Section 1

“CONVECTIVE HEAT AND MASS TRANSFER”

l-02* A. A. ANDRIZHIEVSKII[1], A. G. LUKASHEVICH[2], A. G. TRIFONOV[2]

SPATIAL MODELING OF THERMAL DISCHARGES INTO WATER SYSTEMS

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The methodology of spatial modeling of thermal discharges into water systems is presented. Calculations of the evolution of velocity, pressure, and temperature fields for gas and liquid media, the dynamics of the temperature field in a solid medium, the process of heat and mass transfer over interfacial area are described. Based on the methodology suggested, the software package SPACEMORPH THERMO has been developed. Test experiments on its application to nonstationary three-dimensional modeling of technogenic thermal discharges into both flowing and standing water systems are discussed.

1-03 M. Ya. ANTIMIROV, I. M. VOLODKO

ANALYTICAL SOLUTION OF THE PROBLEM OF A TEMPERATURE FIELD IN UNIFORM FLOW PAST AN ARBITRARY CURVILINEAR HEAT SOURCE

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An analytical solution of the problem of a temperature field in uniform flow of a fluid past an arbitrary curvilinear heat source is obtained. Using the Dirac delta function in the representation of the heat source in a cylindrical coordinate system, the heat conduction equation was brought to a simple definite integral of an elementary function. Sample solutions were obtained when the heat source is a circle, an ellipse, a spiral, and a finite segment.

1-01 A. A. AVRAMENKO, S. I. BASOK

APPLICATION OF THE GROUP THEORY METHODS IN THERMOPHYSICAL PROBLEMS

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The concept of the use of group methods in thermophysics is considered. The

fundamentals of the symmetry group theory of differential equations (Lie groups) are presented. It is shown in which way the solution of various problems of thermophysics can be approached on the basis of this theory. Practical examples are given which describe solution of parabolic equations (heat conduction equation and Prandtl's boundary-layer equation) and elliptical equations of convective heat transfer (Fourier-Kirchhoff) and fluid flow (Navier-Stokes).

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

1-11 V. A. BUDARIN

A METHOD FOR **SOLVING IDEAL LIQUID MOTION**

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The method is intended for finding the equations of motion of continuous and discontinuous flows and uses the motion equations of the elasticity theory with additional conditions taking into account distinctive properties of the flows considered. It is shown that there are two ways of solving each flow which have common assumptions used. An example of using the method for solving a particular problem is given and also some areas of its application are special.

1-08 D. G. BLINOV, V. G. PROKOROV, Yu. V. SHERENKOVSKII, N. M. FIALKO, V. L. YURCHUK, B. V. DAVIDENKO

LOW-DIMENSIONAL MODELING OF **THE PROCESSES OF NATURAL CONVECTION** AND **SOLUTION OF THE CONTROL AND IDENTIFICATION PROBLEMS**

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The problems of construction of low-dimensional models of the processes of heat and mass transfer are discussed. Various aspects of applying the method of polyargument systems being developed by the present authors Karbunen-Loeve method are analyzed. The effectiveness and the prospects of these methods based on the selection of basis functions not a priori, but on the basis of a principle consisting in completeness of functional reflection in the components of all available information on the studied heat and mass transfer process are shown. An example of obtaining a low-dimensional model is given, on the basis of which a control problem is solved for a device providing cooling of a localized heat-generating object by means of natural convection in a confined enclosure.

V. A. BABENKO, T. V. SIDOROVICH, A. D. CHORNYI

NUMERICAL SOLUTION OF EQUATION FOR THE JOINT PDF OF SCALAR **FIELD AND ITS GRADIENT**

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Numerical solution is performed by the model from the previous work of the authors for the joint probability density function (JPDF) of turbulent fluctuation scalar field and its gradient. The coefficients of this model are calculated with the aid of two additional submodels. The knowledge of the JPDF is equivalent to the knowledge of all statistical moments. It enables one to correctly average nonlinear chemical source terms in balance equations. A conservative finite-difference scheme is used which saves the norm of the JPDF. Another method of approximate solution of the JPDF equation is based o the fact that this equation contains small parameter (1/Pe), which can be used for its analysis and numerical solution. With the asymptotic expansion constructed in the work, the original equation can be split into four subsequently solved subsystems. The equations for these subsystems of the expansion are solved numerically. Evolution stages of the joint PDF of a scalar and its gradient are described. Some statistical moments are calculated using the solution of the JPDF equation. These moments are compared to the results of previous studies.

