PLENARY SESSIONS

PL-01 Yu. M. ANOKHIN, S. K. BIKEZIN, V. V. BOLSHAKOV, V. P. ZAVALSKII, V. A. KAPUSTIN, L. L. KOBZAR, D. A. OLEKSYUK, Yu. M. SEMCHENKOV

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATIONS OF THE THERMAL HYDRAULICS IN THE WATER-COOLED WATER-MODERATED NUCLEAR REACTOR CORE AT THE "KURCHATOV INSTITUTE"

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At the "Kurchatov Institute" SRC experimental and computational investigations of thermohydraulic processes in the core of water-cooled water-moderated nuclear reactors have been carried out for more than fifty years. The greatest attention is given to the studies of dry out of nuclear boiling (DNB) in rod bundles. Experiments were carried out on models of existing and designed reactor cores. The results of experimental tests on several bundles modeling assemblies of reactors are discussed in the paper.

Investigation of coolant mixing in rod bundles has been made. The aim of this research is to acquire data on validation of the calculation codes intended for the analysis of thermohydraulic processes in the core of water-cooled water-moderated nuclear reactors.

PL-02 A. O. KUZ'MIN,[1,2] M. Kh. PRAVDINA,[3] V. N. PARMON[1,2]

USE OF TWISTED FLOWS FOR ENHANCEMENT OF MASS TRANSFER PROCESSES IN CHEMICAL TECHNOLOGY

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To carry out interphase and technological processes in the contemporary chemical technology, different types of multiphase reactors are used. However, the possibilities of further intensification of the mass transfer process in the available apparatuses are substantially restricted, since there are limits for the increase in the intensity of the physical effect on the medium processed. At the present time, a stable interest to the intensification of mass transfer processes in restricted twisted flows realized, in particular, in vortex heat-transfer apparatuses.

Flow twisting allows one to substantially enhance mass-transfer processes in a flow due to the appearance of velocity gradients and correspondingly of shear strain and developed turbulence. In the present work, we consider different examples of application of weakly and highly twisted flows for enhancement of the processes of mass transfer in different media and diverse processes.

It is shown that in a multiphase vorticity layer an extremely high intensity of mass transfer processes can be attained. The degree of this intensity can be regulated by increasing or decreasing the degree of physical effect on the medium processed.

PL-03 V. V. KUZNETSOV

HEAT AND MASS TRANSFER IN MICROSYSTEMS WITH PHASE TRANSFORMATIONS AND CHEMICAL REACTIONS

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The laws governing capillary hydrodynamics and heat transfer during flow boiling, evaporation and condensation in small size channels developed in experimental and theoretical studies are considered. New methods for calculating heat transfer with flow boiling and film evaporation in microchannels and minichannels, including the critical phenomena under constrained conditions are suggested. The laws governing phase explosion and explosive boiling of liquid microvolumes under high ambient energy density have been established. The characteristics of multistage chemical reactions and their kinetics in microreactors with a thin film nanocatalyst, including conversion of hydrocarbons into hydrogen, are discussed. A strong influence of thermal and diffusion processes on the rate and sequence of heterogeneous reactions in microchannels has been revealed and the methods for controlling reactions have been developed.

PL-04 V. FORTOV[1], V. EFREMOV[1], E. DIANOV[2], I. BUFETOV[2], A. FROLOV[2], E. KRASNOPEROV[3], G. DOROFEEV[3], Y. U. KUROEDOV[3], A. EREMIN[1], A. EMELIANOV[1], H. JANDER[4], AND H. G. WAGNER[4]

ANALOGS OF DETONATION PROCESSES AT HIGH ENERGY DENSITIES

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The laser-induced damage of the optical fibers core remains to be a limiting factor of laser energy transport by optical fiber. Damages propagation as a function of carried energy density has two distinguished modes: burning and detonation. The laser driven detonation is the fast and most catastrophic of them.

Superconductive electric lines can demonstrate fast propagation of the normal (resistive) phase under definite conditions. These conditions (electric current, external magnetic field) and propagation velocities were investigated for individual superconducting wires consisting of Nb–Ti and Nb–Zr.

Paper reports on the first experimental observation of the influence of condensation of supersaturated carbon vapor formed behind reflected shock waves on the process of propagation of a shock wave and formation of a detonation wave of condensation.

SECTION 1

CONVECTIVE AND RADIATIVE HEAT TRANSFER

1-01* V. A. ALEKSIN

MODELING OF TURBULENT HEAT TRANSFER IN A NONSTATIONARY BOUNDARY LAYER WITH LONGITUDINAL PRESSURE GRADIENTS

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Under the conditions of high free-stream turbulence intensity and action of longitudinal pressure gradient on the basis of the near-wall two-parameter turbulent models, the dynamic and thermal characteristics of stationary and nonstationary flows are investigated. The effect of the free-stream turbulence parameters on the development of the thermal processes in the developed turbulent boundary layer with a variable positive pressure gradient was studied. A comparison of the computed velocity and turbulence kinetic energy profiles with experimental data for the near - separation region was carried out. A combined effect of the harmonic time fluctuation velocity of the outer nonviscous flow and turbulence intensity on the development of the nonstationary characteristics of flow and heat transfer under moderate pressure gradients is analyzed.

1-02 A. A. ANISIN

IMPROVEMENT OF HEAT-AND-POWER EFFICIENCY OF BANKS OF SMOOTH TUBES WITH THE SURFACE OF COMPLEX GEOMETRY IMMERSED IN A CROSS FLOW

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The results of the analysis of heat-and-power efficiency of the surface of banks of tubes of various configurations immersed in a cross flow are presented. Characteristic features of the mechanism of heat transfer intensification are shown and the possibility of increasing the heat efficiency of the surface with the use of smooth shaped tubes of complex geometry and of variable cross section is substantiated. New variants of tubes and schemes of their arrangement into banks are suggested.

1-03 P. V. ANTONOV, V. S. BERDNIKOV

CONJUGATE CONVECTIVE HEAT TRANSFER IN GROWING CRYSTALS AND INGOTS BY THE BRIDGMAN–STOCKBARGER METHOD

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Conjugate convective heat transfer in crucible–melt–crystal systems is investigated numerically. Investigations were carried out for three geometries of crucibles. The problems have

* The number corresponds to the number of the report/communication on a CD-R.

been solved in a conjugate axisymmetrical nonstationary statement with account for the release of phase transformation heat at the crystallization front. The physical parameters were selected to be close to those used in technological experiment at the Institute of Geochemistry of the Siberian Branch of the Russian Academy of Sciences when obtaining ingots of multisilicon and single crystals of barium fluoride.

1-04 V. A. ARKHIPOV,[1.2] I. K. ZHAROVA,[1] V. D. GOLDIN,[1] V. T. KUZNETSOV[1], N. I. KURILENKO,[3] G. Ya. MAMONTOV[4]

INVESTIGATION OF THE RADIATION COEFFICIENTS OF HEAT-SHIELDING MATERIALS

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During the use of heat-protection materials at high temperatures, it is necessary to take into account the contribution of the radiative part in the total heat transfer. The paper proposes a modified integral unsteady method for measuring the integral emissivity. The theoretical basis of this method is the use of the apparatus of inverse problems of heat conduction. Two variants of the scheme of measurements in numerical solution of the model problem of determining the integral emissivity of pyrographite are considered. An analysis of the results of computational experiments with the use of the two versions of the sample temperature measurement scheme has shown that the proposed method improves the accuracy of measurement of the integral emissivity of materials surface with low thermal conductivity values, by taking into account the temperature field irregularity inside the sample.

1-05 V. A. BABENKO, T. A. BARANOVA, N. N. GNEZDILOV, I. M. KOZLOV

MODELING OF HIGH-VELOCITY IMPACT BY A METHOD OF SMOOTHED PARTICLES

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The problem of high-velocity impact was modeled on the basis of smoothed particle hydrodynamics (SPH). The modification of the SPH method has been developed. In this modification, the summation approach and the continuous approach are equivalent, and the problem of boundary particle deficiency is successfully resolved. A comparison of the modified SPH and Eulerian finite-difference approaches shows good agreement. The results of calculations can be useful for estimating the efficiency of anti-meteorite protection shields, providing information on the shape and dimensions of the apertures and jets formed.

1-06 B. I. BASOK, B. V. DAVYDENKO, M. P. NOVITSKAYA, S. M. GONCHARUK

AERODYNAMICS AND HEAT TRANSFER FROM THE SURFACES OF ENCLOSING STRUCTURES OF THREE-STORIED OFFICE BUILDING

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In view of increase in world prices for energy resources and the environmental degradation, energy conservation becomes particularly important for each country. The modern construction standards in calculating the levels of energy consumption and thermal insulation of buildings specify the values of heat transfer coefficients on the external and internal surfaces to be equal to 23 W/(m^2·K) and 8.7 W/(m^2·K), respectively. However, the use of constant values of heat transfer coefficients on internal and external surfaces of enclosing structures can lead to inaccuracies in determining heat losses. The paper presents the dependences of the average heat transfer coefficients on the outer surfaces on the scale of the free-stream flow velocity, obtained on the basis of numerical solution of the aerodynamics and heat transfer problems.

1-07 V. K. BITYUKOV, V. A. PETROV, I. V. SMIRNOV

RADIATIVE-CONDUCTIVE HEAT TRANSFER UNDER CONDITIONS OF HEATING ALUMINA BY LASER RADIATION FLUXES OF DIFFERENT DENSITIES

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The results of a detailed study of the influence of flux density on heating (and melting) of alumina by concentrated laser radiation are considered. One-dimensional nonstationary radiative--conductive heat transfer on heating, by CO_2 laser radiation with a wavelength of 10.6 μm, a plane layer of nonscattering alumina with specularly reflecting surfaces is analyzed.

1-08 I. V. CHERMYANINOV, V. G. CHERNYAK

ONSAGER'S THEORY FOR A ONE-COMPONENT GAS IN THE FIELD OF LASER RADIATION IN THE PRESENCE OF PRESSURE AND TEMPERATURE GRADIENTS

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The paper presents the results of investigations of heat and mass transfer of a one-component gas in a capillary in the field of resonant laser radiation in the presence of pressure and temperature gradients. On the basis of the kinetic Boltzmann equations for atoms in two quantum states (ground and excited), expressions for the entropy production and the Onsager coefficients were obtained. It is shown that the coefficients satisfy the reciprocity in the whole range of Knudsen numbers and arbitrary nature of the interaction of atoms with a surface. Stationary states with a minimum entropy production were considered. Analytical expressions for the Onsager coefficients averaged over the channel cross section were obtained for a nearly free molecular regime.

1-09 A. D. CHORNYI,[1] E. M. ZAYATS,[2] D. I. KRIVOVYAZENKO[2]

CALCULATION OF THE PARAMETERS OF HEAT TRANSFER UNDER CONDITIONS OF ELECTROCOAGULATION OF WHEY PROTEINS

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The efficiency and reliability of protein electrocoagulation depends on the uniformity of electric and temperature fields during the treatment of whey, potato juice, and other liquids with the aim to extract proteins. The reasons for temperature variations are the volume-inhomogeneity of electrical and thermal properties of a liquid, the conditions for its motion and contact with current-supplying electrodes, etc. In practice, electrode systems (coagulators) are used in the form of flat or coaxial tubes.

The present study is aimed at developing a mathematical model for electric and thermal fields in an electrically-conducting liquid (whey) moving in the membrane-separated anode and cathode regions of space bounded by the current-supplying electrodes. It includes the dependences of heat flux on permittivities of the membrane and liquid, of velocity on the transverse coordinate in the form of the parabolic profile for a laminar flow and "one seventh" power law for a turbulent flow, as well as the unsteady heat conduction equation. The model enables one to calculate allowable values of membrane electrical conductivity and electric strength in the liquid to be treated, as well as variations of other thermal and dynamic parameters depending on the time of treatment. The optimization criterion can be represented by the permissible membrane temperature or its excess over the average liquid temperature.

1-10 I. A. DAVLETSHIN, N. I. MIKHEEV, A. K. KIRILIN

HEAT TRANSFER ENHANCEMENT IN A CHANNEL WITH DISCRETE ROUGHNESS UNDER SUPERIMPOSED PULSATIONS OF FLOW VELOCITY

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Experimental results of the investigation of heat transfer in a rectangular channel with discrete roughness in pulsating airflow regimes are presented. Discrete roughness in the form of semicylindrical ribs was applied to two opposite wide walls of the channel. Flow pulsations in a wide range of frequencies were generated by periodic overlapping of the channel cross section with a flap behind the test section. Additional heat transfer enhancement associated with superimposed pulsations in comparison with heat transfer in steady regimes has been revealed. Depending on the frequency and amplitude of flow rate pulsations, the heat transfer enhancement reached 60%.

1-11 I. G. DUDAREVA,[1,2] A. D. CHORNYI[2]

SIMULATION OF THE AERODYNAMICS IN A VIRTUAL WIND TUNNEL

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[2]*A.V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus*

The paper presents the results of applying the Virtual Wind Tunnel program (CHAM, Great Britain) to calculation of the basic aerodynamic characteristics of the wing profile and of the flying vehicle airframe. The data obtained were compared with available experimental data. The lift coefficient of the airframe is negative for a negative angles of attack α, close to zero for the zero α, and increases almost linearly up to a critical value at angles $10 < \alpha < 150$. The character of such a behavior of the coefficients is typical of highly streamlined bodies (of the type of the wing profile) such as the airframe considered. An analysis of the polar of first kind indicates that the best aerodynamic quality is attained at an angle of attack close to 1.5º.

1-12 A. Yu. D'YACHENKO, Ya. I. SMULSKII, V. I. TEREKHOV, N. I. YARYGINA

INTERACTION OF DIFFERENT-SCALE TURBULENT SEPARATED FLOWS

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The paper presents the results of experimental investigation of the passive method of influence of an additional element in the form of mini turbulator, whose geometric scale is significantly smaller than that of main obstacle on a turbulent separated flow and heat transfer. The separated flow is controlled by an additional vortex sheet introduced into the separation zone which causes cardinal changes in the structure of recirculation and relaxation zones, displacement of the point of flow reattachment, and correspondingly in the redistribution of the pressure and heat transfer coefficients. The restructuring of the flow is clearly illustrated by distributions of longitudinal velocity and its longitudinal rms fluctuation measured by the PIV method.

1-13 É. Ya. ÉPIK, T. T. SUPRUN

HEAT TRANSFER AFTER LOCAL CLOSED SEPARATION ON THE INLET EDGE OF A STREAMLINED SURFACE

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Local closed separations on the inlet edge of a working surface occur widely in the continuous flow part of heat power equipment. The distributions of the coefficients of local heat transfer in the relaxation zone after the separation depend on the type of separation and its intensity. The results of experimental investigations are presented for four variants of organization of separation after which a pseudolaminar boundary layer, bypass laminar-turbulent transition or quasiturbulent boundary layer appeared. The data obtained can be used for the development of

advanced methods of calculation of complex flows as well as the database for the specification of phenomenological approaches and verification of numerical methods.

1-14 A. E. ERSHINA, Sh. A. ERSHIN, R. K. MANATBAEV

EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER OF THE NASA-0021 AIRFOIL CHANNEL AT DIFFERENT ANGLES OF ATTACK AND SPEEDS

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Heat transfer experiments were carried out to determine the quantitative and qualitative influence of the three main parameters: warm air flow rate Q, angle of attack φ, and velocity V on the intensity of heat exchange of the NASA–0021 airfoil heated by a warm air flowing inside, as well as the external air flow around the wing. The results of the experiments allow us to suggest effective methods and an original design of a wind turbine, capable of working stably in severe climatic conditions.

1-15 A. I. FILIPPOV, O. V. AKHMETOVA, A. S. RODIONOV

HEAT TRANSFER OF A TURBULENT FLOW IN A WELL

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Temperature measurements along the borehole are widely used in the oilfield business, geophysics, hydrogeology, and exploration for solving a variety of problems of scientific, geological, and commercial applications. These measurements are often carried out in a turbulent flow of liquid, whose contribution to the study of temperature fields in fluid flows is a general scientific problem. The paper presents a solution for the temperature field of a turbulent flow in the well by modifying the « on the average precise» asymptotical method.

1-16 V. A. FROST[1], V. A. BABENKO[2]

MIXING IN HOMOGENEOUS TURBULENCE

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[2]*A.V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus*

The evolution in the field of homogeneous stationary turbulence of a spherical “cloud”, the concentration of the passive admixture in which at the initial moment differs from that in the environment is considered. The action of turbulence on the scalar field is defined by two-point correlation function. In the process of calculation, the mixing is taken into account for evaluating both the admixture transport in space and the change in the chemical composition of the mixture under the action of molecular diffusion.

1-17 K. Kh. GILFANOV, I. F. GATAULLIN, D. R. MAKHMUTOV, I. F. MINGATIN

EFFECT OF THE DISTANCE FROM THE ENTRANCE TO THE PLACE OF LOCATION OF A PAIR DIMPLE ON THE FLOW STRUCTURE IN A CAVITY WITH A SHARP EDGE

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Surface heat transfer intensifiers in the form of hemispherical (segmental) depressions are widely used in heat exchange equipment. Interest in this type of intensifiers increased after the reports on the superior increase in heat transfer over that in flow resistance in a certain range of velocities. They make it possible to considerably increase the efficiency of heat exchangers.

We consider the regime of columnar vortex in a depression. According to the results of experiments, we determined the structure of the flow and flow regimes in pair depressions made in the form of spherical segments at different lengths from the edge of the experimental surface.

1-18 K. Kh. GILFANOV, I. F. ZAKIROV, I. I. MINGATIN, I. F. SIBGATULLIN

NONSTATIONARY CONVECTION OF A HORIZONTAL SEMI-INFINITE CYLINDER ON INCREASE IN THE SURFACE TEMPERATURE

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Results of simulation and experimental investigation of nonstationary natural gravitational heat transfer of a semi-infinite cylinder are presented. A thin-walled stainless steel cylinder the surface temperature of which is measured by low inertia thermocouples is used as a sample. Seven thermocouples were welded to the surface of the cylindrical test section through the central angle of $\varphi = 30°$ starting from the frontal critical point. Nonstationary conditions are realized on switching on and off of electric heating. Generalized dependences of local heat transfer coefficients are suggested.

1-19 A. N. GOLOVANOV, A. S. OKOLELOV, E. V. STEPANOVA

HEAT AND MASS EXCHANGE BETWEEN A WALL AND A PLASMA JET IN THE PRESENCE OF LIQUID INJECTION THROUGH A POROUS MATERIAL

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Aerodynamic heating causes a substantial increase in the temperature of the flying vehicle structure elements, resulting in the impairment of the strength characteristics of materials with a noticeable change in the aerodynamic shape of a flying vehicle and in the functioning of its instrumentation. This proves the urgency of solution of the problem posed.

1-20 V. G. GOROBETS

INFLUENCE OF HIGH-EMISSIVITY COATINGS ON THE CHOICE OF OPTIMAL DIMENSIONS OF FINNING

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In most cases, the existing constructions of solar collectors consist of smooth surfaces with light-absorbing coatings having a high emissitivity factor. The heat efficiency of such collectors can substantially be improved if the smooth surfaces are replaced by finned ones with a special configuration.

The paper considers the problems connected with the development of solar collectors on the basis of finned walls with coatings possessing a minimal mass. On using the methods of variational calculus, the optimal shape of fins with coating and a minimal mass has been determined. The influence of the thermophysical characteristics of carrying fins and coating on the geometrical dimensions of fins of minimal mass was considered. Comparison between a smooth and a finned surfaces with coatings is made. It is shown that the use of such finnings makes it possible to improve several times the quantity of heat flux removed from the unit area of supporting surface, which ultimately allows one to substantially increase the thermal efficiency of solar collectors as compared with the existing ones.

1-21 Yu. F. GORTYSHOV, I. A. POPOV, D. V. RYZHKOV, A. V. SHCHELCHKOV

HYDRODYNAMICS AND HEAT TRANSFER ON HEAT TRANSFER SURFACES WITH DIMPLES OF VARIOUS SHAPES

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In creating highly efficient heat exchange devices with a forced heat-transfer agent flow, the most promising method of heat transfer enhancement is the use of surface intensifiers, including systems of spherical, cylindrical, and trench-like dimples. The mechanisms underlying the heat transfer enhancement in channels and on surfaces with dimples of various shapes have been revealed and justified. Recommendations for determination of flow regimes and calculation of hydraulic and heat transfer for development of thermal and hydraulic efficient heat exchangers are suggested.

1-22 D. G. GRIGORUK,[1,2] P. S. KONDRATENKO,[1,3] M. E. CHIZHOV[1,2]

THREE-DIMENSIONAL MODELING OF CONVECTIVE HEAT TRANSFER PROCESSES UNDER CONDITIONS OF EXOTHERMIC REACTION ON SOLID SURFACES

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A mathematical model of heat and mass transfer of a hydrogen--air mixture in plane channels with chemical transformations on solid surfaces has been developed. Analytical estimates for temperature and concentration distributions along the channel were obtained. The influence of the catalyst thermal conductivity and variability of gas medium properties on the heat and mass transfer processes was studied. Verification of the developed model was performed with the aid of the fluid dynamic code FLUENT in 3D setting. The computations were carried out for various

geometries of catalyst surfaces. The results obtained are consistent with the results of the catalyst facility tests on the stand of the Thermal Engineering Institute.

1-23 A. M. GRISHIN, A. N. GOLOVANOV, V. I. ZINCHENKO, K. N. EFIMOV, A. S. YAKIMOV

ON HEAT SHIELDING OF HYPERSONIC VEHICLES

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A physicomathematical model for investigating the entry of bodies in dense atmospheric layers has been developed. A brief description of the results of theoretical and experimental investigations of the thermochemical decomposition of spherically shaped bodies entering into the Earth's atmosphere with a supersonic velocity is given.

An analysis of the efficiency of heat-shielding materials under experimental conditions (in hot gas flows and plasma jets) has been made. The results obtained can be used in practice when preparing specialists, as well as in mechanical engineering design bureaus, in theoretical and experimental investigations.

1-24 Y. L. HE AND W. Q. TAO

NUMERICAL STUDIES OF THE INHERENT INTERRELATIONSHIP BETWEEN FIELD SYNERGY PRINCIPLE AND ENTRANSY EXTREME PRINCIPLE FOR ENHANCING CONVECTIVE HEAT TRANSFER

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The purpose of this paper is to reveal the inherent interrelationship between the ideas of the field synergy principle and the entransy extremum principle. From the physical intuitive considerations it is natural to expect that for given heat transfer conditions a better synergy should lead to a larger entransy dissipation (for a given temperature condition) or less entransy dissipation (for a given flux condition). Numerical simulations are conducted for six examples of convective heat transfer, including laminar and turbulent flows, inner and outer flows, simple and complicated geometries. All the numerical results demonstrate the correctness of the above physically intuitive expectation.

1-25 S. A. ISAEV,[1] P. A. BARANOV,[1] S. V. GUVERNYUK,[2] O. O. EGORYCHEV,[3] O. I. PODDAEVA,[3] Yu. V. ZHUKOVA,[4] A. D. CHORNYI,[4] A. E. USACHOV,[5] B. I. BASOK,[6] N. V. KORNEV[7]

ENERGY-EFFICIENT TALL BUILDINGS BASED ON THE USE OF THE PRINCIPLE OF CONTROLLING LARGE-SCALE VORTEX STRUCTURES AND WIND-ENERGY INSTALLATIONS

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[6]*Institute for Engineering Thermophysics, Kiev, Ukraine*
[7]*University of Rostock, Rostock, Germany*

The problems of modeling wind action upon many-storey buildings with regard to the locality relief and building density are considered numerically and experimentally. One of the analyzed promising concepts of city building is connected with the formation of architectural ensembles using the principles of reduction in wind action. The paper discusses the research lines in architecture aerothermodynamics, including the use of flow control principles to enhance energy saving and energy efficiency of buildings, to reduce loading on them, and to elaborate a beneficial strategy of designing an architectural ensemble in terms of optimal aerodynamics.

1-26 S. A. ISAEV,[1] A. I. LEONTIEV[2]

VORTICAL HEAT TRANSFER ENHANCEMENT BY DIMPLES IN CHANNELS AND TUBES. THE PROBLEM STATE-OF-THE ART AND PROSPECTS

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Based on the analysis of effective generation of jet-vortical structures, a rational shape of dimples with a profiled outlet for a swirled flow is discussed. A classification of reliefs with a limited number of dimples is suggested. Single-row dimple reliefs in narrow channels are analyzed, the threshold value of the number of dimples for stabilized thermal and hydraulic characteristics of a dimpled channel is found. For flows in channels and pipes with an infinitive number of dimples, the limiting characteristics of dimple reliefs are determined from the consideration of periodic modules with one or several spherical and oval dimples. The advantage of oval dimples in comparison with spherical ones is justified.

1-27 A. G. IVANITSKII, A. S. MIKANOVICH, K. L. STEPANOV, L. K. STANCHITS, Yu. A. STANKEVICH

CHARACTERISTICS OF THERMAL EFFECTS OF THE EXPLOSION FIRE BALL AND OF THE FLAME OF COMBUSTION OF HYDROCARBONS

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In this paper we consider the hydrodynamic and radiation processes that accompany explosions of condensed explosives and of fuel–air mixtures. The maximal parameters of shock waves in air close to the epicenter have been determined. Computer simulation of fireball radiation was carried out. Using methane as an example, we consider the optical properties of the products of combustion of hydrocarbon fuels. The dependence of the heat flux from the region occupied by the explosion products, on its temperature and geometrical characteristics has been established. Distributions of thermal loads on the targets of different orientation in the vicinity of the zone of energy release have been obtained using the theory of angle coefficients. A comparison of radiation parameters on the detector surface with the criteria of ignition of flammable materials and thermal injury of people allowed us to determine safe distances for thermal action.

1-28 A. G. KARIMOVA, S. G. DEZIDERIEV, A. V. GIMBITSKII, R. N. GILFANOV, D. G. ZAKIROVA, E. Yu. SARKEEV

CALCULATION OF THE EFFECTIVENESS OF DIFFERENT SCHEMES OF THERMAL PROTECTION WITH THE USE OF IMPERVIOUS AND PERMEABLE SCREENS

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Variants of constructive schemes of thermal protection by screening from the heat fluxes generated by the body of a high-temperature stationary gas turbine engine are presented. A scheme of an experimental rig with a working section is given. Methodical approaches to the heat transfer calculations with different types of screens (porous, perforated, impervious), with forced and free cooling air convection and different parameters are described. The results of one variant of thermal protection are given.

1-29 O. N. KASHINSKII, P. D. LOBANOV, A. S. KURDYUMOV, N. A. PRIBATURIN

STUDY OF FLOW HYDRODYNAMIC STRUCTURE IN AN ANNULAR CHANNEL WITH A PARTIALLY BLOCKED SECTION

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Detailed experimental investigations of 3D flows are now practically absent. This significantly impedes the process of developing new 3D codes for thermohydraulic simulation of the processes and makes impossible detailed verification of such codes. The paper presents results of experimental investigation of the hydrodynamics of liquid flow in an axisymmetrical annular channel part of the cross section of which is blocked by an obstacle. This geometry allows one to produce the flow with a strongly expressed large scale three-dimensional structure caused by the deflection of streamlines. The effect of the obstacle on the local flow structure is studied.

1-30 O. N. KASHINSKII, P. D. LOBANOV, A. S. KURDYUMOV, V. V. RANDIN

HEAT TRANSFER AND HYDRODYNAMICS OF AN UPWARD TWO-PHASE FLOW IN AN AXISYMMETRIC ANNULAR CHANNEL

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Experimental investigation of the hydrodynamic characteristics and heat transfer of a bubble two-phase flow in an annular channel is carried out. The distribution of averaged and fluctuation wall shear stress is studied. The results of measurements show the effect of gas phase addition on wall shear stress and heat transfer. The increase of wall shear stress as compared to single-phase flow is more pronounced for the inner wall of the annular channel. The increase of average wall shear stress and its rms fluctuations is more significant for low liquid velocities. The significant increase in heat transfer at low liquid velocities is observed similar to the behavior of wall shear stress and its fluctuations. The distinctive feature of this study is the presence of big bubbles in the flow resulting in the parabolic distribution of local void fraction over the channel cross section.

1-31 O. N. KASHINSKII, P. D. LOBANOV, A. S. KURDYUMOV, N. A. PRIBATURIN, S. E. VOLKOV

HYDRODYNAMICS AND HEAT TRANSFER IN A MODEL OF FUEL ROD SIMULATORS WITH A SPACING GRID

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The spacing grid in a fuel rod assembly is considered not only as a supporting element that introduces additional hydraulic resistance but also as the element disturbing the flow. It is necessary to know the value and the length of the perturbation caused by the grid. An experimental study of local hydrodynamic structure and heat transfer from the wall to the flow in a 37-rod assembly of fuel rod simulators with a spacing grid is presented. The strongest nonuniformity of the flow around the rod is shown to be in the region of the flow just downstream the spacing grid. A uniform distribution of flow hydrodynamic characteristics is observed at high distances from the grid.

1-32 O. N. KASHINSKII,[1] V. V. RANDIN,[1,2] A. V. CHINAK[1]

HEAT TRANSFER AND WALL SHEAR STRESS IN A GAS–LIQUID FLOW IN AN INCLINED FLAT CHANNEL

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The results of an experimental study of bubble gas--liquid flow in an inclined rectangular channel are presented. Measurements were carried out at superficial liquid velocities from 0.3 to 1.1 m/s and different values of volumetric gas flow rate ratio. The hydrodynamic structure of the flow was studied using miniature wall shear stress probes. The averaged values and r.m.s. fluctuations of wall shear stress and heat transfer coefficient were measured at different channel inclination angles. It was demonstrated that the wall shear stress and heat transfer in a bubble gas – liquid flow depend significantly on channel inclination angle.

1-33 K. Yu. KATSALAP, E. A. ERSHOV-PAVLOV, L. K. STANCHITS, K. L. STEPANOV

EROSION PLASMA EXCITATION IN ANALYSIS OF THE COMPOSITION OF METAL ALLOYS BY LASER INDUCED BREAKDOWN SPECTROSCOPY METHODS

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This paper describes the possibility of determing the efficiency of excitation of laser erosion plasma. The plasma properties are typical of the laser induced breakdown spectroscopy methods of quantitative analysis. The approach described is based on modeling the plasma parameters in explosion approximation. The dependence of emission spectra on plasma excitation degree is considered. The excitation degree for the typical conditions of laser-induced breakdown spectral analysis is evaluated.

1-34 A. A. KHALATOV,[1] I. I. BORISOV,[1] A. S. KOVALENKO,[1]
Yu. Ya. DASHEVSKII,[2] S. V. SHEVTSOV[1]

FILM COOLING OF A FLAT SURFACE PLATE BY MEANS OF ONE- AND TWO ARRAYS OF HOLES LOCATED IN SPHERICAL DIMPLES

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[2]*Gas Turbine Research & Production Complex "Zorya"-"Mashproekt", Mykolaiv City, Ukraine*

The paper presents experimental data on film cooling of a flat surface by means of one and two arrays of inclined holes located in spherical dimples. It is shown that the efficiency of cooling by such a configuration of holes exceeds significantly the traditional scheme of cooling by cylindrical holes without dimples. The one-array dimpled configuration is close to the trench cooling configuration, whereas the two-arrays dimpled scheme, to the holes of the fan-shaped configuration, which is considered to be most promising at the present time. The span-wise cooling effectiveness of dimpled configuration is more uniform, than of the traditional film cooling scheme without dimples, especially in the initial flow region. This provides better film coverage of the protected surface.

1-35 P. P. KHRAMTSOV, O. G. PENYAZKOV, V. M. GRISHCHENKO, M. Yu. CHERNIK, I. A. SHIKH

SPARK DISCHARGE HIGH-PRESSURE CHAMBER AS A BLINKER UNIT FOR SHADOW METHOD MEASUREMENTS

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Shadow method diagnostics of bright plasmas is highly complicated because of the need of using a brighter blinker than the plasma investigated. That is why for obtaining shadow patterns of compressed plasma in the plasma flows collision area, suitable not only for qualitative analysis but also for quantitative interpretation of experimental data, a blinker based on a spark impulse discharge in argon has been developed. Argon pressure in a discharge chamber was 2 atm. The schematic circuit of blinker power supply, time dependence of discharge brightness and investigation of discharge glow spectrum are presented and discussed in the paper. The electron temperature based on the spectral characteristics and electron density in argon plasma were calculated and amounted to 4 eV and $4.9 \cdot 10^{18}$ cm^{-3}, respectively.

1-36 A. V. KIREENKO, Yu. V. ZHUKOVA

USE OF THE OPENFOAM PACKAGE FOR CALCULATING CONJUGATE PROBLEMS OF CONVECTIVE HEAT TRANSFER

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The OpenForm package is an open platform for numerical simulation. It allows one to solve as the problems of hydrodynamics, so the problems of heat conduction in a solid body, and conjugate problems. The paper is devoted to the analysis of the results of investigation of ventilation in a closed volume.

1-37 O. G. KLYUEVA

CREATION OF UNIFIED HEAT EXCHANGER FOR A SINGLE-CHAMBER LIQUID-PROPELLANT ROCKET ENGINE

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The principal problem in designing heat exchanger for a liquid-propellant rocket engine (LPRE) is the creation of more efficient processable, reliable, and convenient in operation and economical construction. The paper presents the description of the construction of a heat exchanger for a single-chamber LPRE, developed on the basis of the results of analysis of the fabrication and service of a heat exchangers of the NPO "Energomash" of the RD-107 engine for the rocket carrier «Soyuz» and RD-171 engine for the rocket carrier «Zenit». This construction is more refined and unified and allows one to create a heat exchanger for other LPREs by changing only the number of plates and details for the supply and removal of hot and cold gases.

1-38 V. L. KOLPASHCHIKOV, A. S. SVIRIDOVICH

INFLUENCE OF HEAT AND MASS TRANSFER PROCESSES IN A GAS PIPELINE ON THE ACCURACY OF DETERMINING THE NATURAL GAS VOLUME FLOW RATE IN SOLVING IMBALANCE PROBLEMS

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In analyzing above-ground gas pipelines, a considerable imbalance of natural gas was detected caused by the thermal diffusion processes of division of mixture's light and heavy constituents, and also by phase transitions of the condensing part of the mixture at temperatures below the heavy components' dew point. Complex thermal–hydraulic flow regimes in an above-ground uninsulated pipe can cause an additional error in volume flow rate measurements that can significantly exceed the certified default level of gas metering stations. A method of obtaining metering data for consumed gas is suggested. It is based on solving the inverse problem of error theory proceeding from the factual natural gas imbalance rate.

1-39 V. A. KONDRATYUK, A. M. TEREKH, A. I. RUDENKO

HEAT TRANSFER AND AERODYNAMICS OF FLAT-OVAL BUNDLES OF TUBES IN A CROSS FLOW

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The paper presents experimental results on heat transfer and aerodynamic drag of staggered bundles of flat-oval tubes in the range of Reynolds numbers Re = 3000–30 000 at different longitudinal and transverse tube pitches. The results obtained are compared with the well-known calculation dependences for bundles of differently shaped streamlined tubes. An analysis of these results has shown that the intensity of heat transfer of the considered bundles is at the level of round tube bundles, with the aerodynamic drag of the examined bundles being much lower than that of round tubes and correlating well with the calculation dependences for bundles of differently shaped streamlined tubes.

1-40 E. V. KOROBKO, S. A. GUBAREV, A. A. MOKEEV, E. A. BASHTOVAYA

MICROCONVECTIONAL THERMAL CONDUCTIVITY OF ELECTRO-RHEOLOGICAL FLUIDS (ERF) IN A ROTATING ELECTRICAL FIELD

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The problem of heat transfer in a flat layer of an electrosensitive heat carrier in an alternating electrical field is formulated and solved numerically. When modeling the problem, microconvection is taken into account on the basis of a constructed physicomathematical model of the motion of a single polarized dispersed phase particle. The case of a moderate concentration of particles in an electrorheological fluid is considered, when there is no influence of the particles on

each other and the dispersed medium in the interlayers flows freely without an electrical field. Under the influence of a rotating electrical field, the fluid particles rotate with a period much longer, than the time of polarization relaxation of particles and their chain structure. It is shown that the presence of internal rotations substantially intensifies the process of heat transfer in an electrorheological fluid, which can be used for creating heat transfer units controlled by external electrical field.

1-41 D. V. KOSENKOV, A. V. PALTSEV, P. I. BUDARIN, K. B. PANFILOVICH

SPECTRAL CHARACTERISTICS OF COMPRESSED PROPYLENE

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The scheme of an experimental installation for measuring the transmittance spectra at pressures of 0.1–10 MPa within the temperature range 293–500 K is presented.

The transmittance spectra and absorption coefficients of propylene (gaseous and liquid phases) at pressures of 0.1–7 MPa within the ranges of temperatures 293–333 K and wave numbers 400–4000 cm^{-1} are presented. The mass spectral absorption coefficients were calculated using the data on transmittance spectra.

1-42 T. KUCIŃSKI,[1] K.SEWERYN,[1] R.WAWRZASZEK,[1] P. KASPROWICZ,[2]
L. MANKIEWICZ,[3] F. ŻARNECKI[4]

THERMAL CONTROL OF CCD CAMERA DEDICATED FOR AUTONOMIC ASTRONOMICAL OBSERVATION WORKING IN EARTH ENVIRONMENT

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[4]*Institute of Experimental Physics, Physics Faculty, University of Warsaw*

Within the "Pi of the sky" project, several CCD cameras for astronomic observations have been developed and manufactured. Their thermal design consists of thermoelectric module with a radiator and fan-cooled heat sink. As spin-off project, a new CCD camera for both scientific observations and monitoring is being developed. Its main features are high-sensitivity and low noise (3-5 electrons at 2Mhz). It will also be equipped with a Digital Signal Processor, which will enable effective computing for pattern recognition. The paper presents experimental and simulation results obtained by the previous-generation cameras, which aided in the understanding of the key-driven parameters impacting on CCD module temperature. Additionally, numerical simulation of the new camera thermal model was developed and used to compare possible thermal designs.

1-43 I. G. KUKHARCHUK, A. D. CHORNYI

EXPERIMENTAL INVESTIGATION OF HYDRODYNAMIC CAVITATION IN THE CONTINUOUS-FLOW CHANNELS OF MIXERS

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The paper presents the results of experimental study of the processes occurring in a turbulent flow of fluids in the course of hydrodynamic cavitation for determining the influence of air and water ejection, as well as of a change in the general flow rate on the intensity and magnitude of the sound speed in the flow passage part of mixers. A conclusion can be drawn that an increase in pressure in the active zone (the region of the collapse of bubbles) has a positive effect on the magnitude of the sound pressure amplitude. At an inlet cavitation module pressure of 58 atm and an excess pressure in the active zone of 0.3 atm, a maximum recorded pressure of the shock wave was 500 atm. An increase in the flow velocity led to an increase in the tensile stress in the fluid that caused an increase in the number of bubbles (or in the size). The frequency analysis in the cavitation mode of fluid motion has demonstrated that calculation of channels with the resonance frequencies coinciding with the most energy-carrying of a specific signal or fabrication of channels with a multitude of resonance frequencies (complex-shape channels), and experimental selection of the fluid flow rate and pressure in the region of the collapse of bubbles for setting up resonance regimes are the possible trends for solving the problem of creating new cavitation facilities.

1-44 O. Yu. KULESHOV, V. M. SEDELKIN

CORRECTION ZONING METHOD FOR CALCULATING RADIATIVE AND COMBINED HEAT TRANSFER IN POWER EQUIPMENT

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The new approach to calculate radiative and combined heat transfer in high-temperature units – the corrective zoning method – is proposed. The method uses single calculation of the base opticogeometric characteristics of radiation (OGCh) for zonal geometric unit's model with subsequent correction of OGCh on variation of optical properties of the zonal system in the coarse of iterative process of solving this thermal problem or on passing to other heat regimes of unit's operation.

1-45 O. Yu. KULESHOV, V. M. SEDELKIN

CALCULATIONAL METHOD FOR LOCAL CHARACTERISTICS OF RADIATIVE AND COMBINED HEAT TRANSFER IN COMBUSTION CHAMBERS OF FURNACES AND BOILERS WITHIN THE FRAMEWORK OF ZONING APPROACH

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A numerical method for calculating the local characteristics of radiative–convective heat transfer within the framework of resolvent zoning approach in application to calculation of combustion chambers of furnaces and boilers has been developed. The method allows one to detail the characteristics of resulting heat transfer in the case of geometrically complex, non- uniformly irradiated heating surface by means of additional calculation of local generalized angle factors using statistical modeling of radiation. On this basis, the calculational technique for local heat fluxes

along the tube perimeter in combustion chambers of tube furnaces and boilers have been developed. The calculational technique is tested on a real tube furnace of gas industry.

1-46 G. V. KUZNETSOV,[1] N. I. KURILENKO,[2] V. I. MAKSIMOV,[1]
G. Ya. MAMONTOV,[3] T. A. NAGORNOVA[1]

CONJUGATE HEAT TRANSFER IN A SYSTEM WITH A RADIATIVE SOURCE OF HEATING

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The results of mathematical simulation of conjugate heat transfer in a closed rectangular region with a local source of radiative heating are presented. The two-dimensional nonstationary problem is solved within the framework of the Navier – Stokes model for gas and thermal conductivity of solid walls. An analysis of the dynamics of heat propagation in a closed region in the course of time is carried out and a comparison of representative temperatures calculated by the balance model and the model formulated in the present work is made. It is established that a large portion of heat accumulates in the enclosing constructions exposed to the influence of thermal radiation. Conclusions about the expediency of applying the formulated model for calculating heat transfer in the presence of a radiative heating source are made.

1-47 A. R. LEPESHKIN

THREE-DIMENSIONAL MODELING OF THE THERMAL STATE OF DISKS ROTATING IN AN ELECTROMAGNETIC FIELD

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Finite-element three-dimensional models for calculating electromagnetic and temperature fields and inductor parameters on heating rotating disks have been developed with the use of the finite-element method. The investigation of a new effect occurring on induction heating OF rotating disks is carried out consisting in additional release of thermal energy in an article due to rotation. The influence of rotation frequency on the formation of the power of internal heat sources in a rotating disk with the use of different inductors has been analyzed. The results of investigations of temperature distributions in rotating disks with the use of different inductor designs are presented, and an inductor of optimum shape has been obtained.

1-48 A. P. LEPESHKIN

INVESTIGATION OF PROPAGATION OF HEAT IN ROTATING DETAILS

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The method of investigation of heat propagation in rotating details in the field of centrifugal accelerations and forces is suggested. A device has been developed for determining the characteristics of heat propagation and speed of heating of heat conductors over a spin rig with the use of a vacuum chamber under conditions of centrifugal accelerations and forces. The heat conductors were installed on a disk. The results of investigations of nonstationary heating of heat conductors in the field of action of centrifugal accelerations and forces are presented. The speeds of heating heat conductors increase with the frequency of rotation. Using the results obtained, estimates of the speeds heating of heat conductors with account for the increase in the electronic conductivity of metal (influence of the inertia of electrons) are presented.

1-49 K. Yu. LITVINTSEV, A. A. DEKTEREV, P. A. NEOBYAVLYAYUSHCHII

INFLUENCE OF THE METHODS OF CALCULATION OF RADIATION HEAT TRANSFER ON THE RESULTS OF SIMULATION OF A BURNER FOR AFTER BURNING OF ANODE GASES OF ELECTROLYSIS PRODUCTION

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The paper presents the simulation results of radiation heat transfer in a burner intended for combustion of anode gas. The CFD software «σFlow» was used by the authors for calculations of the burner. The radiation heat transfer equation was solved by the finite-volume method, discrete-ordinates method, and the P1 approximation. The “gray” gas approximation, WSGG model, and the gray band model based on HITRAN were used to calculate the absorption coefficient.

