical plane z and a circle of radius a is laid out on the auxiliary plane ζ . The mapping function relating the two complex planes has the form of the Laurent series

$$(1.4) \quad z = \zeta + c_0 + \sum_{n=1}^{\infty} c_n a^n \zeta^{-n}$$

Its coefficients are calculated by the method described by Zavadovskiy and Rusetskiy [4].

The complex flow potential is divided into two terms, the first of which is associated with the circulation of an ideal liquid around the airfoil and the second with the additional velocities that provide the displacement of the streamlines necessary in order for the influence of viscosity to be taken into consideration:

$$(1.5) \quad W = W_1 + W_2 \\ W_1 = \zeta \exp(-i\alpha) + a^2 \zeta^{-1} \exp(i\alpha) + \frac{\Gamma}{2\pi i} \ln \zeta$$

Here α is the angle of attack and Γ is the circulation of the additional eddy.

The condition for determination of the calculated circulation in the viscous liquid is the requirement that the vortical flows converging from the upper and lower surfaces of the airfoil in the wake be equal, which was first proposed by Taylor in 1924 [5]. In the wake, the condition that the vortical flows calculated for its upper and lower portions be equal is equivalent to the requirement that the pressures at the wake axis be continuous:

$$(1.6) \quad I_+ = 2 \int_0^{a_+} \omega_+ u dy_+ = I_- = 2 \int_0^{a_-} \omega_- u dy_-; \quad p_{0+} = p_{0-}$$

where I is the vortical flow through the wake cross-section, ω_z is the vorticity at the point in question, and p_0 is the pressure at the wake axis; the plus and minus subscripts pertain to the upper and lower portions of the wake respectively.

Neglecting the change in pressure across the wake, we obtain $V_{\delta+} = V_{\delta-}$ for the modulus of the velocity vector V_{δ} at the outer boundary of the wake. When applied to points at the outer limit of the boundary layer corresponding to the trailing edge of the airfoil (the initial cross-section of the wake), this relationship can also be employed to determine the calculated circulation.

In order to provide the requisite displacement of the streamlines in the potential portion of the stream, bringing them into conformity with the flow pattern in a real liquid, a system of inflows and drains is laid out at the surface of the airfoil and the wake axis; their flow rates are determined in the linear-theory approximation, from the condition $\frac{1}{2}Q_z = \Delta v_n$, where Δv_n are the additional normal velocities that develop in the viscous liquid at the interface between the boundary layer and

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and wake. The values of Δv_n are found from the continuity condition for the velocities on passage through the boundary between the viscous and potential flow zones:

$$(1.7) \quad \Delta v_n \approx \frac{d}{dx} [V_{\delta 1} \delta^* + (V_{\delta 2} - V_{\delta 1}) \delta]$$

Here x is the longitudinal coordinate. The subscripts 1 and 2 are for the parameters determined in viscous and ideal liquids respectively.

Equation (1.7) contains the unknown $V_{\delta 1}$ and the quantities δ and δ^* dependent on it, so that the problem of determining the additional velocities produced by the reciprocal influence of the viscous flow zone on the potential flow is solved by the successive-approximation method.

In order to determine the circulation integral for the additional eddy in the viscous liquid, the flow parameters are calculated for a series of values of Γ and the circulation integral for which the condition $V_{\delta+} = V_{\delta-}$ is satisfied is then found.

The resultant circulation figure is employed for recalculation of the distributed hydrodynamic characteristics of the airfoil by which the viscous liquid flows. For each circulation value, the flow parameters are determined in a sequence of iterations that includes calculation of the characteristics of the ideal liquid, boundary layer, and wake and their interaction. A relaxation constant of 0.5 is introduced to ensure convergence of the successive-approximation process in calculating the velocities at the interface between the two flow zones. The successive-approximation procedure is terminated on satisfaction of the condition

$$(1.8) \quad |V_{\delta+}^k - V_{\delta+}^{k-1}| < 0.01; \quad |V_{\delta-}^k - V_{\delta-}^{k-1}| < 0.01$$

In Eq. (1.8), the velocities V_{δ} are determined for points corresponding to the trailing edge of the airfoil, while the superscript k represents the iteration number.