1-05 V. A. BABENKO[1], Ju. V. ZHUKOVA[1], J. HIERRO[2]

EVALUATION OF STATISTICAL CHARACTERISTICS OF TURBULENT FLOW SUBJECTED TO FORCING

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Statistical characteristics of turbulent mixing can be described with the equation for the joint probability distribution function (JPDF) of a conservative scalar and its gradient. The closed equation for the JPDF was derived earlier in the paper of authors. As time-dependent coefficients this equation contains statistical moments of turbulent velocity and scalar fields such as the variance and dissipation rate of a turbulent scalar in line with a set of the third order moments. The above-mentioned statistical values can be calculated from solution of an auxiliary set of equations. As such a system, two models – set of equations – were proposed. These describe transfer of turbulent kinetic energy and intensity of scalar fluctuations in spaces of length scales and wave numbers. In the given paper the models constructed and tested before for the coefficients are extended for the case of the presence of generation of turbulence kinetic energy. Outcomes of the numerical solution for these models were compared to the data of direct numerical simulation of turbulent velocity and scalar fields and show good agreement.

1-04 V. A. BABENKO, S. N. PETROVICH, B. NAUD

COMPARISON OF EULER AND LAGRANGIAN APPROACHES TO MODELING TURBULENT MICROMIXING

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Modeling turbulent micro mixing of a passive isotropic scalar field is carried out on the basis of three Lagrangian models: mapping closure, method of linear square mean estimation, and method of coalescense-dispersion of particles. Calculation results for evolution of the variance and dissipation rate of the scalar field fluctuations are compared for these three stochastic models and the model of one of the authors, based on the equation for the joint probability density function of a scalar and its gradient. The conditional rate of a scalar dissipation is also found. All these statistical characteristics are compared to the similar data of the direct numerical simulation which have been carried out for the same conditions.

1-06 N. B. BAZYLEV, A. M. BRATCHENYA, S. A. FILATOV

CROSS-CORRELATION ANALYSIS OF THE IMAGES OF CONVECTIVE FLOWS IN A REAL TIME

6- **V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus,** *bnb@hmti.ac.by*

A brief description of an experimental technique based on PIV methods for non- contact investigation of convective flows is suggested. Simple algorithms are given for statistical processing of experimental results on a PC in the real time regime. The results of computations are illustrated by the vector fields of velocities obtained in analyzing images of convective flows in fluids.

1-09 M. A. BLINOV[1], M. E. LEBEDEV[1],1. S. MUKHINA[1], L. A. FELDBERG[1],

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V. Yu. MITYAKOV[2], V. V. RIS[2], S. Z. SAPOZHNIKOV[2], E. M. SMIRNOV[2], Yu. S. CHUMAKOV[2], A. V. TERENT'EV[3], S. **F.** YURAS[3]

NATUREL AND MIXED CONVECTION HEAT TRANSFER OF A COOLING AIR IN FISSILE MATERIAL AND SPENT FUEL STORAGE FACILITIES

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The experiments carried out on test benches designed for studying fluid mechanics and heat transfer in air-cooled fissile material storage facilities are presented. Based on the results obtained, recommendations are given for carrying out thermal and fluid mechanics calculations for cooling channels. It is shown that the results of numerical simulation of the processes under discussion take into account main features of flow in all types of storage and can be used for positive estimations.

1-10 V. T. BUGLAEV, A. A. ANISIN, A. K. ANISIN

HEAT TRANSFER AND AERODYNAMIC DRAG OF BUNDLES OF SMOOTH TUBES WITH DIFFERENT GEOMETRIES OF THE SURFACE IN A CROSS FLOW

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The possibility of enhancing heat transfer from a symmetric in-line bundle of smooth tubes immersed in a cross flow with the use of smooth cylindrical agitating rods arranged in succession at the centers of square tubular cells is analyzed. Implementation of the proposed array of tubular elements as a combined heat-transfer surface of tube bundles of different outer diameters with triangular and linear schemes of arrangement and the experimental thermo-aerodynamic characteristics obtained point to the advisability of practical application of the proposed approach to enhancement of heat transfer and increase of the energy efficiency of tubular heat exchanging facilities and apparatuses.