1-50 A. A. LOPATIN, A. V. SHCHELCHKOV

DIMPLED SURFACES IN FORCED CONVECTIVE SYSTEMS OF COOLING RADIO ELECTRONIC EQUIPMENT

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At the present time, power radio-electronic components with high heat emission have gained wide acceptance in various areas of modern industry. The main problem that faces developers of elementary base is the creation of systems of cooling and thermal stabilization capable of removing high-density heat fluxes, but working in a wide range of ambient temperatures. While creating such systems, along with the thermal characteristics it is necessary to take into account the weight dimensional characteristics of a device as a whole, therefore much depends on the choice of heat transfer intensification technique. The paper considers the problems connected with application of dimples as superficial intensifiers in systems of cooling radio electronic equipment.

1-51 V. A. LOSHKAREV

TECHNIQUE OF DOUBLE EXPERIMENT IN ASSESSMENT OF A RADIATIVE HEAT FLUX WITH A QUANTUM ELECTRON OF TERMAL EMISSION

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The paper presents the results of investigations of the behavior of quantum electrons of thermal emission in Frank – Hertz's experiment with a neon and mercury vapor with the aid of the 3B-SCIENTIFICS equipment. This has made it possible to advance a hypothesis about a discrete-discontinuous character of the behavior of a quantum thermoelectron of a tungsten substrate in interaction with atoms of neon and separately with atoms of mercury, as well as to estimate the influence of this digitization on the character of the radiative heat flux. A technique of double experiment in assessment of the radiative heat flux is suggested. Attention is paid to the qualitative and quantitative difference of the electrons of thermal diffusion from substrates of solid substances of different chemical compositions.

1-52 V. G. LUSHCHIK, M. S. MAKAROVA, A. E. YAKUBENKO

TEMPERATURE STRATIFICATION IN A TURBULENT BOUNDARY LAYER ON A PERMEABLE SURFACE

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Numerical simulation of a turbulent boundary layer with the use of a differential turbulence model showed that during suction of gas from the turbulent boundary layer of a supersonic flow on a permeable surface it is possible to obtain a significant temperature difference between the gas in the boundary layer and the sucked gas. The influence of Prandtl and Mach numbers of the free-stream flow and of the suction intensity on temperature stratification was considered. The largest stratification is observed for gases with small and high Prandtl numbers.

1-53 T. Sh. MAGRAKVELIDZE

ON DETERMINING VALUES OF SIMILARITY NUMBERS FOR THE CASE OF LIQUID MIXING IN A POOL

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The results of experimental investigation and their generalization with the aid of dimensionless equations for the process of heat transfer from a circular pipe immersed in a distilled water in a cylindrical vessel at different heights and number of straight mixer blades are presented.

1-54 T. Sh. MAGRAKVELIDZE, N. N. LEKVEISHVILI, N. O. BANTSADZE, A. N. MIKASHAVIDZE, Kh. N. LOMIDZE

LOCAL CHARACTERISTICS OF THE FORMATION OF DEPOSITS ON SMOOTH AND ROUGH SURFACES

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Experiments were carried out to determine the local coefficients of heat transfer from smooth and rough surfaces under conditions of the formation of deposits. Experimental results for a pipe with hemispherical dimples showed that in this case the intensity of deposit formation is higher than for a pipe with two-dimensional roughness.

1-55 M. S. MAKAROV

NUMERICAL INVESTIGATION OF ENERGY SEPARATION FOR A COMPRESSIBLE GAS FLOW IN A FLAT CHANNEL

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Researchers use the term energy separation to describe different processes that lead to the effects of cooling one part of a gas flow and heating its other part only by means of the gasdynamics of flow. The method of energy separation in the Ranque--Hilsch vortex tube is the most famous of them. In this paper, the method of energy separation in a supersonic flow, suggested by A. I. Leontiev, is studied by numerical modeling. A compressible gas (Dorodnitsin gas, helium--xenon gas mixture) flow in a flat channel separated by a heat transfer wall is analyzed. The most important characteristics of energy separation like the pressure loss, the cooling and heating effectiveness, and adiabatic efficiency have been obtained.

1-56 P. A. MANDRIK,[1] L.V. RUDAK,[1] K. L. STEPANOV,[2] A.V. TETEREV[1]

SIMULATION OF THE PASSAGE OF COMET-LIKE SPACE OBJECTS THROUGH THE PLANET'S ATMOSPHERE

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The liquid drop model used for simulation of the falling of comet-like space objects and its mathematical representation are described. The results of numerical modeling of the falling of rarefied, superrarefied, and comet-like space objects through the planet's atmosphere are presented. Characteristic features of their destruction by a gas-dynamical stream are discussed. The reasons and conditions for the formation of a rotational stream on the lateral surface of a body are analyzed. The conclusion on a stabilizing role of such a stream leading to deeper penetration of smaller size bodies into the atmosphere has been drawn.

1-57 S. O. MARACH, A. I. SHNIP

ON APPLICATION OF THE PID REGULATOR IN THE SYSTEM OF THERMAL STABILIZATION OF ORBITAL OPTOELECTRONIC INSTRUMENTATION

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The work is devoted to one of the most topical problems, i.e., the optimization of the parameters and of the working algorithm of the thermal regulation and thermostating system (TTS) of a space vehicle (SV), use of the modern methods of controlling in the active elements of the TTS. The proportional–integral–differential (PID) regulation should be related to such methods. The present investigation was carried out using as an example the astroorientation device (star

probe). A thermal model of the star probe is constructed making it possible to model various schemes of TTS organization. Two principles of TTS organization have been worked out: on the basis of the relay and PID regulation. The advantages of the PID regulation in the onboard optoelectronic instrumentation of SV allowing one to increase the accuracy of thermal regulation and decrease power consumption are shown.

1-58 I. A. MELNIKOV,[1] Yu. P. IVOCHKIN,[2] N. G. RAZUVANOV,[2]
V. G. SVIRIDOV,[1] E. V. CHEKMENEVA,[1] A. V. SHASHURIN[1]

INVESTIGATION OF THE MHD OF LIQUID METAL HEAT TRANSFER DURING FLOW IN A VERTICAL TUBE

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The goal of the joint MPEI-JIHT activities is to investigate the liquid metal flow in a vertical heated tube without a transverse magnetic field (MF) and in it. This case corresponds to a flow in the tokamak fusion reactor blanket. Mean temperatures, temperature fluctuations, and heat transfer intensities were measured. As a rule, MF suppresses turbulence and decreases heat transfer. But the abnormal high temperature fluctuations were observed in a certain flow regime in a transverse MF.

1-59 M. MILIEŠKA, V. VALINČIUS, V. GRIGAITIENĖ, R. KĖŽELIS

EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER DURING TURBULENT MULTIPHASE PLASMA FLOW IN A CIRCULAR TUBE

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One of the most important processes taking place during ceramic material fibrillation in a plasma-chemical reactor which makes fiber formation successful is heat transfer between the multiphase plasma flow and melted disperse raw material. However, occurring there is also the heat loss to the reactor walls. The control of heat flux from the plasma flow to the dispersed material and heat loss to the reactor walls becomes the most important issue to optimize the fibrillation process. In this work, heat transfer to the plasma-chemical reactor walls is experimentally investigated and its dependence on the plasma flow parameters is generalized with and without the presence of dispersed material in the reactor channel.

1-60 A. M. MOLCHANOV, P. V. NIKITIN, L. V. BYKOV

CALCULATION OF HIGH-SPEED REACTING FLOWS BASED ON THE MODELING OF TURBULENT PRANDTL AND SCHMIDT NUMBERS

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Turbulent heat and mass transfer modeling and the problem of the influence of turbulent pulsations on chemical reaction rates are of paramount importance in investigation of high-speed

turbulent flows with chemical reactions. The compressibility effect is also very important, since it decreases the rate of mixing of reacting components.

This paper suggests a new turbulence model based on modeling the "slower" part of the pressure-scalar value gradient correlation, which is assumed to depend on the characteristic time of the scalar value pulsations (the ratio between scalar value variance and its dissipation rate). It is also assumed that turbulent mixing is mainly affected by the velocity pulsations normal to the streamlines. Based on the analysis of the equations of turbulent transport of scalar values and on the assumption of the equilibrium of the terms in these equations, simple formulae for the fluxes of scalar values have been developed.

1-61 V. M. MOLOCHNIKOV, N. I. MIKHEEV, O. A. DUSHINA, A. A. PAERELIY

DEPENDENCE OF THE STRUCTURE OF TRANSITIONAL CHANNEL FLOW BEHIND A SPANWISE RIB ON THE RIB SHAPE

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The results of comprehensive experimental research of a channel flow past a semicylindrical rib and a thin spanwise rib in laminar, transitional, and turbulent flow regimes are presented. The experiments included flow visualization, hot-wire measurements of local velocity and PIV measurements of instantaneous velocity vector fields and vorticity fields behind the rib. Data on the evolution of kinematic and vortical flow structure and fields of statistics in the channel with a spanwise rib depending on the rib shape have been obtained. Attention was specially paid to the processes of generation of large-scale vortices in the mixing layer behind the rib at the late stages of transition to turbulence.

1-62 V. A. NEMTSEV,[1] G. F. BETENYA,[2] V. V. VOROB'EV,[1] A. G. LUKASHEVICH[1]

HEAT TRANSFER UNDER CONDITIONS OF COOLING HIGH-TEMPERATURE PLANE SPECIMENS IN A POOL OF SUBCOOLED WATER

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The paper presents the results of experimental investigation of temperature fields and heat transfer intensity in film and transient boiling of highly subcooled water in the process of cooling of high-temperature plane metal samples in a pool of water. It is shown that the average rate of cooling in the region of intense heat removal amounted to 700–800 K/s, with the maximal rate attaining 1500 K/s. The results obtained by numerical simulation by the methods of inverse heat conduction problems for the dynamics of the change in the temperature field of the sample are given. Visual investigation has shown that the pattern of intense heat transfer coincided with the start of the process of vapor film "falling" from the plate surface (the so-called "vapor explosion").

1-63 P. A. NEOBYAVLYAYUSHCHII, A. A. DEKTEREV, K. Yu. LITVINTSEV

INVESTIGATION OF COMBINED HEAT TRANSFER IN MULTICOMPONENT GAS MIXTURES IN APPLICATION TO DEVICES OF BURNING AND TRANSPORTATION OF ANODE GASES OF ELECTROLYSIS ALUMINUM PRODUCTION

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The paper presents the results of complex computational and experimental investigation of aerodynamics and heat transfer in burners and complex ducts of the system of transportation and thermal neutralization of anode gas of aluminum production. The CFD software «σFlow» and «Star CCM+» were used for calculations. Optimization of the elements of the system for anode gas detoxication and transport was carried out by means of computational experiments.

1-64 N. I. NIKITENKO

ON THE PRICIPLES OF THE MOLECULAR RADIATIVE THEORY OF TRANSFER AND PROMISING DIRECTIONS OF ITS DEVELOPMENT

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The molecular radiative theory of transfer, in contrast to the phenomenological theory, allows one to determine the thermophysical characteristics of substances, depending on the temperature and properties of microparticles. An integro-differential equation of transfer, passing in the limit to the Fourier heat conduction equation, and the law of spectral radiation intensity of particles yielding Planck's formula for black body emission and the law of energy distribution of particles in activation processes, passing in the limit to the Maxwell--Boltzmann distribution law have been obtained. Formulas for the heat capacity, thermal conductivity of metals and dielectrics, diffusion, evaporation, and condensation have been found. The theory of energy and momentum transfer for the phenomena of the diffraction of photons and matter particles, Doppler effect, and of the relative motion has been further developed.

1-65 A. V. NOVOZHILOVA,[1] Z. G. MARYINA,[1] A. Yu. VERESHCHAGIN,[1] V. B. KUNTYSH[2]

INVESTIGATION OF FREE-CONVECTIVE HEAT TRANSFER OF IN-LINE FINNED-TUBE BUNDLES WITH DIFFERENT ANGLES OF INCLINATION OF TUBES

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By their operational and technical–economical characteristics, heat-exchange apparatuses with bundles of finned tubes can be used in a free convection mode. At the present time, there are practically no investigations of in-line bundles installed at an angel to the horizontal plane. The regime of flow past such bundles allows one to obtain higher heat-transfer coefficients without

deterioration of the aerodynamic properties of the bundle. Two-, three-, and four-row bundles with longitudinal and cross-section pitches S_1 = 70 mm and S_2 = 61 mm and S_1 = 76 mm and S_2 = 64 mm are investigated. The generalizing dimensionless equation for calculating the average heat-transfer coefficient of inclined bundles of tubes is obtained.

1-66 V. V. OKOLO-KULAK, A. S. SMETANNIKOV, K. L. STEPANOV

COMPUTER MODELING OF THE HYDRODYNAMICS OF EXPLOSION ABOVE THE EARTH'S SURFACE

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In this paper, we describe the modeling of the explosion of a cylindrical charge above the surface in the approximation of immediate detonation. A two-dimensional fully conservative difference scheme in the Eulerian variables with coordinated momentum and mass flows were used for numerical computation. The state of the explosive was described by the Jones–Wilkins–Lee equation, the environment – by the state equation of an ideal gas with a constant adiabatic index. The detailed description of the space–time flow pattern is obtained. The forming, spreading, interaction, and fading of the shock wave are considered. The proposed model can be used for constructing simple techniques for assessing the parameters of blast waves from near-surface explosions.

1-67 S. G. ORLOVSKAYA, M. S. SHKOROPADO, F. F. KARIMOVA

PHYSICOMATHEMATICAL MODELING OF STATIONARY HIGH-TEMPERATURE HEAT AND MASS TRANSFER OF TUNGSTEN FILAMENTS HEATED ELECTRICALLY IN AIR

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A tungsten filament heated electrically is a main operating element of numerous devices (incandescent lamps, ionization filters, heat-loss anemometers and others). To design such devices, we have to analyze in detail the high-temperature heat transfer of a hot filament for a number of heating currents and different filament diameters. The temperature distribution along the filament should be taken into account. The results of the high-temperature heat transfer modeling with account for oxidation reactions are presented; the specific mechanisms of heat transfer are analyzed.

1-68 M. A. PAKHOMOV, V. I. TEREKHOV

MODELING OF FLOW AND HEAT/MASS TRANSFER IN A TURBULENT GAS–DROPLET BOUNDARY LAYER

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The flow dynamics and heat/mass transfer in a turbulent boundary layer on a flat vertical plate have been investigated numerically. A wide range of factors that affect heat and mass transfer and the structure of thermal and concentration fields in the laminar and turbulent boundary layers

has been analyzed. The increase in the droplets mass fraction results in significant intensification of heat transfer rate compared to the one-phase air flow. The predictions tested against experimental results are indicative of good agreement over the entire range of initial conditions.

1-69 L. N. PANASENKO[1], E. M. ERMOLAEVA[2], Yu. A. KHAREVICH[1]

MODELING OF RADIATION PROCESSES OCCURING DURING DISPOSAL OF HAZARDOUS WASTES

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In modeling the process that involves the usage of a plasma stream for disposal of hazardous wastes, radiation transfer of a plasma generating substance should be taken into account. The method of partial characteristics used for the purpose complicates calculation of the temperature field in a processing unit. The paper describes a method used to calculate the specific power of radiation with account for reabsorbtion. The method can be used to solve engineering problems in order to shorten calculation time without large losses in accuracy.

1-70 N. PELEVIC, Th. H. VAN DER MEER

NUMERICAL INVESTIGATION OF THE INFLUENCE OF SURFACE ROUGHNESS ON HEAT TRANSFER

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In this paper, the advantage of the lattice Boltzmann model has been used in order to investigate the influence of the real surface roughness and of the thermal conductivity of the roughness elements on the heat transfer enhancement. First, a random generated roughness has been created. Then, the hydrodynamic and thermal field has been solved by using the lattice Bolthmann equation.

1-71 O. G. PENYAZKOV, P. P. KHRAMTSOV, I. N. SHATAN

APPLICATION OF THE METHOD OF AVERAGED TALBOT IMAGES TO THE STUDY OF TURBULENT MIXING IN AN AXISYMMETRIC METHANE JET

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In the recent years there has been a considerable progress in the field of experimental and numerical investigation of turbulent mixing and combustion. Despite the fact that the modern methods of optical diagnostics based on fluorescence, Rayleigh and Raman scattering make it possible to measure a great number of parameters with a sufficient temporal and spatial resolution, their use has a number of technical difficulties associated with the small value of measured signals, or with the choice of appropriate fluorescent tracers. The paper describes the adaptation of the

method based on the Talbot effect for the diagnostics of turbulent mixing. The experimental data measured for the turbulent axisymmetric methane jet were used to calculate the averaged concentration of methane in the flow field.

1-72 B. V. PEREPELITSA

EXPERIMENTAL INVESTIGATION OF A TEMPERATURE FIELD ON STEPWISE CHANGE IN A HEAT FLUX IN A CHANNEL WITH CORRUGATED WALLS

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The results of experimental investigations of unsteady temperature field in a stream and on the surface of a channel with a corrugated wall on stepwise change in the time of heat release are presented. The measurements were performed for air flow in a rectangular channel where one, heated wall consisted of a corrugated plate with triangular cross-section corrugations oriented at an angle of 45 degrees to the direction of the main stream. Measurements were carried out using microthermocouples of thickness less than 10 microns. The investigations carried out have revealed characteristic lows governing the evolution of temperature in the stream and along the perimeter of the heated fin.

1-73 V. A. PETROV

NONSTATIONARY RADITIVE–CONDUCTIVE HEAT TRANSFER IN HIGH-TEMPERATURE FIBROUS INSULATION AND THE MODEL OF RADIATION DIFFUSION

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A description of the complex approach to the problem of nonstationary radiative – conductive heat transfer in fibrous heat insulation is given based on the model of radiation diffusion and simultaneous solution of direct and inverse problems and on experimental determination of spectral and temperature dependences of absorption and radiation diffusion coefficients and on the temperature dependence of the intrinsic thermal conductivity coefficient.

1-74 E. N. PIS'MENNYI, A. V. BARANYUK, L. V. PASHINSKAYA

CFD MODELING OF THERMOHYDRAULIC CHARACTERISTICS OF EQUALLY DEVELOPED HEAT TRANSFER SURFACES

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To improve the weight and size characteristics of tubular air heaters widely used in circuits with a simple gas turbine regenerative cycle, helical tubes with equally developed inner and outer surfaces were developed at the Kiev Polytechnic Institute. To use such tubes in the constructions of heat exchangers, it is necessary to study their thermal and aerodynamic

characteristics, which to date have not been investigated. In this study, the technique of modeling and some results of numerical studies of transport processes in a turbulent air flow inside an equally developed surface, which in the first variant is a single-start helical tube with the initial inner diameter d = 36 mm, are considered.

1-75 I. A. POPOV, A. V. SHCHELCHKOV, M. Z. YARKAEV, D. V. RYZHKOV

THERMAL AND HYDRAULIC EFFICIENCY OF THE CHANNELS OF HEAT EXCHANGERS IN TRANSIENT FLOW REGIMES

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One of the industrially promising methods of increasing the efficiency of heat exchanger is the use of discretely rough tubes. At the present time, the thermal and hydraulic characteristics of channels with turbulent flow regimes have been well studied. In the case of laminar and transient flow regimes the use of heat transfer intensifiers with parameters optimal for a turbulent flow can lead to a sharp decrease in the thermal and hydraulic efficiency of devices. Recommendations for the calculation of heat transfer and hydraulic resistance in transient and laminar flow regimes in tubes with two- and three-dimensional roughness are given. The results of tests of heat exchangers are presented and a comparative analysis of their thermal and hydraulic efficiencies was made.

1-76 P. V. PROSUNTSOV, S. V. REZNIK

PLANNING OF TEMPERATURE MEASUREMENTS IN INVESTIGATIONS OF HEAT TRANSFER IN HIGHLY POROUS THERMAL INSULATION MATERIALS

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A characteristic feature of high-temperature thermal insulation SiO_2- and Al_2O_3-based materials is their high porosity and semitransparency of fibers for the thermal radiation. The paper presents methods which allow one to simultaneously perform determination of all the thermophysical and optical properties of highly porous thermal insulation materials using the data obtained as a result of a single test with the use of the apparatus of multidimensional inverse problems of radiative and conductive heat transfer. A new method of temperature measurement planning has been developed. It includes a selection of test scheme, optimization of its parameters, and the determination of the number of temperature sensors and their coordinates. The influence of the main factors such as the heating rate and the thickness of the material under consideration on the solution results of the problem of temperature measurement optimal planning was investigated.

1-77 V. V. REINO, V. M. SAZANOVICH, R. Sh. TSVYK, M. V. SHERSTOBITOV

EXPERIMENTAL INESTIGATIONS OF MODEL FIRE TORNADOS

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Results of investigations of fire tornado under modeling conditions are presented. The tornado was formed by means of air flow twisting by blades, rotating under a stationary tank filled with a burning substance (spirit). The dependence of a heat flux, burning rate, frequency of the spectral function of fluctuations of the center of gravity of the image, and of the intensity of the laser beam that passed through the tornado, on the speed of twisting has been found. It is shown that the parameters measured in the regime of tornado grow linearly with increase in the speed of twisting. These parameters (with account for the portion of tornado formation) are well described by the equation $a + bn + c\exp(-n/k)$, where *a, b, c and k* are the constants depending on the parameter measured.

1-78 V. M. REPUKHOV

EXTENSION OF THE SOLUTION OF TRANSPORT EQUATIONS OF COMPOUND (RADIATIVE AND CONVECTIVE) HEAT AND MASS TRANSFER BY THE METHODS OF THE FIELD THEORY

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The existence of the canonical system consisting of transfer line and the transport equations for characteristic quantities to within the transfer vectors in the orthonormal base of the four-dimensional Euclidean space (continuum), where the time is a common measure of all forms and their types of motion is justified. The reversible quasilinear transformation with the defect and relative laws of state and transfer in the small neighborhood of the point of the continuum above the field of functions for linear increment of coordinates, transfer vectors and transported quantities (speed, energy), but nonlinear gradients and divergences is used. The transformation equations--conditions that permit one to extend the solutions of various forms of transport and their types (properties, boundary), in particular, to generalize the Lorentz transformation are analyzed.

1-79 S. V. REZNIK, T. G. AGEEVA

DETERMINATION OF MODEL PARAMETERS FOR THERMAL TESTING OF COMPOSITE WING PANEL

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Due to the large overall dimensions of the tourist-class reusable space vehicle composite wing (the wing span exceeds eight meters), its experimental development is a difficult task. It is necessary to justify the validity of thermal and strength tests of models with smaller overall dimensions and made from cheaper materials than the full-scale object. The essential point is that the wing consists of a multiply composite material and the creation of a model of smaller size does not mean the reduction of the layers thickness. The paper outlines a possible way of solving the problem, i.e., the use of the affine similarity theory method to determine the parameters of the composite wing model.

1-80 B. S. RINKEVICHYUS, I. L. RASKOVSKAYA, A. V. TOLKACHEV

INVESTIGATION OF THERMOPHYSICAL PROCESSES IN A FLUID BY LASER REFRACTOGRAPHY

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The paper is devoted to the description of the application of laser refractography to the investigation of the termophysical processes occurring in fluids. The laser refractography is a novel measuring technique for the diagnostics of optically inhomogeneous flows of liquids and gases, based on the idea of using spatially structured probe laser radiation in combination with its digital recording and computer techniques for the differential processing of refraction patterns.

A description of the experimental setup that involves multicolored lasers designed to visualize temperature gradients in the fluid in two orthogonal planes is presented. The results of qualitative and quantitative visualization of temperature distribution in thin boundary layers near various heated and cooled bodies placed in water are shown. The results of the study of natural convection in water near bodies of various shapes under different conditions of heating and cooling are presented.

1-81 V. A. ROGACHEV, A. V. BARANYUK, A. A. KIRICHENKO

CFD MODELING OF HEAT TRANSFER AND FLOW IN CIRCULAR TUBES WITH TURBULATORS

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One of the effective methods of heat transfer enhancement in tubular heat exchangers can be the use of turbulizing inserts or change in the internal profile of a pipe. Because of the urgency of the problem, investigations of heat transfer and flow under the condition of air flow separation in circular tubes with agitators were carried out at the Kiev Polytechnic Institute. By means of ANSYS-FLUENT a numerical (CFD) model has been developed allowing one to perform calculations of heat and hydrodynamic parameters in a separated flow in the range of Reynolds numbers from $2 \cdot 10^3$ to $30 \cdot 10^3$. Verification of the applied numerical models was implemented using the coefficients of average heat transfer and hydrodynamic resistance obtained experimentally.

1-82 O. N. SEMKO,[1] Yu. P. IVOCHKIN,[2] I. O. TEPLYAKOV[2], O. V. KAZAK[1]

MODELING OF ELECTROVORTEX FLOWS IN A FINITE VOLUME OF LIQUID METAL

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Electrovortex flows (EVF) originating under the action of electromagnetic forces as a result of spatial inhomogeneity of the current density in a liquid conductor are observed in many technological processes: electroslag remelting process (including DC and AC EAFs, electrolysis

cells, and submerged-resistor induction furnaces), arc welding, semiconductor crystals growing, electrovortex engines, etc. Therefore, the elucidation of the regularities and characteristic features of EVF is of great theoretical and practical importance. The paper presents the results of modeling EVF for model problems of various technological processes.

1-83 A. A. SHAKHNOVSKAYA,[1] A. D. CHORNYI[2]

CALCULATION OF HEAT TRANSFER IN VITRIFICATION SYSTEMS WITH INTEGRATED HEATERS

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[2]*A.V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus*

The paper considers heat transfer in a laminated glass with an electrically conducting layer in the form of convex polygons. A model for estimating stationary heat transfer in such a glass during the passage of electric current through such an electrical conducting layer is presented. The model includes the two-dimensional Laplace equation for determining the electrical potential in the electrically conducting layer and boundary conditions with account for two current-supplying bars fixed on part of the glass contour. The theory of heat transfer through multilayer walls was used for temperature calculations.

1-84 Yu. I. SHANIN, O. I. SHANIN

HEAT TRANSFER AND HYDRAULIC RESISTANCE OF COMPACT SYSTEMS OF COOLING LASER MIRRORS

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Heat transfer between a porous material and a coolant flowing through it is characterized by high intensity because of the developed surface of their contact. Therefore, the use of permeable matrices in heat-exchange devices is one of the effective ways of process intensification.

In this paper, we consider the use of a porous element in a laser mirror, where it acts as a fin and it should meet the requirements: 1) high thermal conductivity of the skeleton, and 2) a perfect thermal contact with the heated surface.

Results of experimental investigation of hydraulic resistance, heat transfer, and their generalization for several cooling systems with different porous elements are given.

1-85 Yu. I. SHANIN, O. I. SHANIN

HEAT TRANSFER AND HYDRAULIC RESISTANCE OF SYSTEMS OF COOLING LASER MIRRORS FROM CORRUGATIONS

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The processes of hydrodynamics and heat transfer in cooling systems made of corrugations most closely correspond to processes in channels of triangular profile with some

special features: a) one-sided heating, b) departure of the profile of corrugated channels from the ideal triangular profile, and c) the presence of surface rughness and warpings on the walls.

The aim of this work was to carry out: a) analytical and experimental study of hydrodynamics and heat transfer of cooling systems on the basis of corrugated inserts, b) generalization of the data, c) determination of reasonable use of such systems for laser mirrors, d) development of recommendations for improving their characteristics and comparison of the results obtained with the results for channels of triangular cross section.

1-86 M. A. SHEREMET

NUMERICAL ANALYSIS OF CONJUGATE REGIMES OF NATURAL CONVECTIVE HEAT TRANSFER IN A SYSTEM OF PASSIVE COOLING OF SEALED ELECTRONIC CELLS

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The development of new sealed electronic devices is associated with the use of high enough powers in rather small volumes, which leads to a sharp increase in the scattered energy density. A detailed numerical analysis of the effect of finite-thickness heat-conducting solid walls on natural convection in an enclosure with a sustained power source located on the bottom surface of the analyzed system is performed. The process of heat transfer is described by means of Oberbeck–Boussinesq unsteady two-dimensional convection equations in the gas cavity and the transient two-dimensional heat conduction equation in the presence of volumetric heat generation in the heat source and the equation of transient two-dimensional heat conduction in solid walls. The mathematical model has been formulated in dimensionless variables such as the stream function, vorticity, and temperature. A numerical analysis has been carried out in a wide range of key parameters such as the Rayleigh number, thermal conductivity ratio, and the thickness of solid walls, reflecting the working conditions of natural convection for typical cooling sealed electronic devices. It was shown that the usage of the combined cooling system such as natural convection in the gas cavity and heat conduction in solid walls is more efficient. The correlations for the average Nusselt number at the heat source surface have been obtained.

1-87 A. P. SKURATOV

PROBLEMS OF MATHEMATICAL MODELING COMBINED HEAT TRANSFER IN HIGH-TEMPERATURE TECHNOLOGICAL PLANTS OF NONFERROUS METALLURGY

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The paper considers the problems of the use of the apparatus of mathematical modeling of combined heat transfer in improvement of power-intensive thermal technological processes and installations of nonferrous metallurgy. The problems of creating efficient and reliable equipment for new power- and resource-saving ecologically safe technologies, improvement of operating pyrometallurgical plants, and introduction of the methods of their intensification and optimum control have been solved. Mathematical models of various levels of complexity were used in

investigating the technological processes and installations for production of copper, aluminum and its alloys, casting of a number of precious metals and alloys.

1-88 S. D. SLEPTSOV, N. A. RUBTSOV

MATHEMATICAL MODELING OF RADIATIVE–CONDUCTIVE HEAT TRANSFER IN A MODIFIED CLASSICAL STATEMENT OF THE STEFAN PROBLEM

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Numerical simulation of a modified statement of the classical Stefan problem in semitransparent gray media with different optical properties of the boundaries is carried out. Thermodynamic justification of phase transition in equilibrium conditions taking into account the permeability of the boundaries for radiation is given. The temperature fields, the field is the resultant radiation flux, the dynamics of phase separation, and the evolution of the rise in the temperature of the left border of a sample are obtained. It is shown that the modified classical statement allows one to obtain stable results over a wide range of optical parameters of surfaces.

1-89 L. K. STANCHITS, K. L. STEPANOV, E. A. ERSHOV-PAVLOV, K. Yu. KATSALAP

MODELING OF SELECTIVE THERMAL RADIATION FROM A PLASMA OF COMPLEX CHEMICAL COMPOSITION

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B. I. Stepanov Institute of Physics, National Academy of Sciences, Minsk, Belarus

The paper describes the physical and computer models to calculate the selective radiation of laser plasma produced on exposure of the sample surface to nanosecond laser pulses. This model is used in the problems of laser-induced emission spectroscopy to determine the chemical composition of the target material. In this paper, we consider the model of hydrodynamics of a laser plume and the methods of calculating the line emission of erosion plasma.

1-90 N. I. STETYUKEVICH, V. F. SHEVTSOV, V. A. FIRAGO, M. V. KHILKO

INFLUENCE OF THE EMISSIVITY UNCERTAINTY ON THE RESULTS OF THERMOGRAPHIC CONTROL

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The error in the measurement of the temperature of an object due to the emissivity certainty and the influence of background is analyzed. The results of measurements of the temperature of metal surfaces in the conditions of heating are presented. Methods are suggested that provide minimization of the above-indicated error depending on the conditions of measurements and the parameters of the equipment used.

1-91 S. E. TARASEVICH, A. B. YAKOVLEV, A. V. SHISHKIN, A. A. GINIYATULLIN

CHARACTERISTIC FEATURES OF HEAT AND MASS TRANSFER IN CHANNELS WITH RIBBED TWISTED TAPE INSERTS

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The paper presents the results of investigation of heat and mass transfer in circular tubes with inserted twisted tapes with ribs discretely fixed at an angle to the tape axis. The experimental data are confirmed and supplemented by the results of numerical modeling. The ribs on the tape promote displacement of flow from the tape to the tube heat transfer surface. An analysis of the flow structure and heat transfer in laminar and turbulent regimes and an analysis of velocity profiles in these channels are carried out. The possibility of effective use of twisted tape inserts with ribs for heat and mass transfer enhancement in tubes is shown.

1-92 V. I. TEREKHOV,[1] A. V. CHICHINDAEV,[2] A. L. EKAID[1,2]

TURBULENT FREE CONVECTION BETWEEN VERTICAL PARALLEL PLATES WITH ASYMMETRYCAL HEATING

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[2]*Novosibirsk State Technical University, Russia, terekhov@itp.nsc.ru*

The paper presents the results of numerical investigation of flow and heat transfer in the presence of turbulent free convection between vertical parallel isothermal plates with different temperatures. The temperature factor varied in the limits $R_T = -2–1$. The Rayleigh number varied within the range $Ra = 10^7–10^9$, with the ratio between the geometric dimensions of plates and distances between them being constant, $A = L/w = 10$. The presented data on the distribution of velocities and temperatures between the plates, on the local and integrated heat transfer coefficients allow one to more deeply understand the mechanism of transfer processes between parallel plates with asymmetric heating.

1-93 V. I. TEREKHOV, A. D. NAZAROV, A. F. SEROV

INFLUENCE OF CO-CURRENT AIR FLOW PARAMETERS ON HEAT TRANSFER OF PULSE SPRAY

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It is shown experimentally that artificial perturbations introduced into a gas–droplet flow intensify heat exchange between a jet and a heated surface. Great prospects for increasing the efficiency of heat exchange open for the use of controlled aerosol sources in cooling systems. Depending on a heat load of a heat exchanger, such systems allow one to set the parameters of a cooled gas–droplet flow by changing the duration, frequency, and place of supplying the liquid part of the flow to the surface of the heat exchanger, creating the optimum heat transfer mode. The paper

contains the results of an experimental investigation of pulsed gas–droplet heat flux and a flat heat exchanger. The report presents the results of investigations of the influence of a co-current gas flow on the local and integral heat transfer.

1-94 V. I. TEREKHOV, V. V. TEREKHOV

NUMERICAL SIMULATION OF MIXED-CONVECTIVE HEAT TRANSFER IN A VERTICAL CHANNEL WITH A SYSTEM OF DISCRETE HEAT-RELEASING ELEMENTS

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The results of numerical investigation of mixed convection in a vertical channel with parallel walls and a system of discrete heat-releasing elements on one of them are presented. The effect of Reynolds and Grashof numbers, as well as the size of the elements on local and integral heat transfer has been investigated. Contribution of forced and free convection to the total heat transfer was analyzed. The similar and distinctive features of the behavior of local and averaged heat transfer on variation of thermal, dynamic, and geometrical parameters are shown.

1-95 V. I. TEREKHOV, N. I. YARYGINA

CURRENT STATE OF EXPERIMENTAL STUDIES OF HEAT TRANSFER IN TURBULENT SEPARATED FLOWS

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Experimental investigations of heat transfer in turbulent separated flows are considered. The emphasis is placed on changes in the thermal characteristics of the separated region, exposed to high velocity fluctuations at increased free stream turbulence, or to the vortex sheet behind a miniturbulator placed upstream of separation. Visualization of the flow and measurements of pressure, temperature, and velocity fields together with fluctuation values ensured a deeper understanding of the nature of complex interrelated processes in turbulent separated flows. We compared these methods and showed the advantage of each of them. Both methods alter the structure and heat transfer in a separated flow significantly.

1-96 A. V. TETEREV,[1] K. L. STEPANOV,[2] N. A. TETEREV[3]

SIMULATION OF THE FALLING OF FRAGMENTATED SPACE OBJECTS

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The Sand Bag model for simulating the falling of an initially destroyed space body in the form of a swarm of separated fragments is described. The results of numerical simulation of the

parametric calculations performed are presented. The characteristic features of the separation of space object fragments and formation of a common shock wave are discussed. Data on the passage of the largest fragments of a body through the shock wave front are obtained. Their further falling proceeds individually outside the cloud of fragments.

1-97 M. S. TRET'YAK,[1] V. V. CHUPRASOV,[1] A. F. KLISHIN[2]

INFLUENCE OF THE NOZZLE PROFILE ON THE CHARACTERISTICS OF A SUPERSONIC FLOW AND ITS EFFECTS ON A BARRIER

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Investigations of the destruction of heatproof material are usually carried out in high-temperature supersonic jets. The velocity of the entrainment of samples depends on the distribution of gas-dynamical parameters over the jet radius and sample edge. In supersonic jets, the barrier experiences the action of the jet core, hanging shock, oblique shocks, and the region of mixing of a jet with the surrounding medium. The paper presents the parameters of the under- expanded and calculated supersonic jets and the results of their interaction with organic glass and Teflon samples are presented. It is shown that in the regions of action of the mixing layer and oblique shocks, an increase in the thermal and dynamic loading leads to an increase in the entrainment velocity and sharpening of samples.

1-98 N. M. TSIREL'MAN

JUSTIFICATION OF THE COMPLETE STRUCTURE OF SIMILARITY EQUATIONS INVOKING FUNDAMENTAL RELATIONS OF THE HEAT TRANSFER THEORY

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Similarity equations for describing convective heat transfer are derived with the aid of the methods of physical modeling. The structure of the corrections which are contained in them and which take into account the influence of the variable properties of the medium on the heat transfer intensity lacks theoretical justification and relies only on the intuition of researchers. Based on dimensionless equations of convective heat transfer, dimensionless equations (for Nu and St) taking into account the influence of the variable properties of the medium on heat transfer intensity have been obtained.

1-99 A. A. TSYNAEVA, E. A. TSYNAEVA

SIMULATION OF HEAT TRANSFER ENHANCEMENT IN A SUPERSONIC PIPE BY TEMPERATURE STRATIFICATION WITH THE USE OF HEAT PIPES

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Nowadays, the pressure reduction is the most common method of regulation of gas supply systems. Usage of isothermal gas pressure regulators on the basis of thermal stratification is one of the promising ways of cost reduction. Isothermal regulation requires an increase of efficiency in the thermal stratification, which can be attained by means of heat pipes. The paper presents an analysis of the possibility of increasing the efficiency of a supersonic pipe of temperature stratification by means of heat pipes made in the form of longitudinal fins on the heat transfer surface.

1-100 V. D. TYUTYUMA

AN URGENT PROBLEM OF HEAT TRANSFER IN A FLOW OF A VISCOUS COMPRESSIBLE MEDIUM

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The problem of introduction of wave notions and the possibility of carrying out a deciding experiment in the hydrodynamics of viscous flows are discussed.

1-101 Yu. V. VIDIN, D. I. IVANOV, R. V. KAZAKOV

APPROXIMATE METHOD FOR CALCULATING THE TEMPERATURE DISTRIBUTION IN A RECTANGULAR FIN ON HEAT REMOVAL BY RADIATION FROM ITS SURFACE

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Finned surfaces are widely used in technique for significant intensification of heat transfer processes. In many cases, heat exchange between extended surfaces and the environment is carried out mainly by radiation. In the literature you can find an analytical solution of this problem, which, however, is of very complicated mathematical nature and thus inconvenient for practical calculations. More appropriate is an approximate solution of this problem. The paper suggests a method for calculating the temperature field of a rectangular fin with the aid of analytical relationships. The approach can be used for finned surfaces of various configurations, as well as for convective-radiative heat transfer.

1-102 Yu. A. VINOGRADOV, K. S. EGOROV, S. S. POPOVICH, M. M. STRONGIN

EXPERIMENTAL INVESTIGATION OF HEAT AND MASS TRANSFER ON PERMEABLE SURFACE IN A SUPERSONIC BOUNDARY LAYER

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A vast statistical information on experimental investigation of heat and mass transfer processes in high-speed gas flows on permeable surfaces has been accumulated by now. However, up to now the problem on the influence of the intensity on the temperature recovery factor has not been resolved unambiguously. This factor is one of the determining characteristics in carrying out engineering calculations of compressible gas flows around thermally stressed surfaces. The urgency

of the statement of the problem and the technique of studying heat and mass transfer on a permeable surface in a supersonic boundary layer are discussed. The paper also contains the description of experimental equipment and of the results of conducted experiments.

1-103 I. V. VOSHCHULA, V. A. DLUGUNOVICH, A. Yu. ZHUMAR

BIDIRECTIONAL REFLECTION OF POLARIZED RADIATION BY THERMOCONTROLLING COATINGS AND HEAT SHIELDING MATERIALS

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For calculation of the radiative heat transfer of spacecraft systems, information on the angular distribution and polarization characteristics of radiation scattered by thermocontrolling coatings and heat shielding materials is required. The parameters of the Stokes vector of radiation scattered in the range from 5° up to 85° by thermocontrolling coatings (silvery, black, and silver paints) applied to aluminum and polymer composite materials (phenolic plastic coated with green paint and carbon fiber reinforced plastic) illuminated with He–Ne laser radiation were investigated. The parameters that allow one to calculate the function of the distribution of bidirectional reflectance of the investigated materials illuminated with both linearly polarized and unpolarized radiation at any geometry of illumination and observation have been determined.

1-104 Yu. V. ZHUKOVA, A. D. CHORNYI

HEAT TRANSFER ENHANCEMENT IN A HEAT CARRIER FLOW IN TUBES WITH INNER LONGITUDINAL FINNING

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Gas boilers are intended for water heating in heating and hot water supply systems. The technical and economical study has shown that the shortening of the axial length of a heat exchanger and reducing the gas pressure drop over the gas path are promising tasks of improving the commercial efficiency of boilers. The paper presents our results on tube finning optimization and on the development of the methods of heat transfer enhancement.

1-105 Yu. V. ZHUKOVA,[1] A. M. TEREKH,[2] S. A. ISAEV,[3] E. N. PISMENNYI[2]

NUMERICAL SIMULATION OF AERODYNAMIC CHARACTERISTICS AND OF HEAT TRANSFER OF ROUND TUBE BUNDLES WITH OUTER INTENSIFIERS IN A CROSS FLOW

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[2]*National Technical University of Ukraine "Kiev Polytechnical Institute", Kiev, Ukraine*
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The development of passive heat transfer enhancement methods is of interest from the viewpoint of improving the efficiency of heat exchanging equipment when it is being designed and updated. The present paper covers the numerical simulation results on the aerodynamic characteristics and heat transfer of round in-line tube bundles in a cross flow The bundles are provided with outer intensifiers located in the rear part of the tube. In addition, for a computational algorithm, use is made of the experimental data on heat transfer of a single tube equipped with plates over the Reynolds number range corresponding to the transient regime in the tube wake.

1-106 O. ZIKANOV, Ya. LISTRATOV, E. SVIRIDOV, V. SVIRIDOV, D. OGNERUBOV, D. KRASNOV

DIRECT NUMERICAL SIMULATION OF MIXED CONVECTION IN A HORIZONTAL PIPE WITH A STRONG TRANSVERSE MAGNETIC FIELD

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The paper presents the results of direct numerical simulations of mixed convection in a liquid metal flow in a horizontal pipe with a constant transverse magnetic field. The pipe walls were electrically insulated and the lower part of the pipe was subjected to heating. The simulations show agreement with experimental observations and provided insight into the dominant mechanisms of the flow. In particular, it was found that, in the case of strong magnetic fields at Hartmann numbers far exceeding the laminarization threshold, natural convection becomes a major factor resulting in strong fluctuations of temperature field.

1-107 RE. ZUJUS, R. POŠKAS, A. GEDIMINSKAS

NUMERICAL SIMULATION OF AIDING MIXED CONVECTION IN A VERTICAL FLAT CHANNEL

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Many researchers analyzed laminar and turbulent mixed convection in channel flows, but despite wide investigations there are still many cases, which are not well understood and difficult to predict. Investigations of heat transfer in the laminar–turbulent (transition) region under the effect of buoyancy are rather limited. In this paper we present the results on numerical investigation of the local aiding mixed convection heat transfer in the laminar–turbulent (transition) region in a vertical flat channel. Numerical three-dimensional steady-state simulations were performed using the Ansys Fluent code in air flow. The results of modeling demonstrate that a circular flow takes place near heated walls.