After determination of the calculated circulation integral and the characteristics of the boundary layer and wake, the lift coefficients C_y , the profile drag C_x , and the momentum C_m are found from the relationships [6]

$$C_y = \frac{R_y}{0.5\rho U_0^2 L} = -\frac{2\Gamma}{U_0 L}; \quad C_x = \frac{R_x}{0.5\rho U_0^2 L} = \frac{2\delta_{\infty}^{**}}{L}$$

$$C_m = \frac{M_z}{0.5\rho U_0^2 L^2} = \frac{4\pi a}{U_0 L^2} \left[-\frac{\Gamma}{2\pi a} (c_{0R} \cos \alpha + c_{0i} \sin \alpha) + c_{1R} \cos 2\alpha - c_{1i} \sin 2\alpha \right]$$

Here U_0 is the flow speed of the incident stream, L is the airfoil chord length, δ_{∞}^{**} is the momentum-loss thickness at an infinite distance beyond the airfoil, and c_{0R} , c_{0i} , c_{1R} , and c_{1i} are the real and imaginary parts of the mapping-function coefficients. The momentum M_z is determined relative to the coordinate origin,

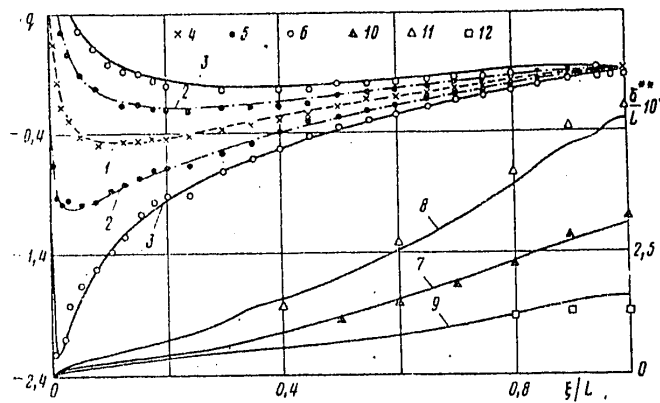


Figure 1

Table 1

α	Calculations			Experiment [7]	
	C_x	C_y	C_{y_0}	C_x	C_y
0	9,97	0	0	10,0	0
3	10,11	0,3277	0,3598	10,4	0,317
6	11,42	0,6604	0,7184	11,76	0,634

which is located at the tip of the profile. The value of δ_{∞}^{**} is found by applying the Squire-Young formula [6] to the cross-section of the wake lying at a distance beyond the trailing edge of the airfoil equivalent to 60% of its length:

$$\delta_{\infty}^{**} = \delta_{+}^{**} \left(\frac{V_{0+}}{U_0} \right)^{0,5(5+H_+)} + \delta_{-}^{**} \left(\frac{V_{0-}}{U_0} \right)^{0,5(5+H_-)}$$

where δ_{+}^{**} , δ_{-}^{**} , V_{0+} , V_{0-} , $H_+ = \delta_{+}^{**}/\delta_{+}^{**}$, and $H_- = \delta_{-}^{**}/\delta_{-}^{**}$ are determined with $\xi/L = 1.6$. The coordinate ξ is reckoned from the tip of the profile along the airfoil chord and its continuation.

2. The proposed method was used to write a program in the ALGOL-60 language for a BESM-6 computer. The initial data specified for calculations with this program are the mapping-function coefficients for the airfoil, the profile chord (L), the angle of attack (α), the flow speed of the incident stream (U_0), its degree of turbulence (ϵ), the kinematic viscosity constant (ν), and the parameters defining the influence of the polymer additives (ν_0^* and β).