1-07 R. BUNKER[1], M. Ya. BELENKII[2], M. A. GOTOVSKII[2], B. S. FOKIN[2], S. A. ISAEV[3]

HEAT TRANSFER ENHANCEMENT IN A SHORT RECTANGULAR DUCT WITH SUBSTANTIAL INLET VELOCITY DEFLECTION FROM AXIAL DIRECTION

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Experimental and computational investigation of heat transfer in a short rectangular duct which is an element of a header system with a rectangular supplying channel of constant cross section is carried out. Position of the duct in the header system is modeled by supplying channel duct flow rate ratio. Tests have shown that the transitional flow effect on heat transfer can be substantial for a high flow rate ratio. In the case of a maximum deflection of flow inlet from the axial one, heat transfer enhancement was 60-100% depending on axial position. Numerical investigations revealed a substantial influence of spatial separated flow on convective heat transfer.

1-75 B. CESNA

INFLUENCE OF THE PITCH OF WIRE TWISTING ON LOCAL HEAT TRANSFER IN A BUNDLE WITH ONE-WAY WIRE COILING IMMERSED IN A LONGITUDINAL FLOW

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This paper presents the results of experimental investigation of local heat transfer of a 85-rod bundle whose rods were spaced by means of a two- or four-layer unidirectional wire coiling. The relative pitch of the bundle arrangement was P/d = 1.23 and the relative pitch of the wire coiling was T/d = 14, 28, and 69.8. Experiments were carried out in the range $3 \cdot 10^3 < Re \leq 7 \cdot 10^4$. In the present work the program DARS developed in the Lithuanian Energy Institute and based on

subchannel method of calculation was used to analyze experimental data. Using this program, distribution of flow temperatures in elementary cells along the bundle length was estimated.

1-76 A. D. CHORNYI, B. A. BABENKO

LENGTH AND TIME SCALE DISTRIBUTIONS OF PASSIVE CONCENTRATION FIELD IN HOMOGENEOUS TURBULENCE

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The process of fine-grained mixing (micromixing) of passive concentration field by interaction of turbulent fluctuations and molecular diffusion in homogeneous turbulence is considered. The length and time scalar scales are defined on the basis of joint statistics of scalar and its gradient fields. The connection between length scale PDF and joint PDF of scalar and its gradient magnitude in view of integral relation and balance equation is found. The equation is solved numerically with the aid of cumulative distribution function and using the DNS data for the coefficients from the equation. The results obtained show the dynamics of change of the forms of length scale PDF depending on scalar field segregation and different values of Prandtl-Shmidt numbers.

1-49 T. V. CUCIUC, M. K. BOLOGA, P. G. DUMITRAS

HEAT TRANSFER AND HYDRODYNAMICS IN CAVITATIONAL FLOW AROUND A SYSTEM OF CYLINDERS

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Experimental results of the investigations on cavitation effect on hydrodynamics and heat transfer from a pair of cylinders are reported. Phenomenons of cavitational pseudo blocking of flow and accompanying hysteresis are found. Ii is also revealed that enhancing of the heat transfer of a pair of cylinders under cavitation takes place on appearance of cavitational eddies near the surface of the cylinders. At small distances between the cylinders, we can single out the range of cavitation numbers in which the mode with detaching twin cavitational eddies from the first cylinder appears with a frequency more than three times exceeding the frequency of eddies detaching from a single cylinder. The modes of flow when cavitation significantly decreases heat transfer from cylinders have been found.