SECTION 2

HEAT AND MASS TRANSFER IN PHASE TRANSFORMATIONS

2-01 S. P. AKTERSHEV

HEAT TRANSFER IN CONDENSATE WAVE FILM FLOW

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The influence of waves on heat and mass transfer in a condensate film flowing down an isothermal substrate is investigated by numerical methods. To describe the wavy character of film flow, the IBL model is applied in which the parabolic profile of velocity of a liquid is supposed. In simulations, waves were generated by small perturbations of the flow rate at the entrance of the computational domain. If the frequency wave belongs to the area of instability, perturbations increase rapidly in the direction of flow and evolve into quasi-stationary traveling waves. In the zone of quasi-steady waves there occurs an appreciable intensification of heat transfer in comparison with a smooth film. The influence of thermophysical and hydrodynamic parameters on the intensification of heat transfer by waves in a film is studied.

2-02 S. P. AKTERSHEV, V. V. OVCHINNIKOV

FORMATION OF EVAPORATION FRONT IN A LAYER OF HIGHLY OVERHEATED LIQUID

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Boiling-up in a strongly superheated near-wall layer of liquid under the conditions of saturation and subcooling in the volume below a saturation temperature is investigated. At overheats above some threshold value, evaporation fronts appear due to the development of interphase instability in the zone of contact of a vapor bubble with the heater surface. The fronts translocate along the heater with a constant velocity. Behind the front of evaporation, a cone-shaped vapor cavity is formed. A mathematical model that describes the dynamics of such a vapor cavity after the incipience of boiling has been developed. The results of numerical simulation agree well with available experimental data. The model gives an adequate description of both the growth of a primary vapor bubble and the shape of the conical vapor cavity.

2-03 M. AIT SAADA,[1] S.CHIKH,[1] L. TADRIST,[2] S. RADEV[3]

DROP EVAPORATION ON AN ISOTHERMAL OR ADIABATIC SOLID SURFACE

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[3]*Department of Fluid Mechanics, Institute of Mechanics, BAS, Sofia, Bulgaria*

The problem of evaporation of a small water drop on solid adiabatic and isothermal surfaces is considered. A numerical analysis is carried out using the diffusion model, which accounts for heat conduction in both liquid and gas phases, as well as water vapor diffusion in the surrounding air. The temperature field in the liquid drop and the concentration field in the gas are coupled through the law for the variation in the saturation concentration at the interface with temperature. The numerical results obtained by the finite volume method show that the life time of an evaporating water drop on an adiabatic solid surface is far longer than that on isothermal one.

2-04 F. G. AKHMADIEV, R. R. FAZYLZYANOV, R. A. GALIMOV

NONISOTHERMAL FLOW OF TWO-PHASE MEDIA ON PERMEABLE SURFACES

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The flow of heterogeneous media with complex rheological behavior on impermeable and permeable surfaces is encountered in many industrial processes. It is often necessary to maintain a certain temperature regime in a mixture film. In this regard, we consider the description of nonisothermal film flow of two-phase media for the zone of developed thermal layer with account for carrier phase filtering through the flow surface. To solve this problem, we use an adapted method of surfaces of equal flow rates. Numerical calculations for the case of a stationary nonisothermal film flow of a two-phase media down an inclined permeable surface and a conical region in the field of centrifugal forces were performed, and mutual influence of various parameters on the hydrodynamic conditions has been established.

2-05 P. V. AKULICH,[1] A. V. AKULICH,[2] A. V. TEMRUK[3]

SIMULATION AND EXPERIMENTAL INVESTIGATION OF HEAT AND MOISTURE TRANSFER UNDER CONDITIONS OF SHF CONVECTIVE DRYING OF VEGETABLE MATERIALS

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The results of investigation of heat and moisture transfer under conditions of combined SHF convective drying of vegetable materials are discussed. The dependences of the kinetics and dynamics of the process on the operating parameters, in particular, on the intensity of the SHF influence have been determined. The results of numerical simulation agree satisfactorily with the experimental data. The model presented and the results of experimental investigations can be useful

for optimization of the technological parameters and controlling the process of combined SHF convective drying of vegetable materials.

2-06 E. S. ALEKSEIK, V. Yu. KRAVETS

EFFECT OF THE NUMBER OF TURNS ON THE HEAT TRANSFER CHARACTERISTICS OF A SINGLE TURN OF OSCILLATING HEAT PIPES

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Oscillating heat pipes have wide perspectives of being used as heat transfer devices due to the simplicity of construction and high heat transfer characteristics. Therefore this type of heat pipes is of great interest for research workers. One of the methods of investigation of these objects is separation of a single turn as an element of oscillating heat pipe. The paper presents the description of an experimental setup for investigation of heat transfer characteristics of a single turn. The results of investigations are presented, the effect of the number of turns on the heat transfer characteristics of a single turn is shown, and main working regimes of oscillating heat pipes are described.

2-07 V. G. BAIDAKOV,[1] A. M. KAVERIN,[1] V. N. ANDBAEVA,[1] A. O. MAKSIMOV,[2] A. S. PANKOV[1]

INITIATION OF BOILING-UP OF SUPERHEATED CRYOGENIC LIQUIDS

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The development of the methods of initiating the boiling-up of a superheated liquid and the theoretical description of this process are the topical scientific and engineering problems. In the paper we discuss three ways of initiating phase transitions: activated points on the surface coming in contact with the liquid, low-boiling additives, and ionization radiation. To investigate the boiling-up of superheated liquids, we used two methods: measurement of the time till the incipience of boiling and continuous lowering of pressure. It is shown that the values of the liquid superheatings of liquids in glass and copper pipes are close, even though there are systematic discrepancies in both the superheating absolute value (less superheating in copper pipes) and in the nucleation rate log isobar slope. An analytical expression for the nucleation rate on a surface with defects in the form of spherical depressions whose radius is Gaussian distributed is presented.

2-08 B. I. BASOK, T. A. REZAKOVA

INVESTIGATION OF TEMPERATURE AND CONCENTRATION FIELDS IN AN UNDERGROUND POROUS STRATUM

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With the aid of the Phoenics program package, the filtration processes in an underground permeable collector upon injection of a liquid into it are considered. The time dependences of the injected liquid velocity for a real gas-saturated water-bearing stratum have been obtained. The indices of using a geothermal cogenerating plant operating on gas-saturated thermal water have been estimated.

2-09 V. A. BATOV, O. E. KHARICHEV, G. I. EFREMOV

DESCRIPTION OF DRYING KINETICS WITH THE INNER PROBLEM BEING LIMITED BY THE MINIMUM OF EXPERIMENTAL DATA

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The description of drying kinetics with limitation of the inner problem by modified quasi-stationary method (MQSM) at a minimum number of experimental data is given. The application of MQSM to the drying kinetics at different temperatures of wheat grain drying is considered. Literature data were used. If the index of hydrodynamic activity m in the process of drying remains constant in the entire range of temperatures, then to construct any drying kinetics line it is sufficient to know only one experimental point of this line. Equations for calculations of drying kinetics are given.

2-10 A. E. BERGLES,[1] A. S. KOMENDANTOV,[2] A. F. KRUG, [2] Yu. A. KUZMA-KICHTA,[2] E. D. FEDOROVICH[3]

INVESTIGATION OF BOILING CRISIS IN TWISTED FLOWS

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[2]*National Research University MPEI, Moscow, Russia*
[3]*Joint Boiler and Turbine Institute, St. Petersburg, Russia*

The present paper is devoted to investigation of boiling crisis in twisted flows. The databank of world-known investigations of critical heat fluxes (CHF) in twisted flows amounts to 881 points from 21 sources. Equations for calculating the CNF in twisted flows generated by using twisted tapes inside tubes on the basis of experimental data for both subcooled and saturated boiling are proposed. These equations describe over 85% points of the CHF array for subcooled and saturated swirled flow within ±30%. The influence of heated length on q_{CHF} is described by the correlation that involves the pressure effect. The equations are recommended for the following ranges of parameters: tube inner diameter $1.6 < d < 20$ mm, heated length $0.95 < L_H/d < 480$, tape twisting ratio $1 < y < 34.5$, pressure $0.1 < p < 20.1$ MPa, mass flux $200 < \rho W < 39{,}000$ kg/m^{2}s, and exit quality $0.45 < x < 0.95$.

2-11 M. K. BOLOGA, F. P. GROSU, I. V. KOZHEVNIKOV, A. A. POLIKARPOV, O. V. MOTORIN

HEAT TRANSFER IN ELECTROHYDRODYNAMIC PUMPING OF A TWO-PHASE HEAT CARRIER

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The problems of heat and mass transfer in an evaporative-condensing system (ECS) containing an electrohydrodynamic (EHD) ”needle--ring”-type pump are considered. In contrast to traditionally used EHD converters embedded into ECS, in this investigation it is a separate part of the loop, which provides a higher efficiency and reliability confirmed by experimental data on heat and mass transfer. The dependences of the temperature of the heat-releasing surface on the interelectrode potential difference and heat fluxes are presented. The dynamics of vapor bubbles at the exit of the evaporative region and the change in the local heat transfer coefficient are described. It is proposed to use electric Reynolds number, taking into account the velocity of electric wind in the EHD converter, in the dimensionless equations because the heat transfer coefficient depends on the current of the EHD pump. Directions of further investigations in the area of experimental data generalization by means of dimensionless equations aiming at their practical application are given. The obtained results are interesting from the scientific point of view and can be used for enhancing and thermostating various processes and devices.

2-12 E. A. BONDAREV, I. I. ROZHIN, K. K. ARGUNOVA

INFLUENCE OF NONISOTHERMAL EFFECTS ON GAS PRODUCTION IN NOTHERN REGIONS WITH ACCOUNT FOR THE POSSIBLE HYDRATE FORMATION IN THE WELL BOTTOM HOLE

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The influence of mathematical model parameters on the dynamics of pressure and temperature fields during nonisothermal gas filtration is investigated in a numerical experiment. A nonlinear system of partial differential equations obtained from the energy and mass conservation laws and the Darcy law was used to describe the process, and physical and caloric equations of state were used as closing relations. The boundary conditions correspond to gas sampling at the given pressure at the bottom of the hole. It is shown that the influence of the temperature field on such integral characteristic as cumulative gas production is most pronounced at moderate pressure drops. The size of the possible zone of hydrate formation in a gas-carrying pool is determined for some real production histories.

2-13 G. P. BROVKA, K. A. AGUTIN

SIMULATION OF TEMPERATURE AND MOISTURE CONDITIONS AND FROST HEAVING IN FREEZING DISPERSE MEDIA

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To simulate the temperature and moisture conditions and frost heaving in freezing disperse media, a mathematic model, computational scheme, and an algorithm for numerical calculation have been developed and implemented as computer software. The basis for the mathematical model is represented by the equations of state accounting for the dependence of the water phase composition on temperature, filling of the pores of the material, and the hydrostatic pressure as well

as equations of transfer of water and water-soluble compounds, structure rebuilding of skeletal material during the freezing process.

2-14 G. P. BROVKA, K. V. PYATKEVICH

TECHNIQUES OF NUMERICAL SIMULATION OF COUPLED HEAT AND MOISTURE TRANSFER PROCESSES AND OF THE STRESSED–STRAINED STATE OF ROCKS

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Techniques of numerical simulation of coupled heat and moisture transfer processes, as well as of the formation of the stressed-strained state in rocks have been developed. A modified two-dimensional structural elements' method taking into account the variation of Poisson's ratio on a large scale is proposed for solving the problems of the stressed-strained state of rocks with axial symmetry but heterogeneous along the axis. Generally, when 3-directional heterogeneities take place and 3-dimensional formulation of appropriate problems is required, a fundamentally new approach based on a 3-dimensional cubical grid and intercoupling of control volumes is suggested.

2-15 O. G. BURDO, G. F. SMIRNOV, S. G. TERZIEV

HEAT TRANSFER IN VAPORIZATION ON PROFILED SURFACES OF LOW-TEMPERATURE HEAT PIPES

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The problem of vaporization on profiled heat exchange surfaces (PS) is considered. The results of analytical and experimental modeling of vaporization processes on PS are presented. The possibility of existence of 3 vaporization regimes on PS such as vaporizing, vaporizing-pulsating and boiling is substantiated. The vaporizing regime rate was analyzed by the method of electrothermal analogy. Generalizing relations have been obtained. The regimes of boiling were studied on an experimental test bench arranged by the principle of a heat concentrator. The conditions of transition from the vaporizing-pulsating regime to boiling have been established. The generalization of the authors' experimental results and literature information for boiling on copper, steel, and aluminium surfaces is carried out.

2-16 O. G. BURDO, G. F. SMIRNOV, S. G. TERZIEV

TRANSFER PROCESSES IN HEAT PIPES IN LONG SERVICE AND THE PROBLEM OF THEIR RESOURCE

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The voluminous information on heat pipes (HP) resource characteristics has been analyzed. The methods of speeded up HP resource tests carried out by the authors is substantiated.

Three stages of HP operation are substantiated: run-in, regular aging regime, and fault. Time intervals of these stages are ascertained. Correlations for calculation the HP thermal resistance during long service of HP of different constructions are obtained. The principle of generalization of the HP resource characteristics is suggested. It is shown how the results of HP resource tests carried out by the authors and many other researchers are coordinated with the help of the generalized aging curve.

2-17 O. G. BURDO, I. I. YAROVOI, O. M. KURAKOV

COMBINED PROCESSES IN RAW MATERIAL DEHYDRATION

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Moisture transfer schemes and mechanisms in dehydration of capillary-porous materials are considered. The mechanical, thermal, and diffusive mechanisms for different forms of moisture bond are analyzed, and the driving forces and the coefficients of the rate of the processes are estimated. The prospect of dehydration in the field of the microwave frequencies range is shown. A new generalized complex that takes into account the specificity of micro- and nanokinetics of moisture transfer in products is proposed. The explanation of the mechanism underlying the barodiffusive moisture transfer in a product is given. The results of experimental investigations are presented in which specific energy of 1.9 MJ per 1 kg of removed moisture is reached. The tests results of a band drier with microwave and infrared energy generators are presented.

2-18 K. A. BUSOV, A. V. RESHETNIKOV, N. A. MAZHEIKO

REACTIVE FORCE OF SUPERHEATED LIQUID JETS AT OUTFLOW THROUGH A SLIT CHANNEL

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The results of experimental study of the characteristics of boiling liquid jets–the shape of the jet and its reactive force at outflow through a short slit channel – are discussed. Water, ethanol, aqueous ethanol were used as tested substances in our experiments. The studies were conducted at the initial parameters (temperature, pressure) corresponding to the saturation line and at a fixed pressure. In this work, the critical phenomena in the behavior of both the jet shape and the reactive force of superheated liquid jets flowing through the short slit channel have not been revealed.

2-19 V. N. BUZ, K. A. GONCHAROV, G. F. SMIRNOV

ON THE ROLE OF SURFACE TENSION FORCES IN HEAT TRANSFER IN FILMWISE CONDENSATION

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The results presented by the authors in the paper show that: 1.The filmwise condensation under the conditions of suction is accompanied by strong and nonmonotonic changing in the pressure gradient along the film length. The assumption about its constancy is wrong. 2. The great changes in the pressure gradients lead to great changes in the condensate film thickness. 3. At small intensities of suction it is possible to consider the change to be linear. The authors present a numerical analysis of the two most typical cases of filmwise condensation on microfinned surfaces: a) on triangular fins and b) on rectangular ones.

2-20 S. I. DMITRIEV, P. S. GRINCHUK, N. V. PAVLYUKEVICH

MATHEMATICAL MODEL AND EXPERIMENTAL RESULTS FOR THE PROCESS OF FORMATION OF CARBON BLACK IN HIGH-TEMPERATURE GAS MIXTURES

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An experimental setup for producting carbon black with productivity of up to 10 kg/h has been developed. Its principle of operation is based on spraying liquid hydrocarbon in a gas flow with a temperature of 1300–1500°C. During experiments, the physical and technological parameters of the process were determined, as well as the structure of the carbon black obtained was studied. A mathematical model of evaporation of hydrocarbon raw material droplets in the high-temperature gas flow has been formulated. This model describes the temperature, variation of diameter, density, and velocity of droplets during their flight in the reactor channel. The distance over which the hydrocarbon fluid droplets evaporate completely was calculated depending on the process parameters. It is shown that the evaporation of hydrocarbon droplets is not the rate-determining stage of the technological process of carbon black production.

2-21 O. R. DORNYAK,[1] L. V. MARKOVA[2]

NUMERICAL MODELING OF TRANSFER PROCESSES IN THE VAPOR–GAS PHASE UNDER CONDITIONS OF THERMAL TREATMENT OF COLLOIDAL CAPILLARY-POROUS MATERIALS

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Numerical investigations of the processes of heat and mass transfer in a three-phase nonsaturated colloidal capillary-porous medium is carried out. Characteristic features of the development of vapor concentration fields, as well as pressure and speed in the gas phase at intense thermal effects are considered on the basis of the three-temperature mathematical model.

2-22 G. I. EFREMOV

FINDING THE TEMPERATURE DEPENDENCE FOR THE FIRST PERIOD OF DRYING BY THE METHOD OF PLANNING AN EXPERIMENT

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The drying kinetics in the 1st period of drying is described by the linear dependence of the moisture content of material (kg of moisture/kg of dry material) vs. the drying time. The 2^2 factorial experiments are considered for finding the temperature dependence for the first period of drying.

A comparison between the prediction with the use of the general equation of the process and experimental data for convective drying of cotton fabric in the 1st period of drying for two temperatures (48 and 83°C) is made. The experimental data correspond well to the lines obtained by the factorial design, which means that this method can be used successfully to determine the temperature dependence when there is a limited number of experimental data.

2-23 R. Sh. ENALEEV,[1] A. F. GABIDULLIN,[2] É. Sh. TELYAKOV,[1] G. M. ZAKIROV[3]

HEAT AND MASS TRANSFER IN A PACKAGE OF CLOTHES SUBJECTED TO INTENSIVE HEATING

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[3]*"Nizknekamsneftekhim" Joint-Stock Company, Nizhnekamsk, Russia*

For the first time, the dynamic index for evaluating the consequences of exposure to variable heat flows has been justified. The results of experimental investigations of simultaneous heat and mass transfer in the «package of clothes–skin cover» system are presented. A computational–experimental method to predict different degrees of burns caused by dynamic heating is suggested.

2-24 G. V. ERMAKOV, E. V. LIPNYAGOV, S. A. PERMINOV

A REVIEW OF EXPERIMENTAL AND COMPUTATIONAL WORKS ASSOCIATED WITH THE EVALUTION OF THE VALIDITY OF THE CLASSICAL THEORY FOR HOMOGENEOUS BOILING-UP OF SUPERHEATED LIQUIDS

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In this work, the fundamentals of the classical nucleation theory have been checked experimentally. The density of distribution of the probabilities of liquid boiling-ups in a given time has been measured. On the basis of probabilistic analysis, the hypothesis of distribution exponentiality is rejected. We calculated the radius of a critical bubble by the Gibbs formula and from the slope of the experimental temperature. The dependence of the theoretical and empirical work, related to the empirical one, is 23–159% and even 350%, which greatly exceeds the calculation error. With the help of high-speed video filming it is shown that the boiling-up of a superheated liquid always takes place on the wall of its vessel in separate reproducing centers.

2-25 M. Z. FAIZULLIN, V. P. KOVERDA, A. V. VINOGRADOV

VITRIFICATION AND CRYSTALLIZATION OF LOW-TEMPERATURE AMORPHOUS CONDENSATES OF WATER–METHANE AND WATER–PROPANE MIXTURES

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Low-temperature condensates of water–propane and water–methane mixtures were investigated in the temperature range 65–200 K. Amorphous samples were obtained by molecular beam deposition under vacuum conditions on a substrate cooled by liquid nitrogen. The vitrification and crystallization temperatures were determined from the changes in the dielectric properties of condensates on heating. The temperature conditions for the growth of thick methane crystalline hydrate layers during the low-temperature condensation of molecular water–gas mixture beams have been found.

2-26 M. A. FATYKHOV, L. M. FATYKHOV

EXPERIMENTAL STUDY OF PHASE TRANSITIONS IN AN ELECTROMAGNETIC FIELD

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The phase transition of the type of melting or crystallization is characterized by two operating parameters: temperature and specific melting heat. The latter operating parameter is defined in terms of the change in entropy during transition from one state into another and of the temperature of fusion. It was established with the help of the methods of thermodynamics of irreversible processes that in a high-frequency electromagnetic field the change in the entropy of the substance is possible. The physics of this process has not been studied. The paper expounds the theory, methods, and the results of experimental studies of temperature and heat of fusion of paraffin wax in a high-frequency electromagnetic field.

2-27 M. A. FATYKHOV, S. B. SHAGAPOV

ENTHALPY APPROACH TO THE STUDY OF PHASE TRANSITIONS IN ELECTROMAGNETIC HEATING OF DEPOSITS IN A COAXIAL SYSTEM

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The formation of plugs in pipelines and boreholes caused by fallout of gas-hydrates and paraffins is a frequent complication in oil- and gas production. One of the most efficient methods of bulk heating is the heating by high-frequency electromagnetic waves. The attempts at describing this phenomenon on the basis of the classical Stefan problem have led to the results contradictory to the physics. A mathematical model of integrated Stefan problem is adopted in this paper in order to obtain the initial technological operating parameters of the process investigated. The paper describes this model in application to the process of heating and paraffin wax fusion in the trunk of oil well, and as well as the results of numerical investigations.

2-28 A. I. FILIPPOV,[1] O. V. AKHMETOVA,[2] G. F. ZAMANOVA[1]

FILTRATION-WAVE FIELDS IN A HETEROGENEOUS POROUS MEDIUM

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The "on the average exact" asymptotic method of investigation of wave fields in the layered heterogeneous porous medium in application to the problems of acoustic carottage and seismic exploration of oil and gas fields has been developed. Dependences of the speed of wave and also of the attenuation factors on frequency are constructed. Analytical formulas for the wave fields up to the second order of expansion have been found. It is shown that "on the average exact" expressions of wave perturbations in the zero and first approximations coincide with the expansion coefficients of the exact solution by the asymptotic parameter.

2-29 A. I. FILKOV, A. M. GRISHIN, D. A. GLADKII

PARAMETRIC ANALYSIS OF A MATHEMATICAL MODEL OF DRYING A PEAT LAYER

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Peat fires occur regularly. Despite the extensive rains or attempts of fire fighters, it is very difficult to extinguish them. At the same time, a scientifically based system of fire prediction has not been developed as yet.

One of the fundamental factors influencing the initiation of peat fires is the ability of plant fuels (PF) to ignite and propagate fire, i.e., a condition under which a fire can propagate spontaneously along the layer of PF. It is obvious that they are directly connected with the moisture content and drying of PF. Therefore, the solution of the problem of drying PF is of great importance for predicting fire hazard.

The paper presents a one-temperature mathematical model of drying a peat layer. Using the results of numerical calculations, we analyze the changes in the initial volume fractions of phases, pressure, and temperature for various time intervals. The mathematical study conducted shows that the numerical results obtained are in qualitative and quantitative agreement with experimental data.

2-30 M. N. GAMREKELI

COLD AS THE ENERGY SAVING FACTOR IN TWO-STAGE DRYING OF DISPERSE MATERIALS

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The design procedure and technical and economic indices of a two-stage process of drying disperse materials are considered. After the first high-temperature drying stage, the drying air, preliminarily drained by cooling as a result of condensation or freezing of a moisture contained in it

is used at the second stage, with subsequent heating at the expense of utilization of the heat of the first drying stage exhaust air. The redrying of the product at the second stage is carried out due to the occurrence of the high interphase moisture transfer potential. In addition to the increase in the heat-using efficiency, the fire danger of the process decreases due to the decrease of the drying air final temperatures.

2-31 B. M. GASANOV,[1] N. V. BULANOV[2]

BOILING OF EMULSIONS WITH A LOW-BOILING DISPERSED PHASE ON THE SURFACE OF A WIRE HEATER

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[2]*Ural State University of Railway Transport, Ekaterinburg, Russia, NBulanov@usurt.ru*

The paper presents the results of an experimental investigation of heat transfer from thin platinum wires to emulsions with a low-boiling dispersed phase. The nucleation, growth, and detachment of vapor bubbles during boiling on a horizontal and vertical heated surface were shown. The dependence of the temperature of a delay in the beginning of boiling on the emulsion concentration has been obtained.

2-32 I. A. GISHKELYUK,[1] N. N. GRINCHIK,[2] S. P. KUNDAS[1]

NUMERICAL SOLUTION OF THE SYSTEM OF EQUATIONS FOR NONISOTHERMAL TRANSFER OF MOISTURE AND DISSOLVABLE SUBSTANCES IN CAPILLARY-POROUS MEDIA

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[2]*A.V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus*

A mathematical model of nonisothermal moisture and solute transfer in capillary-porous media has been developed. The numerical method of solving the equations of nonisothermal moisture and solute transfer that is based on the weighted residual method has been suggested. The method mentioned is distinguished by the unconventional splitting of the problem with respect to physical processes. Such an approach made it possible to raise the accuracy of the solution and accelerate its convergence.

2-33 N. M. GORBACHEV, N. L. SOLNTSEVA, K. G. CHIZHIK, O. V. PROKOPOVICH

STUDY AND DEVELOPMENT OF THE METHODS OF ACCELERATED DRYING AND MODIFICATION OF WOOD FOR IMPARTING NEW CONSUMER PROPERTIES

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A promising trend in improving the technology of wood drying and its modification is the use of a joint process of thermomechanical drying by the pressure relief method that combines mechanical and thermal dehydration followed by termomodification. In this technique, a wet material is preheated in a sealed chamber with increasing pressure, then on rapid decrease of pressure in the volume of the material, rapid vaporization occurs due to the accumulated heat. The drying process is cyclic and can be repeated several times. When the wood moisture content attains about 8–10%, its termomodification is made. The method can be recommended for fast and high-quality drying and modification of wood.

2-34 M. A. GORESHNEV, V. V. LOPATIN, F. G. SEKISOV, O. V. SMERDOV

CHARACTERISTIC FEATURES OF WOOD DRYING BY A COMBINED METHOD AT REDUCED PRESSURE

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Wood drying is the most energy-consuming operation in the process of woodworking. The main problem of drying is the uniformity of moisture content distribution in the bulk of a workpiece. The determining criterion of drying is the internal moisture transfer. The energy supplied for wood drying can be in two forms: thermal energy and electromagnetic radiation. It is more profitable to use thermal energy for wood drying; however, different thicknesses of timber can lead to nonuniform heating. Conductive and convective introduction of energy can make it possible to achieve a fairly uniform distribution of temperature and moisture content in the bulk of the stack. However, the timber is heated nonuniformly over its thickness, which leads to the gradient of temperature and moisture content, as well as cracking in the area of mechanical stresses. The aim of the present work is to study the dynamics of temperature, moisture content and internal excess pressure in the wood subjected to HF and conductive heating at a reduced pressure.

2-35 N. N. GRINCHIK, Yu. N. GRINCHIK, A. L. ADAMOVICH

HEAT AND MASS TRANSFER IN CAPILLARY-POROUS MEDIA UNDER CONDITIONS OF MICROWAVE HEATING

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A physicomathematical model and the method of calculation of simultaneously proceeding heat-and mass transfer processes, phase transformations, and energy dissipation in capillary-porous materials containing moisture and subjected to intense electromagnetic radiation are suggested.

2-36 O. N. KASHINSKII, P. D. LOBANOV, A. V. CHINAK, M. A. VOROBIEV

FORMATION OF GAS BUBBLES IN A VERTICAL LIQUID FLOW

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An average size of gas bubbles produces a significant effect on heat- and mass transfer processes in a two-phase flow with the same liquid and gas flow rates. Depending on the parameters of the mixture flow, the change in the size of gas bubbles may result in either an increase or a decrease of the intensity of turbulent fluctuations, heat transfer coefficient, and hydraulic resistance. An investigation of gas bubble formation during the detachment from the capillary in the liquid flow is performed. It is established that for the same liquid and gas flow rates the mean bubble diameter is smaller for the detachment from the capillary in the central part of the channel compared to the capillary at the wall. The shape of the histogram of bubble size distribution changes qualitatively when some critical detachment frequency is exceeded. The data obtained may be used to control the heat and mass transfer processes.

2-37 V. I. KONDRASHOV, A. M. MOISEENKO

HEAT AND MOISTURE CONTENT ANALYSIS OF AN INHOMOGENEOUS MASS OF STORED AGRICULTURAL PRODUCTS

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A mathematical model of interrelated heat-and-mass transfer in a mound of stored biological product with centers of spontaneous self-warming is suggested. The finite-element solution has been developed. An analysis of heat and moisture content state of the mound was carried out, making it possible to determine optimum storage procedures.

2-38 N. M. KORTSENSHTEIN, E. V. SAMUILOV

HEAT AND MASS TRANSFER IN THE PROCESS OF BULK CONDENSATION UNDER CONDITIONS OF HETEROGENEOUS REACTION

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The processes of nucleation and condensation growth of droplets which determine the intensity of heat and mass transfer during bulk condensation under conditions of heterogeneous reaction are considered. Within the framework of the thermodynamic analysis an expression for the generalized supersaturation ratio has been obtained. This expression determines the size of the critical nucleus, the work of its formation, and the equilibrium size distribution of critical nuclei. Within the framework of the kinetic analysis for a heterogeneous reaction of certain kind, the assumption on two stage progress of reaction with formation of intermediate complexes is formulated. As a result, expressions for the nucleation rate and growth rate of condensed particles are obtained which give a closed description of the kinetics of bulk condensation in certain complex systems.

2-39 N. M. KORTSENSHTEIN,[1] A. K. YASTREBOV[2]

HEAT AND MASS TRANSFER UNDER CONDITIONS OF BULK CONDENSATION IN A DUSTY VAPOR–GAS FLOW

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[2]*National Research University "MPEI", Moscow, Russia, ars48@yandex.ru*

The process of condensation under conditions of flow of a mixture of vapor, gas, and solid particles was investigated with the use of numerical solution of the kinetic equation for the droplet size distribution function. It was found that, in general, there is the influence of two factors: condensation on solid particles and homogeneous condensation. The condensation on the solid particles can be neglected if the total surface of dust particles is small compared to the total surface of the droplets formed. In this case vapor condenses on the surface of droplets more intensively than on the surface of dust particles, and the process can be considered as a homogeneous condensation. In the other limiting case, the formation of droplets and the condensation on their surface can be ignored. In the intermediate case, the effects of both factors are comparable.

2-40 V. N. KOVALNOGOV, T. V. PAVLOVICHEVA, E. V. FOKEEVA

MODELING OF THE INFLUENCE OF A RECOVERABLE DRYING AGENT ON THE THERMAL AND MOIST STATE OF CERAMIC BRICK IN THE TECHNOLOGICAL PROCESS OF DRYING

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A substantial reserve for increasing the power efficiency of the process of drying ceramic brick is the recirculation of a drying agent. The paper considers a mathematical model for investigation and prediction of the thermal and moist state of bricks in the process of their convective drying with account for the parameters of the drying agent, and the results of the computational investigation are given. The laws governing the influence of temperature and humidity of the drying agent applied at different stages of the drying cycle on the drying process duration have been established. The results of the study will be used for developing new, and improving existent, technological processes of convective drying of brick with drying agent regeneration.

2-41 V. P. KOVERDA, V. N. SKOKOV

STABILITY OF LOW-FREQUENCY PULSATIONS IN CRITICAL AND TRANSIENT REGIMES OF HEAT AND MASS TRANSFER WITH PHASE TRANSITIONS

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An analysis of master–slave hierarchy in a system of nonlinear stochastic equations describing fluctuations with a $1/f$ spectrum during interaction of nonequilibrium phase transitions has been made. The governing equation of the system has a distribution function with Gaussian tails. Therefore this distribution functions may be used for finding the Gibbs–Shannon information entropy. The local maximum of this entropy has been found. It corresponds to the tuning of the parameters of the equations to criticality and points to the stability of fluctuations with a $1/f$ spectrum. An analysis of stability of complex stochastic processes under conditions of deterministic action on the stochastic process with $1/f$ power spectrum has been carried.

2-42 A. P. KRYUKOV, V. Yu. LEVASHOV

MOLECULAR–DYNAMIC SIMULATION OF EVAPORATION AND CONDENSATION PROCESSES. COMPARISON WITH KINETIC APPROACH

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In this paper, the problem of thin liquid layer evaporation into vacuum is studied by molecular dynamics simulation and molecular kinetic theory methods. Attention is mainly paid to the determination of the velocity distribution function for molecules escaping from liquid in the process of evaporation. A comparison of the “kinetic” and “molecular–dynamic” distribution functions for the vacuum evaporation process are presented. The results obtained show that this distribution function is half-Maxwellian with zero mean velocity at the vapor--liquid interface temperature.

2-43 A. P. KRYUKOV, Yu. Yu. PUZINA

SUPRESSION OF OSCILLATIONS OF THE VAPOR--LIQUID INTERFACE DURING BOILING OF SUPERFLUID HELIUM INSIDE A POROUS BODY

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The processes of helium-II boiling on the heater surface under different conditions are investigated. The task of determing the dynamic characteristics in the process of evolution of a vapor film on the cylindrical heater in the presence of limiting coaxial porous structure is analyzed. Processes in a free volume and in a confined space are compared. The experimental data on helium-II boiling on a sphere, as well as helium boiling in conditions of microgravity on a thin wire have been compared.

2-44 Yu. A. KUZMA-KICHTA, A. V. LAVRIKOV, M. V. SHUSTOV, P. S. CHURSIN, A. V. CHISTYAKOVA, N. A. STENINA

INVESTIGATION OF BOILING ON THE SURFACE WITH A SUBMICRON RELIEF

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The present paper contains the results of investigation of boiling heat transfer enhancement by means of submicron relief indentation.

The investigation of boiling heat transfer coefficient for water on the surface with the SiC- and Al_2O_3 nanoparticles relief was carried out in a pool at atmospheric pressure. It was determined that the heat transfer coefficient increases in the case of boiling on the surface with the SiC relief, and decreases on the surface with the Al_2O_3 relief in comparison with the smooth heater. The high-speed video filming with a digital post-processing was carried out to reveal the reason for the change in the boiling heat transfer coefficient.

2-45 M. A. LEKSIN, A. R. ZABIROV, O. V. SHAPOVAL, V. V. YAGOV

EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER UNDER CONDITIONS OF COOLING METAL BALLS IN A SUBCOOLED LIQUID

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The problem of intensive cooling of bodies heated to temperatures considerably exceeding a temperature of the limiting superheating of a cooling substance by a subcooled liquid is of scientific and practical importance. In particular, today, explanation is required for the very high heat transfer rate in film boiling of subcooled liquid. Experimental data on cooling a metal ball in a subcooled liquid and the procedure of restoring the surface conditions on its surface using the results of measurement of temperature at several points on the surface are presented. The availability of the substantial temperature gradient inside the ball dictated the need of solving a 2D problem.

2-46 A. R. LEPESHKIN

A COMPLEX MATHEMATICAL MODEL OF INDUCTION HEATING AND HARDENING OF PARTS WITH ACCOUNT FOR PHASE TRANSFORMATIONS AND INTENSIVE COOLING

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A complex mathematical model of induction heating and hardening of parts is suggested with account for phase transformations and intensive cooling. With the use of the developed software package, computational investigations of the modes of induction heating for the surface hardening of a cylindrical ferromagnetic steel part were carried out. Using the results of investigations, the nonstationary thermal state of the part on heating and intensive cooling with account for phase transformations was determined. At the final stage of computational modeling, the distributions of residual stresses in the part with account for the variable thermal stress, deformed, as well as phase and structural state of the material have been obtained.

2-47 E. V. LIPNYAGOV, M. A. PARSHAKOVA, G. V. ERMAKOV

HIGH-SPEED VIDEO FILMING OF BOILING-UP OF A SUPERHEATED N-PENTANE AT ATMOSPHERIC PRESSURE IN TWO MUTUALLY PERPENDICULAR DIRECTIONS

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The boiling-up of a superheated n-pentane in a glass capillary at atmospheric pressure has been observed for the first time with the help of high-speed video filming in two mutually perpendicular directions. The availability of two such frames allows one to see on which side of the wall a bubble is precisely formed: whether there are two boiling centers located in close proximity

or there is one with a deformed image due to the curvature of the capillary. The data obtained point to the distinct heterogeneous character of the incipience of boiling.

2-48 E. V. LIPNYAGOV, M. A. PARSHAKOVA, G. V. ERMAKOV

STUDY OF THE BOILING-UP OF A SUPERHEATED N-PENTANE IN A GLASS CAPILLARY DEPENDING ON TEMPERATURE BASED ON THE DATA OF HIGH-SPEED VIDEO

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For the first time with the aid of a high-speed video camera the boiling of superheated n-pentane in a glass capillary with, inner diameter of 2.4 mm was observed. The temperature range from 120 to 144.2 ºC was investigated. It can arbitrarily be divided into three smaller ranges. In the first range, from 120 to 134 ºC, boiling is represented by the growth of one or two separate vapor bubbles. Over the range from 135 to 142 ºC the number of growing bubbles increases to three or even four. In these two ranges boiling is just an increase in bubble sizes. Usually it proceeds till contacting with the opposite wall. Thereafter, bubbles form already on the liquid–vapor interface, and the pattern takes on a chaotic character. In the temperature interval from 120 to 136 ºC the shape of bubbles is close to a ball segment with a nonequilibrium wetting angle of more than 90º. This allows numerical estimation of bubble parameters. The height, base radius, sphere surface radius, wetting angle – all these quantities vary linearly with time. Close to the attainable superheat boundary (142.5–144.2 ºC) the boiling pattern becomes considerably complicated. Too many bubbles appear till the observed pattern resembles the description of film boiling.

2-49 A. A. LOPATIN, G. I. IDRISOVA, L. A. MAKAROVA

BOILING OF IMPINGING JETS OF FREON R-134a ON FINNED MICROSURFACES

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In connection with the continuous development of microelectronics and introduction of nanotechnologies in working out new samples of semiconductor components, the problem of thermal emission has also grown considerably. For effective operation these devices require adequate means of cooling which would ensure minimum dimensions of the equipment and stable temperatures. All this leads to the necessity of using new methods of cooling. One of such means is evaporate cooling. The paper considers the problems connected with the intensification of heat transfer in boiling of impinging jets of freon on minifinned surfaces. The influence of the height of finning and of the distance from the feeding channel to the working surface on heat transfer is shown.

2-50 M. Yu. LYAKH, O. S. RABINOVICH, L. L. VASILIEV

EFFECT OF CAPILLARY CONDENSATION OF SORBATE ON THE EFFICIENCY OF ABSORPTION THERMAL ENERGY CONVERTERS

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The paper presents a mathematical model of heat-and mass transfer in a single adsorber with account for the capillary condensation of sorbate. Based on the results of numerical calculations, two types of thermal converters have been investigated: in one of these, the condenser and evaporator are manufactured as separate blocks; in the other, condensation and evaporation proceed directly in the adsorber. It is shown that the implementation of thermal conversion in the region of the parameters ensuring capillary condensation of sorbate directly in the low-temperature adsorber allows one to decrease the minimum temperature of the refrigerating machine and to increase the specific cooling power. The numerical results obtained agree well with experimental data obtained in the regime of condensation/evaporation of ammonia in the adsorber.

2-51 V. A. MIKHAILIK, Yu. F. SNEZHKIN, N. V. DMITRENKO

BOUND WATER IN WOOD

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In the light of modern ideas about the energetics of intermolecular interactions, water in the wood can be considered as being in two different states. In one state, it has the properties similar to the properties of pure (free) water, and in the other, it originates as a result of hydration – favorable energetic interactions with the biopolymers, molecules, and ions of the tree sap (bound). The information on the state of water in the wood as a result of dehydration is very important both from scientific and practical point of view, since the removal of bound water is accompanied by deterioration of the kinetics and by increase in energy expenditures. The paper presents the results of investigation made by the method of differential scanning calorimetry of water state in young shoots of poplar, willow, and alder in the process of dehydration.

2-52 P. N. MIKHAILOV, A. I. FILIPPOV, A. P. MIKHAILOV

MODELING OF HEAT AND MASS TRANSFER DURING FILTRATION OF CHEMICAL AND RADIOACTIVE FLUIDS IN LAYERED MEDIA

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Modeling of filtration of active solutions leads to the need of solving the conjugation problems whose exact solution can be obtained only in simple cases. Using as an example the heat

and mass transfer in filtration of radioactive substances, the possibility of employing the asymptotic methods for constructing approximate solutions is shown.

2-53 A. V. MOROZOV, O. V. REMIZOV, D. S. KALYAKIN

STUDY OF HEAT TRANSFER PROCESSES IN UNDEVELOPED WATER BOILING ON A SINGLE HORIZONTAL TUBE HEATED BY CONDENSING STEAM

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The experimental study of undeveloped nucleate boiling on a single horizontal tube heated by condensing steam has been carried out at the Physical-Power Engineering Institute. The characteristic feature of the processes investigated was the presence of natural circulation in the primary circuit of the facility. Experiments were carried out at heating steam pressure P_{s1} = 0.35 MPa. As a result, an empirical correlation for predicting the heat transfer coefficient has been obtained. This correlation can be used for substantiating the operation of the VVER steam generator in the condensation mode.

2-54 R. I. NIGMATULIN, A. A. SOLOVYEV, K. V. CHEKAREV

HEAT AND MASS TRANSFER DURING CONDENSATION IN AN AIR–WATER SYSTEM

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In the current estimates of the ocean –atmosphere interaction, the heat and mass transfer component associated with condensation of moisture on the water surface remains still uncertain. The experimental data obtained in the study of the condensation component of the molecular moisture exchange are very controversial and do not give answer to the question about the significance of the influence of condensation on the energy exchange between the ocean and atmosphere. The paper presents a precise method and experimental data of condensation coefficient of vapor molecules on the water surface. As to the estimates of the condensation component of water and heat balance in climatic models, a quantitative analysis of the heat and mass transfer parameters within the framework of the Hertz–Knudsen model is presented.

2-55 N. I. NIKITENKO, Yu. F. SNEZHKIN, N. N. SOROKOVAYA

DEVELOPMENT OF THE MOLECULAR--RADIATIVE THEORY OF HEAT AND MASS TRANSFER IN THE PROCESSES OF DRYING AND ADSORPTION

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A system of equations of heat and mass transfer and phase transformations in porous bodies during adsorption and desorption is constructed that takes into account the difference in the forces of interaction between the molecules of adsorbent and adsorbate. The formulas obtained on the basis of the molecular–radiative theory of transfer are presented for the area of contact of liquid and gas in a unit volume of a porous body, the intensity of phase transitions, heat of phase conversions, equilibrium partial vapor pressure, and for the thickness of the adsorbate layer on the surface of capillaries with account for the influence of adsorption forces. The results of comparison of calculated and experimental data are given.

2-56 N. I. NIKITENKO, Yu. F. SNEZHKIN, N. N. SOROKOVAYA, Yu. N. KOLCHIK

METHOD OF DISCRETE ALIGNMENT TO SOLVE THE INVERSE COFFICIENT PROBLEM OF MOISTURE DIFFUSION IN POROUS SYSTEMS

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Most of the existing experimental methods of obtaining data on the diffusion coefficient in condensed media involve determination of the local concentration of a component. This leads to significant errors. The paper describes the method for determining the coefficient of moisture diffusion in capillary-porous bodies depending on the volume concentration of moisture by solving the inverse problem of diffusion based on the method of discrete alignment. As an indirect information in solving this problem, the results of weighing a sample of arbitrary shape at different time instants are used. The results of calculation of the weight of the sample, which were obtained by using the expression for the diffusion coefficient found by solving the inverse problem, are in good agreement with measurements of the sample weight.