Figure 1 and Table 1 compare the results of calculations of hydrodynamic characteristics made for a Zhukovskiy-type airfoil having a relative thickness of 11.8 percent with experimental data [7].

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The factor 10^{-3} is omitted for all the drag coefficients in Table 1 and henceforth. In accordance with the experimental conditions employed by Preston and Sweeting [7], the calculations were made for a degree of free turbulence $\epsilon = 1.75$ percent and a Reynolds number $Re = U_0 L / \nu = 4.2 \cdot 10^5$. For purposes of comparison, Table 1 also gives the lift coefficients calculated for flow of an ideal liquid past the airfoil (C_{y2}). Figure 1 compares the distributions calculated for the pressure coefficient q at the outer limit of the boundary layer with the results of pressure measurements made at the airfoil surface with the aid of drainage tubes. Curves 1-3 and experimental points 4-6 are for angles of attack α of 0, 3, and 6° respectively. This figure also compares the calculated (curves 7-9) and experimentally determined (points 10-12 [7]) dimensionless values of the momentum-loss thickness δ^{**}/L . Curve 7 and point 10 are for an angle of attack $\alpha = 0$, curve 8 and point 11 are for $\alpha = 6^\circ$ and the upper surface of the airfoil, and curve 9 and point 12 are for $\alpha = 6^\circ$ and the lower surface of the airfoil.

The results given indicate satisfactory agreement between the calculated and experimental data for both the force parameters and the distributed hydrodynamic characteristics.

In order to analyze the influence of introduction of small amounts of polymer additives into the stream on the hydrodynamic characteristics of flat airfoils, we made systematic calculations for a laminarized NACA66 airfoil with a relative thickness of 5 percent and a curvature of 1 percent.

The calculations were carried out for Reynolds numbers of $6 \cdot 10^6$ and $3 \cdot 10^7$ with angles of attack of -3, 0, 1.5, and 3°. We assumed $L = 1$ m and $U_0 = 9$ m/sec with $Re = 6 \cdot 10^6$ and $L = 1.6$ m and $U_0 = 30$ m/sec with $Re = 3 \cdot 10^7$. The value of ν_0^* was assumed to be 0.023 m/sec and the parameter β was assigned values of 0, 2.5, 4.34, and 7.5, which roughly corresponded to flow of homogeneous aqueous solutions of WSR-301 polyethylene oxide with concentrations of 0.5, 10, and 25 ppm past the airfoil. The degree of free turbulence was presumed to equal 2% in all the calculations.

Figures 2 and 3 show the distribution of the pressure coefficient over the airfoil in a nonviscous liquid (curves 1) and over the upper limit of the boundary layer in a viscous liquid at $Re = 6 \cdot 10^6$ and $\beta = 0$ (curves 2) and at $Re = 6 \cdot 10^6$ and $\beta = 4.34$ (curves 3). All the results are for flow past the profile with $\alpha = 3^\circ$.

Equidistant displacement of the q curves corresponding to flow of a viscous liquid past the airfoil in relation to the curves calculated for a nonviscous liquid was observed over virtually the entire length of the airfoil, except for the extreme tip and tail regions. Introduction of polymer additives into the stream caused the calculated pressure coefficients q to approximate to the values corresponding to flow of a nonviscous liquid past the airfoil. A quite substantial pressure redistribution resulting from the appearance of viscosity forces was observed in the vicinity of the leading-edge critical point. It must be noted that, according to our calculations, introduction of small amounts of polymer additives into the stream should not lead to any perceptible change in the decompression peak near the tip of the airfoil. In the immediate vicinity of the trailing edge, q underwent a change from 1 in a nonviscous liquid to 0.12-0.14 in a viscous liquid.