1-26 M. S. DIKOV

SLIGHT INCREASE IN THE MASS FLUX AT THE GAS-LIQUID INTERFACE UNDER THE CONDITIONS OF A SLOW FLOW AND OVERSHOOTING OF

THE CRITICAL HEAT FLUX FROM THE SURFACE

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Mass transfer at the gas-liquid interface at a low velocity of flow under the conditions of an appreciable heat flux density is investigated. Theoretical results are based on the reported model of natural convection development in the region of the liquid cooled from above using for the purpose the description of microconvection by the Navier-Stokes equations in the Baussinesq zero approximation. Expressions have been obtained for the mass transfer coefficients depending on the conditions of heat transfer at the interface without allowance for chemical reactions and vapor generation, as well as thermophysical parameters of the liquid and gas. The assumptions made predetermine the predominant use of the obtained relations to estimate the parameters of mass transfer at the interface in inert gas-liquid metal combination.

1-28 G. A. DREITSER, V. M. KRAEV

INVESTIGATION OF THE FREQUENCY SPECTRA OF PULSATIONS IN GAS TUBE FLOW UNDER UNSTEADY CONDITIONS

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Investigation of the processes of heat transfer and hydrodynamics in turbulent flows and development of a technique for their calculation are extremely urgent tasks for engineering practice. These processes are determined by the structural parameters of turbulent flows. The investigations of the frequency spectra of turbulent pulsations carried out show that hydrodynamic unsteadiness substantially influences the process of development of turbulent eddies, namely, it intensifies (in flow acceleration) or attenuates (in flow deceleration) dissipation - destruction of large energy - carrying eddies into smaller ones.

1-27 G. A. DREITSER, I. E. LOBANOV

LIMITING INTENSIFICATION OF HEAT TRANSFER IN TUBES DL f TO ARTIFICIAL TURBULIZATION OF A FLOW

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The problem of calculation of the limiting isothermal values of heat transfer rate and resistance in turbulent channel flow due to turbulization of the latter has been solved theoretically. The corresponding drawbacks occurring in analogous previous works have been eliminated. Calculation results on the limiting heat transfer rate and resistance have been obtained for a wide range of Reynolds and Prandtl numbers. It has been proved theoretically that intensification of heat transfer via flow turbulization is more preferable for gases than for liquid metals and dropping liquids. The method developed in this investigation enables one to predict the limits of intensification of heat transfer with a higher degree of accuracy.

1-29 A. Yu. DYACHENKO, V. I. TEREKHOV, N. I. YARYGINA

HEAT TRANSFER IN A TRANSVERSE EXTENDED CAVITY WITH INCLINED WALLS IN A FLOW WITH TURBULIZATION

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Experimental investigations of the influence of an external turbulence degree on heat transfer intensification in a cavity with a small aspect ratio with the angles of inclination of the lateral walls being varied from 30° to 60° were carried out. It is found that in a rectangular cavity the surface-average heat transfer coefficient at a turbulence level of 6.5% increases by a factor of 1.2, whereas at 16% by 1.4. Visualization of the patterns of vortex formation has shown that at $\varphi = 60°$ and 70° the flow becomes extremely unstable depending on the Reynolds number. For these angles an appreciable increase in heat transfer is observed which is enhanced at a high turbulence of a free stream and much more appreciably than in a rectangular cavity.

1-24 **B. V. DZYUBENKO**

EFFECT OF FLOW SWIRLING ON CONVECTIVE HEAT TRANSFER IN TWISTED TUBE BUNDLES

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In this paper, the generalization of the comprehensive data on heat transfer and hydraulic resistance in twisted tube bundles is presented. For bundles of helical tubes, the experimental heat transfer results are described by a relation in the form of second-order multiterms in logarithmic coordinates. The studies of heat transfer indicate that the flow swirl significantly enhances heat transfer over a wide range of geometric and operating parameters. The discovered specific features of thermal and hydraulic processes made it possible to determine the mechanisms of their enhancement in helical tube bundles. The representation of experimental data on heat transfer and hydraulic resistance in helical tube bundles in the form of dimensionless relations extends the possibilities of simulation of heat transfer and reduces the number of experiments necessary to establish these relations.