2-57 M. I. NIZOVTSEV, A. N. STERLYAGOV, V. I. TEREKHOV

INVESTIGATION OF HEAT TRANSFER PROCESSES ON MOISTENING POROUS MATERIALS BY THE METHOD OF IR THERMOGRAPHY

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With application of the method of IR thermography, the study of heat transfer processes in porous media under various moistening conditions is carried out. Capillary impregnation of a porous material and occurrence of single drops of water on the surface of a porous material was examined. Experimental data on the motion of the thermal front in the porous medium with capillary impregnation were obtained, and the magnitude of the thermal effect in a porous material with different moisture contents was determined.

2-58 S. N. OSIPOV

NEW DIRECTIONS IN CREATION OF NONFREEZING HEAT EXCHANGERS FOR LOW-POTENTIAL STEAM-TO-GAS MIXES

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For the most effective counterflow air-air heat exchangers-recuperators, the danger of corking the channels with a warm wet air, hoarfrost, and ice usually occurs at external air temperature less than 5 ºC.

The most simple solution of combatting such corking of channels consists in the use of heat exchanging partitions with the thermal resistance changing over the length in the zone of probable frosting-up or increase in the heat transfer intensity. The latter is especially effective with the use of “foamy" materials (copper, aluminum, etc.) with high values of thermal diffusivity coefficients.

2-59 F. V. PELEVIN, V. V. LOZOVETSKII, P. Yu. SEMENOV

HEAT TRANSFER AND HYDRODYNAMICS IN POROUS METALS WITH TWO-DIMENSIONAL COOLANT FLOW

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Consideration is given to a new method of heat transfer intensification with the use of porous mesh materilas and of the principle of interchannel coolant tranpiration. The method combines the high heat transfer intensity inherent in high heat conducting porous materials and low hydraulc losses. New data on heat transfer and hydraulic resistance in two-dimensionl coolant flow through a porous mesh material have been obtained. The optimal parameters of the material have been determined. A comparison with various ribbed channels was performed.

2-60 P. P. PERMYAKOV, A. P. AMMOSOV, G. G. POPOV

ESTIMATION OF THE EXTENT OF HEAVING AND SHRINKAGE OF LINEAR STRUCTURES IN FROZEN GROUNDS

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A mathematical model of heaving and thermal slump is suggested, based on the assumption that the expansion (shrinkage) of soil volume occurs vertically (towards the soil surface) as a result of the growth of porous matter due to the transition of water into ice, as it is taken in the problem on compression sealing of grounds. The numerical solution of the system of differential equations of heat and moisture transfer is carried out according to the methods of directional differences. The results of numerical experiment on prediction of exogenous processes under the gas main and ESPO pipeline are given.

2-61 I. A. POPOV,[1] N. N. ZUBKOV,[2] S. I. KASKOV,[2] A. V. SHCHELCHKOV[1]

POOL BOILING OF VARIOUS LIQUIDS ON MICROSTRUCTURED SURFACES

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[2]*N. E. Bauman Moscow State Technical University, Moscow, Russia*

The development of modern technologies requires the removal of considerable specific heat fluxes from rather small areas. The problem is solved by using boiling enhancement in cooling systems, allowing one to reach the beginning of nucleate boiling at smaller temperature differences, higher heat transfer coefficients, and higher critical heat fluxes. The paper presents the results of experimental investigation of heat transfer and critical heat fluxes during pool boiling of water, ethanol, water–glycerine solution, and of an antifreezing agent on microstructured surfaces obtained by the method of warping cutting. The 9 times enhancement in heat transfer and the 4.1 times increase in the critical specific heat flux have been attained. The bases of the physical models of pool boiling enhancement are given.

2-62 E. Yu. RAZUMOV, R. R. SAFIN, P. A. KAINOV

HEAT AND MASS TRANSFER IN LUMBER IN THE PROCESS OF THERMAL MODIFICATION

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One of the serious shortcomings of the finished product from thermomodified lumber is high cost and the presence of pungent odor of burnt wood, so the researchers were faced with the problem of reducing energy costs for carrying out the process of heat treatment and prevention of odors in the finished product. One of the ways of solving these problems is to carry out the process of the termomodification in vacuum-conductive devices, which helps in preventing heat losses into the environment and in removing burnt smell at the stage of cooling. The paper presents the results of studies of the proposed technology and methods of calculation.

2-63 A. V. RESHETNIKOV, K. A. BUSOV, N. A. MAZHEIKO, V. P. KOVERDA

EXPLOSIVE BOILING-UP IN SUPERHEATED LIQUID JETS DISCHARGING THROUGH A SLIT CHANNEL

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An experimental study of boiling water jet during its outflow through a short slit channel into the atmosphere with variable external geometrical conditions was carried out. At large divergence angles jet close to 180 degrees in the presence of an adjacent plane in the outlet cross section of the channel, complete divergence of the jet was observed – the jet spread along the plane with preservation of the axial component of the jet. In the case of complete jet divergence, a significant reduction of the jet recoil was noted as compared to a jet without divergence. Pulsations with the power spectrum varying in inverse proportion to frequency (1/f fluctuations) were detected in transition boiling regimes and transitions to complete divergence of the jet.

2-64 A. V. RESHETNIKOV, V. N. SKOKOV, V. P. KOVERDA

RELAXATION AND SPECTRAL CHARACTERISTICS OF FOAMS

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To establish a connection between the relaxation characteristics and the power spectrum of a random process, the foaming dynamics of water–glycerin solutions was investigated. Foaming occurred on decay of gas-saturated solutions and bubbling of solutions through a porous filter. The two modes of foam relaxation have been revealed: the power-law and exponential ones. The power-law relaxation was observed in the case of additional action of an ultrasonic field. The interrelation of the power-law character of relaxation and low-frequency distribution of power spectra was established. The power-law relaxation was connected with the power-law pulsation distribution and with the low-frequency divergence of power spectra.

2-65 L. V. ROMANOVA,[1] I. I. GOGONIN,[2] A. R. SAL'MANOV[1]

EXPERIMENTAL INVESTIGATION OF HEAT AND MASS TRANSFER IN CONDENSATION OF A MOVING VAPOR–GAS MIXTURE ON THE SURFACE OF AN INCLINED CONDENSER

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The parametric characteristics of a gas-cleaning condenser and the hydrodynamic conditions needed for trapping dust particles of fusion cake, alkaline droplet moisture, and of the absorption of sulfur-containing gases by the condensate film with simultaneous utilization of ejection heat in condensation of steam from vapor–gas ejections of the technological sources of sulphate-pulp production have been determined.

2-66 V. I. RYAZHSKIKH, A. V. RYAZHSKIKH, A. A. BOGER

DISSOLUTION OF THE PRECIPITATE TRACE CASTING OF NITROGEN AND OXYGEN DURING STORAGE OF LIQUID HYDROGEN IN CRYOGENIC TANK

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One of the major explosion-proof problems of liquid cryogenic systems is a critical thickness of the high-boiling residue trace of nitrogen and oxygen in liquid hydrogen, which can be determined only on the basis of a detailed analysis of laws governing phase transfer. Despite some advances in the experimental study and modeling of crystallization from supersaturated solutions of impurities, deposition of solids in dispersion medium free convection mixing and the formation of a locally nonuniform sediment on wetted surfaces, the mechanism and kinetics of dissolution of these sediments in the conditions of the existence of heat inflows through the walls of the reservoirs for storage of cryogenic liquids remain unclear.

2-67 A. V. SERYAKOV

APPLICATION OF STEAM JET NOZZLE IN HEAT PIPES OF MEAN TEMPERATURE RANGE

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At the present time the problem of intensification of the heat-transfer characteristics of heat pipes of medium temperature range measurement used for cooling of the heat-loaded elements of electronic equipment including those used in spacecraft is exceptionally urgent. The heat transfer and operating efficiency of heat pipes with capillary porous inserts are determined by a closed circulation motion of a heat carrier undergoing the liquid–steam phase transition with heat absorption in the evaporation zone, steam phase transfer though a steam channel, vapor phase transition with heat liberation in the condensation zone and heat carrier return into the evaporation zone of the heat pipe.

In the paper, new data concerning the application of the heat pipe steam channel made as a nozzle analogous to the Laval nozzle is presented. The results of measurement of the steam flow velocity in the critical nozzle section and standard cylindrical steam channel is presented.

2-68 O. V. SHARYPOV,[1,2] P. A. KUIBIN[1]

EFFECT OF INERTIA AND THERMOCAPILLARITY ON THE STRUCTURE OF NONISOTHERMAL LIQUID FILM FLOW

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[2]*Novosibirsk State University, Novosibirsk, Russia*

The effect of a moving local heat source on the flow structure in a gravity-driven thin liquid film is studied. The 2D steady-state conjugated hydrodynamic and thermal problem is solved in the long-wave approximation. The flow structures in different regimes are compared: from the regime of flow along a vertical substrate with a fixed heat source to the regime with a moving heat source relative to the horizontal liquid layer.

2-69 Yu. F. SNEZHKIN

ENERGY EFFICIENCY IN THE PROCESSES OF DRYING

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The process of drying is a rather energy-consuming technique of dehydration of materials. It is known that 8–10% of the whole energy in the world is spent on the process of drying. Therefore, the problems of energy efficiency in the processes of drying are of great importance. The works of many researchers are directed at the reducing the expenditure of energy on moisture evaporation from materials. The paper considers several methods of dehydration of materials, which significantly reduce the expenditure of energy on evaporation of water and which were developed at

the Institute. The potential of energy saving gained from introduction of these developments in Ukraine was calculated.

2-70 Yu. F. SNEZHKIN, Zh. A. PETROVA, V. M. PAZYUK

ENERGY EFFICIENT REGIME OF DRYING ANTIOXIDANT VEGETABLE RAW MATERIAL

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Preparation of antioxidant powders is to combine protein and fat-containing raw materials with carrots. The paper is devoted to the choice of an optimal method of drying functional-purpose combined protein--carotene mixtures. Antioxidant raw material, by its structure, physicochemical and biochemical composition is very prone to drying. To determine the mode of drying, numerous experiments that took into account the specific heat consumption and conservation of antioxidant qualities of raw materials were carried out. The paper describes the state-of-the art of the study of antioxidant raw materials as an object of drying.

2-71 G. N. STANKEVICH,[1] O. I. GAPONYUK,[1] I. N. BUTSENKO[2]

TOPICAL PROBLEMS OF HEAT AND MOISTURE TRANSFER IN MODERN METAL GRANARIES IN UKRAINE

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In the last decades, the increase in the number of modern elevators is attributable to intense construction of large-capacity corrugated steel silos. There are some advantages of these modern systems of grain storage, however, companies lack experience of their maintenance. There are problems with ensurance of the stored grain quality. The paper presents the results of the analysis of heat and mass transfer processes occurring during storage of grain in modern metal granaries. The conditions of thermal and humid diffusion processes are considered, as well as convection, migration, and subsequent condensation of moisture in the mass of grain in metal granaries. Methods of leveling out the grain temperature leveling of undesirable processes of the thermal diffusion of moisture, prevention of the self-warming phenomenon, the growth of pests and spoiling of the stored grain in metal silos.

2-72 G. N. STANKEVICH, L. K. OVSYANNIKOVA, E. G. SOKOLOVSKAYA

INVESTIGATION OF THE LAWS GOVERNING THE DRYING OF FLAX SEEDS

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The main and most energy consuming technological process of the post-harvest processing of grains and oilseeds ensuring their secure storage is thermal drying. In the current economic conditions, producers of grain determine themselves the crops to grow, from which they will gain the most benefit. Often these are small-seeded cultures, for which the current regulatory

documentation for drying is not available. The paper presents the results of studies of physical and technological properties and regularities of the kinetics of drying flax seeds for commercial purposes. The effect of the initial humidity of seed and drying regimes on the key indicators of linseed oil quality is determined. Techniques of improving the post-harvest processing of flax seeds are shown.

2-73 V. A. SYCHEVSKII, V. L. DRAGUN, B. K. LOVETSKII, N. M. GORBACHEV

EXPERIMENTAL DETERMINATION OF STRESSES ON THE SURFACE OF SAW-TIMBERS IN THE PROCESS OF DRYING

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The drying of wood relates to the sphere of mass industrial production where even a small percent of spoilage leads to significant material and financial expenditures. An increase in productivity demands intensification of the process of drying. With this purpose hard modes which give smaller duration of drying, but lead to the development of stresses in a material are more often used. Now there are no reliable and exact methods of determining these stresses. In this connection, creation of experimental methods to determine stresses in saw-timbers is of interest. The purpose of the work was the development of the ways of determining stretching stresses on the surface of saw-timbers caused by gradients of moisture content arising in the process of drying.

2-74 S. TABAKOVA,[1,2] F. FEUILLEBOIS,[3] V. DARU,[3,4] S. RADEV[2]

FREEZING OF A MOVING FILM DUE TO AN AIR FLOW CARRYING SUPERCOOLED DROPLETS

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[4]*Arts et Metiers ParisTech, DynFluid lab, Paris, France*

Freezing of a moving liquid film due to supercooled droplets-laden air flow is considered. A model of a liquid film swept by the air moving around an obstacle (cylinder) and fed by impinging droplets is proposed. The film movement is described by the momentum equation for a thin film, as well as by the non-slip condition on the cylinder surface and the condition of equality of the shear stresses on both interface sides. It is found that the film thickness is small compared to the droplet size. Since the rate of the droplets is irregular due to the turbulent flow carrying them, one would expect the cylinder to be covered with a water film only in places.

2-75 E. A. TAIROV

EFFECT OF HEAT TRANSFER IN GRANULAR MEDIUM ON THE VALUE OF EQUILIBRIUM VELOCITY OF SOUND IN VAPOR--LIQUID MIXTURE

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A theoretical study of equilibrium velocity of sound in a vapor--liquid mixture that contains a closely packed layer of spherical particles was carried out. The thermodynamic analysis involves account for nonstationary heat exchange between the mixture and heat-conducting particles in the compression half-wave. The theoretical model shows the experimentally observed considerable decrease in the equilibrium velocity from its adiabatic value with increase in the vapor content of the mixture. The results of calculations agree well with the experimental data obtained for a vertical channel during filtration of vapor--liquid mixture through closely packed layers of spherical particles made from steel and glass.

2-76 E. A. TAIROV, A. A. LEVIN

AN EXPERIMENTAL STUDY OF THE INITIAL STAGE OF INTENSIVE VAPORIZATION WITH PULSED HEAT RELEASE ON A TUBULAR SURFACE

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In fluid systems a significant limiting factor for maximum heat fluxes is the occurrence of critical heat fluxes. This is the area in which the problems of the development of critical phenomena in nonstationary conditions and on industrial heaters are least studied. The present research is based on heat measurements and high-speed video-filming, and is aimed at studying the physical mechanisms and forms of the critical heat flux development in nonstationary conditions on large heaters. An experimental study of the effect of forced fluid motion velocity on the emergence of high-intensity pressure pulsations in the flow channel was made. A nonmonotonic character of the relationship between the expectation time of intensive vaporization and flux velocity has been revealed.

2-77 V. I. TEREKHOV, N. E. SHISHKIN

HEAT AND MASS TRANSFER OF DROPS OF BINARY LIQUIDS IN AN AIR FLOW

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The results of an experimental investigation of evaporation of suspended drops of a binary liquid (water solutions of ethanol, methanol, and acetone) are presented. The data given in the present papers were obtained for constant temperature of air (T_0 = 18.6 ºC) and its velocity (U_0 = 4.5 m/s), but with variation of the concentration of components in the entire possible range. Measurement of temperature of the flow on the surface of drops and of change in time was made with the aid of an infrared thermograph camera. The influence of the composition on the rates of evaporation and heat and mass transfer is shown.

2-78 V. E. TUZ, N. L. LEBED, R. V.NEILO

HYDRODYNAMICS OF GAS–LIQUID SYSTEMS IN CHANNELS WITH A NETWORK COVERING

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One of the basic principles underlying the design and operation of contact nozzle-type devices is to provide stability in the interaction between a liquid film and a gas flow. Unlike a smooth surface, where the condition of film rupture is determined by the physical properties of the liquid, wetting of the surface, and depends on the balance of forces acting on an elementary volume of the film, for the surface with the network coating it is necessary to additionally take into account the capillary effects in the cell of the network. The paper presents an analytical model of the liquid film rupture, which takes into account the capillary effects in the cell of the network. Based on the numerical realization of this model, the minimum thickness of the film is calculated depending on the geometric characteristics of the network.

2-79 M. VALINCIUS, A. KALIATKA, E. USPURAS

EXPERIMENTAL INVESTIGATIONS OF INTERPHASE SHEAR IN A STRATIFIED TWO-PHASE CONDENSING FLOW

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This work was performed at Lithuanian Energy Institute in order to evaluate the influence of condensation on the interphase stability of a two-phase stratified flow in a horizontal rectangular channel. The interphase shear stresses have been investigated under various flow conditions as the key parameters of the interphase Kelvin–Helmholtz instabilities. The instability of a stratified two-phase flow can increase condensation and under certain conditions can cause the phenomenon of hydraulic shock. The paper presents experimental and analytical investigations of interphase shear stresses of a two-phase stratified flow. Five flow regimes have been investigated: 1) single-phase air flow; 2) single-phase steam flow; 3) two-phase stratified air–water flow; 4) two-phase stratified steam–water flow without condensation; 5) two-phase stratified steam–water flow with condensation. An analysis of the interphase shear stresses has shown indirectly that the condensation exerts its influence and reduces the interphase stability. The results obtained will be used for creating a model to predict the initiation of rapid condensation in a stratified two-phase flow.

2-80 L. L. VASILIEV,[1] L. P. GRAKOVICH,[1] M. I. RABETSKII,[1] D. V. TULIN[2]

POROUS LAYER EFFECT ON EVAPORATION FROM CAPILLARY GROOVES

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The most accepted method of thin liquid film creation on the evaporation surface is capillary porous coating. The system of capillary grooves is one of the types of such a structure. The possibility of coating the groove surface with an additional thin (25–100 μm) nanoporous layer forms the next stage of heat transfer enhancement. The goal of experimental investigations was the derivation of the quantitative relations for evaporation and boiling intensity quantity relations for surfaces with capillary grooves and detection of porous layer effect. Augmentation of heat transfer coefficient by a factor of 1.3-1.6 was achieved.

2-81 L. L. VASILIEV Jr, M. Yu. LYAKH

INVESTIGATION OF HEAT AND MASS TRANSFER IN MINICHANNELS AS THE LHP CONDENSER

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This paper presents a theoretical model to predict heat transfer during film condensation in horizontal microchannels of the LHP condenser. The model describes the process of laminar condensate flow in a rectangular minichannel with the action of surface tension and axial vapor shear stress. Numerical results are given for propane and channel size (width × height) 3.0 mm × 7.0 mm and 300 mm in length. The general behavior of the condensate flow pattern, streamwise vapor flow variation, and local mean heat-transfer coefficient have been analyzed for different initial and boundary conditions. The results of modeling have been validated by experimental data.

2-82 L. L. VASILIEV, A. S. ZHURAVLYOV

HEAT TRANSFER DURING EVAPORATION OF LIQUID IN A HEATED POROUS WALL OF A HORIZONTAL CYLINDER

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The presence of a porous layer on heat exchanging surfaces raises the intensity of vapor generation due to the greater number of vapor-phase nucleation zones. At low heat loads, heat is transferred mainly by means of heat conduction in the wick skeleton and liquid whereas at high heat loads, due to phase transition in the pores of a coating. The results of investigation of heat transfer in a narrow annual cylindrical channel with a heat releasing porous wall are presented. The characteristic features of the hydrodynamics of a two-phase flow under such conditions at moderate heat loads promote an increase in the heat transfer intensity in comparison with the process on the same surface in a liquid pool.

2-83 L. L. VASILIEV, L. L. VASILIEV Jr.

VAPOR-DYNAMICAL THERMOSYPHON AS EFFICIENT HEAT-TRANSMITTING DEVICES FOR LONG-DISTANCE HEAT TRANSFER

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Vapor-dynamical thermosyphons (VDT) have been devised at the Laboratory of porous media of the A. V. Luikov Heat and Mass Transfer Institute in the mid-1980s, and they differ fundamentally from other thermosyphons and heat pipes of the same diameter renowned throughout the world. Modernized vapor-dynamical thermosyphons with the use of nanotechnologies are intended for the transmission of a heat flux horizontally for long distances (tens and hundreds of meters). Their efficiency exceeds 90%. The latest innovations in the VDT's design associated with the use of nanotechnologies make it possible to use VDT's as heat exchangers of heat pumps, heat and cold accumulators, and other heat transmitting devices.

2-84 S. V. VERSHININ, Yu. F. MAIDANIK

RESULTS OF TESTING FLEXIBLE MINIATURE LOOP HEAT PIPES

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Two flexible miniature loop heat pipes (mLHPs) have been developed. Their flexibility was attained by means of tubular spiral inserts into the vapor-liquid pipeline. One of the devices had an effective length of 840 mm and was equipped with a cylindrical evaporator 8 mm in diameter. Another was device 500 mm long and had a flat disk-shaped evaporator 32 mm in diameter and 13 mm in thickness. The pipeline diameter of both mLHPs was equal to 2 mm. Thermal tests were conducted at different orientations of the mLHPs in space at heat loads from 20 to 160 W and heat sink temperatures from -10^{o}C to +30^{o}C. The minimum thermal resistance of the first device was 0.21 K/W and of the second one, 0.42 K/W.

2-85 V. E. VINOGRADOV, P. A. PAVLOV

COLLAPSE OF A VAPOR FILM OF WATER AND FREON 113 ON THE SURFACE OF A HOT PLATINUM WIRE

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The vapor film collapse on a thin platinum wire in water and freon 113 under the influence of an external pressure pulse of amplitude from 1.7 MPa to 7 MPa and duration of 3 μs is investigated experimentally. Formation of a secondary pressure pulse generated by the vapor film collapse on the heater surface is revealed. Dependences of the secondary pressure pulse amplitude on the wire temperature and magnitude of the external pressure pulse are obtained. It is shown that the secondary pressure pulse can exceed the primary one 2-3 times. Heat fluxes from the heated wire in a liquid in the process of vapor film collapse have been measured.

2-86 O. V. VYSOKOMORNAYA, G. V. KUZNETSOV, P. A. STRIZHAK

NUMERICAL INVESTIGATION OF HEAT AND MASS TRANSFER IN THE SYSTEM "SINGLE DROP OF WATER–HIGH-TEMPERATURE GAS MIXTURE"

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Numerical investigation of macroscopic laws governing the interaction of a single water drop with high-temperature combustion products of a typical substance (flame) is carried out. The dependence of the time of complete evaporation of a liquid drop from its size at mean fire temperature is determined. The temperature and steam concentration fields in a small neighborhood of drop motion path are determined.

2-87 V. V. YAGOV, M. V. MINKO

APPROXIMATE MODEL OF THE ENTRAINMENT OF DROPLETS IN AN ANNULAR-DISPERSED TWO-PHASE FLOW

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An approximate physical model allowing one to calculate the dependence of the critical velocity of vapor at the onset of entrainment on the well-known parameters of the process is suggested. According to the model, the entrainment depends on the Weber number based on the film thickness, which is calculated from the conditions preceeding to the beginning of the separation of droplets. There is a satisfactory agreement of the present model with experimental data. For the conditions when the concentration of droplets in the flow core is small and the rate of deposition can be neglected, an approximate model of entrainment of droplets from the film surface has been developed. The computational equation in most of the cases typical of steam–water flows at moderate and high reduced pressures can be simplified to a monomial dependence with one numerical factor selected from experimental data.

2-88 V. V. YAGOV, M. V. MINKO, N. V. KAPUSTINA

HEAT TRANSFER OF VAPOUR–LIQUID FLOWS IN HEATED SMALL-DIAMETER CHANNELS

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A procedure for calculating heat transfer in a boiling turbulent flow at high reduced pressures is proposed on the basis of a homogeneous model of flow structure. This method allowed us to successfully describe experimental data for different liquids. The reduced pressure-based lower limit of applicability of the predicting method is considered. A comparison with experimental data showed that at a reduced pressure, $p_r < 0.2$, it is necessary to use the annular flow model for calculating the convective HTC. Such an approach makes it possible to describe all experimental data on heat transfer and hydraulic resistance using physically substantiated ideas of the two-phase flow structure taking into account the value of void fraction.

2-89 I. K. ZHAROVA,[1] G. V. KUZNETSOV,[2] E. A. MASLOV,[2] V. I. TEREKHOV[3]

NUMERICAL SIMULATION OF THE INTERACTION OF A TURBULENT TWO-PHASE FLOW WITH BARRIER OF COMPLEX SHAPE

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One of the important problems in the practice of design and operation of different technical equipment and devices is the determination of thermal and gas-dynamical characteristics near the surface of solid barriers of complex shapes in a wide range of the main stream of parameters. The complexity of the physical and chemical processes taking place near the barrier surface makes it more difficult to select experimentally the necessary mode of high-temperature action of heterogeneous jets. A mathematical model of interaction of a turbulent heterogeneous jet with a solid surface with various geometrical characteristics is presented. A comparison of theoretical and experimental results has led to the conclusions about the efficient use of various methods for adjusting the velocity and pressure fields in solving the Poisson equation.

2-90 V. M. ZHUKOV,[1] Yu. A. KUZMA-KICHTA,[2] V. A. LENKOV[1]

ENHANCEMENT OF HEAT TRANSFER DURING TRANSIENT AND FILM BOILING OF NITROGEN ON DIMPLED SPHERES WITH LOW-CONDUCTIVITY COATING UNDER THE CONDITIONS OF FREE CONVECTION AND NATURAL CIRCULATION

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The influence of dimple relief and low-conductivity coating applied to copper spheres in film and transient regimes of liquid nitrogen boiling under the conditions of free convection and natural circulation was investigated. Experiments were carried out with samples heated above the Leidenfrost temperature after immersing them into liquid nitrogen at a saturation temperature and atmospheric pressure. The distribution density of dimples (d = 3 mm and h/d = 0.17) on the surface of spheres was equal to 45%. It was found that the highest increase in the intensity of heat removal was observed with the use of dimple relief with low-conductivity coating under the conditions of natural circulation.

SECTION 3

HEAT AND MASS TRANSFER IN TECHNOLOGICAL PROCESSES AND EQUIPMENT

3-01 A. A. AL-MUSA,[1] S. I. SHABUNYA,[2] V. V. MARTYNENKO,[2] V. I. KALININ,[2] S. I. AL-MAYMAN,[1] M. S. AL-JUHANI,[1] K. B. AL-ENAZY[1]

EFFECT OF PREHEATING AND THERMAL LOSSES ON THE COMPOSITION OF METHANE PARTIAL OXIDATION PRODUCTS IN CATALYTIC REACTORS

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Chemical thermal treatment of steels in industrial furnaces requires a controlled atmosphere with a low content of carbon dioxide and steam. Such properties are typical of endogas formed as a result of partial oxidation of hydrocarbons. The paper presents the results of the study of the fast (oxidation) stage of methane catalytic conversion, the effect of initial mixture preheating and of thermal losses on the outlet mixture composition.

3-02 S. ALTAIULY[1], S. T. ANTIPOV[2], I. O. PAVLOV[2]

ANALYSIS OF MASS TRANSFER ON REMOVAL OF MOISTURE FROM PHOSPHOLIPID EMULSIONS IN A ROTARY-FILM APPARATUS

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Mathematical simulation of the process of mass transfer on removing moisture from the phospholipid emulsion of sunflower oil in a vacuum cylindrical rotary-film apparatus is considered. The solution of the nonstationary axisymmetric problem of mass transfer is obtained in cylindrical coordinates by the method of finite elements using a four-node isoparametric finite element, which is implemented in a mathematical symbolic package *Maple*. The method allows one to most optimally carry out investigation of the removal of moisture from the phospholipid emulsion of sunflower oil and design highly efficient constructions of rotary-film apparatuses.

3-03 V. A. ARKHIPOV,[1, 2] S. S. BONDARCHUK,[1, 2] A. S. ZHUKOV[1]

EVOLUTION OF A PRECURSOR DROP IN PLASMACHEMICAL SYNTHESIS OF CERAMIC POWDERS

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Optimization of the technology of production of ceramic powders (mainly metal oxides) by the method of plasmachemical synthesis is an actual problem in connection with a steady trend towards the expansion of the application of these materials. The efficiency of the technology of plasmachemical synthesis is determined by its productivity, power consumption, and economy in obtaining the preassigned structure of the product, i.e., the particles of metal oxides. A physical-mathematical model of the operating processes in a plasmachemical reactor for ceramic powders synthesis is presented. The analysis of the results of numerical investigation has made it possible to estimate the influence of the reactor operating conditions and initial solution (precursor) characteristics on the morphology of the ceramic particles formed.

3-04 V. N. BANDURA,[1] S. M. BUIVOL[2]

HEAT AND MASS TRANSFER IN EXTRACTION OF OIL FROM A RAW MATERIAL WITH THE USE OF MICROWAVE POWER SUPPLY

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One of the important trends in the production of oil is intensification of the extraction process. At present, oil production from a raw material almost does not use electromagnetic heating, which gives a good result. Owing to the influence of the electromagnetic field, we can get greater percent of oil yield with more valuable components, reduce the time of the technological process, energy costs, and to intensify this process.

It is shown that on supply of microwave energy to the cell structure, part of it is assimilated in the cell and increases the pressure inside it.

3-05 P. M. BAZHIN,[1] L. S. STELMAKH,[1] A. M. STOLIN,[1] E. V. KOSTITSINA[2]

ON COMPETITION OF THE PROCESSES OF SHIFT DEFORMATION AND VOLUMETRIC PACKING OF CERMET MATERIALS IN SHS-EXTRUSION

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Numerical simulation of the process of SHS-extrusion of electrode materials based on application of a nonisothermic rheodynamic model was carried out. It is established that the dependence of the press plunger speed applied for fixed moments of time has a nonmonotonic character, i.e., the speed of the press plunger in the real situation is always limited, which is caused by the competing influence of mechanical action on the material and its packing. Direct comparison of numerical and experimental data showed the possibility of using the proposed models for predicting experimental results.

3-06 P. M. BAZHIN, A. M. STOLIN, A. E. SHTEINMAN

CHARACTERISTIC FEATURES OF THE PROCESS OF SHS-EXSTRUSION ON MULTISTAGE PRESSING

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In the present work, we investigate the influence of multistage pressing, allowing one to increase the intensity of deformation in the process of SHS-extrusion of inorganic hard-alloy materials. As a result of multistage pressing of a synthesized material, reduction in the average size of grain, decrease in the amount of agglomerates, aggregates and grains of irregular shape have been revealed as well as an increase in the microhardness of a material up to 30%.

3-07 V. V. BELOUSOV, V. I. BONDARENKO, F. V. NEDOPEKIN, Ya. V. PAVLOV

DEVELOPMENT OF SOFTWARE FOR CALCULATING THE PROBLEMS OF HYDRODYNAMICS AND HEAT AND MASS TRANSFER FOR SOLIDIFICATION OF A STEEL INGOT

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A mathematical model and computational algorithm of hydrodynamic and heat and mass transfer processes in a solidifying steel ingot have been formulated. A package of application software with a user-friendly interface has been developed. This software allows one to simulate the modes of formation of ingot casting and take into account the influence of external and internal effect on the solidifying metal, without intervening into the mathematical model and computational algorithm by a user.

3-08 M. P. BERNIK, A. S. LUPASHKO, N. Ya. TSISLINSKAYA, E. I. CHOBANU, M. G. RĂDUKAN, Yu. G. DOHMILĂ

PULSED SUPPLY OF INTERNAL HEAT SOURCE IN THE PROCESS OF DRYING OIL-BEARING CROPS

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The paper considers the possibility of drying oil-bearing crops using a source of pulsed internal energy. Mathematical dependences of heating and relaxation periods on the drying process parameters have been obtained. The correct selection of the durations of heating and relaxation under conditions of pulsed internal heat supply can increase the value of one of the driving forces of the drying process, namely, the temperature gradient at relatively low product temperatures.

3-09 V. A. BILYK, E. V. KOROBKO, A. A. MAKHANEK

SIMULATION OF HEAT TRANSFER IN NONSTATIONARY DISSIPATIVE FLOW OF AN ELECTROREOLOGICAL FLUID IN AN ANNULAR CHANNEL WITH ACCOUNT FOR THE CHANGE IN THE RHEOLOGICAL CHARACTERISTICS WITH THE TEMPERATURE AND ELECTRIC FIELD STRENGTH

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The problem of heat transfer and hydrodynamics of electrorheological fluid (ERF) in an annular channel with account for the dissipation energy is formulated. Numerical calculations of the velocity profile and pressure difference at different values of the volumetric flow rate in a range of temperatures from 10 to 80 ^{o}C and electric field strength from 0 to 2.5 kV/mm are carried out. It is shown that with increase in the temperature by 30^{o}C the pressure drop ΔP in the channel decreases approximately 3 times, and with increase in the electric field strength from 0 to 2.5 kV/mm, ΔP increases not less than 5 times at the volumetric flow rate in a range of 2–120 sm^3/s. A comparison of the efficiency of heat transfer under conditions of ERF flow in the annular channel with account for the influence of the electric field strength and temperature on the rheological characteristics of a viscoplastic fluid by analyzing the local and integrated values of the Nusselt number has been made.

3-10 A. F. BUBLIEVSKII,[1] A. V. GORBUNOV,[1,2] D. A. BUBLIEVSKII[3]

DUAL MODE JET MODEL OF ELECTRIC ARC IN A TWIN-TYPE PLASMA TORCH

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The research object is an electric arc in twin dc plasmatrons torches (TPT). TPTs are the optimal type of treating some kinds of industrial wastes because of such a factor that the length of the open part of TPT's arc is maximal. It is known that electric current in a near axial zone of plasma jet prevents the flow turbulization due to a significant rise of plasma gas viscosity at high temperatures. At the same time, there is turbulence in the peripheral currentless zone of plasma jet. This paper presents the results of consideration of the jet model of electric arc based on the assumption of different flow modes into the TPT' arc column and on its peripheral zone. As a result of research, some new equations for the distribution of the "thermal conductivity potential", as well as of electric field and the radius of conductive zone in the TPT's arc were obtained.

3-11 A. A. DOLINSKII, D. M. CHALAEV, L. N. GRABOV

DEVELOPMENT AND INVESTIATION OF A RECUPERATIVE HEAT EXCHANGER BASED ON A VAPOR–LIQUID THERMOSYPHON

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Recuperative heat exchangers based on the vapor–liquid thermosyphon as high-performance heat transmitting devices have been widely used in ventilation and air conditioning. Conventional thermosyphon heat exchangers are composed of individual heat pipes located in a single case. We propose an efficient and economical design of a thermosyphon heat recuperator in which all pipes are connected by return bends. The apparatus has only one branch for filling the system with a working agent. The recuperator of this design can smooth out temperature nonuniformities of the air flow due to mass and heat transfer between adjacent tubes. The aim of the research is to obtain the working characteristics of the recuperator.

3-12 B. V. DZYUBENKO, A. S. MYAKOCHIN, N. U. SHCHERBAKOVA

ENHANCEMENT OF HEAT TRANSFER IN SALT AND COKE DEPOSITION IN CHANNELS WITH THE USE OF VORTEX TECHNOLOGIES

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The process of enhancing heat transfer in salt and coke deposition inside twisted oval tubes and tubes with discrete turbulence promoters with a cold water flow involving temporary hardness salts and hydrocarbon fuels as coolants in enhanced tubes of heat exchangers is considered. The process takes place under the condition of wall layer turbulization with the formation of vortex structures and of a swirled flow. The generalization of experimental data on heat transfer with mineral deposition fouling of the heat transfer surfaces of channels and on the fouling thermal resistance obtained in a wide range of characteristic parameters is presented.

3-13 S. O. FILATOV, V. I. VOLODIN

NUMERICAL MODELING OF THE CONTOUR OF EVAPORATOR AND BOREHOLE HEAT EXCHANGER

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One of the tendencies in the development of the technologies of renewable energy is the use of heat pumps for recovery of the heat of soil. The design of such systems should be based on valid mathematical models. The principal drawback of the existing mathematical models of ground-source heat pumps is the simplifying consideration of one of the elements of the system: borehole heat exchangers or heat pump. The paper suggests a model of joint operation of of a borehole heat exchanger and of a heat pump evaporator. Based on numerical simulation, the influence of different factors on the parameters of joint operation of borehole heat exchangers and of the heat pump evaporator is shown.

3-14 N. M. GORBACHEV, D. S. SLIZHUK, I. V. ZHAVNERKO, N. E. STAKHOVSKAYA

THERMAL TREATMENT AND DRYING OF RECYCLED REFUSE MATERIAL OF THE MINERAL WOOL SLABS PRODUCTION

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The recycling technology of refuse material of mineral wool slabs production at the «Gomelstroimaterialy» JSC has been developed. The technology provides shredding of the refuse material, briquetting with waterless silicate sodium as an additive, and further reuse as a feedstock after thermal treatment and drying.

Based on the extensive research and design work, a two-chamber convective drier with reversible cross-flow circulation of a heating gas agent has been built at the «Gomelstroimaterialy» production plant. The industrial implementation of the developed technology results in a more than 10 per cent reduction of the raw material demand as well as in an essential improvement of the environmental situation around the plant.

3-15 D. G. GRIGORUK, E. V. KASILOVA

MASS TRANSFER OF A BINARY FUEL MIXTURE IN THE ANODE OF A SOLID OXIDE FUEL CELL

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The main challenge in the calculation of concentration polarization in a solid oxide fuel cell (SOFC) is associated with the presence of a total pressure gradient in the porous anode. An analytical solution of mass transfer equations on assumption of dusty gas model for a binary mixture in the anode of SOFC was obtained. Error of concentration distribution in the anode due to neglecting the pressure gradient was estimated to be less than 10% for H_2 and less than 1% for CO for typical anode parameters and without volume chemical reactions in the anode.

3-16 D. G. GRIGORUK, V. D. KELLER, E. B. KHRISTENKO, É. N. TSERTSVADZE

INVESTIGATIONS OF HEAT AND MASS TRANSFER IN PASSIVE AUTOCATALITYC RECOMBINERS OF HYDROGEN

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In the case of a nuclear power plant (NPP) accident associated with the violation of reactor cooling, a great quantity of hydrogen can be released due to vapor oxidization of the core construction materials and, first of all, of zirconium. The main present-day solution for hydrogen safety in NPP facilities is catalytic oxidation of hydrogen on solid surfaces, performed by passive autocatalytic recombiners (PAR). The operating conditions of PARs correspond to interdependent processes of heat and mass transfer and hydrodynamics. So, incorrect account for the interrelations can lead to the PAR performance reduction. The paper presents the results of experimental investigations of heat and mass transfer in PARs. Taking into account the results, a new generation of PARs with higher performances has been developed.

3-17 L. E. KANONCHIK

NUMERICAL ANALYSIS OF COMPLEX HEAT AND MASS TRANSFER PROCESSES IN A SORBER WITH HYDROGENOUS GAS AND A HEAT PIPE

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Successful development of hydrogenous gas adsorptive storage system presumes the presence of an active thermal regulation and special properties of constructional materials. The inefficient heat transfer in the sorption bed is connected with the relatively low thermal conductivity of carbon sorbents and appreciable heat release during adsorption of gas molecules.

The paper presents numerical simulation of complex processes of heat and mass transfer in an activated carbon packed-bed sorber. A two-dimensional transient model is suggested to analyze refueling of such a storage system, where the hydrogenous gas is present in adsorbed and compressed states. It is shown that application of a finned heat pipe as a heat exchanger in the sorber-cylinder and a high-conductivity sorbent enable one to enhance the heat transfer and adsorption phenomena. The influence of the effective conductivity of the sorbent packed-bed and finning parameters of the heat pipe on the total amount of the gas stored is investigated.

3-18 I. V. KHVEDCHIN, V. V. SAVCHIN, A. S. OLENOVICH, G. V. DOLGOLENKO

APPLICATION OF THERMAL PLASMA TECHNOLOGY FOR VITRIFICATION OF ASH RESIDUES OF POWER PLANTS

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Power production and fossil fuel combustion are the main sources of environmental pollution. The result of power station operation is the production of toxic ash (including fly ash). Special requirements are imposed on fly ash handling: volume decrease, transformation of ash into the form suitable for both transport and storage, and into an environmentally safe form. A laboratory plasma facility for processing fly ash was designed and manufactured. An analysis of the presence of heavy metals was made by using the optical emission analysis of an inductively coupled plasma. The leaching rate of macrocomponents from a vitrified sample for the investigated elements was less than $1 \cdot 10^{-7}$ g/(cm^2·day).

3-19 V. V. KLUBOVICH,[1] M. M. KULAK,[1] B. B. KHINA[2]

EFFECT OF ULTRASONIC OSCILLATIONS ON THE SHS PROCESSES IN A MULTICOMPONENT TITANIUM–CARBON–NICKEL–MOLYBDENUM SYSTEM

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At present, the self-propagating high-temperature synthesis (SHS) is one of the most promising methods for producing refractory compounds. An urgent problem in this area is controlling phase formation during SHS. One of the most efficient means for affecting the

composition and structure of SHS products is the use of physical fields such as ultrasonic oscillations, permitting one of controlling *in situ* the magnitude of influence on the product formation mechanism and interaction kinetics with the ultimate goal of obtaining novel materials with improved physical and mechanical properties. In this paper, the results of investigation of the effect of ultrasonic oscillations on SHS are presented for the "titanium–carbon" and "titanium–carbon--metal binder" systems.

3-20 V. L. KOLPASHCHIKOV,[1] G. E. MALASHKEVICH,[2] M. N. KAPSHAI,[3] B. V. PLYUSHCH[3]

HIGH-HYDROXYL QUARTZ GLASSES AND HEAT TRANSFER PROCESSES IN DRAWING FIBER FROM THEM

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[3]*Gomel State University, Gomel, Belarus*

The paper presents a mathematical model which describes the processes of hydrodynamics and heat transfer in drawing of optical fiber from quartz ingots produced by the sol—gel technology. The characteristic features of the regimes of drawing that ensure the preassigned parameters of drawn optical fibers have been revealed.

3-21 M. K. KOSHELEVA, Yu. A. CHABAEVA, A. P. BULEKOV

MASS TRANSFER IN THE FINISHING PRODUCTION PROCESSES OF TEXTILE TECHNOLOGIES

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The process of cleaning flat textile materials of technological contamination is one of the most common and energy-intensive processes of finishing the production at textile enterprises. The mathematical description of the process, without which it is impossible to improve its efficiency, has been developed inadequately. A mathematical description of the process based on the diffusion model is suggested. Recommendations to increase the diffusion coefficient by using physical fields and other influences on the leaching solution have been developed. Evaluation of their effectiveness constitutes the experimental part of this research.

3-22 Yu. K. KRIVOSHEEV, V. L. KOLPASHCHIKOV, A. I. SHNIP

SIMULATION OF MCVD PROCESSES OF THE SYNTHESIS OF NEW MATERIALS

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The paper presents the developed and investigated mathematical model of MCVD processes of deposition of nanoparticles from a gas phase applied in various contemporary technologies of obtaining new materials (for the fibrous and nonlinear optics, laser technology,

nanoelectronics and so on). The distinctive feature of the model considered consists in the account for the motion of the gas mixture heating source along the reactor which initiates chemical reactions and forms a temperature field. The system of equations of heat and mass transfer comprising the mathematical model was solved numerically with account for the variability of coefficients and of convective, conductive, and radiative heat transfer. The basic parameters have been determined and engineering recommendations for optimizing and monitoring the process of deposition of nanoparticles in a reactor are given.

3-23 E. B. KULUMBAEV, T. B. NIKULICHEVA

MASS, HEAT, AND CURRENT TRANSFER IN A TWO-JET ELECTRIC ARC

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On the basis of a system of stationary two-dimensional magnetohydrodynamic equations for equilibrium plasma, a numerical analysis of the processes of mass-, heat-, and current transfer in a two-jet electric arc is carried out. Characteristic features of the formation of the general plasma stream by the jets are established. The results of calculation of temperature and electric structure agree qualitatively with the available data on experimental investigation of a two-jet electric arc.