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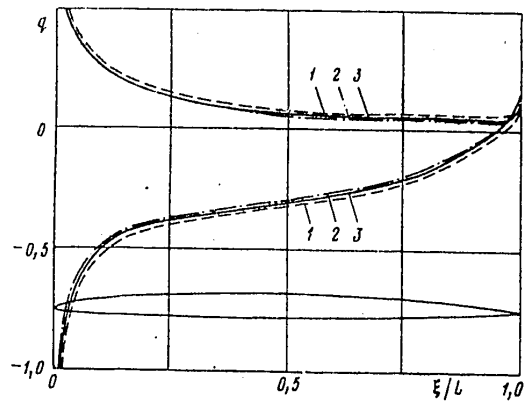


Figure 2

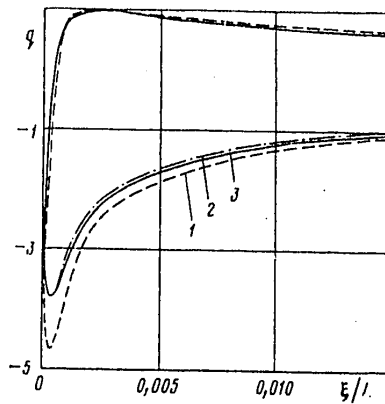


Figure 3

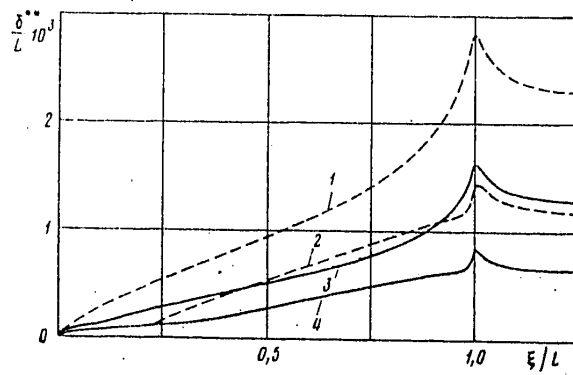


Figure 4

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Table 2

β	$\alpha=-3^\circ$			$\alpha=0^\circ$			$\alpha=1,5^\circ$			$\alpha=3^\circ$		
	C_y	C_x	C_m	C_y	C_x	C_m	C_y	C_x	C_m	C_y	C_x	C_m
$Re=6 \cdot 10^6$												
0	-0,1918	6,356	-0,0147	0,1176	6,568	0,0577	0,2724	6,632	0,0940	0,4278	6,697	0,1305
2,5	-0,1956	4,397	-0,0166	0,1207	4,571	0,0592	0,2787	4,607	0,0971	0,4371	4,627	0,1351
4,34	-0,1962	3,537	-0,0169	0,1224	3,688	0,0599	0,2812	3,713	0,0983	0,4405	3,723	0,1368
7,5	-0,1971	2,611	-0,0173	0,1237	2,759	0,0607	0,2839	2,744	0,0997	0,4444	2,746	0,1388
$Re=3 \cdot 10^7$												
0	-0,1970	5,287	-0,0176	0,1194	5,262	0,0585	0,2776	5,338	0,0866	0,4358	5,480	0,1373
4,34	-0,2011	2,564	-0,0193	0,1234	2,581	0,0606	0,2864	2,594	0,1004	0,4473	2,641	0,1411

Figure 4 represents the distribution of the momentum-loss thickness in the boundary layer and wake beyond the NACA66 airfoil. The results were obtained for $Re = 6 \cdot 10^6$ and $\alpha = 3^\circ$. Curves 1 and 2 correspond to the values of δ^{**}/L obtained for the upper and lower surfaces of the airfoil with $\beta = 0$ and curves 3 and 4 correspond to those obtained for these surfaces with $\beta = 4.34$. The influence of polymer additives resulted in a substantial reduction in the momentum-loss thickness δ^{**} in the regions occupied by the turbulent boundary layer and wake.