1-25 B. V. DZYUBENKO, G. A. DREITSER, R. I. YAKIMENKO

HEAT EXCHANGERS WITH FLOW SWIRLING BY TWISTED TUBES AND ESTIMATION OF THEIR THERMOHYDRAULIC EFFECTIVENESS

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Analysis of the thermohydraulic effectiveness of heat exchangers with twisted tubes and with various turbulence promoters was carried out by the method of effective parameters. The main reference conditions in this method are described by equation for identical main operational parameters: heat duty, power for pumping a heat carrier, and heat carrier flow rate. It is suggested to compare the thermohydraulic effectiveness of heat transfer surfaces on the basis of the dependences of effective Nusselt number on effective Reynolds number. For the same value of the effective Reynolds number at a higher value of the effective Nusselt number the heat exchanger is characterized as more effective. The regions of change in the effective Reynolds number where one type of a heat transfer surface has preference over others have been determined.

1-79 E. EPIK

PROBLEMS OF PREDICTION AND CALCULATION OF UPPER THERMAL LAMINAR-TURBULENT TRANSITION

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The results of an experimental investigation of local heat transfer are presented for the case of the origination of upper thermal laminar-turbulent transition after a pseudolaminar boundary layer. The latter is characterized by substantial growth of local heat transfer coefficients, which smoothes their distributions along the streamlined surface and causes the upper approximation to a turbulent or a quasiturbulent boundary layer. Four practically important cases of the appearance of the upper transition initiated by external and internal disturbances (increased free stream turbulence, separation near the leading edge, their combination and periodic velocity nonstationarity) are described. Special attention is paid to the problems of the prediction of an upper transition and derivation of calculation methods, taking into account the total intensity of disturbances and effective viscosity on the outer edge of a dynamic boundary layer.

1-68 A. I. FEONYCHEV

FLOW AND HEAT AND MASS TRANSFER IN THE PROCESSES OF THE GROWING OF CRYSTALS WITH THE ACTION OF A ROTATING MAGNETIC FIELD ON GRAVITATIONAL AND THERMOCAPILLARY CONVECTION

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The flows of an electrically conducting liquid in a cylinder under the action of a rotating magnetic field and also during its interaction with thermal gravitational and thermocapillary convection are considered. The limits of transition to an oscillating mode of convective flows are considered. The regimes of flow have been revealed in which microsegregation of impurity in the crystals grown by the Bridgman method and the method of a floating zone is decreased. It is shown that for gravitational convection exposed to the action of a rotating magnetic field there are flow regions in which one can observe both a smooth increase in macrosegregation of impurity

and changes in the form of distinct extremes. In growing crystals by the method of a floating zone with a rotating magnetic field on the earth, the appearance of pulsating vibrations and wide impurity bands is possible.

1-67 A. I. FEONYCHEV

SURFACE STANDING WAVES AND THEIR EFFECT ON THE STABILITY OF THERMOCAPILLARY CONVECTION AND HEAT AND MASS TRANSFER IN GROWING OF CRYSTALS IN WEIGHTLESSNESS

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Numerical investigation of the effect of standing surface waves on the stability of thermocapillary convection, temperature field, and distribution of doping impurities in growing crystals by the method of a floating zone under weightlessness conditions is carried out. The standing waves considered may form during vibration motion of a fluid as a single whole (inertial-capillary waves) and vibrations of a growing crystal (capillary waves). The limit of transition from a laminar to an oscillating (turbulent) mode of flow has been determined. Based on the results obtained the mechanism underlying the deterioration of the stability of thermocapillary waves in closed volumes is discussed.

1-18 L. G. GENIN, V. G. ZHILIN, Yu. P. IVOCHKIN, Ya. I. LISTRATOV,

N. G. RAZUVANOV, R. A. SARVIN, V. G. SVIRIDOV **EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER OVER THE HORIZONTAL PIPE LENGTH WITH A LIQUID METAL HEAT CARRIER FLOW IN A TRANSVERSE MAGNETIC FIELD**

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Liquid metal flow heat transfer in a heated horizontal pipe under longitudinal and transverse magnetic fields was investigated on the joint experimental complex MPEI-IIHI. The flow conditions simulate those in a Tokamak fusion reactor. Temperature fields, streamwise distributions of local and average heat transfer intensities affected by transverse magnetic field are investigated. The effects of longitudinal and transverse magnetic fields on the measured parameters were essentially different.