3-24 V. V. KUZMICH, N. F. KAPUSTIN, É. K. SNEZHKO, D. V. DEGTEROV

PROSPECTS OF USING HEAT ENGINES IN SOLAR ENGINEERING DEVICES FOR PUMPING LIQUIDS

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Taking into account the ongoing degradation of the environment, it is already today that renewable energy sources are the only alternative enabling the human society to live in harmony with nature. So in many devices for the use in agriculture, thermal and photovoltaic techniques of transformation of a solar energy and their combinations are employed increasingly wider, for example, for transportation or circulation of heat carriers fluids or for pumping liquids in automated self-contained units: in collector water or air heaters, systems of drip irrigation of plants, etc. The paper summarizes the present state of the problem of practical use of solar energy converters of the type of heat engines, considers the techniques of raising their energy efficiency and the prospects of application, for example, for pumping fluids in the solar engineering and irrigation systems in the agricultural sector.

3-25 A. V. LOZHECHNIK, A. L. MOSSE, I. V. KHVEDCHIN, V. V. SAVCHIN, A. N. NIKONCHUK

DESTRUCTION OF TOXIC WASTE IN A PLASMA REACTOR

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An alternative to the conventional low-temperature methods of toxic waste incineration is waste processing in a thermal plasma at a high temperature. The process can be efficiently realized in a multi jet plasma reactor that ensures good mixing of plasma with treated wastes. The paper describes the technology of thermal plasma processing of toxic halogenic waste in a plasma reactor with a three-jet mixing chamber. The results of simulation of the processing of a mixture of benzene and hexachlorobenzene are presented. The results of experimental investigation of the processing of izofen and concentrate of butyl ether of 2,4-dichlorphenoacetic acid demonstrated the efficiency of the proposed technology.

3-26 A. N. MAKAROV, V. V. RYBAKOVA, E. V. KRUGLOV

USE OF REVEALED REGULARITIES FOR REDUCING ELECTRIC ENERGY CONSUMPTION IN ELECTROMETALLURGICAL FURNACES

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The technique of calculation of heat transfer in electric arc and torch furnaces, fire boxes and combustion chambers is presented. Calculations of heat transfer in an electric arc steel-making furnace are carried out. The calculation results agree with the results of measurement of heat fluxes in an electric arc furnace. New designs of electric arc furnaces and techniques of steel melting in them have been developed.

3-27 A. MARQUESI,[1] A. GORBUNOV,[1] C. OTANI,[1]G. PETRACONI FILHO,[1]
A. BUBLIEVSKII,[2] A. GALINOVSKII[2]

THERMOPHYSICAL INVESTIGATION OF EFFICIENCY PARAMETERS FOR PLASMA ARC-ASSISTED GASIFICATION OF SPRAYED HYDROCARBON-BASED WASTES

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Treatment of heavy hydrocarbon petrochemical wastes to produce a syngas for modern "green energy" systems using thermal plasma processing can offer commercial advantage for industry. As basic feedstock for research, the liquid oil sludge (with 43.2% organic oil matter) being currently the standard waste has been chosen. Thermophysical assessment of plasma gasification process' energy balance and products yield has been carried out. It was determined that to reform this feedstock to a syngas, an energy consumption level of 8–10 MJ/kg is sufficient. This requires the use of regimes with the ratio of mass flow rates of steam gasifying agent (GA) to feedstock 0.1–0.5, with a calorific value of produced syngas of 16–20 MJ/kg. Under the realization of parametrical analysis the thermodynamic calculations allowed us to obtain such data as comparative effects of temperature, pressure and ratio of flow rates of GA to feedstock on the syngas composition and on gasification efficiency parameters, including the exergy efficiency.

3-28 O. G. MARTYNENKO, N. M. GORBACHEV, V. A. BABENKO, O. V. PROKOPOVICH

CHARACTERISTIC FEATURES OF THE DEVELOPMENT OF HIGH-ENERGY SHELL-AND-TUBE HEAT EXCHANGERS

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An algorithm and program of calculation of shell-and-tube heat exchanger with corrugated tubes have been developed. Both hydrodynamic and thermal calculations were made. The results obtained show that with the same number of tubes, the intensity of heat transfer is higher in a heat exchanger with corrugated tubes than in a heat exchanger with smooth tubes.

3-29 O. G. MARTYNENKO, N. M. GORBACHEV, V. A. BABENKO

EFFECTIVENESS OF HEAT TRANSFER INTENSIFICATION IN A COMPACT SHELL-AND-TUBE HEAT EXCHANGER

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A shell-and-tube heat exchanger with corrugated tubes has been developed on the basis of a heat exchanger with smooth tubes. The influence of the loss of pressure at the inlet and outlet from tubular bundles on the intensity of heat transfer is considered. The optimal characteristics of a compact shell-and-tube have been determined.

3-30 V. G. MINKINA, S. I. SHABUNYA, V. I. KALININ, V. V. MARTYNENKO, H. YOSHIDA

SODIUM BOROHYDRIDE FOR PRODUCTION OF HIGH PURITY HYDROGEN

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At the present time, sodium borohydride is considered as a promising material for hydrogen storage and a fuel for fuel cells. Borohydride-based systems have several advantages: they are easy to transport, have low toxicity, and do not oxidize storage tanks, and moreover, they are environmentally friendly, since the decay products are water and borates. When developing a hydrogen generator, several problems have been studied. They are related to the way of sodium borohydride storage before it is used in a reactor, the efficiency and durability of used catalyst, the accumulation and recycling of the hydrolysis product – the conversion of sodium metaborate into sodium borohydride. The dependences of hydrolysis rate of sodium borohydride during storage within a wide range of concentrations and temperatures have been obtained. The scheme and principle of hydrogen generator operation are also presented.

3-31 N. I. MIRMOV, M. A. PLESHCHINSKII, A. A. VASILIEV

COMBINED SOLAR COLLECTORS WITH HEAT PIPES

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For effective use of solar energy, various structural designs of solar collectors and heat absorbers are applied, as well as photoelectric panels. Combine collectors are intended for absorption of solar heat energy. A few new structures of combined solar collectors of modular type have been developed. A combined collector involving heat pipes consists of the module of solar energy absorption, the module of water heating, and the module for electricity production. The water heating module is fabricated as a double-pipe heat exchanger and consists of sections, the number of which corresponds to the number of heat pipes. Tests of the collectors were carried out with water heating in accordance with the seasonal diagram for active and passive systems of heating. The combined collectors are mainly intended for absorption of solar thermal energy. The photoelectric panels provide electric energy. Comparative tests of the pumping system of heated water circulation in a standard and combined collectors have shown that the quantity of the thermal energy absorbed by the combined collector is 1.26 times higher than by the standard collector, with the heat absorbing surface of the combined collector being 1.4 times smaller than of the standard one. The estimation of the effectiveness of the collector as the ratio of the specific thermal effectiveness P to the magnitude of solar radiation G for the given latitude and longitude of the locality ($\eta = P/G$) makes it possible to get a true objective values for various structures of solar collectors.

3-32 A. L. MOSSE, V. V. SAVCHIN

HEAT TRANSFER PROCESSES IN PLASMA FURNACES FOR WASTE PROCESSING

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As an alternative to low-temperature combustion of waste it is planned to use plasma furnaces. Waste processing is made by arc plasma torches that generate plasma flows. One of the most serious problems of operation of plasma furnaces is heating a plasma furnace in optimal time. Real conditions of heat transfer in plasma furnaces do not fit into the classical models of convective heat transfer. It is expedient to use experimental data obtained directly for heat transfer conditions in high-temperature thermotechnical units. The thermal technical parameters of plasma furnace operation were obtained. Method of heat calculation of a plasma furnace has been developed. The method is based on the experimental dependence of Nusselt number on the function of the specific flux of a pulse.

3-33 B. R. MUBARAKSHIN,[1] F. Sh. SERAZETDINOV,[2] V. G.TONKONOG[1]

USE OF EJECTOR IN DEVICES OF NATURAL GAS ODORIZATION

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According to the long-term plans of the development of "Gazprom" Joint Stock Company, the volumes of production and consumption of natural gas are ever increasing. This leads to the situation that the gas consumption regimes change substantially and new systems of the preparation of gas for operation with low and high flow rates are required. The paper presents the state-of-the art in developing the problem of natural gas odorization and the possible ways of its solution. The proposed ejector system of natural gas odorization presupposes the supply of an odorant in a liquid and gaseous state. The modes of operation of the system of odorization in the range of flow rates were investigated and testing of the conditions of odorant evaporation and determination of the ejection coefficient were made.

3-34 A. G. MURAV'EV, A. S. ZHDANOV, V. N. DUNIN, R. I. KHISAMOV

INVESTIGATION OF HEAT AND MASS TRANSFER PROCESSES IN HOLLOW CONTACT ECONOMIZERS

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The research was carried out on the basis of the earlier proposed mathematical model allowing one to obtain theoretical dependences of changes in temperature of smoke gases, water, and the concentration of steam in the gas on the apparatus height for the cases of co-current and counter-current motion of phases. It was established that graphs of variation of steam temperature and concentration of steam in the gas have an obvious extremum. Moreover, such parameters as the time of achievement of a maximum temperature of heated water and the maximum value of its temperature differ slightly for the cases of co-current and counter-current motion of phases under the same conditions at the entrance of the apparatus. In the time interval up to the moment of the heated liquid temperature maximum a decrease in the concentration of nitrogen oxides in smoke gases and an increase in the fraction of their content in water is negligible.

3-35 F. V. NEDOPEKIN,[1] V. A. KRAVETS,[2] V. V. BODRYAGA,[1] V. V. BELOUSOV,[1] V. M. MELIKHOV[1]

HEAT AND MASS TRANSFER PROCESSES IN A DROP OF PIG IRON DURING FORMATION OF RED FUME

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The mechanism of red fume formation during down flow weir of pig iron and the interaction of large and small metal sparks with an oxidizing medium are considered. A model of

heat and mass transfer processes proceeding inside of drops and on their surface is given. A critical diameter of a metal drop is calculated. A comparative analysis of the obtained results with experimental data is carried out.

3-36 M. N. NIKITIN

EXPERIMENTAL INVESTIGATION OF THE PROCESS OF PRODUCTION OF A GAS--VAPOR HEAT TRANSFER AGENT IN CONTACT STEAM-AND-SMOKE MIXTURE GENERATOR

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The world scale energy strategy determines the developing and implementation of new designs of heat generators and decentralization of the generation of heat carriers as promising trends in the development of industry. Steam-and-smoke mixtures (SSM) are promising heat carriers with unique properties for a number of technological processes. There are different design concepts of simple and efficient SSM generators. However, the optimal geometry of heat generators is determined empirically, so the cost of individual orders can be overstated.

The paper describes the method of engineering calculation of SSM generators, confirmed by the results of experimental studies.

3-37 A. N. NIKONCHUK, A. L. MOSSE, I. V. KHVEDCHIN, V. V. SAVCHIN, A. V. LOZHECHNIK, D. S. SKOMOROKHOV

MODELING OF THE PROCESS OF BIOMEDICAL WASTE PROCESSING IN PLASMA FACILITIES

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The plasma methods of treatment of biomedical waste are characterized by decomposition destruction of toxic substances at a high temperature. A model of the process of waste treatment has been developed. In this model, the plasma facility is divided into three parts: mixing chamber, reactor, and a quenching module. A mixture of ethyl and isopropyl alcohols and acetone, taken in equal parts, was chosen as a model substance. This mixture simulates wastes of pharmacological production, which are formed after cleaning of tanks with pharmacological byproducts. The analysis of the simulation data showed that during the waste processing the lack of oxygen results in generation of a large amount of H_2 and CO syngas, which can further be used for energy production.

3-38 V. V. ODINOKOV,[1] G. Ya. PAVLOV,[1] V. K. SAMOILIKOV,[2] P. A. IRAKIN[1]

EFFECT OF GAS DYNAMICS ON THE PROCESS OF VAPOR DEPOSITION OF STRUCTURES ACTIVATED BY A LOW-TEMPERATURE PLASMA

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Processes of chemical vapor deposition activated by a low-temperature plasma (PE CVD) are widely used in the production of a modern elemental base of micro-and nanoelectronics. The quality and uniformity of the PE CVD layers largely depend on the gas dynamics of the working gas injected into the vacuum chamber. In this paper, the deposition of a silicon nitride film with a single-feed of working gas micro jet SiH_4: N_2 into ICP discharge with RF inductor located near the surface of a silicon plate are studied. The paper provides an analysis of the results and recommendations for optimization of design and technological conditions of deposition layers on large-diameter wafers.

3-39 E. A ORLOVA, F. A KOZLOV, V. V AlEKSEEV, A. V. DROBYSHEV, V. G ZHMURIN, S. A. ZAGREBAEV, I. I. ZASORIN, I. Yu. TORBENKOVA, V. S. EGOROV, A. N. VOLOV

MASS TRANSFER IN LIQUID METAL USED IN THE TECHNOLOGY OF PHOSPHATE WASTE REPROCESSING

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In production of phosphates from fluorapatite, wastes of type Na_2SiF_6, H_2SiF_6, etc. are formed. The production of phosphate fertilizers has been developed at the «Gomel Chemical Plant" JSC in Belarus and at a number of factories in Russia. We suggest an ecologically pure low-temperature technology of complex reprocessing of Na_2SiF_6 having no analogs in the world, which uses fundamental principles of liquid metal technology of nuclear power industry developed at our Institute. High-purity silicon and NaF are produced. A method for forming protective coatings on steels MgF_2 has been developed. Silicon is virtually in unlimited demand on the world market due to the fact that its main users are the solar power ingeneering and electronics which are being developed at a faster pace. The price of silicon increases.

3-40 D. A. PARSHIN, L. S. STELMAKH, A. M. STOLIN

INFLUENCE OF THE DISPERSITY OF METAL-BOND ON THE KINETICS PACKINGS OF PACKING DURING THE SHS-COMPACTION OF REFRACTORY MATERIALS

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Based on mathematical simulation of the SHS compaction(pressing and extrusion) of refractoty materials in a cylindrical mold, the influence of the dispersity of the metal-bond on the fundamental characteristics of the material (density and its variation at the height of the article produced) is investigated. It is shown that with the use of ultra-and nano-dispersed powders as the metal- bond, specimens of better quality are obtained: rods compact to a maximum density over the entire length (except for the small part near the hole rod of the shaping matrix).

3-41 E. N. PIS'MENNYI

INTENSIFIED TUBULAR HEATING SURFACES FOR «GAS–GAS» – TYPE HEAT EXCHANGERS

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One of the ways of increasing the efficiency of natural gas transportation is the increase of the degree of heat regeneration in gas-turbine plants of gas pumping units to the values r = 0.82–0.88. This makes it possible to increase the efficiency of such facilities by 3–4% and significantly reduce fuel gas consumption. Tubes of circular cross section, usually employed in the regenerators of gas-turbine plants, have exhausted their potentialities and practically do not allow one to achieve the desired values of r. It is proposed to replace the circular-pipes heat transfer surfaces of air headers by flat-oval or "equally developed" surfaces, which will significantly reduce the mass of the heat exchanger, time-consumption for its manufacturing, the cost, and pressure losses e in the gas and air ducts of air heaters.

3-42 S. P. RUDOBASHTA,[1] V. T. KAZUB,[2] A. G. BORISOV[1]

MASS EXCHANGE DURING SPUTTER-ION EXTRACTING OF TARGET COMPONENTS FROM VEGETABLE RAW MATERIAL

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The existing methods of extracting target components from vegetable raw material are characterized by long duration and incomplete extraction of products. More complete and rapid extraction can be achieved by applying the method of sputter-ion extraction (SIE). However, the method has not been investigated adequately, which predetermined the necessity of carrying out this investigation. The paper presents the results of experimental investigation of mass transfer during SIE of alkaloids from the leaves of the Belladonna plant. The obtained experimental data on mass-transfer coefficients are generalized by dimensionless equations. The nonstationarity of mass transfer in SIE cycles might be one of the factors of intensification of mass exchange during SIE. An analytical expression for calculation of mass- transfer coefficient in SIE cycles has been derived.

3-43 A. R. SALMANOV

SCHEME AND ALGORITHM OF CALCULATION OF A GAS-PURIFYING CONDENSER

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Physical model of trapping dust particles and gaseous components are generalized by the algorithm of zonal calculation of a gas-purifying condenser. The calculations of the efficiency of gas trapping and absorption are performed in parallel on the basis of initial data and results of the thermal calculation of the condenser. The results of calculations in comparison with experimental

data obtained under industrial conditions on actual mixtures have an error of 20-25%, which allows one to use them for calculating gas-purifying condensers.

3-44 S. I. SHABUNYA, A. A. NESTERUK

EXPERIMENTAL STUDY OF SODIUM BOROHYDRIDE HYDROLYSIS AT HIGH ALKALI CONCENTRATION IN SOLUTIONS

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The characteristic features of the hydrolysis kinetics for sodium borohydride water--alkali solutions at high alkali concentration are described. The kinetics is based on account for hydration complexes formed by ions in a solution. For high NaOH concentrations, three possible asymptotics of the behavior of the fundamental eigenvalue of kinetic equations are given. For the most probable asymptotics, the activation energy for the Arrhenius form of the fundamental eigenvalue of kinetic equations is determined.

3-45 M. I. SHILYAEV, E. M. KHROMOVA

A PHYSICOMATHEMATICAL MODEL OF HEAT AND MASS TRANSFER AND OF ABSORPTION–CONDENSATION DUST–GAS-CLEANING IN JET SCRUBBERS

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A physicomathematical model of the complex process of heat and mass transfer and of condensation–absorption cleaning of gases of dust and harmful gaseous ingredients in jet apparatuses is proposed. Numerical implementation of the model for concrete conditions is well confirmed by the known test data and can be used for engineering calculations and optimization of constructional and operating parameters of hollow jet dust–gas-cleaning installations of both direct and counter current type. In the work, calculation of absorption of CO_2, H_2S, SO_2, CH_4 on water drips in a hollow direct jet scrubber and in the Venturi scrubber from a moist air is carried out and as an example the joint absorption- condensation cleaning of air in these apparatuses from H_2S and fine dust is calculated.

3-46 T. V. SIDOROVICH, V. I. BAIKOV

MEANS FOR INCRESING THE POWER EFFICIENCY OF MINIATURE RECUPERATIVE HEAT-EXCHANGE EQUIPMENT FOR VISCOUS FLUIDS

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The regularities of laminar steady and unsteady heat transfer in flat internal channels of a miniature recuperative heat-exchanging apparatus have been established from numerical simulation for the case where channels differ in the shape of the passage sections through the corresponding

arrangement of pinches (symmetric and asymmetric) with well streamlined profiles. The ways for increasing the power efficiency of the operation of heat-exchanging equipment for viscous fluids are recommended.

3-47 A. V. SOKOLOV, A. Yu. BOLSHIKHIN, V. S. BELOUSOV

CHARACTERISTIC FEATURES OF THE THERMAL REGIME OF ROTATING REGENERATIVE AIR HEATERS

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The research deals with analytical solution of the problem of nonuniform gas temperature distribution downstream of a rotating regenerative air heater. A sufficient gas temperature gradient is observed here. The results presented allow the conclusion that part of outgoing gas can be used for industrial usage and utilities.

3-48 B. S. SOROKA, N. V. VOROBYOV, V. A. ZGURSKII, V. S. KUDRYAVTSEV

HEAT TRANSFER AND HYDRAULIC RESISTANCE IN A HIGH- TEMPERATURE RECUPERATOR

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To enhance heat transfer in tubes of contemporary high-temperature recuperators, inserts (secondary emitters) are used that make it possible to considerable (60–120 °C) increase the air heating temperature and correspondingle decrease the temperature of the tube walls. The use of heat transfer intensifiers that increase the service life of the apparatus is accompanied by an increase in the hydraulic resistance of heat exchangers. The decisive role in selecting the design of inserts is played by the combined thermal and hydraulic characteristic (THC) of heat exchanger. On the basis of experimental investigations and the results of CFD modeling, the THC of the units with inserts of various geometry were compared and the equations for heat transfer calculation along with the recommendations for the choice of the type of secondary emitters have been proposed.

3-49 L. S. STELMAKH, A. M. STOLIN

MATHEMATICAL SIMULATION OF THE SOLID-PHASE EXTRUSION OF FLUOROPOLYMERS

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Based on theoretical description of the process of solid-phase plunger extrusion of fluoropolymer materials with account for the rheodynamics, heat exchange, structuring, and kinetics of compressible medium compaction, the possibility of oscillatory regimes of deformation for the technological parameters that correspond to these materials is shown. Explanation and interpretation of experimental results obtained during extrusion of fluoropolymers from smooth nozzles of different diameters are given.

3-50 L. S. STELMAKH,[1] A. M. STOLIN,[1] B. B. POLYAKOV,[2] D. S. DVORETSKII[2]

OPTIMAL DESIGN OF A MOLD FOR THE HIGH-TEMPERATURE SYNTHESIS OF HARD-ALLOYED MATERIALS

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The self-propagating high-temperature synthesis (SHS) pressing as one of the directions of SHS-technology includes thermal and dynamic loadings. During the SHS process high temperatures of up to 2000–3000°C can develop and in the process of pressing extra pressures of up to 200 MPa can be reached. The presence of high pressure and temperature loads superposed in different time intervals requires more detailed study of the process during equipment design. An algorithm of two-stage optimization has been developed whose efficiency is demonstrated using the examples of optimal design of a mold for the high-temperature synthesis of hard-alloyed materials.

3-51 D. A. TAKOPULO, S. P. FISENKO

HEAT AND MASS TRANSFER DURING FORMATION OF SUPERSATURATED CARBON SOLID SOLUTIONS IN THE WALL OF A PLASMACHEMICAL REACTOR

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It has been shown for the first time that in a plasmachemical reactor a supersaturated solution of carbon is formed in the reactor wall by diffusion of carbon atoms and growth of a layer of highly porous carbon on the catalytic wall. This layer is formed as a result of deposition of carbon nanoparticles from the plasma flow. It is shown that for air–plasma flows with a temperature above 1000 K, the porous layer of thickness 100 microns blocks the heating of the catalytic surface by plasma flows and radiation. The paper presents the results of simulation of heat and mass processes in a gas–porous layer–metal system.

3-52 A. TAMOŠIŪNAS, P. VALATKEVIČIUS, V. VALINČIUS, V. GRIGAITIENĖ

HEAT TRANSFER IN THE ARC DISCHARGE CHANNEL STABILIZED WITH A STEAM VORTEX

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The experimental investigation deals with the analysis of thermal characteristics of a linear direct current (DC) arc plasma generator stabilized by tangentially injected stream of steam. A hot tungsten-rod cathode is used as an electron emitter for causing ionization of injected gas. A step-shaped anode was used to minimize the pulsations of arc in the discharge chamber and for longitudinal stabilization of arc. The steam overheated up to 450 K was used as a working gas. The torch operates at atmospheric pressure with a current intensity of 115 to 200 A and voltage 220–390 V. Heat transfer mechanism to the walls of the water vapor plasma torch was investigated and

generalized employing the theory of similarity. Additionally, heat transfer in the wide part of the anode was carried out comparing the results with classical heat and mass transfer theory.

3-53 Yu. A. TARAN

POSSIBILITIES OF ENERGY SAVING IN THE TECHNOLOGIES OF GRANULATION AND CAPSULATION ON CRISTALLIZATION OF MELT DROPS

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In the process of granulation by crystallization of melt drops, the emitting heat of conversion is not used even in the production of such large capacity products as nitrogen-containing mineral fertilizers, alkalines, slags, and others. The paper suggests, describes, and investigates the schemes of utilization of heat released in granulation with the aid of a heat pump in application to granulation of melt drops on cooled surfaces and in flows of liquid vapor-drop cooling agent. In the latter case, the process of granulation is combined with the capsulation process by using a solution of capsulation agent as a cooling agent. The full cycle of NIR and in some cases NIOKR has been carried out. Satisfactory correspondence of computational experiment with practice has been confirmed.

3-54 Yu. A. TARAN, T. I. PYNKOVA, A. L. TARAN

ECO-FRIENDLY AND ENERGY-SAVING TECHNOLOGIES OF GRANULES ENCAPSULATED BY WATERPROOF THIN POLYMERIC MEMBRANES

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To improve the environmental safety, we propose to use aqueous emulsions of polymer solutions in the combined technology of granulation process by crystallization of melting drops in a solution of encapsulating component. Then the capsulated component separates from the solvent granules by the residual heat of phase transformation. Also in this work we considered the dynamics of formation and destruction of emulsions for the mathematical description of which we proposed to use a formal analogy between the processes of rearrangement of the original system.

3-55 S. G. TERZIEV, N.V. RUZHITSKAYA, A. A. BORSHCH

KINETICS OF HEAT AND MASS TRANSFER PROCESSES IN THE TECHNOLOGY OF FOOD CONCENTRATES

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The problem of using infrared (IR) radiators for organization of drying processes in the technologies of food concentrates is analyzed. Description of an experimental stand which shows drying lines, drying rate lines, thermograms on-line on the computer screen is given. The results of

experiments on drying coffee sludge and peas are presented. The influence of IR power-to-surface ratio and air velocity in the chamber on drying kinetics is revealed. The prospect of using IR in food concentrate technologies is proved. The possibilities of further use of dried coffee sludge for clean and aromatized coffee oil extraction are considered. The prospect of microwave technologies for oil extraction from coffee sludge is shown.

3-56 V. I. TIMOSHPOLSKII, I. A. TRUSOVA

ASPECTS OF NONLINEAR THERMOPHYSICS IN METALLURGICAL FURNACES

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Mathematical modeling is one of the most important research directions of heat transfer processes in high-temperature metallurgical furnaces. The results of simulation of nonlinear thermal physics processes in modern melting and heating furnaces are presented in the paper. In solving the metal melting and heating problems, such features of nonlinear heat transfer processes as the design features of furnaces, hydrodynamic, design and location of treated metal, etc. were considered.

3-57 V. G. TONKONOG

GASIFICATION OF CRYOGENIC FLUIDS

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Intense increase in the production and consumption of liquefied natural gas and other cryogenic fluids presupposes the creation of their usage, including the development of the processes and creation of facilities for gasification of cryogenic fluids. An apparatus for field gasification is proposed. The vapor phase is created as a result of choking during its operation. The apparatus has highly efficient dynamic characteristics; the cryogenic fluid storage tank is being cooled during the operation process. Experimental and numerical modeling of the two-phase flow characteristics in the gasifier vaporization unit is made. Experiments were carried out with nitrogen. Numerical modeling was made for both one- and two-dimensional statements for different working substances: nitrogen, hydrogen, and methane.

3-58 V. B. TROSHEN'KIN,[1] K. M. KHOMYAK,[2] B. A. TROSHEN'KIN[1]

HEAT AND MASS EXCHANGE IN PRODUCTION OF HYDROGEN BY RADIOLYSIS OF WATER--COAL SUSPENSION

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[2]*National Technical University «KhPI», Kharkov, Ukraine*

Major coal deposits of the Donetsk Basin are located at considerable depths. The borehole radiolytic method of underground gasification of deep-lying deposits has been developed.

On exposure to radiation, water decomposes with the formation of active radicals. Simultaneously, under irradiation the atomic bindings in the crystal lattice of coal are violated, which facilitates the interaction of carbon with the active radicals. As a result, hydrogen and the carbon dioxide are formed.

Evaluation of the intensity of heat exchange between the phases shows that the heat release coefficients during radiolysis increase approximately 1.5–2 times in comparison with the coefficients in electrolysis of coal slurry.

3-59 N. Ya. TSISLINSKAYA, M. P. BERNIK, A. S. LUPASHKO, E. Ya. CHIOVANU

ENERGY SUPPLY OPTIMIZATION OF THE PROCESS OF DRYING WITH AN INTERNAL HEAT SOURCE

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As the food moisture has different forms of bonding that require large amounts of energy for their breaking, we attempted to simulate the optimization of energy supply and to present it as a function of the energy needed for evaporation depending on the energy needed to break the bonds between the moisture and the product using an internal heat source.

3-60 E. A. TSYNAEVA, A. A. TSYNAEVA

NUMERICAL SIMULATION OF DYNAMIC REGIMES OF OPERATION OF THE SYSTEMS OPTIMIZING HEAT CONSUMPTION BY BUILDINGS

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The application of the systems that optimize heat consumption by buildings allows one to significantly reduce the cost of heat for a consumer. Large-scale implementation of heat-consumption optimization systems is hindered by the lack of adequate models and methods of developing a most efficient system. The communication considers mathematical models of heat-consumption optimization systems and the results of numerical simulation of the dynamic regimes of operation of such systems.

3-61 L. L. VASILIEV, A. S. ZHURAVLYOV, A. A. ANTUKH, O. S. FILATOVA, L. A. DRAGUN, A. P. TSITOVICH, M. N. KOVALYOVA

NONELECTRICAL SORPTION MACHINES FOR GENERATION OF COLD

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A sorption refrigerator consists of two adsorbers, filled with a sorbent, and a temperature control system based on heat pipes. Vapor-dynamic thermosyphons are provided for heating solid sorbent blocks. The continuity of operation of the refrigerator is attained due to the presence of two identical contours operating in antiphase. The adsorbers are filled with an activated carbon fiber, saturated with chlorides of metals. Investigations have shown that the processes of physical and chemical sorption of a coolant (ammonia) in the given synthesized material proceed independently, which provides its high sorptive capacity. The paper describes the principles of operation of

sorption refrigerators, the results of investigations of composit sorbents and refrigerator components.

3-62 V. I. VOLODIN,[1] V. B. KUNTYSH,[1] N. G. PETREEVA,[1] A. N. BESSONNYI,[2] E. A. BESSONNYI[2]

INFLUENCE OF EXTERNAL FOULING ON THE EFFICIENCY OF AIR-COOLED HEAT EXCHANGERS

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[2]*«Lenniikhimmash» Co.Ltd, St. Petersburg, Russia*

The paper considers the technique of calculation to assess the impact of fouling on the operation of air-cooled heat exchangers. Their heat transfer surface is made of bimetal finned tubes with circular cross-section ribs. Operational fouling from the ribbed surface reduces the heat flow in the apparatus. This is shown that to compensate this phenomenon it is required to increase the rate of cooling air. This is associated with a significant increase in the fan power for pumping. Fouling reduces the energy efficiency of the apparatus.

3-63 M. K. ZAKHAROV, O. A. SAZONOVA, A. M. IL'CHENKO

ANALYSIS OF ENERGY SAVING IN RECTIFICATION OF BINARY AND TERNARY MIXTURES

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It is shown that in the case of the same quality of separation of binary and ternary mixtures, energy saving in the processes of rectification increases on increase in the reflux ratio.

3-64 G. I. ZHURAVSKII, A. S. MATVEICHUK

THERMOLYSIS OF ORGANIC MATERIALS IN A VAPOR–GAS ENVIRONMENT

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We describe the results of experimental investigations of the physical and chemical processes proceeding during the traditional (slow) and high-speed steam thermolysis of organic materials. The possibility of influencing the properties of final solid, liquid, and gaseous products by creating the assigned compositions from initial processed raw materials has been justified.

3-65 G. I. ZHURAVSKII, A. S. MATVEICHUK

THERMAL TECHNOLOGIES OF OBTAINING FUELS FROM ORGANIC WASTES

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At the present time, the most promising are thermochemical methods of processing solid organic waste. The paper presents the results of the works carried out at the A. V. Luikov Heat and Mass Transfer Institute in the areas of thermolysis processing of polymer waste, investigations of biomass high-speed pyrolysis, and creation of gas-generation equipment for obtaining combustible gases from an organic waste.

SECTION 4

HEAT AND MASS TRANSFER IN POWER ENGINEERING FACILITIES

4-01 A. V. AKULICH, V. A. BORODULYA, L. M. VINOGRADOV, O. S. RABINOVICH

SOME PREREQUISITES FOR THE DEVELOPMENT OF SOLAR POWER ENGINEERING ON THE BASIS OF POLYCRYSTALLINE SILICON IN THE CONDITIONS OF THE REPUBLIC OF BELARUS

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An analysis of the prerequisites for the development of the solar power engineering in Belarus on the basis of polycrystalline silicon is performed. Charts of the intensity of illumination of the Europe have been analyzed. The prospect of the production of silicon in a fluidized bed rector is noted.

4-02 V. V. ALEKSEEV, E. V. VARSEEV, E. A. ORLOVA

COMPUTATIONAL MODEL OF THE PROCESS OF TWO-LAYER OXIDE COATING FORMATION ON THE SURFACE OF STEEL IN A LEAD COOLANT

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Many years of operating experience on facilities with a lead--bismuth coolant and numerous studies of lead as a coolant shows that in them impurities are formed, followed by transport and localization of the products of their interactions. The endurance of steel in a lead--based coolant is achieved by the formation, on the steel surface, of a diffusion barrier to mass transfer of steel components in the coolant. Therefore, a coolant loop with a heavy liquid metal needs to be passivated, i.e., coated with a protective oxide film, which limits the corrosion and the output of its products into the coolant.

In this paper, we have solved the modeling of the two-layer oxide film formation on the surface of steel in a circuit with the lead coolant problem. The model contains a mathematical description of the oxidation process with formation of two kinds of oxide film layers. Simultaneous solution of these equations with given boundary conditions allows us to calculate the growth of each sublayer and their thickness. An agreement between the calculated and experimental data on the oxidation of steel at the operating parameters of advanced reactors has been obtained.

4-03 Yu. A. ANIKIN,[1,2] I. S. ANUFRIEV,[1] D. V. KRASINSKII,[1] V. V. SALOMATOV,[1,2] E. Yu. SHADRIN,[2] O. V. SHARYPOV[1,2]

NEW-TYPE VORTEX STEAM GENERATOR: MODELING OF FURNACE PROCESSES

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The work is devoted to experimental and numerical investigation of the aerodynamics in the model of a new-type furnace device with a horizontal vortex and distributed tangential input of fuel jets. Measurements of the aerodynamic characteristics of flow were performed with the aid of the laser Doppler measurement system. Computations have been performed with the use of the CFD package FLUENT. The results showed that due to the presence of additional bottom nozzles the given construction is more flexible in controlling aerodynamic structure of the flow and allows one to realize more favorable regimes of vortex furnace operation.

4-04 A. S. ASKAROVA, S. A. BOLEGENOVA, V. Yu. MAKSIMOV, A. BEKMUKHAMET

INVESTIGATION OF HEAT AND MASS TRANSFER PROCESSES IN BURNING OF PULVERIZED COAL FUEL IN THE COMBUSTION CHAMBER OF A BKZ-160 BOILER USING THE METHODS OF THREE-DIMENSIONAL SIMULATION AND THE «OVERFIRE AIR» TECHNOLOGY

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Numerical experiments were conducted using the «overfire air» technology in burning pulverized coal flame in the combustion chamber of the BKZ-160 boiler of Almaty TPP, which allow one to reduce carbon dioxide CO_2, nitric oxide NO, and nitrogen NO_2 emissions and to minimize energy losses. Results of computational experiments on the effect of additional air supply (OFA technology) to the basic characteristics of heat and mass transfer are presented. A comparison with the basic mode of combustion of solid fuels, when there is no supply of additional air (OFA = 0%) is carried out.

4-05 S. S. BAZYUK,[1] N. Ya. PARSHIN,[1] E. B. POPOV,[1] Yu. A. KUZMA-KICHTA[2]

DEVELOPMENT OF THE ENGINEERING METHOD OF CALCULATING THE REFLOODING CHARACTERISTICS IN SIMULATION OF PROJECTED ACCIDENTS

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Design-basis (DBA) and beyond design (BDA) accidents are investigated on single fuel rod simulators and on 19 and 37 model WWPR-type fuel rod assemblies (FA's) with standard constructional elements, including the stage of cooling bottom and top by water or combined cooling (reflooding stage) on the PARAMETER rig (ownership of "LUCH"). To determine the water flow rate and the time required for cooling the model of fuel assembly of different configuration and scale, an approximate technique based on the balance of heat accumulated in the FA before the reflooding stage and that removed during liquid supply has been developed. The results of computation of the cooling duration under bottom reflooding conditions are in good agreement with the obtained experimental data for model WWPR-type fuel assemblies and can be used for the development of measures for increasing the NPP safety.

4-06 I. A. BELYAEV,[1] M. A. KADURINA,[1] Ya. I. LISTRATOV,[1] N. G. RAZUVANOV,[2] V. G. SVIRIDOV[1]

EXPERIMENTAL INVESTIGATION OF LIQUID METAL HEAT TRANSFER IN AN INCLINED CHANNEL AS APPLIED TO A TOKAMAK REACTOR

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It is planned assumed to use a liquid metal (LM) as a coolant in promising nuclear and thermonuclear plants. In the latter case, the LM flow will be affected by strong magnetic fields (MF), which can lead to a catastrophic increase in the resistance to flow. However, reasonable arrangement of heat exchange channels can minimize the negative effects manifested in the magnetic field. The impact of magnetic field on the flow in the presence of strong heat fluxes that give rise to buoyancy forces is ambiguous and cannot be reduced only to the suppression of secondary flows and turbulence. An experimental investigation of flow in an inclined tube (the slope to the horizontal is 1/5) in a longitudinal MF was carried out. The inclination corresponds to the conditions of the ITER project of tokamak reactor. The results obtained in the regimes without an MF can be of interest for the design of nuclear reactors cooled by LM and for metallurgical processes.

4-07 I. A. BOKUN, V. N. NAGORNOV

EXTERNAL HEAT TRANSFER IN A PULSATING BED OF LARGE PARTICLES

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The results of an experimental investigation of heat exchange between a heating surface and a low-frequency pulsating bed of large copper cinder particles of equivalent diameter 2.5 mm are given. Experiments have shown that the heat transfer coefficient in the pulsating bed of large particles is 15–20% higher than in an ordinary fluidized bed. The higher value of the heat transfer coefficient is attributable to the increased agitation of the boundary film and intense replacement of particles near the heating surface.

4-08 É. A. BOLTENKO

INCREASE OF THE EFFICIENCY OF REACTOR FUEL ASSEMBLIES BY THE METHODS OF HEAT REMOVAL INTENSIFICATION

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The increase of the efficiency of fuel assemblies (FAs) of reactors is possible due to the introduction of new technical solutions that raise the intensity of heat removal on convex heat-releasing surfaces and departures from nucleate boiling. In FAs there is a considerable nonuniformity of the distribution of a coolant over the cross section of a FA. An increase in the values of departures from nucleate boiling is possible by eliminating the nonuniformity of the parameters over the FA cross section and using intensification methods. The paper considers technical solutions that will allow one to reduce the nonuniformity of the distribution of a coolant over the cross section of the assembly, increase heat removal on convex heat transfer surfaces, and to increase the values of the departures from nucleate boiling in the FA of a reactor.

4-09 V. A. BORODULYA, É. K. BUCHILKO, L. M. VINOGRADOV

SOME CHARACTERISTIC FEATURES OF BURNING WATER–COAL FUELS IN A FLUIDIZED BED

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The paper considers characteristic features of fluidized bed burning of water--coal fuel (WCF) based on Belarusian brown coals and peat. A mathematical simulation of the process of combustion of individual WCF droplet is performed and qualitative estimation of its stages is made. The sequence and duration of the stages of WCF combustion depending on the type of the original solid fuel and bed temperature have been confirmed. The temperature and temporal dependences of the content of sulfur and nitrogen oxides and carbon in flue gases have been studied. The concept of effective use of Belarusian brown coals by obtaining WCF with subsequent burning in a fluidized bed furnace is considered.

4-10 V. A. BORODULYA,[1] S. M. DOBKIN[2]

TECHNOLOGY OF COMBUSTION IN A FLUIDIZED BED: EFFECTIVE METHOD OF USING LOCAL FUELS FOR DECENTRALIZED ENERGY SUPPLY

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Under the contemporary conditions in Belarus and other CIS countries, the rational and effective use of local fuel-power resources and renewable energy sources become of increasing importance.

It is generally accepted that one of the promising technologies allowing the use of low-calorie and high-ash fuels (wood, peat, brown coals) in power engineering is the technology of their direct combustion in a bubbling (fluidized) bed.

4-11 V. A. BORODULYA, V. L. MALEVICH

METHOD OF CALCULATING THE PARAMETERS OF HEAT AND MASS TRANSFER IN DEEP COOLING OF A STEAM--GAS MIXTURE

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A method for calculating the surface condensing heat exchangers, which allows one to obtain the distribution of local parameters in deep cooling of a steam–gas mixture flow along the tubes and their banks, as well as to optimize the parameters of tubes and of tube bundles is proposed. The calculations showed their satisfactory agreement with the experimental data obtained in tests of the condensing heat exchanger installed in the DE-10-14GM boiler at the Ulyanovsk TPP-3.

4-12 V. A. BORODULYA, O. S. RABINOVICH, L. M. VINOGRADOV, A. Zh. GREBEN'KOV, V. E. IVANOV, A. M. MIKHAILOV

SYNTHESIS OF HIGHLY TECHNOLOGICAL MATERIALS IN A FLUIDIZED BED: NEW APPROACHES AND PROSPECTS

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The paper presents an analysis of the state-of-the art in the field of application of the bubbling bed technology for the synthesis of highly technological materials: carbon nanotubes, silicon carbide, polycrystalline silicon for solar elements. Basic problems are considered whose solution is needed for successful development of the considered technologies. Among such problems there are: elucidation of the nature of the bubbling bed electrical conductivity and of the laws governing it, prediction of its behavior at the fluidization limit in the case of a wide fractional composition, investigation of the influence of acoustic, mechanical, and electromagnetic effects on a bubbling bed. New experimental and theoretical results in the field of the synthesis of materials in a bubbling bed are presented.

4-13 A. A. BRIN, A. I. PETRUCHIK

NEW WAYS OF ACHIEVING PROJECT PARAMETERS OF WATER COOLING IN WATER TURN-OVER CYCLES WITH COOLING TOWERS

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An applied problem of ensuring the needed parameters of water cooling in circulating water cycles with cooling towers is considered. This technique is extensive, since the decrease in

the water temperature in a circulating water cycle is reached due to the increase of the circulating water flow rate, the frequency rate of circulation or of the irrigation area. The choice of the practical realization scheme of the given technique depends on the cycle characteristics: quantity and capacity of pumps, efficiency and loading of cooling towers, etc. Frequently the needed temperature of the water, arriving at cooled equipment is below the actual water temperature at the cooling tower outlet. In this case it is required to raise the efficiency of the cooling tower. The efficiency of a cooling tower is theoretically limited by the temperature of wet bulb thermometer and technologically – by the flow rates of coolants.

4-14 Yu. M. BRODOV, N. V. ZHELONKIN, A. Yu. RYABCHIKOV, K. É. ARONSON
INVESTIGATION OF HEAT TRANSFER IN PROFILED TUBE BUNDLES OF STEAM TURBINE OIL COOLERS
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The characteristic features of oil flow and heat transfer in bundles of profile tubes are investigated. The effect of neighboring tubes on heat transfer of the tube investigated is studied. Comparative results on heat transfer in oil flow past profiled tube bundles are obtained.

4-15 E. E. CHAIKOVSKAYA
ENERGY SAIVING TECHNOLOGIES BASED ON INTELLECTUAL CONTROL OF HEAT AND MASS TRANSFER PROCESSES
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The well-known methods of optimization (economic, exergy, and thermoeconomic) make it possible to determine optimum conditions of the working capacity of power engineering systems at a static level without account for their accumulating capacity. It is proposed to evaluate the degree of change in the accumulating capacity on the basis of information as a measure of the reflection of the ratio between the production and consumption of energy in a single information space. On the basis of mathematical and logical modelling, in the composition of the proposed technological systems, technologies for the support of power systems functioning at the level of making decision have been developed. The methods of regime realization of power engineering systems are presented. Examples of the developed technologies are given, and their efficiency has been evaluated.