The results yielded by calculation of C_x , C_y , and C_m for the NACA66 airfoil are given in Table 2. The values found for the lift coefficient and momentum coefficient in a nonviscous liquid with $\alpha = -3, 0, 1.5, \text{ and } 3^\circ$ were $C_{y2} = -0.2116, 0.1312, 0.3026,$ and 0.4737 and $C_{m2} = -0.0246, 0.0645, 0.1099, \text{ and } 0.1533$ respectively. These data show that the dependence of C_y on the angle of attack in a viscous liquid remained linear. An increase in the Reynolds number or introduction of small amounts of polymer additives into the stream caused C_y and C_m to change in such fashion that they approximated to the corresponding figures found in a nonviscous liquid. The drag coefficient C_x decreased as the Reynolds number rose and fell sharply when polymer additives were introduced into the stream. An increase in the polymer concentration in the solution produced a larger change in all the integral hydrodynamic characteristics of the airfoil. It must be noted that the polymer additives had their strongest effect on the profile drag, causing only minor changes in the lift and hydrodynamic momentum of the airfoil.

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THERMODYNAMICS, HEAT-AND-MASS TRANSFER IN LOW-TEMPERATURE APPARATUS

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA I ORDENA OKTYABR'SKOY REVOLYUTSII ENERGETICHESKOGO INSTITUTA, TEMATICHESKIY SBORNIK: VOPROSY TERMODINAMIKI I TEPLOMASSOBYMENA V NIZKOTEMPERATURNYKH USTANOVKAKH in Russian No 491, 1980 (signed to press 16 Mar 81) pp 2, 107-111

[Annotation and abstracts from collection of articles "Questions of Thermodynamics and Heat-and-Mass Transfer in Low-Temperature Apparatus", edited by Doctor of Technical Sciences Professor V.M. Brodyanskiy, Moscow Power Engineering Institute, 500 copies, 111 pages]

[Text] This collection includes papers from two departments of the Energy Physics Faculty--Cryogenic Engineering and Engineering Thermal Physics--as well as from the Heat-and-Mass Transfer Processes and Apparatus Department of the Industrial Heat and Power Faculty.

The first group of papers contained in this collection directly concerns problems arising in the calculation and design of cryogenic apparatus and machines. Papers of this group include an analysis of influx of heat in microcryogenic throttling systems; calculation of solid phase - liquid equilibrium for mixtures of nitrogen with saturated hydrocarbons at low temperatures; analysis of the influence of the ratio of the overall dimensions of the low-temperature unit on the magnitude of losses from the influx of heat through the insulation; an analysis of factors determining the energy efficiency of a thermomechanical pump for low-temperature products; and an evaluation of the feasibility of using jet pumps for transferring liquefied natural gases.

The second group is made up of experimental works relating to the study of heat transfer in thermosiphons of the slotted type and in a closed evaporation-condensation system with separate channels for the liquid and steam.

Papers included in the third group concern general questions of heat transfer. Methods are discussed for a numerical solution to problems of heat transfer with free laminar convection around a vertical plate for helium in the supercritical region of parameters and with the flow of an incompressible fluid around a moving surface.

Questions relating to heat transfer in He-II are represented in papers in which a new procedure is suggested for determining the temperature of the heating

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surface in the film boiling of He-II are an experimental apparatus for studying maximum heat loads is described. Finally, two papers are devoted to studying the viscosity of compressed gases at low temperatures.

This collection is intended for scientific and technical personnel and engineers involved in designing cryogenic equipment and studying the processes taking place in them, as well as for graduate students and students in the corresponding areas of specialization.

UDC 621.59

ANALYSIS OF INFLUX OF HEAT IN MICROCRYOGENIC THROTTLING SYSTEMS

[Abstract of article by Boyarskiy, M.Yu., Lunin, A.I., Gusakov, A.G. and Aloyan, O.B.]

[Text] It is demonstrated that in calculating the influx of heat in microcryogenic throttling systems it is necessary to take into account heat transfer between the reverse flow and resistance thermometer bridges. The procedure is based on solving differential equations describing the change in temperatures of the forward and reverse flows and of the resistance thermometer bridge along the length of the low-temperature unit, taking into account the influx of heat through the insulation. The system of equations was solved by the approximation-iteration method on an MIR-2 computer. Comparison of the calculation results with experimental data for a refrigerator operating on nitrogen has confirmed the appropriateness of the calculation method suggested.