1-19 A.Ya. GORBACHEVSKI[1,2], A. G. CHURBANOV[3], Z. CHARA[2], B. HORENI[2], J. K. LOKHANSKI[1]

SIMULATION OF FLOW IN A CHANNEL WITH A HEATED RECTANGULAR OBSTACLE

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An incompressible viscous flow in a channel with a heated obstacle of square section on its wall is studied numerically on the basis of the Navier – Stokes equations. The range of the Reynolds numbers of the investigated flows is from 10 to 1000 and Grashof numbers Gr 10^4-10^6. The dependence of the critical Reynolds number on the Grashof number which characterizes transition from a steady-state flow regime to an oscillating one with a quasiperiodic vortex shedding has been determined.

1-23 V. N. GUSEV, A. I. EROFEEV

CHARACTERISTIC FEATURES OF HEAT TRANSFER IN RAREFIED GAS FLOW PAST A CYLINDER WITH INTERFERENCE OF AN OBLIQUE SHOCK WITH A BOW SHOCK

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Characteristic features of a high velocity gas flow past blunted bodies in the region of interaction of a bow shock with an oblique shock are investigated. The analysis of the limit regimes is given, the similarity conditions are formulated, and the limit values of the flow parameters in the high pressure stream filament and on the surface of the body are evaluated. The Monte Carlo direct MCDS method is used to study the rarefied diatomic gas flow with an oblique shock past a cylinder. Variations of pressure and heat transfer to the surface against the location of the oblique shock as related to the center of the cylinder, the Reynolds number, and temperature are analyzed. Calculations are compared with experimental data.

1-20 V. G. GOROBETS

CONJUGATED HEAT TRANSFER OF SURFACES WITH FLOW PAST ONE-SIDE AND TWO-SIDES (INTEGRAL METHODS OF CALCULATION)

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The methods of solving conjugated problems of heat transfer which are based on the use of integral methods of calculation of the equations of momentum and energy transfer and the general functional dependence between the density of the heat flux and the temperature on a surface with its arbitrary distribution are surveyed. Based on the developed approach, a number of problems of the conjugated heat transfer for various types of finned surfaces and polymeric films have been solved. Comparison of the results of calculation of local and integral heat transfer characteristics

in problems with conjugated and simplified statements of a problem which do not take into account the influence of nonisothermicity of the surface or use average values of heat transfer coefficients is carried out.

1-21 V. G. GOROBETS

INFLUENCE OF THE NONISOTHERMICITY ON THE HEAT TRANSFER OF A BUNDLE OF FINNED PIPES HAVING COATING ON THE OUTER SURFACE

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Based on integral methods of calculation of the equations of momentum and energy transfer, the conjugated problem of heat transfer for a staggered bundle of pipes with fins is solved in the presence of low-conductivity coating on the outer surface. The scheme of flows with cross current of external and internal heat carriers is considered. Use of simplified calculation procedures not taking into account the influence of the nonisothermicity of the surface or employing average heat transfer coefficients, leads to significant quantitative and qualitative differences for local and integral heat transfer characteristics of a bundle of finned pipes.

1-22 D. G. GRIGORUK, P. S. KONDRATENKO, D. V. NIKOLSKII

A GEOMETRIC FACTOR IN FREE CONVECTION OF A HEAT-GENERATING FLUID

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Theoretical results on steady-state free convection (including heat flux distribution) of a heat-generating fluid enclosed in cylindrical and quasi-2-D (slice-) cavities are presented. Using the method of analytical estimates, it is established that the heat flux depends sharply on the position at the boundary in the lower part of a cylindrical cavity. The maximum heat flux is reached at the upper section of the vertical boundary, and the minimum value is at the bottom boundary. Convection in a slice-cavity was examined for two kinds of heat supply (internal and side heating), from the point of view of adequate experimental modeling of real 3-D convection. In the case of internal (Joule) heating, the condition of adequate modeling reduces to the minorating restriction on the slice thickness. An additional majorating constraint on the slice thickness arises when side heating is employed.