4-16 G. V. DASHKOV, G. L. MALENKO, A. D. SOLODUKHIN, N. N. STOLOVICH, V. D. TYUTYUMA
LABORATORY MODELING OF THE INFLUENCE OF THERMAL AND HYDRODYNAMIC PROCESSES ON THE EFFICIENCY OF OPERATION OF A COMBINED-DRAFT EVAPORATIVE COOLING TOWER
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The estimates of the operation efficiency of a combined-draft evaporative cooling tower have been obtained experimentally on a laboratory model. As the source of a forced air supply (of an added forced draft) in the tower considered we used an internal ventilation mini-tower installed at the centre of the wetting system. It is shown that the creation of the forced draft of a cooling air only in the central zone of the tower leads to the initiation of the second flow of cooling air in the periphery zone (in addition to the natural draft) by ejection of the latter by a jet of the spent air flow of the central tower zone.

Dissimilarities between the processes of water cooling in the tower with combined draft and those in the case of cooling due to the natural draft in a conventional tower are discussed.

The possible ways of technical implementation of the proposed method of creating combined draft in natural evaporative cooling towers have been considered.

4-17 M. Yu. EGOROV, M. A. GOTOVSKII, E. D. FEDOROVICH

POSSIBILITIES OF INCREASING THE EFFICIENCY OF THERMOHYDRAULIC PROCESSES IN SYSTEMS OF INTERMEDIATE MOISTURE SEPARATION AND REHEAT IN NPP WET STEAM TURBINES

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The ways of providing an efficient and reliable operation of intermediate separation and steam reheat for NPPs wet steam turbines are discussed. The results of experimental and computational studies of recent years are used. The long experience of such systems operation in Russian and foreign NPPs is taken into account: organization of stable separated water drainage from the moisture separators-reheaters (MSR), avoiding temperature oscillations in condensable heating steam channels of MSR reheating section and using enhanced heat transfer surfaces. Particularly, the method of heat transfer enhancement by means of artificial roughness produced by continuous deformation (dimpled surfaces) is analyzed.

4-18 M. A. GOTOVSKII, P. V. EGOROV, Yu. G. SUKHORUKOV

ANALYSIS OF HEAT TRANSFER IN SATURATED STEAM CONDENSATION ON THE SURFACE OF SUBCOOLED WATER JETS IN APPLICATION TO DIRECT CONTACT HEAT EXCHANGERS FOR NUCLEAR POWER PLANTS

I. I. Polzunov Joint Stock Company "Scientific Production Association for Research and Design of Power Engineering Equipment", JSC "NPO CKTI", St. Petersburg, Russia, *gotma@rambler.ru*

An important direction in improving modern nuclear power plants is to increase the efficiency of heat exchangers in the feed water duct. Great opportunities in this respect are provided by the use of direct contact heaters (deaerators particularly) in which heated water jets are fed through low-pressure jets and have a relatively high speed. It is possible to provide a more compact direct contact heat exchangers and, consequently, more efficient use of the plant building area. To

implement this direction it is necessary to have sufficiently reliable methods of calculating the intensity of heat and mass transfer processes using injectors. We use the approach proposed by V.G. Levich, who made it possible to the construct dependences having a clearer physical meaning. This relationship helps to avoid errors associated with the use of only the averaged values of jet parameters.

4-19 S. M. FEDOROV, V. V.MATSNEV

APPLICATION OF FLUIDIZED-BED FURNACES FOR BURNING A NATURAL GAS IN LOW-POWER INDUSTRIAL BOILERS

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We present a model of heat exchange between the solid phase of a fluidized bed and an immersed heating surface. The model is based on the conclusions made in the course of experimental investigation and mathematical simulation of the hydrodynamics of a flowing bed with a horizontal tube inside it. The results of calculations by the proposed model are applied for designing a low-power industrial boiler with a fluidized-bed furnace burning a natural gas.

4-20 E. D. FEDOROVICH, Yu. A. KARYAKIN, T. Yu. PRONKEVICH, A. G. TRIFONOV

ANALYSIS OF HEAT AND MASS TRANSFER PROCESSES OCCURING DURING STORAGE OF SPENT NUCLEAR FUEL

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The storage of spent nuclear fuel (SNF) is one of the final stages of the fuel cycle of NPP. The fuel discharged from the reactor initially is directed for storage in a cooling pool to decrease the residual heat release and thereafter is transferred for dry storage. The complexity of treatment of SNF is connected with the high-level radioactivity, the presence of large quantities of fissile materials, and significant heat release after unloading from the reactor. The justification of the safety of storage is related to the introduction, into the practice of SNF, of reliable calculation methods of the thermal parameters of cooling systems. The basis of such techniques is the numerical solution of 2-D and 3-D nonstationary equations of conservation under initial and boundary conditions, which match the conditions of SNF storage. The paper presents the statement of the problem of the assessment of heat and mass transfer processes for different types of SNF storage and examples of numerical solution of the multidimensional system of equations for the conservation of their model analogs.

4-21 A. I. FEDOTOV, E. V. SHAMSUTDINOV

EXPERIMENTAL INVESTIGATION OF PRESSURE LOSS IN HYDROTRANSPORT OF COAL-WATER SLURRY

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The use of coal-water suspension fuel (CWS) in various power plants is by far one of the most promising directions. This necessitates the study of the processes and the choice of effective scientifically grounded modes of operation of coal-water slurry transportation systems. The paper presents the results of investigations on an experimental rig designed for investigation of a coal-water slurry flow in pipes. The dependences of pressure losses on the average flow velocity at different temperatures are presented.

4-22 N. M. FIALKO, V. G. PROKOPOV, R. A. NAVRODSKAYA, Yu. V. SHERENKOVSKII, N. O. MERANOVA, N. V. GNEDOI

SECONDARY ENERGY RESOURCES IN THE ENERGY SECTOR OF UKRAINE

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As is known, the key problem of the world-wide power engineering is, and will be in the nearest future, the problem of energy saving. In this respect, the use of secondary energy resources (SER) is important in the complex of various energy saving measures. The paper considers the characteristic features of using different types of secondary energy resources, namely, fuel, heat and high pressure SER (mechanical). The state of the use of SER in the energy sector of Ukraine is analyzed. Particular attention is paid to the utilization of thermal SER and, especially, the use of low-grade heat waste of industrial and power plants. The environmental aspects of utilization of SER are analyzed.

4-23 A. A. FROLOV, A. A. SEDOV

INVESTIGATION OF THE CHARACTERISTIC FEATURES OF THE THERMAL HYDRAULICS OF FAST MOLTEN-SALT REACTOR-MINOR ACTINIDES BURNER

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The paper considers some thermal hydraulic characteristic features of fast molten-salt reactor which is proposed as a system for burning and transmutation of minor actinides contained in the spent fuel of the WMWCPR-1000 type reactor. A mathematical model of the first loop and the results of model application to investigation of some unrated regimes are presented. The paper also presents the results of calculations of the homogeneous core model carried out with the use of the open source CFD software package OpenFOAM. The calculation results were used to optimize the flow pattern and heat transfer in the core.

4-24 R. M. GILMANOV, É. V. SHAMSUTDINOV

INVESTIGATION OF HEAT TRANSFER AND HYDRODYNAMICS IN THE COAL–WATER SLURRY STORAGE TANK AT DIFFERENT HEIGHTS OF FLOW NOZZLE

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Taking into account the predicted increase in the use of coal in power engineering and the modern ecological requirements, there is an urgent need in the use of water–coal suspensions as a fuel. The creation of the technologies of their effective utilization is impossible without creating scientifically justified recommendations based on the results of theoretical and experimental investigations. The paper presents the results of investigation of heat transfer and hydrodynamics in the tank for storage water–coal suspensions at various heights of location of the supplying flow nozzle.

4-25 A. M. GORBUNOVA, B. G. SAPOZHNIKOV

EXTERNAL MASS TRANSFER IN A VIBROBUBBLING BED OF INERT MATERIAL AND ITS COMPARISION WITH HEAT TRANSFER

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Using as an example a model process of naphthalene sublimation, experimental data on the mass transfer coefficients β were obtained. Experiments were carried out in a vibrofluidized bed of small-grain material. Small-size objects in the form of spheres (ø 13–15 mm) and cylinders (ø 13.4×25 mm) both floating free and fixed in the bed were used in experiments. The effect of vibration parameters and particle size on the mass transfer coefficient was studied. A comparison of the data obtained with the well-known results on heat transfer is given.

4-26 S. I. GORDEEV,[1] A. F. RYZHKOV,[1,2] T. F. BOGATOVA[1,2]

COMPUTATIONAL INVESTIGATION OF THE INFLUENCE OF SOLID-FUEL CCPP OPTIMIZATION PARAMETERS

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The paper is devoted to a comparative analysis of the major schemes of coal combined cycle power plants. As a result, the parameters which have a significant influence on the electrical efficiency of solid-fuel combined cycle power plants have been found: the distribution of flows in the thermal circuit of a setup and the blast type used in the part of gas preparation.

4-27 M. A. GOTOVSKII, P. V. EGOROV, Yu. G. SUKHORUKOV

ANALYSIS OF HEAT TRANSFER IN SATURATED STEAM CONDENSATION ON THE SURFACE OF SUBCOOLED WATER JETS IN APPLICATION TO DIRECT CONTACT HEAT EXCHANGERS FOR NUCLEAR POWER PLANTS

I. I. Polzunov Joint Stock Company "Scientific Production Association for Research and Design of Power Engineering Equipment", JSC "NPO CKTI", St. Petersburg, Russia, gotma@rambler.ru

An important direction in improving modern nuclear power plants is to increase the efficiency of heat exchangers in the feed water duct. Great opportunities in this respect are provided by the use of direct contact heaters (deaerators particularly) in which heated water jets are fed through low-pressure jets and have a relatively high speed. It is possible to provide a more compact

direct contact heat exchangers and, consequently, more efficient use of the plant building area. To implement this direction, it is necessary to have sufficiently reliable methods of calculating the intensity of heat and mass transfer processes using injectors. We use the approach proposed by V.G. Levich, who made it possible to construct dependences having a clearer physical meaning. This relationship helps one to avoid errors associated with the use of only the averaged values of jet parameters.

4-28 O. N. KABANKOV, L. A. SUKOMEL, V. V. YAGOV

A CHANNEL TO MODEL A FLOW AND HEAT TRANSFER OF SINGLE- AND TWO-PHASE MEDIA IN BEDS OF SPHERES

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On the basis of numerical simulation of fluid flows along various variants of curved surfaces, forming the inner space of straight channels, a channel configuration to model a flow in beds of spheres has been proposed. The model channel is a straight-line chain of balls surrounded by a cylindrical surface with nonzero longitudinal velocity component on it. The minimal cross-sectional area of model channel corresponds to the clearance of the bed. The numerical results show a complex flow field in the above-mentioned channel and good agreement between calculated and experimental data on pressure drops. Numerical simulation of the channel flow makes it possible to obtain porous system structure-dependent coefficients in the generalized Darcy law without additional physical experiments.

4-29 K. V. KARTASHOV, G. P. BOGOSLOVSKAYA

THERMOHYDRAULIC CALCULATIONS OF WWER-SKD REACTOR CORE FOR DIFFERENT COOLANT FLOW MODELS UNDER DESIGN CONDITIONS

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Results of thermohydraulic calculations with the use of subchannel SUP and MIF-SKD codes are presented. The SUP code allows the thermohydraulic parameters of a part of the reactor core to be estimated. Input neutron-physical parameters are calculated with the aid of the ACADEM code. The MIF-SKD code gives us the possibility to predict the local thermohydraulic parameters in a separate fuel subassembly. The code was verified on the data gained in experiments on water in a round tube and on freon in a bundle of rods under supercritical conditions.

The thermohydraulic parameters of the part of reactor core and fuel subassembly of WWER-SKD of power 1700 MW for one- and two-way flows within the reactor core are presented.

4-30 Yu. E. KARYAKIN, A. A. PLETNEV, E. D. FEDOROVICH

MODELING OF HEAT AND MASS TRANSFER PROCESSES IN SYSTEMS OF EMERGENCY COOLING OF NUCLEAR POWER PLANT POOLS WITH A SPENT NUCLEAR FUEL

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A mathematical model for calculating local temperatures of spent nuclear fuel storage is presented for normal and emergency situations after loss-of-flow. The model includes the solution of nonstationary heat and mass transfer equations and takes into account the mechanisms of heat conduction, convection, thermal radiation, mass exchange between water and air above the pool, as well as phase transitions: evaporation of water and condensation of steam. The method to control emergency situation in the pool with the use of a hydroaccumulator is presented.

4-31 R. R. KHAFIZOV, E. F. IVANOV, V. V. PRIVEZENTSEV, A. P. SOROKIN

PROBLEMS OF EXPERIMENTAL SIMULATION OF THE PROCESS OF SODIUM BOILING IN A MODEL OF SUBASSEMBLY MOCKUP UNDER EMERGENCY CONDITIONS

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Assessments of safety in the case of off-design accidents performed by means of the limit state analysis characterized by partial or complete failure of active safety systems and safety elements led to the analysis of the fast reactor core cooling under the conditions of sodium boiling. The investigations carried out earlier showed that due to the high intensive heat exchange during liquid sodium boiling there is the possibility of long-term cooling of the fast reactor core under emergency conditions. Further investigations are aimed at the study of boiling process development for a new engineering solution intended for the improvement of the safety of perspective fast reactors – the presence of a sodium cavity above the reactor core.

4-32 A. A. KHALATOV

INVESTIGATIONS IN THE FIELD OF NOVEL COOLING SYSTEMS OF GAS TURBINE BLADES CARRIED OUT AT THE INSTITUTE OF ENGINEERING THERMOPHYSICS OF THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE

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Currently, in the serial-production power gas turbines the inlet flow temperature has reached 1500–1600 ºC and tends to increase further. Since thus far the development materials science lags behind the demands of practice, almost up to 80% of the temperature growth is achieved due to the application of internal and external cooling of gas turbine blades. This paper presents a review of the investigations carried out at the Institute of Engineering Thermophysics in the field of novel blade cooling systems. Three directions of the research program are considered, namely, cyclone (internal) cooling, internal cooling by means of microribbing, oscillating (external) film cooling. Both the experimental approach and computer (CFD) simulation have been employed in this research.

4-33 N. G. KHUTSKAYA, G. I. PALCHONOK, É. M. KOSMACHEVA, I. V. YANTSEVICH

THERMOCHEMICAL CONVERSION OF A WET BIOMASS IN A CHP PLANT

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A thermodynamic analysis of a CHP plant comprising a biomass fired CFB steam boiler and an indirectly heated BFB steam gasifier of wet biomass has been carried out. Heat needed for the gasification process is supplied with the bed material circulating in the external loop of the CFB boiler, which enables an efficient thermochemical conversion of a highly wet biomass. The product gas and char residue from the gasifier are co-fired in the CFB furnace providing stability of the combustion process, as well as reduction of NO_x emission. A characteristic feature of the analyzed plant is the preliminary steam drying of wet biomass to be co-fired in the CFB boiler. The latent heat of condensation of a superheated steam evaporated from the biomass is utilized to heat up water in a district heating system. It has been shown that the energy efficiency of the plant increases from 75 to 87% as the drying deepens, whereas the exergy efficiency is rather low and decreases from 22 to 18%. Main exergy losses are due to irreversibility of the gasification process (9 to 27%) and the co-combustion process of the pre-dried fuel and the gasification products (41 to 49%). The exergy efficiency of the plant could be improved if the gasification products were used for sale.

4-34 V. N. KOVALNOGOV, A. S. RTISHCHEVA, Yu. E. CHAMCHIYAN

MODELING AND INVESTIGATION OF THE INFLUENCE OF PVC WINDOWS ON ENERGY SAVING AND HEAT BALANCE OF A BUILDING

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A mathematical model of the microclimate of a building is suggested and the characteristic features of the influence of PVC windows on heat balance and microclimate of the rooms are considered. It is shown that the true heat energy saving provided by the installation of PVC windows, as a rule turns to be less than the expected value because of the accompanying increase in latent heat losses. The results of modeling the control system of adaptive interconnected heat consumption and ventilation in the building with maintaining a comfort temperature and carbon dioxide concentration in the rooms are presented. It is established that in this case the value of heat energy saving due to the installation of PVC windows can reach up to 30% of the heat energy consumed by the building.

4-35 I. I. LISHTVAN, P. L. FALYUSHIN

STATE AND TENDENCIES OF THE DEVELOPMENT OF FUEL PRODUCTION ON THE BASIS OF SOLID COMBUSTIBLE MINERAL RESOURCES

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The state-of-the art and perspectives of the development of the production of synthetic hydrocarbon fuel were considered. It is shown that new power strategies, aimed at diversification of energy carriers, involvement of solid combustible mineral resources, non-traditional kinds of organic and vegetative raw material and alternative energy sources into industrial processing are realized in the country. The information about reserves, composition, and properties and heat-technical values of peat, brown coal, and combustible shales, sapropels is provided. The results of

scientific-research, test-pilot works, and technical-economical substantiations are indicative of the expediency of industrial mastering of these mineral resources, energy carriers, and various chemical products and materials production.

4-36 Z. V. LOVKIS,[1] A. A. SHEPSHELEV,[1] S. A. ARNAUT,[1]
E. V. KOROBKO,[2] S. V. VILANSKAYA,[2] N. A. ZHURAVSKII[2]

TEMPERATURE DEPENDENCE OF THE RHEOLOGOCAL PROPERTIES OF GRAIN MIXES UNDER THE CONDITIONS OF CONTINIOUS SHEAR DEFORMATION

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The results of experimental investigation, carried out for the first time, of the dependence of the rheological properties of grain mixes (consisting of rye and wheat) of different concentrations in the temperature range 20–80 ^{o}C are presented. It is established that the rheological behavior of rye mixes can be described by the model of Herschel–Bulkley and from wheat – by the model of Carreau–Gahleitner. The dependences of the parameters of the models on temperature and the concentration of solid substances have been determined.

4-37 V. V. LOZOVETSKII, F. V. PELEVIN, V. V. LEBEDEV, I. V. STATKEVICH

IMPROVEMENT OF THE POWER EFFICIENCY OF THE USE OF A POLYGON GAS AS AN ALTERNATIVE RENEWABLE ENERGY SOURCE

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The paper presents a project of complex utilization of the energy of the biogas formed on burying solid domestic garbage on dumping grounds and polygons.

4-38 V. V. LOZOVETSKII, F. V. PELEVIN, A. V. PONOMAREV

COMPUTATIONAL–EXPERIMENTAL INVSTIGATIONS OF A FLOW OF A FILL OF SPHERICAL FUEL ELEMENTS AS A QUASI-NEUTONIAN FLUID IN AN AXISYMMETRIC ACTIVE ZONE

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A fill of spherical elements is considered as some quasi-Neutonian fluid with apparent viscosity. Equations describing its motion and boundary conditions with account for the sliding of granular media particles on the walls of a bunker of axisymmetric geometry have been obtained. The calculated results obained with the use an algorithm that describes the proposed model agree satisfactorily with experimental data.

4-39 V. K. LYUBOV,[1] O. D. MYULLER,[2] A. N. POPOV[1]

MODERNIZATION OF HEATING BOILER PLANTS

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An analysis of the technical state of small-scale power engineering objects showed that a significant part of heat-generators now in operation are not only completely worn out, but are 1.5-2 times higher than their guaranteed life. The results of the analysis of the energetics of a heating plant equipped with fire-tube boilers showed the low energetical and environmental efficiency and allowed us to take a decision about the replacement of the physically worn and obsolete plant by a modern wood granules-fired energy source. The results of comprehensive research of the efficiency confirmed the validity of the decisions taken.

4-40 A. I. MALINOVSKII, O. S. RABINOVICH

EXPERIMENTAL DETERMINATION AND NUMERICAL SIMULATION OF THE ELECTRICAL CODUCTIVITY OF A BUBBLING BED

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Numerical simulation of a bubbling bed means of CFD-DEM (the Euler–Legendre mixed approach with a model of elastic spheres) for finding the coordinates of particles is performed. The efficient thermal conductivity of the bed has been determined by the method of random wanderings. Based on the comparison with experiment, a hypothesis about the passage of currents through the contact sites of particles has been formulated. The passage of bubbles results in a short-time decrease in conductivity.

4-41 Yu. M. MATSEVITYI, S. V. ALYOKHINA, V. N. GOLOSHCHAPOV, A. O. KOSTIKOV

DIRECT AND INVERSE CONJUGATE HEAT TRANSFER PROBLEMS AND THEIR ROLE IN INVESTIGATION OF THERMAL PROCESSES IN POWER ENGINEERING EQUIPMENT

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The solution of conjugate heat transfer problems (CHTP) is a powerful tool for simulation, identification, and optimization of thermal processes in power equipment, since the operation of the latter takes place with participation of moving fluids. The paper deals with direct and inverse CHTP that can be used for diagnostics of power equipment and for its designing. Solving the inverse CHTP allows one to investigate the thermal processes taking place during dry storage of spent nuclear fuel and the influence of rotor speed on the heat exchange intensity in the cavity of a K-200-\130 steam turbine.

4-42 R. NAVAKAS,[1] A. DŽIUGYS,[1] B. PETERS,[2] N. STRIŪGAS[1]

IDENITIFICATION OF HOT SPOTS IN A HEATED GRANULAR MEDIUM BY THE COMMUNITY-DETECTION METHOD

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We present an approach to identify localized groups of particles with similar properties (in the present case, temperatures) in packed beds on the basis of the "community detection" algorithms widely applied in analysis of complex networks. A packed bed of particles on a moving grate in a solid-fuel combustor is considered. For the purpose of analysis, we construct a graph of relations between contacting particles based on the temperature differences between the particles. A number of known "community detection" algorithms are applied to the resulting graph. There are significant differences in the results yielded by different algorithms; this is a known problem in community detection or data clusterization areas. By applying additional postprocessing techniques, the overall result of identification of localized groups of particles can be improved.

4-43 A. I. PETRUCHIK, S. P. FISENKO

SIMULATION OF EVAPORATIVE COOLING OF WATER DROPLETS IN A VACUUM COOLING TOWER

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The paper is devoted to mathematical simulation of evaporative cooling of water droplets in a vacuum tower at a pressure of 10–100 Torr. We describe the physical principles of vacuum cooling tower operation, which are based on the fact that the diffusion coefficient of steam D is inversely proportional to the total gas pressure. A mathematical model of the operation of a vacuum tower developed makes it possible to calculate the efficiency of evaporative cooling of water. Also, the power of a vacuum pump and cooling tower dimensions are evaluated.

4-44 E. A. PITSUKHA[1], Yu. S. TEPLITSKII[2], D. G. BELONOVICH[2]

COMBINED HEAT TRANSFER IN THE AIR HEATER CHANNEL WITH A GRANULAR BED

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As a result of modeling of heat transfer in a high-temperature annular granular bed, it is shown that the temperature field is determined by the Reynolds and Stark numbers, dimensionless temperature of the internal heating surface. Simple relations to calculate the temperature distribution along the annular granular bed and active length of the heat exchanger have been obtained.

4-45 E. A. PITSUKHA[1], Yu. S. TEPLITSKII[2], V. A. BORODULYA[2]

CHARACTERISTIC FEATURE OF BURNING A SOLID BIOFUEL IN A VORTEX-BED FURNACE

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As a result of investigation of burning lumped wood, chips, milled peat, crushed briquetted peat in a vortex-bed furnace of a boiler–air heater, the main characteristic features of the vortex technique of combustion have been established: considerable nonisothermicity in the combustion chamber, appreciable instability of the combustion of chips with moisture content above 55%. A comparison of the found concentrations of CO and NO with the norms of the Republic of Belarus indicate that on combustion of a wood fuel and of briquetted peat by the vortex-bed technology an excess of air at the exit from the furnace can be reduced to 1.07–1.23.

4-46 G. A. RYABOV

TECHNOLOGY OF A CIRCULATING FLUIDIZED BED: THE USE IN POWER PLANTS AND NEW APPLICATIONS

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As applied to power engineering, the implementation of the circulating fluidized bed (CFB) technology began more than 40 years ago in response to more stringent pollution requirements. At the present time, more than 3000 CFB boilers are in operation over the world. The "VTI" JSC has started up systematic experimental and calculation investigations in the field of scientific foundations of CFB technology implementation since 1989. New basic research method of CFB furnaces calculation was suggested based on our own investigations of the hydrodynamics and heat transfer and those reported in the literature. New implementations of CFB technology of CO_2 capture are considered in the paper. Some scientific problems of different methods of application of CFB technology are shown.

4-47 A. F. RYZHKOV,[1,2] V. L. SHULMAN,[1,2] V. E. SILIN,[1,2] T. F. BOGATOVA,[1,2] R. Sh. ZAGRUTDINOV[2,3]

MODULAR REACTORS OF THERMOCHEMICAL CONVERSION AND NEW POSSIBILITIES OF HYBRID IGCC

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[2]*LLC "Universal Energy", Ltd., Ekaterinburg, Russia*
[3]*"EvrazEnergoprom" Private Corporation, Ekaterinburg, Russia*

Two main directions of the development of the gas-generating technologies formed in the world industry up to the present time are considered: creation of larger plants (0.5-1.0 GW unit capacity) of double power and technological use and the alternate direction of development of small

modular plants of up to 25 MW unit capacity. Basic requirements on gas producer facilities of alternate direction: modularity, deep integration by the heat of gas production and treatment and gas-consuming parts of the plant to ensure the chemical heat regeneration, reasonable sufficiency are presented. The characteristic features and advantages of the use of small gas-producing facilities that meet the above-mentioned requirements imposed on the IGCC plants, small thermal power plants with internal combustion engines or gas-turbine units, factories for the production of CTL are given.

4-48 O. V. SEMENOVICH

MODELING AND ANALYSIS OF THERMOHYDRODYNAMIC PROCESSES IN FUEL ROD ASSEMBLIES

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In the paper, an analysis of the methods of simulation of hydrodynamics and heat and mass transfer in the rod fuel assemblies of nuclear power reactors is made. A subchannel multifield multifluid mathematical model, which is used to study the thermohydraulic processes in the fuel assembly with different operating modes (normal operation and accidents), is considered in detail. The paper presents the results of computer simulation.

4-49 O. V. SEMENOVICH, D. L. TRETINNIKOV

MATHEMATICAL MODEL AND COMPUTER CODE FOR CALCULATING THE THERMOHYDRAULIC PARAMETERS OF THE CORES OF LIGHT WATER REACTORS

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In the paper, a brief analysis of mathematical models of modern best thermohydraulic estimate codes is made. It is concluded that a computer code is needed, which is a connecting link between the system code and the subchannel code. A mathematical model of such a code is formulated. A discrete analog of the developed mathematical model is considered.

4-50 V. V. SERGEEV, V. S. FEDOTOVSKII, S. I. SHCHERBAKOV

INFLUENCE OF VORTICAL HEAT TRANSFER LATTICES-INTENSIFIERS ON THE VAPOR PHASE BEHAVIOR IN THE SPACE BETWEEN THE FUEL RODS OF FUEL ASSEMBLIES

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The behavior of a gas phase in the space between the models of fuel rods of WMWCPR fuel assemblies with lattices-intensifiers of vortical type was investigated. In experiments with models of a standard and vortical lattices, installed in the transparent part of fuel assemblies the hydraulic resistance has been determined, and also photographing of the trajectories of the gas

bubbles supplied into a stream through a hole in the fuel rod simulator at various speeds of water stream in the channel was made. Using the results of experimental investigations, the computational code TURBOFLOW was verified, allowing one to calculate both the effect of gas (steam) removal from the surface of fuel rods, and the hydraulic resistance of vortical lattices of natural fuel assemblies.

4-51 E. V. SHAMSUTDINOV

HYDRODYNAMICS OF FLOW UNDER CONDITIONS OF VISCOUS FUEL JET DISTRIBUTION IN A MODEL RESERVOIR

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Black oil is widely used at the majority of objects of industrial or station power engineering as a reserve or kindling fuel. The necessity of periodic preheating of black oil in storage reservoirs demands estimation of the influence of heat and mass transfer processes with account for the rheological features of fuel on the efficiency of its warming up. While in the field of theoretical investigations of the processes of hydrodynamics and heat transfer there are a considerable quantity of works, the carrying out of a natural experiment is hindered by the complexity of its carrying out at industrial boiler-houses, thermal stations, and oil tank farms. The paper presents the results of the visualization of a viscous liquid jet current in a model reservoir for fuel storage.

4-52 Yu. E. SHVETSOV

NUMERICAL SIMULATION OF THERMOHYDRAULIC PROCESSES IN THE UPPER CHAMBER OF A FAST REACTOR

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The GRIF code is widely used to analyze transient and emergency regimes of fast reactors. The paper presents the results of verification of the GRIF code on the basis of experimental data obtained for the MONJU reactor (Japan).

4-53 A. S. SNEGIRJOVS, P. J. SHIPKOVS, G. P. KASHKAROVA, L. S. MIGLA

HEAT LOSSES IN SOLAR THERMAL SYSTEMS

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A significant part of the energy absorbed by solar collectors is spent as heat losses. To determine heat losses over separate portions of a solar thermal system (STS) a dynamic modeling program with real meteorological data was used. The dependence of the quantity of losses on the thermal conductivity coefficients of a solar collector, pipeline and tank insulation was determined with account for their influence on the operation of solar collectors in the entire STS in the regions of Baltic countries. The regularities obtained allow one to more accurately determine the STS efficiency and the possibility of energy saving in the climatic conditions of Baltic countries.

4-54 V. V. SOROKIN

CALCULATION OF VORTEX ATOMIZERS

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Vortex atomizers are often used to produce liquid drops. Cold water drops and atomizers are applied at a nuclear power plant for cooling the vapor-air medium and for preventing radioactivity leakage into the environment in accidents. The method of calculation of atomizers is proposed when the nozzle is arranged asymmetrically relative to the central plane of the body. The calculations agree satisfactorily with experiment. The asymmetry of the boundary layer is taken into account by employing a curvilinear coordinate system. The boundary layer and critical nozzle flows are linked together in calculations.

4-55 A. B. SUKHOTSKII,[1] V. B. KUNTYSH,[1] A. S. MINNIGALEEV[2]

A PROGRAM OF SELECTING STANDARDIZED HEAT EXCHANGERS FOR ENTERPRISES OF THE FUEL AND ENERGY COMPLEX

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[2]*"Oktyabrskhimmash" Private Company, Oktyabrskii, Bashkortostan, Russia, alk2905@mail.ru*

A functional model of the program for thermal and hydraulic calculation of a shell and tube heat exchanger has been developed. The program allows one to calculate the heat transfer coefficient, the store of heat-transfer surface, hydraulic resistance in both ducts for various types (with fixed heat-exchanging networks and with a temperature compensator on the shell (TU 3612-024-00220302-02) with a floating head and U-shaped pipes (TU 3612-023-00220302-01)), variants of design (number of pipers and ducts, of connections of sections) of shell and tube heat exchangers. The program also allows one to calculate the process of cooling various single-phase and two-phase media, and a medium with phase transformation.

4-56 I. I. SVIRIDENKO,[1] V. A. TIMOFEEV[2]

ANALYTICAL MODELING OF PASSIVE REMOVAL OF RESIDUAL HEAT AT WWER-1000 WITH THE USE OF THERMAL SIPHON-BASED HEAT EXCHANGERS

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[2]*Scientific and Technical Center of NNEGC «Energoatom», Sevastopol, Ukraine, i.sviridenko@mail.ru*

The results of computational modeling of residual heat removal of NPP at WWER-1000 with an autonomous Passive Residual Heat Removal System (PRHRS) composed of thermal siphon heat exchangers under beyond-design accident conditions with a total loss of all outside power supply are presented. The influence of contributing factors on potential loss of safe cooling conditions is investigated: the failure of one of PRHRS channels, small LOKA, loss of Boron

injection. The influence of the thermal siphon-based PRHRS on the beyond-design accidental transition to Severe Accident in the case of small LOCA is analyzed. Passive heat protection for emergency heat removal water tank in cold environmental conditions is proposed. Analytical characteristics of heat removal from the reactor under normal operation and in the case of emergency are presented.

4-57 Yu. N. TOKAREV, N. I. DROBYSHEVSKII, O. V. TARASOV, A. S. FILIPPOV

NUMERICAL INVESTIGATION OF HEAT AND MASS TRANSFER IN A THREE-COMPONENT MIXTURE IN HYDROGEN SAFETY ASSESMENT PROBLEMS AT BDB ACCIDENTS IN NPPs

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The severe accidents with core damage in NPPs with light water reactors involve the release of large amounts of hydrogen. One of the most important tasks of the hydrogen safety problem is the estimation of the hydrogen mass, its spatial distribution in NPP containment and fixing the places of large concentration, where it may be close to the ignition threshold. Among three components of hydrogen–air–steam mixture the hydrogen can be concentrated in the upper parts of the containment compartments. This increases the probability of hydrogen ignition. In the paper, a numerical model based on CFD is described, which is assigned for the simulation of turbulent heat mass transfer in a gas mixture. Low hydrogen's molecular weight and arising local nonuniformity of the mixture density demanded, during the model development, appropriate modifications in the momentum and turbulent kinetic energy equations.

One of the ways of the hydrogen stratification reduction is the spray of water on it. In the CFD-methodology under consideration, the spray effect on the gas is modeled through the Eulerian two-phase model. In this model the interfacial momentum, heat, and mass transfer are taken into account along with the influence of the dispersed phase on turbulence. Some results of the validation of experiments are presented.

4-58 I. N. VASILCHENKO, S. E. VOLKOV, V. V. VYALITSYN, D. V. MALCHEVSKII, R. S. POMETKO, Yu. F. SELIVANOV, A. M. SMIRNOV

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATIONS IN SUPPORT OF NPP-2006 FUEL ASSEMBLY DESIGN WITH IMPROVED PARAMETERS

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Provision is made for the application of mixing grids in fuel assemblies of reactor facilities to achieve NPP-2006 design parameters. Two types of mixing grids called “Cyclone” and “Swirler” were developed for NPP-2006 fuel assembly to provide the generation of rotational flows. The results of experimental investigations presented in the paper showed that the swirler-type grid is characterized by more effective impacts on the heat flux and leads to considerable increase in critical heat fluxes. The increase of critical power ranges from 7 to 12% (depending on operating parameters), which may be of use for increasing CHF margins and power generation, optimizing fuel cycles, etc.

4-59 S. V. VASILEVICH

USE OF SOLAR ENERGY FOR WOOD BIOMASS GASIFICATION IN A FLUIDIZED BED

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The paper describes an experimental setup for wood biomass gasification in a fluidized bed using sunlight as a source of thermal energy. Calculation of the overall dimensions of the setup performed on the basis of energy balance is given.

4-60 Yu. A. VINOGRADOV, A. G. ZDITOVETS, M. M. STRONGIN

EXPERIMENTAL INVESTIGATION OF THE MACHINE-FREE METHOD OF ENERGY SEPARATION IN A HIGH-SPEED GAS FLOW

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Among the most well-known devices for gas stream energy separation are Ranque–Hilsh vortex tubes and Hartmann–Sprenger resonance tubes. Their unconditional advantages are the manufacturing simplicity, high reliability, low lag effect, absence of a lubrication system, and the possibility of operation in a wide range of working gas temperatures. However, they also have an essential disadvantage that limits their application in heat engines and plants, namely, the high losses of total pressure. Academician Leontiev in 1997 suggested a new method of machine-free gas stream energy separation making it possible to preserve the total pressure of one of the streams. The experimental results of Leoniev's method are given.

4-61 A. V. VLASOV, V. M. VINOGRAD, V. F. DAVIDENKO, O. G. MARTYNENKO, N. I. RUSAKEVICH, NGO TUANKIET, NGUYEN THUY NGA

INFLUENCE OF THERMAL AND HYDRODYNAMIC REGIMES ON THE CHARACTERISTICS OF WATER-BOILER FUEL

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The paper describes the construction of a rotor-mechanical disperser for treatment of water-saturated boiler oils and the results of laboratory investigations carried out.

4-62 É. P. VOLCHKOV, V. V. LUKASHOV, R. KH. ABDRAKHMANOV

MEASUREMENT OF THE DYNAMIC CHARACTERISTICS OF FLOW IN A VORTEX CHAMBER WITH A CENTRIFUGAL FLUIDIZED BED OF SOLID PARTICLES

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One of the promising directions in the development of heat and mass transfer apparatuses can be represented the technologies, based on the use of a centrifugal fluidized bed of solid particles. The limited knowledge about the conditions for the existence of a stable centrifugal fluidized bed and

the lack of data on the dynamics of motion of particles hinder the development of this area. The paper presents the results of experimental study of the velocity of particles within the bed at different distances from the swirler over the height, and air flow in the space above the bed of particles obtained by optical LDA and PIV methods. In particular, it is shown that in the vortex chamber with a bottom end swirler the particles in a centrifugal fluidized bed move along a helical path.

SECTION 5

HEAT AND MASS TRANSFER IN REACTING SYSTEMS

5-01 A. S. ASKAROVA, S. A. BOLEGENOVA, V. Yu. MAKSIMOV, A. BEKMUKHAMET

INVESTIGATION OF THE PROCESSES OF HEAT AND MASS TRANSFER IN BURNING OF PULVERIZED COAL FUEL IN THE COMBUSTION CHAMBER OF A BKZ-160 BOILER USING THE METHODS OF THREE-DIMENSIONAL SIMULATION AND THE «OVERFIRE AIR» TECHNOLOGY

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Numerical experiments with the use of the «overfire air» technology in burning pulverized coal flame in the combustion chamber of a BKZ-160 boiler at the Almaty TPP, were carried out which allow one to achieve the reduction of carbon dioxide CO_2, nitric oxide NO, and nitrogen NO_2 emissions and to minimize energy losses. The results of computational experiments on the effect of additional air supply (OFA technology) on the basic characteristics of heat and mass transfer are presented. A comparison with the basic mode of combustion of solid fuels, when there is no supply of additional air (OFA = 0%), is made.

5-02 M. S. ASSAD, O. G. PENYAZKOV

INFLUENCE OF HYDROGEN ADDITIONS ON THE THERMODYNAMIC CHARACTERISTICS IN THE CYLINDER OF AN INTERNAL COMBUSTION ENGINE

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In the recent years, a great number of research works on changeover of internal combustion engines to new so-called alternative fuels, including hydrogen, have been carried out very actively. Combustion is the basis of the working process of the engine. The paper presents an analysis of the thermodynamic characteristics of the combustion process during piston engine operation on gasoline with hydrogen additions. The dependences of the indicator parameters on the composition of air--fuel mixture and the amount of hydrogen addition are given. The results obtained show the influence of molecular hydrogen on the dynamics of heat generation and on the limits of possible and efficient leaning of combustible mixtures, which displace to the side of more lean regions.

5-03 V. I. BAIKOV, N. V. KOLYAGO, T. V. SIDOROVICH, N. G. VASKEVICH

INFLUENCE OF THE COMPOSITION OF AN AIR–FUEL MIXTURE ON THE PROCESS OF FORMATION OF NITROGEN OXIDES IN DIESEL INTERNAL COMBUSTION ENGINES

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A change in the composition of an air–fuel mixture at the entrance to a diesel internal combustion engine (DICE) leads to a decrease in the extent of nitrogen oxidation during fuel combustion, which results in a decrease in the nitrogen oxide concentration in exhaust gases. Based on the implemented algorithm for calculating the processes in the DICE and on the procedure for calculating formation of nitrogen oxides in the cylinder of the DICE, the study of the influence of the air–fuel mixture composition at the entrance both on the engine operation and on the content of nitrogen oxides in the exhaust gases has been made.

5-04 N. V. BARANOVSKII, G. V. KUZNETSOV

MATHEMATICAL MODELING OF FOREST COMBUSTIBLE LAYER IGNITION BY A FOCUSED SUNLIGHT

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For monitoring and forecast of forest fires caused by such inevident reasons as a focused sunlight, it is necessary to develop corresponding techniques of forecast on the basis of determined models of ignition of forest combustibles by a radiating thermal flux. The purpose of investigation is numerical modeling of conditions of forest combustible layer ignition as a result of the influence of a focused sunlight flux. The scenario of catastrophic fire danger (no moisture in a forest combustible) is considered in the present work. The process of ignition of a forest combustible layer by a focused sunlight flux is described by a system of one-dimensional non- stationary nonlinear equations of heat conduction and diffusion with corresponding initial and boundary conditions.

5-05 N. V. BARANOVSKII, G. V. KUZNETSOV

MATHEMATICAL MODELING OF CONIFEROUS TREE IGNITION BY THE GROUND LIGHTNING DISCHARGE

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Mathematically, the process of gas-phase ignition of coniferous tree by a ground lightning discharge is described within the framework of the proposed physical model by a system of non-stationary differential equations of heat conduction and diffusion. The system of equations is solved by the local one-dimensional finite difference method. For the solution of difference analogues of one-dimensional differential equations, the pivotal method in combination with a method of simple iteration was used. The influence of the volt-ampere characteristics of ground lightning discharge on the process of wood trunk ignition as a result of the passage of an electric current of the ground lightning discharge is investigated. For approximation of "ideal" crack, the same ignition delay

times, as for a simpler one-dimensional model, are obtained. However, the use of the advanced model has allowed us to reveal exactly that the ignition of a coniferous tree occurs at the sites of localization of cracks.

5-06 B. I. BASOK,[1] V. V. GOTSULENKO,[1] V. N. GOTSULENKO[2]

CONTROL OF VIBRATION COMBUSTION AND THERMOACOUSTIC OSCILLATIONS IN POTENTIALLY UNSTABLE ELEMENTS OF THERMAL AND POWER ENGINEERING EQUIPMENT

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Instability of flow during heat supply or conversion of various forms of energy into the flow head appears in many of potentially unstable elements of thermal and power engineering equipment. The creation of liquid propellant engines requires an enormous number of expensive tests for engine development. In metallurgy, the oscillations of vibrational combustion do not allow one to increase the economic efficiency of blast furnaces. Under the conditions of convective heat supply, oscillations are excited, observed in the Riecke phenomena, in steam generators, in cooling the tuyeres of blast furnaces, chimneys, during cavitation, etc. In this paper, by analogy with the theory of pressurized compressor, the surge characteristic of the transformation of heat into the head, which is determined theoretically, has been introduced. The compressor surge and Riecke phenomenon for discrete systems is formally described by the same system of differential equations. It has been found that periodic oscillatory solutions of this system are not associated with the condition of the Rayleigh hypothesis. It is also substantiated that the geometric arrangement of a heat source in a Riecke tube is determined by the magnitude impedance. As it decreases, the self-oscillations of the phenomenon arise at the location of the heat source directly at the tube inlet, i.e., at the pressure wave node. It has been proven that in ahydraulic system which includes a blade pump with a monotonically decreasing pressure characteristic in the mode of hidden cavitation, a steady-state regime is absolutely stable. Self-sustained oscillations (surge) are excited before disruption in supply in the region of the ascending branches of the cavitation pressure characteristic.

5-07 V. V. BOGDANOVA,[1] O. I. KOBETS,[1] A. A. LYUDKO[2]

ON THE INFLUENCE OF THE PROCESSES PROCEEDING IN THE PREFLAME ZONE OF CONDENSED PHASE ON WOOD AND PEAT COMBUSTION INHIBITION

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Experimental data on the influence of primary processes of thermal decomposition of synthesized fire retardant chemical (FRC) of different chemical composition and physicochemical

properties on their fire-extinguishing efficiency are presented. It is shown that it is necessary to take into account the decomposition temperatures of natural combustible materials (wood, peat) and initial melting temperatures of FRC in regulating their composition. It is established that increase in the thermal insulating (foaming and carbonizing) ability of FRC and in the endothermic reactions' effects of their thermal destruction is useful for changing the conditions of heat and mass transfer between the flame zone and the pyrolysis zone of combustibles.