UDC 621.565

CALCULATION OF LIQUID AND SOLID PHASE EQUILIBRIUM IN MULTICOMPONENT NITROGEN-HYDROCARBON MIXTURES

[Abstract of article by Boyarskiy, M.Yu. and Lunin, A.I.]

[Text] It is demonstrated that calculation of solid phase - liquid equilibrium for mixtures of nitrogen with saturated hydrocarbons at low temperatures ($T = 80$ K) can be performed on the basis of the theory of ordered solutions. An analysis is made of the application of the method to two cases. In the first the solid phase represents one of the components of the mixture in pure form. In the second the components forming the solid phase form a solid solution.

UDC 536.242

EXPERIMENTAL APPARATUS FOR STUDYING MAXIMUM HEAT LOADS IN He-II

[Abstract of article by Spiridonov, A.G. and Ametistov, Ye.V.]

[Text] A description is given of an experimental apparatus designed for studying heat transfer and extremum heat flux in He-II. Some initial experimental data on the maximum heat flux density are presented.

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UDC 536.27.001.5

EXPERIMENTAL STUDY OF HEAT TRANSFER IN A CLOSED TWO-PHASE THERMOSIPHON OF THE SLOTTED TYPE

[Abstract of article by Kormilitsyn, A.A., Snytin, S.Yu. and Fedorov, M.V.]

[Text] The results are given of an experimental study in a closed thermosiphon of the slotted type with extended surfaces of zones of the admission and removal of heat with the heat load supplied varying from 0 to 1400 W.

UDC 621.59.001.2

OPTIMUM PROPORTIONS OF THE OVERALL DIMENSIONS OF THE LOW-TEMPERATURE UNIT OF A HELIUM PLANT

[Abstract of article by Sinyavskiy, Yu.V., Galushko, O.P. and Kan, A.M.]

[Text] The results are discussed of a theoretical analysis of the influence of the proportions of the overall dimensions of the low-temperature unit of a helium plant on the magnitude of energy losses from the influx of heat through the insulation. The major role of the law of variation of the temperature of the plant's elements along its axis is emphasized. The influence of the volume of the low-temperature unit and of the properties of the materials out of which the cryostat is made is demonstrated.

UDC 533.581

INFLUENCE OF THE SIZE OF THE INNER SPACE OF A REGENERATIVE HEAT EXCHANGER ON THE EFFICIENCY OF A THERMOMECHANICAL PUMP FOR LOW-TEMPERATURE PRODUCTS

[Abstract of article by Sinyavskiy, Yu.V. and Sosnina, G.Yu.]

[Text] A qualitative analysis is made of factors determining the energy efficiency of a thermomechanical pump. A procedure is suggested and the results are given of calculations relating to determination of the region of relative spaces of a regenerative heat exchanger corresponding to minimum energy input. The influence of the discharge pressure on shifting of the region of optimum values of the relative spaces of a heat exchanger is discussed.

UDC 536.242

ONE METHOD OF DETERMINING THE TEMPERATURE OF THE HEATING SURFACE IN THE FILM BOILING OF He-II

[Abstract of article by Labuntsov, D.A., Spiridonov, A.G. and Amet'stov, Ye.V.]

[Text] A new procedure is proposed for determining the temperature of the heating surface in the "noiseless" film boiling of He-II, using calculation equations of the linear theory of nonequilibrium processes and the data of photographing the boiling process.

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UDC 621.176:536,258.2

EVALUATION OF THE FEASIBILITY OF TRANSFERRING LIQUEFIED NATURAL GASES BY THE JET METHOD

[Abstract of article by Shpil'rayn, E.E., Sevast'yanov, A.P., Kozlov, V.B., An, I.V. and Grigoryan, A.B.]