1-80 S. D. HARRIS[1], D. B. INGHAM[2], I. POP[3]

TRANSIENT FORCED CONVECTION HEAT TRANSFER PAST A WEDGE

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The transient forced convection heat transfer resulting from an impulsively started and heated Falkner-Skan flow is studied. The thermal boundary layer is produced by a sudden increase of the surface temperature or a sudden increase of the surface heat flux at the same time as the flow is set impulsively into motion from rest. Analytical solutions for the simultaneous development of the momentum and thermal boundary layers are obtained for both small (initial, unsteady flow) and large (final, steady-state flow) times. These solutions are then matched numerically using an implicit finite-difference scheme. Numerical results are presented for some values of the Falkner-Skan exponent m and the Prandtl number Pr being unity.

1-37 S. A. ISAEV

NUMERICAL SIMULATION OF VORTICAL HEAT TRANSFER BY MULTIBLOCK COMPUTATIONAL TECHNOLOGIES

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The work focuses attention on multiblock computing technologies, their genesis, and appropriate development of the analysis of the state-of-the-art of computational hydrodynamics and thermophysics. Some of "critical points", in particular, coding and paralleling are specified. The testing of the advanced multiblock approach is made with emphasis on estimation of the acceptability of Menter's turbulent model. The approach has been widely verified in investigation of the mechanism of vortical heat enhancement. Some of little-known applied problems illustrate its mobility.

1-36 S. A. ISAEV[1], P. A. BARANOV[1], T. A. BARANOVA[2], N. A. KUDRYAVTSEV[1]

NUMERICAL SIMULATION OF VORTICAL HEAT TRANSFER IN TUBE BANKS

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The results of numerical investigation of convective heat transfer in a multi-row, in-line package of round pipes are presented. A multiblock solution algorithm based on crossing Cartesian and cylindrical grids is developed and verified. The model of shear transport according to Menter is applied to analyze a turbulent regime. A simplified approach to the analysis of a separated flow and heat transfer is justified on the basis of periodic boundary conditions. A comparative analysis of the solution of the problem of heat transfer in a periodically repeating module with one cylinder and the problem of heat-carrier motion in a corridor with eight cylinders shows that for a homogeneous package of pipes with a step 2 the simplified approach to interpretation of heat transfer appears acceptable for $Re \leq 250$. The undertaken investigation of evolution with increasing Re of separated flows and heat transfer in the vicinity of a remote cylinder (sixth in the row) shows that their characteristic features are similar to those established

earlier for the cylinder in a periodic module.

1-38 S. A. ISAEV[1], A. I. LEONTIEV[2], V. L. ZHDANOV[3], N. V. KORNEV[4], E. HASSEL[4]

TORNADO-LIKE ENHANCEMENT OF HEAT TRANSFER ON DIMPLE RELIEFS

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The results of numerical investigation of vortical enhancement of heat transfer in turbulent flow past dimple reliefs are presented. It is noted in the analysis of the ten-years period of numerical simulation that the progress in understanding the mechanisms underlying the formation of vortices is attributed to the development of multiblock computation technologies and to the use of a semiemperical model of transfer of the Menter shear stresses. In addition to verification of a computational complex on the available experimental material, the present work is devoted to a comparative analysis of two- and three- dimensional concavities. Comparison of a spherical dimple and a groove as elements of vortical enhancement of heat transfer shows that a three-dimensional concavity of depth 0.22 produces in a wake an increase in heat transfer 1.5 times higher than that from a flat wall and by 10% higher than that for a control length in the wake downstream of the groove. The extension of the dimple surface where the thermal efficiency of the dimple is higher than of the groove is of the order of 0.4d.

1-81 L. F. JIN, C. P. TSO, K. W. TOU

NATURAL CONVECTION HEAT TRANSFER IN A ROTATING ENCLOSURE WITH THREE ROWS OF DISCRETE HEAT SOURCES

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A numerical study is made on air-filled slowly rotating enclosure with 3 rows of discrete heat sources. The enclosure is rotating above its longitudinal horizontal axis. Three physically realizable phenomena, uni-periodic oscillation, multi-periodic oscillation, and chaotic oscillation are identified numerically. In the cases of stationary or low rotation speed, buoyancy force causes clockwise and counterclockwise circulations, and correspondingly there are three or two local peak Nusselt numbers in each periodic oscillation. With increasing rotation, the clockwise circulation is enlarged and tends to dominate the counterclockwise circulation. The second and third peak Nusselt numbers become weakened, and negligible. In the stationary case, heat transfer behavior for the heaters of the top row and bottom row is symmetrical. But with increase in the speed of rotation it gradually becomes asymmetrical.