5-08 B. F. BOYARSHINOV, S. Yu. FEDOROV

INVESTIGATION OF LOCAL MASS TRANSFER IN A BOUNDARY LAYER WITH ETHANOL COMBUSTION BEHIND A BARRIER: INFLUENCE OF EXTERNAL TURBULENCE

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Interactions between turbulence and combustion were analyzed using the averaged differential equations of mass transfer. The terms in the equations were determined from experimentally measured local parameters of the gas. Profiles of the turbulent nitrogen fluxes were obtained. The rates of formation of combustion products and oxygen consumption in the oxidation zone have been estimated.

It is shown that two types of combustion occur in the boundary layer behind the barrier. Frontal combustion occurs near the wall, and chemical reactions occur in large-scale longitudinal structures at the external boundary. In the transition zone between the combustion mechanisms, the rates of formation of combustion products and oxygen consumption are minimal, while the OH radical concentrations are maximal. Air flow turbulence of 8% crushes this pattern.

5-09 D. S. DARAKOV, A. N. ZOLOTKO, A. K. KOPEIKA, P. O. PAVLYUK

COMBUSTION OF RAPESEED METHYL ETHER DROPLETS IN AIR

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The paper presents the results of investigations of combustion of rapeseed methyl ether (RME) and mineral diesel fuel (DF) in air. Within the framework of the proposed model of droplet combustion in an adiabatic shell, the influence of the excess oxidizer coefficient α^* on the burning time t_b is considered. Experimental verification of the results obtained was carried out for 0.8–1.1 mm diameter droplets at atmospheric pressure within the range of the excess oxidizer coefficient 1.7–4. It is shown that the droplet combustion time decreases with increasing excess oxidizer coefficient, and that the droplet burning time for RME is 10% less than for DF over the entire range of α^*, with other things being equal. This result explains in part the effect of increasing combustion efficiency for biofuels, observed in the bench tests, which is especially important when a diesel engine operates with increased load.

5-10 Yu. M. DMITRENKO, R. A. KLYOVAN

METHANE-TO-HYDROGEN CONVERSION IN A REVERSIBLE FLOW FILTRATION COMBUSTION REACTOR

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Conversion of hydrocarbon fuels, methane in particular, due to their high energy content and developed infrastructure is the most extensively used method to produce syngas. The familiar drawbacks of catalytic conversion processes have promoted research and examination of alternative techniques capable of providing a reasonable conversion level without using a catalyst. One of such techniques is partial oxidation of methane within the filtration combustion wave propagating downstream in an inert porous medium during the burning of a rich methane-air mixture. The paper contains the results of experimental investigation of the indicated process in a reversible flow filtration combustion reactor, in which the flame front localization is accomplished by periodically reversing the filtration direction.

5-11 K. V. DOBREGO, I. A. KOZNACHEEV

NUMERICAL STUDY OF THE PROCESS OF WATER PURIFICATION OF ORGANIC IMPURITIES BY THE METHOD OF FILTRATION COMBUSTION

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To purify water of organic substances, thermal, biochemical, electrochemical, or other effects are used. However, most of these methods are ineffective. It is proposed to use the method of oxidative water treatment by filtration combustion in porous media. This paper presents the results of systematic numerical studies of the oxidative process of water purification of dissolved organic compounds by the method of filtration combustion. Acetone was used as a model pollutant. The main objective of research was to determine the minimum concentration of a pollutant that ensures autothermal oxidation, as well as to determine the dependence of concentration on the parameters of the purification system for its optimization.

5-12 M. V. DOROSHKO, O. G. PENYAZKOV

DYNAMICS OF ACETYLENE AND PROPANE PYROLYSIS AT A HIGH TEMPERATURE BEHIND THE FRONT OF A REFLECTED SHOCK WAVE

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In recent years, the negative effect of soot and carbon particles on the environment is the essential direction of research in view of the deterioration of air quality due to the significant amount of harmful emissions. However, the mechanism underlying the formation of condensed carbon particles at a high temperature, as well as the ways of producing particles of a definite structure have not been completely elucidated till now and require further study. The paper

describes the use of optical methods for studying the kinetics of formation of condensed soot particles produced during the pyrolysis of acetylene and propane behind reflected shock waves at high temperatures. Temperature dependences for the induction time of soot condensation and yield were obtained from dynamic measurements of the gas and particle self-emission and of the attenuation of laser radiation.

5-13 R. Sh. ENALEEV,[1] V. A. KACHALKIN,[2] E. Sh. TELYAKOV,[1] Yu. S. CHISTOV[1]
PREDICTION OF SANITARY LOSSES CAUSED BY THERMAL RADIATION IN EMERGENCY SITUATIONS
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[2]Kazan Institute (Branch) Russian State Trade and Economic University, Kazan, Russia

The aim of this study was to correlate the domestic and foreign methods for evaluating the thermal damage caused by thermal radiation. New probit-functions for evaluating different degrees of thermal injuries have been estimated. The invariable, to the speed of heating, thermal criterion of the appearance of burn injuries has been suggested. The computer program for the prediction of sanitary losses in the situation of emergency has been established.

5-14 R. Sh. ENALEEV, E. Sh. TELYAKOV, Yu. S. CHISTOV, A. F. GABIDULLIN
FIRE DANGER OF IGNITION OF COMBUSTIBLE MATERIALS
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An analysis of key positions of the elementary thermal theory of ignition is carried out. A model is constructed taking into account phase transformations, the impact of burnout and volume absorption of radiant energy. The critical condition of ignition for superficial differential volume is proposed. The applicability of model for determining the characteristics of ignition of materials based on cellulose is shown.

5-15 M. A. FATYKHOV, A. I. KHUDAIBERDINA, Yu. Yu. BIKBOVA
HEATING OF OIL AND GAS SYSTEMS WITH CHEMICAL REACTIONS IN AN ELECTROMAGNETIC FIELD
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One of the most important phenomena observed during pumping of aqueous solution of acid into a carbonate oil reservoir is the increase of its porosity. During the volumetric heating of the reservoir in the field of high-frequency electromagnetic radiation, the oil viscosity decreases. With the joint effect of these fields, a substantial increase in the oil flow is possible. The paper describes the state-of-the art of the problem on investigation of the spatial and temporal distribution of temperature. A mathematical model of the heating of a carbonate reservoir by the combined influence of hydrochloric acid and high-frequency electromagnetic radiation is suggested.

5-16 M. A. FATYKHOV, F. A. NAGAEV

HEAT SOURCES IN TWO-LAYER MEDIA WITH OBLIQUE INCIDENCE OF ELECTROMAGNETIC WAVES

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At the present time the prospects of the use of the energy of high-frequency electromagnetic fields to increase oil recovery are beyond question. The results of experimental investigations and theoretical calculations of the initial indices of this technology do not diverge greatly. It is partially explained by the fact that the theoretical studies do not take into account the effect of reflection of electromagnetic waves at the interfaces of the media. The paper describes the state-of-the art of the investigation of temperature fields in multilayer media interacting with high-frequency electromagnetic waves. The heat sources in multilayer media with oblique incidence of electromagnetic waves have been investigated.

5-17 M. A. FATYKHOV, V. A. ABDULLINA

HEATING AND DESTRUCTION OF DEPOSITS IN OIL PIPELINES BY MOVING SOURCE OF ELECTROMAGNETIC RADIATION

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Calculations of the process of heating and melting of plugs of solid sediments in a pipeline, with the help of one of the types of electromagnetic waves propagating in it as in a circular waveguide are carried out. It is assumed that the source of electromagnetic waves is moving. This makes it possible to avoid superheating of the medium at some points and to achieve melting of solid deposits along the length of the plug. With the effect of the considered type of waves on the medium, complex distribution of heat sources and temperature result, especially in the case of a moving source of electromagnetic waves.

5-18 T. N. GENAROVA, I. G. KUKHARCHUK, O. G. PENYAZKOV

INFLUENCE OF HYDRODYNAMIC CAVITATION ON THE CHEMICAL COMPOSITION OF DIESEL FUEL

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The present work is devoted to the investigation of the influence of hydrodynamic cavitation on the chemical composition of a diesel fuel. To facilitate the process of visualization and identification of the chemical composition, we used the method of a comprehensive two-dimensional gas chromatography. The question was raised whether the use of cavitation in a harsh regime of influence on the diesel fuel for improving the performance of its physical-chemical properties is expedient. Optimal parameters of two-dimensional chromatography were selected resulting in the chemical composition of a diesel fuel being defined more precisely than under other conditions. It was elucidated in the course of the experiments, that the content of aromatic hydrocarbons in the fuel increases, which deteriorates, rather than improves, the physicochemical properties of the final product.

5-19 N. N. GNEZDILOV, I. M. KOZLOV, K. V. DOBREGO

THE INFLUENCE OF STEAM CONDENSATION ON PEAT LAYER COMBUSTION

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There are two main differences between combustion of porous media (peat) and gas filtration combustion in inert porous media. The first is the absence of forced gas filtration, with the main driving force of filtration being as a result the transition of the solid phase to the gaseous one, which required the reformulation of the conservation equations of gas motion. The second is the presence of heterogeneous chemical reactions that change the form of the equations of conservation of matter and of the enthalpy for the gas and solid phases. We formulate a mathematical statement of the problem. The paper shows the effect of taking into account the condensation of the steam contained in the products of pyrolysis on gas filtration and the temperature field near the combustion site.

5-20 V. A. GORELSKII, V. F. TOLKACHEV, I. E. KHOREV

INVESTIGATION OF THE PENETRATION OF A CUMULATIVE JET INTO THE MULTILAYER BARRIER WITH ACCOUNT FOR TEMPERATURE EFFECTS

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The hydrodynamic theory of cumulative penetration of armor is based on the theory of jets of an incompressible fluid. Moreover, it has been found that similar penetration is also observed in interaction of rod projectiles with targets made of plastically deformable materials at high impact velocities. The velocities of cumulative jets observed in reality attain 8–12 km / sec. When such a jet meets an obstacle, consisting also of a rigid material, a pressure exceeding the strength of the target appears, and the jet penetrates into the target. The investigations have shown that the temperature of cumulative jets is below the melting temperature. For such materials as copper and iron it is equal to 600–1000 ° C. In this connection it becomes necessary to take into account the strength and temperature effects. The paper presents the results of theoretical and experimental studies of the interaction of high velocity rod projectiles with steel targets during the normal impact and at an angle of 60 degrees.

5-21 A. M. GRISHIN, A. S. YAKIMOV

MATHEMATICAL MODELING OF THE INITIATION AND DISTRIBUTION OF PEAT FIRES

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On the basis of a mathematical model of porous reacting medium, a new statement and numerical solution of the problem on ignition of a layer of peat as a result of the action of the center

of a local fire is given. It is established that at moderate temperatures (T_1 = 750 K), the smoldering of an initial reagent is governed by the processes of heat and mass exchange with the center of forest fire, drying, peat pyrolysis, reaction of oxidation of charcoal gas, by the thermophysical characteristics, and the peat height, as well as by the thickness of a layer of water under the peat layer.

5-22 A. A. KHALATOV, S. G. KOBZAR, G. V. KOVALENKO, O. V. SHIKHABUTINOVA

COMPUTER SIMULATION OF COMBUSTION OF HEAVY LIQUID HYDROCARBONS IN A WICK BURNER

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To attain perfect combustion of a fuel, it is necessary to guarantee sufficiently long residence of a combustible mixture in the zone of high temperature and high-quality mixing of the fuel and oxidizer. A wick burner with vortex air motion and an adjustable height of the primary combustion chamber is capable of providing combustion of a mix of heavy liquid hydrocarbons (waste engine oil), without violating health standards. The time of residence of the air-fuel mixture in the combustion chamber is regulated by changing the outlet chamber area. The temperature required to minimize the concentration of carbon monoxide is provided by the value of the controlled volume of the primary combustion chamber. The degree of turbulence in the vortex chamber above the wick depends on the presence of backflow at the chamber exit. Using the licensed commercial software PHOENICS, the combustion simulation was carried out in a cylindrical vortex chamber with a wick burner. The experiments on combustion of waste engine oil have been performed showing that this process can be conducted with acceptable level of harmful products (NO_x, CO). The calculations have shown a good agreement with experimental data on the temperature at the combustion chamber outlet, an acceptable error (24%) in predicting emissions of CO and a significant disagreement with experiment results on the concentration of nitrogen oxides.

5-23 B. B. KHINA

ON THE THEORY OF MECHANICALLY ACTIVATED SHS

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Mechanical activation (MA) of a powder charge is an efficient means for affecting the SHS processes (the so-called MA-SHS). The physical reasons for the effect of MA on the SHS parameters (the decrease in the temperature of both ignition and combustion and in the activation energy E) have not been elucidated as yet. The decrease in E is typically ascribed to the stored energy of plastic work and acceleration of solid-state diffusion due to the nonequilibrium point defects. In this work, physical estimations are made of both the stored energy in metals and the relaxation kinetics of nonequilibrium vacancies during heating in the SHS wave. It is shown that these factors exert a small effect. The influence of the solid solution zone, which can be formed

during MA, and of the nonequilibrium nanograin boundaries on the nucleation conditions of the product phase has been examined. An important role of the nucleation factor in MA-SHS is demonstrated.

5-24 V. M. KISLOV, S. V. GLAZOV, E. A. SALGANSKII, A. F. ZHOLUDEV, M. V. SALGANSKAYA

FILTRATION COMBUSTION OF CARBON SYSTEMS AT DIFFERENT CONTENTS OF OXYGEN IN A GASEOUS OXYDIZER

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In order to improve the methods of controlling the filtration combustion processes, an experimental investigation of the combustion of mixtures of carbon and inert material particles (10% of carbon) in gaseous oxidizers with oxygen concentration from 5 to 50 vol.% was carried out. Two cases differing in the invariant parameter were considered: 1) the total gas flow rate being constant; 2) the oxygen rate being constant. It is found that in both cases the change in the oxygen concentration lead to the change in the shape of the temperature profile. At a 12–16% oxygen content, the change in the heat structure of the combustion wave occurs. The form of the dependence of the combustion temperature on oxygen concentration is different in two cases: when the total gas flow rate is constant, the temperature increases monotonously, whereas when the oxygen rate is constant, the temperature dependence has a maximum. The maximum ratio $[CO]/[CO_2]$ in gaseous products in both cases is achieved at the same range of oxygen content, on change in the type of heat structure.

5-25 V. L. KOLPASHCHIKOV, S. Yu. YANOVSKII

MODELING OF THERMOMECHANICAL PROCESSES OF HEAT AND MASS TRANSFER IN THE CONTACT ZONE OF COLLISION FOR INVESTIGATION OF THE FRICTIONAL SPARKS OF AN IMPACT

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The paper presents the results of modeling the processes of heat and mass transfer occurring in the zone of collision during experiments on impact-testing setup. The intensity of heat release, distribution of heat fluxes, the temperature of surfaces and their wear have been calculated. The results of modeling can be used for estimating the risk of ignition of combustible mixtures by mean of friction sparks at dangerously explosive productions.

5-26 A. A. KOPTELOV, Yu. M. MILEKHIN, Yu. N. BARANETS

PROBLEMS OF INVESTIGATION OF THE KINETICS OF THERMAL DECOMPOSITION OF POLYMERS: ROLE OF HEAT AND MASS TRANSFER

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The values of formal kinetic parameters of thermal decomposition of any polymer, obtained by various authors, are characterized by wide scatters. The paper considers the possible reasons for these discrepancies connected with limited rates of heat exchange between a heat source and a sample, and also with the dependence of the rate of evaporation of polymer decomposition product on the surrounding gas pressure.

5-27 S. P. KOZLOV,[1] V. V. KUZNETSOV,[1, 2] O. V. VITOVSKII[1, 2]

HEAT AND MASS TRANSFER AND KINETIC PROCESSES IN STEAM CONVERSION OF METHANE IN A MICROCHANNEL REACTOR

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[2]*Tomsk State Polytechnic University, Tomsk, Russia, Vladkuz@itp.nsc.ru*

The conversion of methane into a syngas is used for industrial production of hydrogen, which has broad application, including the supply of fuel cells. For compact systems, the most effective method of producing the syngas is steam conversion of methane in microchannel reactors, where the processes of heat and mass transfer are determinant. This paper presents the results of experimental studies of a complex of chemical conversions in steam conversion of methane in a circular microchannel reactor coated with a highly efficient thin-film catalyst, a method for determining the kinetic parameters of reactions, and a numerical study of heat and mass transfer processes in microchannels of the reactor.

5-28 V. A. LEVIN, N. A. LUTSENKO

MODELING OF GAS FLOW IN POROUS MEDIA WITH ZONES OF HETEROGENEOUS COMBUSTION

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A mathematical model and a numerical method, based on the combination of explicit and implicit finite difference schemes, have been developed for investigating the unsteady gas flows in porous objects with zones of heterogeneous combustion when gas pressure at the object boundaries is known. One-dimensional unsteady processes of heterogeneous combustion in a porous object under free convection have been investigated and analyzed using numerical experiment. Two regimes of combustion wave propagation have been revealed: wave motion up the object (cocurrent burning) and down the object (countercurrent burning). It is shown that these regimes differ significantly from each other by the degree of burnout of solid combustible material, the temperature in the combustion zone, and the speed of combustion wave propagation.

5-29 D. S. LITUN, D. A. MEL'NIKOV, G. A. RYABOV

DETERMINING FRACTIONS OF HEAT RELEASE AND TEMPERATURE IN A BUBBLING BED IN COMBUSTION OF BIOMASS

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A two-zone (bed and freeboard region) model of the thermal calculation of a fluidized-bed furnace has been developed. An approximation for the dependence of the fraction of heat release by volatiles in the bed on air excess in the bed and fluidization number has been found. The algorithm and program of the zone method of the thermal calculation of furnaces for combustion of a biomass in a fluidized bed have been developed.

5-30 E. L. LOBODA,[1] V. V. REINO[2]

INFLUENCE OF FLAMES IN BURNING OF VEGETATIVE COMBUSTIBLE MATERIALS ON REGISTRATION OF HIGH-TEMPERATURE OBJECTS IN THE IR RANGE

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We present the results of an experimental investigation of the influence of the flame formed in burning of steppe fuels on the radiance of absolutely black body (BB). The coefficient of radiation attenuation of a BB by a layer of a flame and dependence of registered radiance BB on its true value and radiance of a flame are presented.

5-31 E. L. LOBODA, A. S. YAKIMOV

MODELING OF THE PROCESS OF PEAT IGNITION

Tomsk State University, Tomsk, Russia

On the basis of a mathematical model of a porous reacting medium, a new statement and numerical solution of the problem on ignition of a layer of peat as a result of the action of the centre of a local fire is given. It is established that ignition of an initial reagent is governed by the processes of heat and mass exchange with the center of forest fire, drying, peat pyrolysis, reaction of carbon oxidation, and moisture content.

5-32 E. S. LOSIK, V. V. LESHCHEVICH, K. L. SEVRUK, O. G. PENYAZKOV

THE CHOICE OF THE MECHANISM OF CHEMICAL KINETICS FOR DESCRIBING THE AUTOIGNITION OF METHANE–AIR MIXTURE AT A TEMPERATURE FROM 900 TO 1740

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The mechanisms of chemical kinetics that model the processes of combustion have become distributed worldwide. However, their construction and verification are difficult without the initial experimental data. Of no small importance is also the coincidence of experiment and theory. In this work, the choice of an optimal mechanism of an chemical kinetics was made for modeling the processes of self-ignition by comparing the ignition delay times for a methane–air mixture.

5-33 A. P. LUSHCHIK, V. L. KOLPASHCHIKOV, S. Yu. YANOVSKII

PROBABILISTIC APPROACH TO THE DETERMINATION OF THE AUTOIGNITION TEMPERATURE OF INFLAMMABLE LIQUIDS

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The process of self-ignition of in flammable liquids in real technological processes and devices is of probabilistic nature and depends on the random size, shape, and number of droplets falling on a heated surface, on the random surface temperature distribution, on the random parameters that determine the conditions on the drop–heated surface and the drop–ambient air interfaces, on the random initial temperature of drops, and on the random composition of in flammable liquid. The paper describes a probabilistic approach to determining the autoignition temperature of in flammable liquids, based on establishing relationships between the main factors determining the autoignition and autoignition probability.

5-34 A. N. MAKAROV

REGULARITIES ACCOMPANYING THE CONVERSION OF FUEL ENERGY AND ELECTRIC ENERGY INTO THE THERMAL ONE DURING FLAME FUEL COMBUSTION AND ELECTRIC ARC BURNING IN METAL VAPORS

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The results of scientific discovery of the trends that accompany the conversion of fuel energy into thermal, radiant one in the flame of heating furnaces, burners, combustion chambers and the conversion of electric energy into the thermal, radiant one in an electric arc in arc, plasma-arc steel-melting furnaces are presented.

A geometric–physical model of a flame as a source of thermal radiation in heating pits, furnaces, combustion chambers, and the validity of the use of the model of electric arc as a cylindrical source of thermal radiation has been confirmed.

5-35 A. D. MAKHAEV,[1] N. V. VALTSEV,[1] A. F. RYZHKOV,[1,2] N. A. ABAIMOV[1]

PHYSICAL AND MATHEMATICAL MODELING OF THERMOCHEMICAL CONVERSION DURING GASIFICATION

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Currently, multifunctional apparatuses of thermochemical conversion (TCC) are required allowing one to obtain gas of power engineering and technological applications with a controlled composition. For this purpose, the gasification process is to be implemented in several stages. The paper presents the results of modeling a low-temperature multizone flow reactor of TCC operating on air blowing in the ANSYS 12.1 CFX program, as well as verification of the model by the data of experiments carried out earlier by the present authors.

5-36 O. G. MARTYNENKO,[1] V. V. KULEBYAKIN,[2] K. V. DOBREGO,[1]
I. A. KOZNACHEEV[1]

NUMERICAL AND EXPERIMENTAL MODELING OF THERMAL DESORPTION OF PETROLEUM PRODUCTS FROM CONTAMINATED SOILS

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[2]Belarusian National Technical University, Belarus

One of the most dangerous phenomena that accompany the practical use of petroleum products is the contamination of environment. The most efficient method to combat these contaminations of soil can be the thermal desorption by heating them with the aid of steams. The results of numerical and experimental modeling of these processes are presented in the paper, as well as the practical problems and the possible ways of their solutions.

5-37 D. O. MOROZOV,[1] A. S. SMETANNIKOV,[1] K. L. STEPANOV,[1] B. V. FALEICHIK[2]

COMPUTER SIMULATION OF A 1D-DETONATION WAVE

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Modeling of the propagation of a 1-D detonation wave in an explosive with the subsequent escape of the shock wave into air has been carried out. The equations of the state of an ideal gas were used as the equations of state. A fully conservative difference scheme in Lagrangian variables was used for numerical simulation. The results agree with the analytical solution of the problem of the detonation wave propagation in the instant energy release approximation. A comparison of solutions with and without account for the detonation has been performed. The correctness limits of the use of the instantaneous detonation model have been determined.

5-38 S. G. ORLOVSKAYA, V. V. KALINCHAK, O. N. ZUI, A. V. TURCHAK

INFLUENCE OF INTERNAL REACTION AND MASS CONCENTRATION ON THE CHARACTERISTICS OF IGNITION AND COMBUSTION OF A GAS SUSPENSION OF CARBON PARTICLES

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The investigation of the high-temperature heat and mass transfer of carbon particles and of chemical transformations is very important for effective utilization of dispersed coal. The characteristic features of porous coal dust combustion have been studied insufficiently, though coal particles usually have a highly developed internal surface. So the impact of the internal structure of carbon particle on the kinetics of chemical reactions with a gaseous oxidizer is studied in the present paper.

5-39 Yu. Ya. PECHENEGOV, O. Yu. KOSOVA

THERMOKINETICS AND HEAT TRANSFER IN OXIDATIVE PYROLYSIS OF OIL SHALE DUST IN DIRECT-FLOW TUBULAR REACTORS

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We consider pyrogasification of dust shale in direct-flow tubular reactors with heat supply to the flow of a fuel gas mixture through the wall from an external source. The technique of calculating the thermokinetic characteristics of the gas suspension flow and heat transfer in a tubular reactor under oxidative pyrolysis of oil shales of the Volga Kashpirskoe field is given. Based on experimental data, dependences for specific outputs of the pyrolysis gas and coke from the reactor, for the thermal effect of pyrolysis reactions, and for the heat supplied through the reactor wall were obtained. An algorithm for calculating the heat exchange of a reacting gas suspension with the reactor wall has been developed.

5-40 O. G. PENYAZKOV,[1] V. N. MIRONOV,[1] D.G. IGNATENKO,[1] B. N. ANTONYUK[1], K. N. KASPAROV,[2] L. I. BELOZEROVA[2]

DYNAMICS AND TEMPERATURE OF COMBUSTION OF IRON DUST IN AN OXYGEN MEDIUM

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The process of burning of iron particles from 63 to 90 μm in size in an oxygen atmosphere (at pressure from 3 to 18 bar) was investigated. At a pressure of 3 bars, the temperature of single sparks was measured, which are particles flying in the field of vision of a photoemission pyrometer (~3.5 mm) in 0.5 ms on the dark background and on the background of melted iron and its oxides (~1850 K). These sparks-particles represent drops escaped from the melt. The temperature of particles in both cases was~3000–3100 K and approached the boiling temperature of iron. At a pressure of 11 bars, the melt surface temperature by the 4th second rises to ~3600 K, which is lower than the boiling temperature of iron at this pressure.

5-41 Yu. V. POLEZHAEV

CHART OF THE REGIMES OF COMBUSTION AND SIMILARITY NUMBERS IN A TURBULENT JET-FLARE FLOW

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The dependence of the observed regime of combustion on several independent parameters such as the fuel flow rate, the Froude and Reynolds numbers is investigated. The limits of transition between the regimes, universal dependences for the combustion rates in laminar and turbulent

regimes have been established. A factor for the correction of the flare height has been found making it possible to attain convergence of experimental data for all gases both for mixed fuel mixtures and unmixed ones,

5-42 Yu. V. POLEZHAEV[1], V. D. GESHELE[1], I. P. RASKATOV[1], V. N. SOLOVIEV[2], I. G. PLESHCHANKOV[2], L.F. BUDA[2], A.S. LEVCHUK[2], I.G. FOKINA[2]

SELF-OSCILLATIONS DURING COMBUSTION OF A SOLID FUEL

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Experimental characteristics of the self-oscillatory process of vibrational combustion of solid fuels: wood, charcoal, dry spirit, pilet were obtained. An analysis of the amplitude diagrams and frequency characteristics of the self-oscillatory process of vibrational combustion of solid fuels, depending on the position of the latter in a Riecke tube, fuel structure and ways of downloading, the following assumption is made. There are two types of processes occurring at the same time in the presence of vibrational combustion of a solid fuel: for the fundamental harmonics, the well known "energy" approach and for high-frequency harmonics, the vortex mechanism. The former is the method of "energy" processes and the latter, the method of vortex processes of experimental verification of this representation: with damper attachment and flags of diffusion flame. The experimental results confirmed the proposed physical model of vibrational combustion of solid fuels. The method of theoretical calculation has been developed. A decrease in the flame temperature in the case of vibrational combustion was noted. Investigation of the distribution of Cs-137 in ash and waste products of pyrolysis, gasification, and combustion of wood fuel, contaminated with radionuclides, as a function of process temperature, oxygen, and sulfur reagent mixture was carried out.

5-43 S. V. PUZACH

ON THE SIMILARITY BETWEEN HEAT AND MASS TRANSFER PROCESSES DURING ROOM FIRE

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Toxic indices of combustion products during fire are measured in small-scale experimental units. Temperatures and concentrations of toxic gases differ very significantly in small and large scaled rooms, because the similarity theory does not hold in such a case. Analytical dependences of the toxic gas density on temperature on combustion of solid and liquid combustibles under different thermal and gas dynamic conditions are derived. Numerical simulation results obtained by using analytical solutions, integral and field models are presented in the case of calculation of monooxide density. A comparison between theoretical and experimental results is made. It is shown that the heat losses coefficient is the necessary criterion of equality between the corresponding toxic indices in small and large rooms.

5-44 S. V. PUZACH,[1] V. G. PUZACH,[2] E. S. ABAKUMOV[1]

TOWARD CALCULATION OF THE FLAME ZONE HEIGHT IN DIFFUSION COMBUSTION OF A LIQUID

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A mathematical model for calculating the flame zone height in diffusion combustion of a liquid with the use of the boundary-layer theory is suggested. A comparison with experimental results obtained in combustion of aviation kerosene is made. Correlation between the angle of convective column and heat release power is obtained. The large discrepancy between the theoretical and experimental data at heat combustion power higher than 4 MW is explained.

5-45 E. A. SALGANSKII, S. V. GLAZOV, V. M. KISLOV, M. V. SALGANSKAYA, A. F. ZHOLUDEV

TRANSFORMATION OF THE THERMAL STRUCTURE OF FILTRATION COMBUSTION WAVE

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If in filtration combustion (FC) of a solid fuel in a mode with superadiabatic heating a sharp change in the parameters occurs that causes transformation of the combustion wave structure (for example, on change in the composition of a solid fuel or gaseous oxidizer), complex transient processes can take place. The processes of transformation of wave structure were studied experimentally in a quartz laboratory reactor and by the method of numerical modeling with the use of the one-dimensional two-temperature mathematical model of the FC of a solid fuel. The experiments have shown that the processes of reorganization of the combustion wave thermal structure can be accompanied in some cases by significant local heating. The results of calculations qualitatively agree with experimental data.

5-46 Vl. V. SALOMATOV,[1,2] Vas. V. SALOMATOV[1]

PHYSICAL AND MATHEMATICAL MODELING OF THE PROCESSES OF TRANSFER AND COMBUSTION IN A FLUIDIZED BED FURNACE

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One of the promising directions in increasing the energy efficiency and ecological safety of the boilers of a thermoelectric power station firing low-quality local coals and solid waste is the use of the technology of a circulating fluidized bed. There are practically no detailed and systematic investigations of the processes of combustion of coals and solid waste and first of all Siberian anthracite in application to the given scheme. With the aid of the physical and mathematical

modeling, the possibility of obtaining information on the laws governing the aerodynamics, heat and mass transfer and combustion in a reacting turbulent circulating two- phase medium is realized.

5-47 B. S. SEPLYARSKII, A. G. TARASOV

LAWS GOVERNING COMBUSTION OF THE POWDER Ti + 0.5C MIXTURE IN A COCURRENT NITROGEN FLOW

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In the present work, we investigated the laws governing combustion of mixtures of titanium with loose-density soot placed in a quartz tube blown through with nitrogen (cocurrent filtration). It is shown that during combustion of the Ti + 0.5C (soot) mixture in a stream of nitrogen a nitration front is formed in addition to the carbidization front. Various regimes of the propagation of the carbidization and nitration regimes have been detected and described. The classification of the regimes of combustion of the powder mixture Ti + 0.5C (soot) in a nitrogen stream is suggested.

5-48 B. S. SEPLYARSKII, A. G. TARASOV

LAWS GOVERNING COMBUSTION OF THE POWDER Ti + TiC MIXTURE IN A COCURRENT FLOW OF NITROGEN

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We carried out investigation of the laws governing combustion of both powdered and granulated Ti + TiC mixtures, placed in a quartz tube, under conditions of blowing with a nitrogen stream. It has been established that blowing of the powder TiC + Ti mixture of loose density by a cocurrent nitrogen stream does not lead to the propagation of combustion front over the mixture, however, the combustion of granulated mixture occurs at the same values of pressure difference, with the rate of combustion not exceeding 2 mm/s. The experiments carried out allow the conclusion that dissolution of TiC(s) in liquid titanium during combustion of the Ti + 0.5.C mixture is a fairly fast process that prevents the nitration of products to a high degree.

5-49 O. V. SHARYPOV,[1,2] I. S. ANUFRIEV[1]

ON THE EFFECT OF HEAT TRANSFER ON SELF-OSCILLATIONS IN A REACTING GAS SUSPENSION

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The dynamics of weak finite-amplitude perturbations in a homogeneous gas suspension (a reactive gas mixture and chemically inert solid particles) is considered. A weakly nonlinear model takes into account the chemical kinetics–gas dynamics interaction and dissipative properties. The influence of interphase heat and momentum exchange on the stability of the homogeneous state of a

system is analyzed. For the model kinetics of reaction, numerical solutions of the evolution equation are obtained in the form of steady self-oscillations. A sharp increase in the characteristic period of self-oscillations and suppression of instability in a gas suspension with small-size particles are described.

5-50 S. A. SHEVYRYOV,[1] S. S. AZIKHANOV,[1] M. V. ALEKSEEV,[2] A. L. SOROKIN[2]

GASIFICATION OF COAL INDUSTRY WASTES

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Investigations of oxygen-free gasification of coal wastes in high-temperature steam (1200˚C) at atmospheric pressure were carried out. The process gas obtained contains not less than 50 vol.% of H_2 and 20 vol.% of CO. The dependences of the yield of the main gas products (H_2, CO, CO_2, CH_4) on temperature were derived. Carbon conversion (X) and conversion rate (k) of the coke char were calculated. The process gas calorific value has been determined and turned out to be not less than 11 MJ/m^3.

5-51 A. G. TARASOV, B. S. SEPLYARSKII, I. A. TARASOVA, R. A. KOCHETKOV

LAWS GOVERNING COMBUSTION OF THE GRANULATED 2Ti + C MIXTURE IN A COCURRENT FLOW OF AN INERT GAS

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Investigation of the laws governing combustion of the granulated mixture Ti + 0.5C placed in a quartz tube with blowing of the packing by argon is carried out. The dynamics of gas release in combustion of this mixture in the presence and absence of blowing is studied. It is shown that the blowing of the granulated mixture Ti + 0.5C by a cocurrent argon stream leads to an increase in the rate of combustion.

5-52 A. G. TARASOV, B. S. SEPLYARSKII, I. A. TARASOVA, R. A. KOCHETKOV

EFFECT OF GRANULATION ON THE MECHANISM OF HEAT TRANSFER IN COMBUSTION OF THE MIXTURE 2Ti + C IN A COCURRENT GAS FLOW

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We carried out investigation of the laws governing combustion of a granulated mixture of titanium with soot in a quartz tube with blowing of the packing with argon or nitrogen. The gas stream (cocurrent filtration) was provided by a fixed pressure drop at the inlet and outlet of the tube not exceeding 1 atm. The possible regimes of combustion of granulated mixtures connected with the more complex hierarchy of scales (micro, macro, and meso) differing from that of powder mixtures (micro, macro) have been analyzed.

5-53 A. A. VASIL'EV, V. A. VASILIEV, A. V. PINAEV, A. V. TROTSYUK, P. A. FOMIN

GAS-DYNAMICAL PARAMETERS OF COMBUSTION AND DETONATION OF METHANE–AIR–COAL DUST MIXTURES

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To evaluate the consequences of accidental ignition of methane in mines and maximally secure the people and equipment against the action of hot products, it is necessary to precisely represent the possible scripts of origin and development of the combustion center. Calculations of the parameters of combustion and detonation of methane–air (oxygen)–coal dust mixtures in the widest range of initial concentration of mixture components and their stoichiometric ratio are carried out. The basic purpose is gaining a quantitative information about the parameters of combustion and detonation waves, its analysis and development of proposals on perspective methods for prevention and mitigation of the consequences of mine explosions.

5-54 É. P. VOLCHKOV, V. V. LUKASHOV, V. V. TEREKHOV

FLAME BLOWOUT CONDITIONS IN THE BOUNDARY LAYER WITH INJECTION AND COMBUSTION OF HYDROGEN

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One of the most important aspects of combustion is the conditions of flame blowout. The data available in the literature are certainly insufficient for constructing a generalized pattern of the process. The aim of the present research was to obtain data on the conditions of flame blowout in a laminar boundary layer with uniform injection of H_2/N_2 or H_2/He fuel mixture into the air stream through a horizontal porous plate. The experimental data, results of numerical simulations and theoretical analysis show that the conditions of ignition and extinction of a flame in a boundary layer can be described by two quantities: the dimensionless parameter of injection and hydrogen concentration in a fuel mixture. It turns out that injection, when flame extinction occurs, is inversely proportional to hydrogen concentration.

5-55 A. S. ZHUKOV,[1] V. A. ARKHIPOV,[1, 2] S. S. BONDARCHUK,[1, 2] B. V. BORISOV[3]

ANALYSIS OF THE PERFORMANCE OF A BIPROPELLANT GAS GENERATOR IN THE FRAMEWORK OF IDEAL MIXING REACTOR THEORY

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A physical–mathematical model of the operating processes in a bipropellant gas generator intended for the production of high-speed heterogeneous flows of combustion products is presented. Such devices are widely used in different technologies of the processing of materials, in particular, in applying strengthening and heat-protection coatings. The propellant components include kerosene vapors and aluminum powder mixed with an atmospheric air. The processes of ignition, steady and nonsteady combustion processes are studied numerically in the framework of ideal mixing reactor theory. An analysis of numerical results shows that the proposed model can be used for preliminary estimation of the optimal operating parameters of the bipropellant gas generator.

5-56 S. B. ZLOBIN, E. S. PROKHOROV, V. Yu. ULYANITSKII

ACCELERATION AND HEATING OF PARTICLES IN A SHAPED BARREL OF DETONATION SPRAYING SET

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The processes of heat and mass exchange between the particles of powder and gas detonation products constitute one of the central problems of detonation spraying technology. Usually, for acceleration and heating of particles detonation sets with a straight barrel having a combustion chamber filled with an explosive gas and a muzzle are used. The paper presents the results of numerical simulation and experimental implementation of the process of interphase interaction of the gas flow and powder particles in shaping (the increase in the diameter with preservation of volume) of the combustion chamber. It is shown that the dimensions of the barrel of the detonation set can be significantly reduced by reducing the length of the combustion chamber up to 4 times without compromising the technological capabilities of the apparatus.

5-57 I. A. ZYRYANOV, S. M. RESHETNIKOV, L. T. GREBENSHCHIKOV

CHARACTERISTIC FEATURES OF PHASE TRANSITIONS IN AN ELECTROSTATIC FIELD IN COMBUSTION OF FLUIDS

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It is shown that in combustion of n-alkanes in an electrostatic field superimposed on the interface phase boundary, the evaporation of liquid passes into explosive boiling. This leads to an increase in the burning rate by almost an order of magnitude. The temperature field in the liquid was calculated, which makes it possible to a qualitatively explain this phenomenon. The process is illustrated by pictures of the flame and fuel surface.

SECTION 6

HEAT TRANSFER IN MICRO-, NANOSIZED, AND BIOLOGICAL SYSTEMS

6-01 S. A. AFANASIEVA, N. N. BELOV, Yu. A. BIRYUKOV, V. V. BURKIN, A. N. ISHCHENKO, A. N. TABACHENKO, M. V. KHABIBULLIN, N. T. YUGOV

DEVELOPMENT AND INVESTIGATION OF ULTRAFINE-GRAINED TUNGSTEN-BASED MATERIALS AT A HIGH-VELOCITY IMPACT

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Some characteristic features of production of tungsten–nickel (TN) and tungsten–nickel–iron (TNI) alloys by means of liquid phase sintering of powdery blanks, including those containing nanodimensional tungsten powders are considered. In a separate case for pore imitation a magnesium oxide filler with substantially lower mechanical properties as compared to other components were introduced into TNI alloys, yielding the so-called pseudoporous alloys. The analysis of the penetrating ability of cylindrical rods made from the developed composite TN and TNI materials into steel armour plates in the range of impact speeds of up to 4000 m/s was carried out.

6-02 E. A. BARANYSHIN, O. G. PENYAZKOV, S. P. FISENKO

RESTORATION OF THE PARAMETERS OF PRIMARY SOOT NANOPARTICLES ON THE BASIS OF PYROMETRIC, GAS-DYNAMICAL, AND ELECTRONIC MICROSCOPIC MEASUREMENTS

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By the present time, an abundance of experimental data on soot formation in flames (diffuse and pre-mixed), reactors, engines, and shock tubes has been accumulated. However, as ever there is no comprehensive description of all stages of soot formation. In the first place, this is due to the complexity of the research object. The characteristic diameter of primary carbon nanoparticles is tens of nanometers, and the time of growth to this size is less than a millisecond. The results of the restoration of the basic parameters of a cloud of primary soot nanoparticles are presented on the basis of our experimental data on the kinetics and products of the pyrolysis of ethylene in a shock tube, carbon nanoparticle sizes, and on the physical-mathematical model of nonisothermal growth of carbon nanoparticles in a gas phase.

6-03 V. A. BORODULYA,[1] O. S. RABINOVICH,[1] A. N. BLINOVA,[1] V. L. KUZNETSOV,[2] D. V. KRASNIKOV,[2] K. V. ELUMEEVA[2]

CHARACTERISTIC FEATURES OF THE CATALYTIC SYNTHESIS OF MULTILAYER CARBON NANOTUBES IN A FLUIDIZED BED

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A nonstationary model of mass transfer in a reactor of catalytic synthesis of multilayer carbon tubes (MCT) in a fluidized bed under conditions of a sharp increase in the volume of product has been developed. An analysis of the possible algorithms of controlling the nonstationary operating conditions of the reactor was performed. It is shown that the decrease in the degree of conversion of a carbon-containing gas to a certain critical value is the most rational criterion which determines the necessity of reactor reloading.

6-04 M. A. BRICH, K. V. DOBREGO, L. I. KRASOVSKAYA

EQUATION OF STATE FOR SYSTEMS COMPOSED OF CARBON NANOSTRUCTURES AND ITS APPLICATION TO MODELING THERMAL ACTION ON CARBON COMPOSITE MATERIALS

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A model of carbon nanotubes heating accompanied by their structural changes and destruction is presented. The model is based on the results of molecular–dynamic calculations of the heating of nanotubes. These results are generalized in the form of equations describing interconnections between thermodynamic parameters of the system (temperature, pressure, relative enthalpy). The model developed is applied to numerical simulation of heating and thermal ablation of a thermoprotecting composite material sample, containing different quantities of carbon nanotubes.

6-05 A. A. BULAVKO,[1] V. V. KULEBYAKIN,[2] O. G. MARTYNENKO,[1] B. M. KHRUSTALEV[2]

RHEOLOGICAL AND THERMOPHYSICAL PROPERTIES OF ULTRADISPERSED COAL–WATER SUSPENSIONS

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Beginning from the middle of the last century, extensive studies of various properties of water–coal suspensions (fuels) have been carried out at leading scientific centers of the world. The problem of further development of coal-based fuels can follow the lines of crushing coal to

submicron-sized (nano) particles. One might expect that various mechanochemical reactions can occur in an aqueous medium with coal particles under the action of cavitation. As a result, new liquid fuels with a wide range of characteristics can be obtained. The paper is devoted to the discussion of the rheological and thermophysical properties of such media, as well as of the practical problems and possible ways of their solution.

6-06 A. A. BULAVKO, A. V. VLASOV, V. M. VINOGRAD, V. F. DAVIDENKO, O. G. MARTYNENKO, M. I. RUSAKEVICH, A. V. SUVOROV

HYDRODYNAMICS DURING OBTAINING OF FUEL ON THE BASIS OF ULTRADISPERSED SUSPENSIONS OF HYDROCARBON NANOPARTICLES IN WATER

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The paper presents the results of investigation into the process of obtaining carbon suspensions with a fraction of carbon particles of size less than a micrometer by the hydromechanical method with the use of a gear-type pump and two rotor-type pulsation pulverizers.

6-07 O. G. BURDO,[1] V.N. BANDURA,[2] T. L. MAKIEVSKAYA[1]

HEAT AND MASS TRANSFER IN NANOSCALE ELEMENTS OF FOOD RAW MATERIAL

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In the present paper it is substantiated that food nanotechnologies (FNT) are a new, independent, and prospective scientific direction. The classification of nanoscale objects of food raw material is given. The principles of transfer of food productions to nanotechnologies are discussed. The possibilities of wave and barodiffusional mechanisms for organizing combined nano- and macrotransfer processes in drying, extraction, pyrolysis, activation, and inactivation of microorganisms are analyzed. The bases of modeling such processes are presented. The results of investigation of the laboratory samples equipment and products that confirm the present authors' hypotheses are given.