[Text] A preliminary theoretical evaluation is made of the use of jet pumps for transferring liquefied gases. A determination is made of the amount of underheating of liquid Freon-12 and methane at the pump's inlet necessary for normal operation of the equipment, as well as of the maximum possible values of pressure developed by the pump with the underheating usual for the storage of gases.

UDC 546.291:533.16

ANALYSIS, SUMMARY OF EXPERIMENTAL DATA AND TABULATION OF THE VISCOSITY OF HELIUM-4 AT CRYOGENIC TEMPERATURES

[Abstract of article by Ulybin, S.A., Makarushkin, V.I. and Skorodumov, S.V.]

[Text] In this paper an analysis is made of experimental results and published tables on the viscosity of helium-4 in the temperature range of 2.5 to 500 K at pressures to 30 MPa. It is shown that the new experimental values at low temperatures differ up to 10 percent from the table values available. Based on an analysis of measurement procedures, the most reliable values for viscosity are singled out, and these have been used by the authors.

UDC 533.16:536.48

EXPERIMENTAL APPARATUS FOR STUDYING THE VISCOSITY OF COMPRESSED GASES AT LOW TEMPERATURES

[Abstract of article by Ulybin, S.A., Makarushkin, V.I. and Skorodumov, S.V.]

[Text] A description is given of an experimental apparatus for studying the viscosity of liquids and gases at low temperatures. Measurements are made by the capillary tube method with a constant rate of flow of the substance being studied. Stationary flow conditions are made possible by means of a pressure regulator of original design. The expected error of experimental results is 1.0 to 1.5 percent.

UDC 536.26.532.2:532.529.2.

CALCULATION OF FREE LAMINAR CONVECTION AROUND A VERTICAL PLATE FOR HELIUM IN THE SUPERCRITICAL REGION OF STATE VARIABLES

[Abstract of article by Yan'kov, G.G. and Popov, V.N.]

[Text] A method is discussed for a numerical solution to a system of differential equations of motion, continuity and energy, written in a boundary layer approximation, for the case of free laminar convection at a vertical plate. An analysis is

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made of parameters of the finite-difference system and of factors influencing the accuracy of the solution. Calculations are made for helium ($P = 0.25$ MPa) for two boundary conditions: constant heat flux and constant temperature of the heat transfer surface.

UDC 621.396.61

STUDY OF A MODEL OF THE BOILING PROCESS IN SLOTTED CHANNELS

[Abstract of article by Galaktionov, V.A., Mironenko, A.V. and Portnov, V.D.]

[Text] A comparison is made between a theoretical model and experimental data on the boiling of a liquid in thermosiphons with slotted channels. It is shown that the experimental data confirm the boiling model suggested.

UDC 532.543

AERODYNAMIC APPARATUS FOR EXPERIMENTAL STUDY OF BOUNDARY LAYER CHARACTERISTICS

[Abstract of article by Kiril'tsev, V.T., Motulevich, V.P. and Sergiyevskiy, E.D.]

[Text] A description is given of an aerodynamic apparatus (ADU) for an experimental study of the characteristics of the boundary layer on a porous plate with the presence of a longitudinal pressure gradient. The data obtained demonstrate that the design of the inlet line makes it possible to make compact ADU's with a sufficiently uniform velocity profile and a low level of turbulence in the inlet to the working section.

UDC 532.536

HEAT TRANSFER IN FLOW AROUND A MOVING SURFACE

[Abstract of article by Zhubrin, S.V. and Sergiyevskiy, E.D.]

[Text] The results are given of a calculation of heat transfer with self-similar flow in the laminar boundary layer of an incompressible fluid with a longitudinal pressure gradient when the longitudinal component at the wall does not equal zero. The influence of the speed of the surface, its direction and pressure gradient on the local heat flux density and the heat transfer parameter is demonstrated. For the limiting case of equality of velocities in the nonturbulent flow and at the wall the analytical relationships for heat transfer in the field of nonviscous flow agree well with the numerical calculation.

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