6-08 S. A. CHIZHIK, S. O. ABETKOVSKAYA, Z. RYMUZA

PROBE METHODS FOR THERMOMECANICAL ANALYSIS OF THE PROPERTIES OF MATERIALS IN NANOSCALE

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The necessity to determine the thermomechanical properties of films with thicknesses in the nanometer range arises due to the use of tribological materials based on polymers in the microelectronics. The surfaces are heated during the friction process, and the properties of polymer

films can change significantly. Thus, the task arises to determine the effect of nanometer thickness of coatings on their thermomechanical properties on nano- and microsized areas of contact, taking into account the mechanical properties of a substrate. This can be performed using the methods of scanning probe microscopy. In this paper, the method for determining the Young's modulus of polymer coatings by indenting them with a microprobe with heating directly in the process of measurement is implemented.

6-09 K. I. DELENDIK, O. L. VOITIK, D. G. IGNATENKO

METAL NANOSTRUCTURED GRID CATALYSTS FOR METHANE CONVERSION

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Metal nanostructured grid catalysts for methane conversion are presented. The micro- and nanorelief preliminarily formed on the holder ensures high specific surface and allows one to increase the catalyst efficiency and to reach maximum level of conversion at relatively low temperatures. The developed catalysts on metal grid holders have some advantages over the traditionally used ceramic ones: high mechanic strength, low resistance for reactant flows and possibility of utilization as an easy-off catalytic cartridges, low costs, energy and material consumption.

6-10 E. S. DROZD[1], M. L. LEVIN[1], E. A. LOSITSKIY[2], S. A. CHIZHIK[1], M. E. MYCHKO[1]

EFFECT OF COMMON COLD EXPOSURE ON HUMAN ERYTHROCYTE DEFORMABILITY

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The aim of this study was to evaluate the effect of cold exposure (cryotherapy) on the modulus of elasticity of red blood cells by atomic force microscopy. It was found that after a session of cryotherapy the value of local elastic modulus is decreased, and thus the deformability of erythrocyte is increased. This fact may be considered as a positive effect, because the ability of the cells to deform is correlated with their transport function at the level of microcirculation. At the same time when the procedure of cryotherapy is repeated from 3 week this effect increases.

6-11 S. A. FILATOV,[1] ALYUSEF YOUSEF MOHAMED,[2] M. N. DOLGIKH,[1] G. S. KUCHINSKII,[1] E. V. BATYREV[1]

HEAT AND MASS TRANSFER IN LOW-TEMPERATURE FUEL CELLS AND CARBON NANOMATERIALS-BASED HYDROGEN BATTERIES

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One of the technical solutions that provide the greatest uniformity of temperature in the low-temperature fuel cell and hydrogen storage is the use of heat pipes. They provide a lower working temperature of the electrodes and membrane over the entire active area of the fuel cell, a decrease of the temperature gradient in the hydrogen storage, and improvement heat exchange with the outer shell. The analysis of the results of experimental studies and numerical modeling of heat transfer processes with account for the mechanical stresses arising in the construction in transient operation modes and sorption-desorption cycles has shown the promising use of numerical modeling techniques for optimizing the design of low-temperature fuel cells and hydrogen storage with heat pipes.

6-12 S. A. FILATOV, M. N. DOLGIKH, G. S. KUCHINSKII, E. V. BATYREV,

EXPERIMENTAL STUDIES OF HEAT AND MASS TRANSFER PROCESSES IN INTERACTION OF RADIATION WITH NANOSCALE MARKERS IN BIOLOGICAL SYSTEMS

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In present-day studies, functionalized nanoparticles are used as optical biomarkers due to selective absorption of them by the structural elements of cells. The most widely used are colloidal gold nanoparticles with specific spectral properties which lie in the transparency window of biological tissues. The experiments confirmed the occurrence of a specific effect of the destruction of nanomaterials in the event of a plasmon resonance. The results of experimental studies and numerical modeling of heat transfer of single nanoparticles in a solution subjected to the effect of an optical radiation pulse made it possible to optimize the design of the optical diffusion tomography to determine the threshold power of noninvasive diagnostic biomarkers.

6-13 S. A. FILATOV, M. N. DOLGIKH, G. S. KUCHINSKII, E. V. BATYREV

CHARACTERISTIC FEATURES OF HEAT TRANSFER IN NANOSTRUCTURED SCATTERING MEDIA

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The use of nanomaterials and composites with a nanosized filler in modern technologies necessitates coping with the specific features of steady and unsteady heat and mass transfer in new composite materials. Experimental study and numerical simulation of heat transfer were carried out on model composite materials comprising a polymer base and a filler in the form of submicron and nanosized glass spheres filled with a gas. Based on the analysis of the results of numerical simulation, the character of temperature distribution in a composite material has been established, the dependence of the effective coefficient of thermal resistance and thermal conductivity of the composite material on the degree of filling of the sample and the diameter of the nanosized filler has been obtained.

6-14 S. A. FILATOV, M. N. DOLGIKH, G. S. KUCHINSKII, E. V. BATYREV, A. A. GUNKEVICH

HEAT TRANSFER PROCESSES OF THE CVD SYNTHESIS OF CARBON NANOMATERIALS

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Preparation of carbon nanotubes by the CVD method most complies with the requirements of modern production. To study the growth of CNTs on various types of catalysts, a CVD reactor ensuring the production of ordered and disordered arrays of single-walled carbon nanotubes on substrates up to 100 mm in diameter has been designed. In order to optimize the growth process, numerical simulation of heat transfer processes in the CVD reactor volume was carried out. The calculations made it possible to visualize the spatial distribution of carbon-dioxide flows in the reactor during the CVD synthesis, to optimize the operating conditions of the reactor, the design of the electrodes and chamber to ensure the controlled growth of carbon nanotubes.

6-15 S. A. FILATOV, G. S. KUCHINSKII, G. S. AKHREMKOVA, T. S. SHAMASHOVA

HEAT AND MASS TRANSFER PROCESSES OF SORPTION ON NANOSCALE CARBON STRUCTURES

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The main purpose of the research was to adapt the traditional method of nitrogen adsorption studies to analyze the properties and processes inherent in the objects of nanometer geometries and low-dimensional systems. Experimental data on the selective properties of nanostructured carbon adsorbents were obtained using the ASAP2020 surface area and porosity analyzer by original methods. The results can be used for modeling heat and mass transfer processes and determining the optimal way of surface functionalization in creation of new high-performance nanostructured carbon adsorbents and heterogeneous catalysts.

6-16 S. P. FISENKO, Yu. A. KHODYKO

THERMOPHORESIS AND BROWNIAN DIFFUSION OF MICRO- AND NANOPARTICLES IN A FLOW REACTOR AT A REDUCED PRESSURE

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The work is devoted to the mathematical modeling of the influence of Brownian diffusion and thermophoresis on the transport of spherical micro- and nanoparticles in a low-pressure flow reactor. The interaction of nanoparticles and droplets with the gas flow is described in the free molecular approximation. It is shown that the thermophoretic effect is significant only in the inlet section. The similarity criteria of the problem have been derived. The influence of key parameters on the deposition of nanoparticles on the reactor walls was investigated.

6-17 S. A. GUBAREV,[1] S. V. VILANSKAYA,[1] Yu. P. ISTOMIN,[2] V. N. CHALOV[2], D. A. TSERKOVSKII [2]

RHEOLOGICAL PROPERTIES OF BLOOD AND PLASMA OF LABORATORY ANIMALS (TUMOR CARRIERS) AFTER SONO-PHOTODYNAMIC EFFECT AT 37 ^{o}C

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The results of experimental investigation, carried out for the first time, of the dependence of the apparent viscosity of whole blood and plasma of laboratory animals (white outbred rats) with subcutaneously implanted glioma C6 after sono-photodynamic effect at a temperature of 37^{o}C on the shear rate in the ranges of 7.5–525 s^{-1} (for the blood) and 225–525 s^{-1} (for the plasma) are presented. «Photolon» (RUP «BelMedPreparaty») was used as a photosensitizer.

6-18 B. É. KASHEVSKII[1], Yu. P. ISTOMIN[2], S. B. KASHEVSKII[1], I. V. PROKHOROV[1], T. I. TERPINSKAYA[3], V. S. ULASHCHIK[3]

ENERGY ABSORPTION, TEMPERATURE REGIME AND EFFICIENCY OF LOCAL MAGNETIC HYPERTHERMIA OF EXPERIMENTAL MALIGNANT TUMORS

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The optimum "field–particle" system parameters for magnetic hyperthermia of cancers with the aid of high-coercivity ferromagnetic nanoparticles has been substantiated. An integral heuristic dynamic model of tumor heating by introduced magnetic particles is suggested; a computerized complex for hyperthermia of small animals is presented. In experiments with model tumors on mice and rats, an optimum regime of tumor thermal treatment and the relation between the delivered energy and the effectiveness of tumor thermal destruction has been established.

6-19 S. B. KASHEVSKII, I. V. PROKHOROV

MAGNETODYNAMICS AND ENERGY DISSIPATION IN DISPERSIONS OF HIGHLY COERCIVE PARTICLES FOR MAGNETIC HYPERTHERMIA IN COMPLEX LIQUIDS

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We present experimental results on magnetodynamics and energy absorption in suspensions of high-coercivity particles specially produced for magnetic hyperthermia of cancers. The role of the liquid mechanical properties and particle concentration is investigated. It is found

that, within the range of AC fields useful for the low-frequency hyperthermia, both particle concentration and liquid properties do not influence significantly the AC field energy absorption. This result is of considerable significance for planning the practical magnetic hyperthermia sessions.

6-20 M. V. KIYASHKO, P. S. GRINCHUK

DETERMINATION OF THE OPTIMUM DEPOSITION TIME OF CARBON NANOMATERIALS ON A CATALYTIC SURFACE

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One of the main methods of producing carbon nanomaterials is CVD, when carbon is obtained as a result of pyrolysis of gaseous hydrocarbons on a catalyst, and it forms nanosized structures like tubes and fibers. It is known that the formation of a carbon material slows down during the deposition on a catalytic surface. This means, that there is an optimal deposition time specified by the conditions of the process, after which further formation of nanomaterials is ineffective. The paper presents the methodology of determining the optimal time for the process. It is based on an analysis of the variation of the outgoing hydrogen concentration versus time. Experimental data demonstrating the conditions of validity of this technique are presented. The effectiveness of this approach in the steady-state conditions of the process is shown.

6-21 E. V. KOROBKO, Z. A. NOVIKOVA, N. A. ZHURAVSKII

THERMALLY STABLE ELECTRORHEOLOGICAL FLUIDS BASED ON NANOSIZED PARTICLES OF TITANIUM DIOXIDE

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Results of rheological investigation of two-component compositions containing Al-doped TiO_2 particles in mineral oil are presented. The investigations were conducted under the conditions of continuous deformation in the range of shear velocities 0.01–100 s^{-1} and temperatures 20–140^{o}C. The conducted rheological investigations indicate the prospects of using Al-doped TiO_2 particles as electrically sensitive fillers of electrorheological fluids.

6-22 A. R. LEPESHKIN, N. G. BYCHKOV

INVESTIGATION OF THERMAL PROTECTION OF MICRONANODIMENSIONAL CERAMIC COATINGS OF GTE BLADES WITH ACCOUNT FOR DIFFERENT TECHNOLOGIES OF DEPOSITION

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The paper presents the developed technique of estimating the efficiency of heat protection of metal with the help of a micronanodimensional coatings deposited by plasma and electron beam technologies on gas-flame heating of object on the rig developed. The results of investigations show

that on gas-flame heating of models the micronanodimensional electric-beam coatings of a column structure protect metal better, than the plasma coatings. The developed original method of an experimental estimation of the efficiency of thermal protection of parts with the help of coatings on gas-flame heating ensures the obtaining of more exact data on parameters and properties of ceramic under the conditions of operation of the turbine parts of aviation gas turbine engines.

6-23 V. V. LEVDANSKII,[1] I. SMOLIK,[2] V. ZDIMAl,[2] P. MORAVETS[2]

CHARACTERISTIC FEATURES OF THE OCCURRENCE OF CHEMICAL REACTIONS IN NANOSCALE PARTICLES

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The influence of the size of nanoparticles on the rate of chemical reactions occuring in nanoparticles is studied theoretically. It is shown that due to the size dependence of the cohesive energy in a nanoscale particle the activation energy for diffusion of reactants as well as the intrinsic activation energy of a chemical reaction are reduced and the effective rate constant of a chemical reaction increases with a decrease in the nanoparticle size. The influence of the nanoparticle size on a change of the reactant concentration with time is considered.

6-24 V. V. LEVDANSKII,[1] I. SMOLIK,[2] V. ZDIMAL,[2] P. MORAVETS[2]

INFLUENCE OF SIZE EFFECTS ON PHASE TRANSITIONS IN SYSTEMS WITH NANOOBJECTS

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The size effects in phase transitions on the surface and in the volume of nanoobjects are investigated theoretically. The influence of mentioned effects on the growth rate of silicon nanowhiskers is considered. It is shown that size effects affecting evaporation and condensation of silicon atoms on the surface of the nanoscale liquid droplet-catalyst (gold–silicon solution) and the size effects that are manifested in silicon nucleation inside the droplet-catalyst act on the nanowhisker growth rate in opposite directions.

6-25 A. S. LOBASOV, A. V. MINAKOV

NUMERICAL SIMULATION OF FORCED CONVECTION IN MICROCHANNELS

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At the present time, a significant growth of interest to capillary hydrodynamics and heat transfer in microsystems, caused by rapid development of electronics and medicine, and also by miniaturization of devices in various areas of technology, for example, in the space industry, transport and energetics is observed. Mini- and microchannels are widely distributed in biological systems. Tiny heat pipes (0.1–1 mm), micro- and minichannels with single-phase and two-phase flows (30–300 mm) are developed and used for cooling microelectronic equipment. The aim of the present work was the study of the hydrodynamics and heat exchange processes in microchannels.

6-26 V. K. PUSTOVALOV,[1] A. S. SMETANNIKOV[2]

MODELING OF NANOPARTICLE HEATING UNDER THE ACTION OF OPTICAL RADIATION AND ITS NONLINEAR HEAT EXCHANGE WITH THE AMBIENT MEDIUM

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Recently, great attention is paid to heat generation in metallic nanoparticles under the action of optical (laser) radiation and heat exchange of nanoparticle with the ambient medium. An analytical model of absorption of laser energy and heating of a nanoparticle by laser pulses and its cooling after ending of laser action with account for the temperature dependences of the parameters of the nanoparticle and medium has been developed. Analytical solutions for the time dependence of the nanoparticle temperature with account for power and exponential dependences of heat conduction coefficient of the ambient medium (liquid, dielectrics, gas, etc.) on temperature are presented. The thermooptical properties of nanoparticles describing their heating efficiency are considered.

6-27 V. I. SAVERCHENKO, S. P. FISENKO, Yu. A. KHODYKO

EVAPORATION OF BINARY PICOLITER DROPLETS ON A METALLIC SUBSTRATE

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This paper presents the results of experimental and theoretical investigation of the evaporation of droplets of water–alcohol solutions under reduced pressure. An experimental setup was made allowing one to produce picoliter droplets and visualize their evaporation. It is shown that the duration of evaporation of picoliter droplets is about hundreds of microseconds and depends on the composition, substrate temperature and pressure. It is established that the initial shape of the droplet depends on the concentration of the solution. A mathematical model of evaporation of binary droplets in free molecular approximation has been developed. The calculations are made in the approximation of the average concentration; the results of the experiments are in good agreement with calculations.

6-28 Yu. A. STANKEVICH, S. P. FISENKO

NONISOTHERMAL DISPLACEMENT OF VAPOR FROM A CVD REACTOR

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A procedure for cleaning the atmosphere of a reactor is of great importance for enhancing the efficiency of a CVD reactor. The slowest process which determines the time for reaching the desired purity of the reactor atmosphere is the process of radial diffusion of residual gas in an inert gas flow.

The paper presents the results of a numerical study, based on the code "Fluent", of purification process for the cylindrical reactor atmosphere by means of nonisothermal laminar flow of inert gas. To estimate the cleaning time, the engineering formula was obtained which takes into account the geometrical parameters, wall temperature, gas flow rate, and the degree of purification. To calculate the cleaning time, it was found that isothermal approximation yields an adequate accuracy.

SECTION 7

GENERAL PROBLEMS OF HEAT AND MASS TRANSFER

7-01 O. M. ALIFANOV,[1] S. A. BUDNIK,[1] A.V. NENAROKOMOV,[1] A. V. NETELEV[1]

IDENTIFICATION OF MATHEMATICAL MODELS OF THERMOKINETICS

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The paper presents an algorithm for solving the problem of identification of the mathematical model of heat transfer in decomposing heat-shielding materials. The algorithm is based on the methodology of solving inverse problems. In solving an inverse problem, a vector consisting of 4 unknown nonlinearly dependent components (heat capacity, thermal conductivity, heat capacity of pyrolysis gas, and thermal effect of decomposition) is formed. The stability of solving an inverse problem is reached by applying the method of iterative regularization in the algorithm. The iterative process of minimization of the vector of required parameters is based on traditional optimization methods.

7-02 O. M. ALIFANOV, V. V. CHEREPANOV, A. V. ZAITSEVA

MODELING OF THERMOPHYSICAL AND SPECTRAL PROPERTIES OF GLASSY CARBON FOAM BY THE MONTE CARLO METHOD

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The paper describes the Monte Carlo method intended for prediction and theoretical determination of some properties of light heat-protecting foam materials with open porosity. By combining it with the methods of the thermal nonstationary experiment and inverse thermal problem, it becomes possible to forecast and determine the properties of these materials otherwise complicated for research. Such properties include radiative and conductive components of overall heat conduction, spectral coefficients of scattering and absorption, etc. These properties exert a great influence on heat transfer in high-porosity heat-protecting materials. A number of significant properties of foam glass carbon were determined and forecasted with the help of the statistical method. The results can be used for creating new materials and application of the existing ones.

7-03 A. A. ANDRIZHIEVSKII, A. G. LUKASHEVICH, A. P. VORONITSKAYA

METHOD OF EXPERT ANALYSIS OF THE THERMOTECHNICAL CHARACTERISTICS OF INDUSTRIAL SPECIMENS OF MULTILAYER CONTACT TRANSFER SURFACES

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One of the methods of reducing production expenses and simplification in the procedure of sales promotion of heat-exchange devices is the development of the methods of numerical analysis of their thermal and hydrodynamic characteristics with the use of industrial specimens of heat exchange surfaces. Such methods make it possible to considerably reduce the entire production process from the design to introduction. The proposed method of analysis of the thermohydraulic characteristics of multilayer transfer surfaces is based on the procedure of the construction of model computational templates for the specimens of heat exchange surfaces for the purpose of further estimation of the real configurations of constructions.

7-04 I. A. ANOSHKO[1], A. V. BEZRUCHENKO[1], V. S. ERMACHENKO[1], L. E. SANDRIGAILO[2], A. A. SMOLSKII[1], V. V. TKACHEV[1], V. S. FINCHENKO[2]

EXPERIMENTAL THERMAL PROTECTION TESTING OF THE SPACE VEHICLE IN THE EARTH ATMOSPHERE SUPERORBITAL ENTRANCE CONDITIONS

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During the entry of space vehicles into the atmospheres of the Earth and other planets with superorbital velocities, the value of radiative component of the total heat flux increases sharply. Correct experimental investigations of heat resistant coatings under the conditions of radiative-convective heating can be provided, if a radiating gas volume is created directly over the obstacle surface by decelerating the high-speed plasma flow. A plasma Hall accelerator has been successfully used for solving such problems. The presence of a strong external magnetic field aids in creating high-speed high-power plasma flows with relatively small static enthalpy. The radiative heat flux to the frontal surface of a model is created, just as in natural conditions, by radiation of the gas volume (decelerated at the surface), the spatial structure and thickness of which are similar to the natural ones.

7-05 N. M. BARBIN, D. I. TERENTIEV, S. G. ALEKSEEV

THERMODYNAMIC MODELING OF EVAPORATION OF Pb–Bi MELTS AT HIGH PRESSURES

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Using the method of thermodynamic modeling, the software package TERRA and the model of ideal solutions of interaction products, the composition of vapor phase is determined and the liquid–vapor phase equilibria diagrams at pressures of 10 and 100 bar are constructed.

7-06 A. P. EFIMOV, N. V. DILIGENSKII

THE STRUCTURE OF CLASSES OF MATHEMATICAL MODELS IN TECHNOLOGICAL THERMAL PHYSICS

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An effective approach for obtaining approximate solutions of the problems of thermal physics is the construction of accurate solutions in the space of Fourier transformations of generalized functions, expansion of Fourier transforms in asymptotic series, and further transfer to generalized functions – inverse transforms. In such a way, a variety of different classes of asymptotic and quasi-asymptotic singular models with different substantial and approximate features have been developed.

Sets of developed models can be represented in the form of commutative and non-commutative morphisms constructed on the basis of the methodological Bohr principle of complimentarity.

7-07 L. E. EVSEEVA, S. A. TANAEVA

INFLUENCE OF EXTERNAL PHYSICAL EFFECTS ON HEAT TRANSFER CHARACTERISTICS IN POLYMER COMPOSITES

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The behavior of polymer composites in dynamic environmental conditions is a critical aspect of their application. The thermal characteristics of epoxy composites with different fillers have been investigated under the influence of low temperatures, thermal cycling, and ultraviolet irradiation. It is shown that repeated thermal cycling results in a significant decrease in the thermal conductivity of unidirectional CFRP. The introduction of 0.1 wt.% carbon nanofillers into epoxy enhances both the thermal conductivity of the composite and its cryogenic stability. It is shown that there is an essential decrease in the nanocomposite's thermal conductivity both during UV irradiation of a cured composite and UV irradiation only of a carbon nanofiller.

7-08 R. I. GAVRILIEV

TEMPERATURE FIELD OF A TWO-LAYER SEMI-INFINITE MEDIUM AT A VARIABLE SURFACE TEMPERATURE

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There are many cases in the engineering practice when various materials with foreign covers are used in a severe operational environment. This causes the need for predicting their temperature field in order to select optimum operational conditions. Solutions to the thermal problem for composite bodies are known in the literature, including that for a two-layer semi-infinite medium with a plane cover at a constant surface temperature. On the other hand, it would be more universal to consider the case with a variable temperature at the surface of a composite system. In this paper, a variable surface temperature is given in the form of piecewise linear functions of time. An analytical solution of the problem with a surface temperature varying linearly with time is found in each time interval.

7-09 A. M. GRISHIN, A. N. GOLOVANOV, V. I. ZINCHENKO, K. N. EFIMOV, A. S. YAKIMOV

MATHEMATICAL AND PHYSICAL MODELING OF THERMAL PROTECTION

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The paper is devoted to theoretical and experimental investigation of the processes of aerodynamics and nonstationary conjugate heat and mass transfer with account for thermochemical destruction of heat-shielding materials, of gas injection into a boundary layer, and also of thermal protection of some composite materials exposed to the action of small energy perturbations. New ways of controlling thermal regimes in the case of axisymmetric and spatial flow around bodies of various geometries, based on the influence of the blowing of a gas cooler, thermochemical destruction in the curtain zone and the organization of overflowing of heat in the field of maximum thermal loadings by means of the use of highly conducting materials have been substantiated.

7-10 S. A. GRISHIN,[1] A. L. PETYUK,[1] V. A. SELYANTIEV[1], S. O. MARACH,[2] A. G. BATISHCHEV,[3] V. V. DOKTOROV[4]

METHODOLOGY, HARDWARE AND SOFTWARE FOR DEVELOPING AND EXPERIMENTAL TESTING OF A THERMAL REGULATING SYSTEM FOR SPACECRAFT BOARD SCIENTIFIC EQUIPMENT

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Reliable operation of scientific instrunentation installed on the open platform of a spacecraft is heavily dependent on thermal control systems, which are most frequently developed with the use of miniature heat pipes with high thermal conductivity. The paper considers the methodology, hardware and software used for the development of the thermal control system of a magnetic meter intended for operation on an open spacecraft platform. The main stages of the development of the thermal control system on the basis of a low-temperature heat pipes with arterial capillary powder structure are considered, a computer model of temperature field distribution, and the description of the hardware and software for thermal testing are presented.

7-11 É. M. KARTASHOV

THERMAL RESPONSE OF VISCOELASTIC BODIES TO A HEAT SHOCK

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New model concepts of quasi-statistical and dynamic thermoviscoelasticity in the theory of a thermal shock have been developed. On the basis of the Maxwell and Kelvin linear rheological models, the constitutive relations have been formulated leading to new boundary-value problems in the thermomechanics. A new mathematical tool has been developed, as well as a new relation of operational calculus; numerical experiments which show characteristic features of the thermal response of viscoelastic bodies to a heat shock were carried out.

7-12 B. B. KOLUPAEV, V. V. KLEPKO, E. V. LEBEDEV

INTERRELATION BETWEEN HEAT CONDUCTION AND THERMAL PRESSURE OF PHONONS IN HETEROGENEOUS POLYMERIC SYSTEMS

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The urgent problem of the physics of polymers is calculation of the properties of a body on the basis of the inter- and intraatomic interaction potential. With the use of the phonon mechanism of heat transfer in systems based on polyvinylchloride (PVC) containing nanodispersed copper, potentials of interaction between structural elements and the equations of the state of a body, the interrelation between the thermal conductivity coefficient and thermal pressure of phonons have been established. The assessment of the results obtained indicates the generality of energy exchange processes caused by the anharmonicity of connections. In the communication, the ways of forecasting and directed regulation of the thermal and acoustic properties of PVC systems are indicated.

7-13 V. N. KOVALNOGOV, A. N. NIKIFOROV

THERMOPHYSICAL ANALYSIS AS A BASIS FOR RAISING THE EFFICIENCY OF DRILLING HOLES BY MEANS OF ULTRASOUND

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A mathematical model and the results of numerical investigation of thermal deformations and thermal interaction between a workpiece and a drill are presented. The possibilities of an appreciable (up to 5 times) reduction of thermal strain and, consequently, of release and run-off of drills, by efficient application of ultrasonic vibrations in drilling are shown. According to the results of research to be implemented in production, the ultrasound technology and drilling technique with superimposed ultrasonic vibrations onto the cutting tool and coolant are suggested.

7-14 V. A. KUDINOV, A. V. EREMIN, I. V. KUDINOV

ANALYTICAL SOLUTION OF THE STEFAN PROBLEM WITH ACCOUNT FOR ABLATION ON THE BASIS OF DETERMINING THE TEMPERATURE PERTRUBATION FRONT

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The classical exact analytical methods in application to solving boundary-value problems with account for phase transformations on a moving boundary turn to be ineffective because of the

difficulties of coordinating the solution of the parabolic equation with the unknown one in the process of solving the problem by the law of boundary motion. In this connection, the methods used in this paper become especially important, since they allow one to find approximate analytical solutions of the indicated problems. Very effective turn out to be those methods that use the concept of temperature front perturbations in combination with additional boundary conditions. With the use of such conditions, the accuracy of solutions obtained on the number of approximations which is not limited in this case.

7-15 V. A. KUDINOV, I. V. KUDINOV

HYPERBOLIC EQUATIONS IN HEAT CONDUCTION AND HYDRODYNAMICS

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The heat conduction hyperbolic equation which takes into account the heat diffusion final rate was derived on the basis of the Maxwell–Kattaneo–Luikov equation for heat flux to overcome the well-known paradoxes of the heat conduction theory. Numerous investigations of the solutions of this equation led to the conclusion that while removing some paradoxes the equation gives rise to another one, such as sharp changes of temperature inside the region, the appearance of negative temperatures in the process of heat transfer, etc. The paper presents an analysis of the reasons for such phenomena and makes a conclusion about the necessity of taking into account the inertial relaxation properties of not only of heat flux in the Fourier transform equation, but also of the temperature gradient.

7-16 V. V. KUZNETSOV, I. A. KOZULIN, O. V. VITOVSKII

METASTABLE STATES AND THEIR DECOMPOSITION AT A HIGH EXTERNAL AND INTERNAL STORED ENERGY DENSITY

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Controlled decomposition of a metastable liquid is widely used for rapid transition from liquid to gas. At high external and internal stored energy density the phase transition occurs as a wave of spontaneous vapor generation. The laws governing an explosive boiling of water and alcohols on a microheater at the rate of temperature growth of up to 200 MK/s were established experimentally and discussed. The results of an investigation of the surface decomposition of refrigerant R-11 under the action of high intensity rarefaction waves are presented for the case of high stored thermal energy density. It was found the rapid phase transition in a propagating adiabatic evaporation wave is accompanied by multiscale turbulence generation and convective heat supply to the front of the evaporation wave.

7-17 G. V. KUZNETSOV, V. Yu. POLOVNIKOV

NUMERICAL SIMULATION OF THERMAL REGIMES OF HEAT TRANSPORTATION SYSTEMS

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Numerical investigation of heat transfer in the zones of laying thermal networks is carried out with the use of a conjugate conductive–convective–radiative transfer model. In modeling the thermal operating modes of thermal networks, the scales of the influence of heat transfer by radiation in the cavity of the channel of the heat conductor on thermal losses and the expediency of application of the proposed approach are shown.

7-18 M. Yu. LIVSHITS, M. Yu. DEREVYANOV, S. A. KOPYTIN

DISTRIBUTED CONTROL OF TEMPERATURE REGIMES OF THE CONSTRUCTIONAL ELEMENTS OF AUTONOMOUS OBJECTS

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One of the possible approaches to solving the problem of thermal deformation stabilization of the elements of load-carrying constructions of autonomous objects is suggested. Controlled heat producing elements of limited capacity are used to provide the temperature field uniformity within the object volume under the condition of most unfavorable disturbance from the side of heat producing devices located on the constructions. An appropriate problem of automatic system synthesis is solved for object temperature field stabilization with the help of discretely distributed control. The method of Green's function is applied to obtain an equivalent computational scheme, which is similar to the structures used in the computational practice of the theory of control systems with lumped parameters.

7-19 I. E. LOBANOV

EXACT ANALYTICAL SOLUTIONS OF THE NONLINEAR NONSTATIONARY INVERSE HEAT CONDUCTION PROBLEM FOR LOW-THERMAL CONDUCTIVITY BODIES OF ONE-DIMENSIONAL GEOMETRY

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An analytical solution of the nonlinear transient inverse heat conduction problem for bodies of one-dimensional geometry with low coefficients of thermal conductivity is given. The urgency of the work is due to the fact that the use of low-thermal conductivity materials for the thermal protection is becoming increasingly important.

7-20 I. E. LOBANOV

EXACT ANALYTICAL SOLUTION OF THE PROBLEM ON COMPLETE DISTRIBUTION OF TEMPERATURES UP TO THE ENDS OF A REGENERATOR WITH A HIGHLY CONDUCTING PACKING WITH AN ARBITRARILY DISTRIBUTED INITIAL TEMPERATURE (ANZELIUS–NUSSELT PROBLEM)

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An exact analytical solution of the problem on complete temperature distribution up to the ends of a regenerator with highly conducting packing having both the same and arbitrarily assigned initial temperature (the so-called Antselius–Nussel problem) is obtained. These cases are often encountered in engineering practice in calculating regenerative heat exchangers.

7-21 I. E. LOBANOV

EXACT ANALYTICAL SOLUTION OF THE PROBLEM ON TEMPERATURE DISTRIBUTION IN A CROSSCURRENT RECUPERATOR WITH A PURELY CROSS CURRENT

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Complete temperature distribution in a crosscurrent recuperator with a purely cross current is determined using solutions for the temperature distribution in a regenerator. The obtained exact analytical solutions have advantages over the existing approximate solutions.

7-22 Yu. M. MATSEVITYI, A. P. SLESARENKO

REGIONAL-STRUCTURAL REGULARIZATION OF SOLVING MULTIPARAMETER INVERSE HEAT CONDUCTION PROBLEMS

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The regional-structural regularization of the solution for the multiparameter inverse problem of heat conduction (MIPHC) is proposed. It is based on the parallelization of analytical information in boundary conditions when constructing regularizing algorithms for solving MIPHC, as well as on regional parallelization of functional elements of the approximation, which consists in regional-analytical approximation of the desired function with the "cover" of the regional border areas of neighboring regions. The specified minimum value of the norm of the difference of two identified neighboring approximations is the criterion of stopping parallelization of analytical information on the functional relationships of identified regional boundary functions.

7-23 Yu. M. MATSEVITYI, V. A. TARASOVA, D. KH. KHARLAMPIDI

REGENERATION OF THERMAL POTENTIAL OF GROUND DUE TO THE CHOICE OF RATIONAL OPERATING REGIMES OF A HEAT PUMP SYSTEM

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The paper considers the problem of regeneration of the temperature field of ground after winter operation of heat pump installation by reversing the cycle and release of the condensation heat into a ground heat exchanger during the summer period. A mathematical model taking into account the multidimensionality and nonstationarity of the process of heat transfer in the ground, a change in heat extraction during a long-term process of service of the ground heat exchanger has been developed. The influence of operating conditions of the heat pump and cold supplying system on the temperature field was investigated.

7-24 A. V. NENAROKOMOV, D. M. TITOV

STUDY OF HEAT TRANSFER PROCESSES IN THERMOINSULATING MATERIALS

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The problems of estimating the thermal and radiation properties are of great practical importance in the study of the properties of materials used as nondestructive surface coatings in the objects of space engineering, power engineering, etc. In many practical situations it is impossible to measure directly such characteristics of analyzed materials as thermal and radiation properties. The only way, which can often be used to overcome these difficulties, is indirect measurements. The goal of this paper is to estimate the thermal and radiation properties of advanced materials (as for example, the thermal conductivity $\lambda(T)$, heat capacity $C(T)$ and the emissivity of material $\varepsilon(T)$ and the emissivity of a heater $\varepsilon_h(T)$) with the use of the experimental methods of identification of the mathematical models of heat transfer based on solving the inverse problems as one of the modern effective methods of solution.

7-25 A. V. NIKITIN, A. Yu. BACHURINA

NUMERICAL METHOD OF CALCULATING THE THERMAL CONDUCTIVITY COEFFICIENT OF FILLED POLYMERS

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A numerical method of calculating the effective heat conductivity coefficient of composite systems is suggested. The essence of the method consists in direct solution of the heat conduction equation with account for the boundary and initial conditions by the finite-difference methods. The model of a filled polymer is considered. The proposed method allows one to calculate various distributions of a filler in a matrix. Moreover, we can consider the influence of an interphase layer on the thermal properties of a composite. A comparison of calculated and experimental data is made.

7-26 A. E. PIIR,[1] V. B. KUNTYSH,[2] V. I. VOLODIN, [2] A. SH. MINNIGALEEV,[3] V. P. MULIN[3]

INVESTIGATION OF CONTACT HEAT EXCHANGE OF BIMETALLIC TUBES WITH KLM–RIBS

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Bimetalic finned tubes with aluminum spiral ribs are widely used in air-cooled heat exchangers of the fuel-power engineering complex, electrical power engineering, food and gas industry. Their power efficiency depends on the thermal contact resistance which reaches 20% of the thermal resistance of heat transfer. The paper presents the results of an experimental investigation of intensification of contact heat transfer by changing the cross-sectional shape of pin material and the geometric parameters of the artificial roughness in the contact area, the temperature parameters and the technology of finning tubes computational dependences are given.

7-27 V. A. PINSKER

CALCULATION OF THE FIELDS OF THERMAL STRESSES IN A MASSIVE BODY HEATED BY A POINT CONTINUOUS HEAT SOURCE

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Thermoelastic fields in a heated body at any values of Poisson's ratio, including negative ones are studied. The forms of the isobars of zero stresses that separate the regions of tension and compression are investigated. For each such isobar, asymptotes are determined analytically. Extrema of stresses, and also the values of coordinates corresponding to them are calculated. Diagrams of movement of the points of extrema on the coordinate field and corresponding changes of their values are presented. It is shown that radial stretching stresses appears for the first time in materials with value of Poisson's ratio exceeding-0.7, on the symmetry axis the radial and circumferential stretching is possible only at the value exceeding-0.19. For the radial and circumferential components the existence of surfaces along which in each of them the dependence on Poisson's ratio disappears has been proved. Intervals of stresses, as well as the maximal and minimal coordinates of these surfaces are found and their shape is defined in an implicit form.

7-28 V. A. PINSKER

CALCULATION OF THE FIELDS OF THE THERMAL STRESSES IN A MASSIVE BODY HEATED BY THE GAUSSIAN HEAT FLUX

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The problem of uncoupled quasistatic linear thermoelasticity is considered theoretically. An exact analytical solution is obtained in a closed integral form. Important particular cases in which the temperature field and the components of the stress tensor take a simpler form are considered. The asymptotics of the found formulas at small and great values of dimensionless time near and far from a heat source are investigated. Approximate distributions of axial and shear components at the beginning of heating are constructed in a closed form. The maximum values of all the components of the thermoelastic field at various values of Poisson's ratio are found and the location of these maxima are calculated. It is shown that during stationary heating only compressing stresses are possible. The curved profile of the free boundary needed in studying thermal deformations of the elements of laser optics is determined. The possibility of mechanical destructions in a heated body is investigated.

7-29 T. M. POGORELYI, V. G. MIRONCHUK

MATHEMATICAL SIMULATION OF THE RECRYSTALLIZATION PROCESS ON THE BASIS OF ANALYTICAL SOLUTIONS OF NONSTATIONARY HEAT CONDUCTION PROBLEMS IN A TWO-DIMENSIONAL CASE FOR RECTANGULAR REGIONS WITH INHOMOGENEOUS BOUNDARY AND INITIAL CONDITIONS

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During the progress of the process of mass crystallization of sucrose, the process of recrystallization according to the asymmetric mechanism is observed. The recrystallization process simulation is discussed in terms of the cellular model of collective growth and dissolution of sucrose dispersed phase. It is necessary to determine the recrystallization process contribution weight of passing directly to sucrose crystallization. In this connection it became necessary to find analytical solutions of the following two nonstationary heat conduction problems in two dimensions for rectangular regions with inhomogeneous boundary and initial conditions: the first heat conduction problem is considered for the case of a continuous inhomogeneous boundary conditions on each of the sides; the second heat conduction problem – for case with discontinuous, on one side, and continuous, on all other sides, inhomogeneous boundary conditions.

7-30 V. M. POPOV, O. L. ERIN, A. P. NOVIKOV

THERMAL REGULATION OF THERMALLY STRESSED TECHNICAL SYSTEMS WITH COMPOSITE ELEMENTS

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The results of experimental investigations of the process of contact heat transfer on introduction of fillers of different nature and geometry into the section zone are presented. It is shown that in such a way it is possible to regulate, in a wide range, the thermal resistance in the contact zone for connections functioning at small mechanical loadings. The parameter proposed in the work in the form of dimensionless thermal resistance as a characteristic of various combinations of the main metal of a contact pair and a filler allows one to carry out directed thermal regulation in thermally stressed technical systems with low-loaded sectional and all-in-one connections.

7-31 A. I. SHNIP

NECESSARY AND SUFFICIENT CONDITIONS OF THERMODYNAMIC ADMISSIBILITY OF NONLINEAR CONSTITUTIVE EQUATIONS IN THE GENERALIZED THEORY OF THERMODYNAMIC SYSTEMS WITH INTERNAL VARIABLES OF STATE

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A full set of thermodynamic restrictions to be satisfied by the constitutive equations for the fulfillment of the second law for nonlinear thermodynamic systems with internal variables of state with linear internal relaxation has been obtained. The first of these restrictions requires that the equilibrium component of the generalized force is to be expressed as a gradient of configuration of some scalar function. The second restriction can be represented as the requirement of the definiteness of sign of the nonequilibrium part of thermodynamic action in any process starting from the equilibrium state. This condition can be interpreted as the requirement of the passing state of some accompanying dynamic system, which allows one to use the formalism of the theory of passive dynamic systems for constructing the nonequilibrium thermodynamic potential, in particular, entropy. This has been done for some particular cases.

7-32 A. P. SLESARENKO, A. S. SOROKA

INVERSE RETURN MULTIPARAMETRIC PROBLEMS OF HEAT CONDUCTION IN MODELING AND OPTIMIZATION OF THERMAL REGIMES OF CONSTRUCTIONS AT MAXIMUM HEAT ACCUMULATION

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A theoretical–experimental approach, allowing one to identify energy fluxes in the elements of heat accumulating electric-heating system is suggested on the basis of solving a series of inverse problems of heat conduction with account for the real data on the thermal condition of a heating system in the mode of real time. The identification of parallelized energy fluxes will allow one to develop the algorithms of efficient control of heating the working surface of a heater according to the assigned standards with simultaneous maintenance of maximum energy accumulation and, thereby, to provide a steady mode of heating a room in the case of variable climatic factors.

7-33 D. O. SVETLOV, V. V. ISAEV, Yu. V. SVETLOV

METHOD OF CALCULATION OF THE THERMAL CONDUCTIVITY OF HEAT-INSULATING MATERIALS: EXPERIMENT AND A MACROQUANTUM MODEL OF HEAT TRANSFER

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A method to calculate the thermal conductivity of heat-insulting materials is suggested. The investigated materials (fabrics, leather, heat-insulting ones) are considered as capillary-porous materials whose skeleton has the properties of a lyophilic substance, i.e., the walls of capillaries and pores collect gases, vapors, and liquids. An equation for calculating the effective thermal conductivity of a material has been obtained based on the well-known energy balance relation with the source term.

7-34 TAO XIE, YA-LING HE, WEN-QUAN TAO

THEORETICAL AND NUMERICAL STUDY ON THERMAL PROPERTIES OF FIBROUS MATERIALS

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Effective thermal conductivity combined conductivity, and radiative heat transfer in fibrous media were investigated theoretically and numerically. Several theoretical models are introduced to account for the conductive thermal conductivity of two kinds of fibrous media, and the Rossland approximation is used to consider the radiative thermal conductivity. In addition the theoretical model, a numerical method is adopted to investigate the thermal performance of fibrous

media. Based on the theoretical models and numerical method, the conductive thermal conductivity of fibrous media for heat conduction are calculated and examined. A modified model is proposed for fibrous media with specified orientation which is in good agreement with the numerical results.

7-35 Yu. V. VIDIN, D. I. IVANOV, R. V. KAZAKOV

AN APPROXIMATE METHOD TO CALCULATE THE THERMAL CONDUCTIVITY OF A RADIAL EDGE WITH CONSTANT THICKNESS

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Radial finning is widely used for a substantial increase of heat transfer of convex surfaces. In particular, round edges are used for external finings of cylindrical surfaces of internal combustion engines with air cooling, as well as other thermally stressed apparatuses. Often, such developed surfaces are made from expensive metals with high thermal conductivity and corrosion resistance. In designing such developed surfaces intended for the transfer of high heat fluxes, it is necessary to optimize the geometric dimensions of edges in order to reduce their dimensions and mass characteristics. It is shown that in the general case the radial edge is less effective in thermal respect than a similar rectangular one.

7-36 A. V. ZABOLOTSKII

MODELING OF DYNAMIC THERMAL FIELDS IN BODIES OF COMPLEX SHAPE

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In solving the problem of thermal stability of a structure, the necessity of determining the temperature field and the rate temperature change arises at the first stage. The geometry of the construction can be responsible for the different conditions of heat exchange of its elements. The most common mathematical method for solving such problems is the finite element method. In view of the fact that in the general case the temperature field of the body is formed under the influence of several heat fluxes, it is necessary to optimize the division of the body into elements and the order of calculation of these elements. The solution of the problem is considered using as an example the temperature field of the vacuum degasser pipe. Vacuum degassers are used at steel industry for dissolving gases from metal melt.