1-40 A. G. KARIMOVA[5], S. G. DEZIDER'EV[1], V. M. ZUBAREV[2], I. Kh. SATTAROV[2], M. G. HABIBULLIN[2]

INVESTIGATION OF THE INFLUENCE OF VARIOUS FACTORS ON THE EFFICIENCY OF THE TRANSPIRATION COOLING OF THE OUTER SHELL OF THE CASING OF A GTE FOR GROUND APPLICATION

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An experimental investigation of the temperature state of the outer wall of the casing of a gas-turbine engine for ground application on different regimes of coolant flow rate and intensity of heating is carried out. It is necessary to carry out a full program of experiments for elaborating regularity.

1-69 A. A. KHALATOV, G. V. KOVALENKO

HEAT TRANSFER IN AIR FLOW PAST DIFFERENTLY SHAPED DEPRESSIONS

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Computer simulation of heat transfer and hydrodynamics in transverse air flow past differently shaped grooves with the aid of the code PHOENICS v. 3.5 was carried out. Intensification of the average heat transfer on surfaces with grooves in comparison with a flat plate was observed at Reynolds numbers limited from above by the value found in range from 33,700 to 93,800 depending on the type of a groove. The curvature of input and output edges of grooves has a negative effect on the average heat transfer coefficient.

1-82 **A. A. KHALATOV, A. BYERLEY,** D. **OCHOA, S.-K. MIN, R. VINSENT**

APPLICATION OF ADVANCED TECHNIQUES TO STUDY FLUID FLOW AND HEAT TRANSFER WITHIN AND DOWNSTREAM OF A SINGLE DIMPLE

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A few advanced experimental and computational techniques were employed towards the deeper understanding of fluid flow and heat transfer patterns inside and downstream of a single spherical or cylindrical dimple. The experimental technique includes a Dye Visualization Technique, Laser Doppler Velocimetry, Steady Liquid Crystal Technique (heat transfer). The numerical simulation was performed using the COBALT software, simulating steady and unsteady flow. The "shallow" dimples (h/D<0.1) were investigated at laminar and turbulent flow conditions ranging the Rednumber from 3,000 to 23,600. Results of this study have demonstrated the

effectiveness of advanced techniques in providing a deeper insight into the fluid flow and heat transfer nature of the vortex flow.

1-70 A. A. KHALATOV, S. V. SHEVTSOV, A. S. KOVALENKO

HYDRODYNAMICS AND HEAT TRANSFER AT A CONVEX SURFACE IN A FLOW WITH ACCELERATION

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We present the results of an experimental investigation of an averaged and pulsational structure and heat transfer in turbulent flow at a convex surface of constant curvature and with free stream acceleration. The experimental data demonstrate a close relationship between the heat transfer and the boundary layer characteristics. As a result, the law governing heat transfer for a convex surface in an accelerated flow can be presented with account for separate influence of the surface curvature and favorable pressure gradient.

1-71 S. N. KHARLAMOV, A. A. NIKIFOROV

NEAR-WALL MODELING OF TURBULENT HEAT TRANSFER IN CHANNELS

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Using a model of turbulence which includes transport equations for the components of Reynolds stress tensor and turbulent heat fluxes with a reference base consisting of differential equations for the kinetic energy of turbulence and characteristic scale of the velocity field oscillation time, modeling of turbulent heat transfer in tubes and channels is carried out. It is found that the selected closing relations for higher-order terms in the equations of the model and the base itself are rather versatile and can successfully describe the parameters of flow and heat transfer in the class of internal flows.

1-72 S. N. KHARLAMOV, A. A. NIKIFOROV

TURBULENT HEAT TRANSFER IN CIRCULAR TUBES ON THE BASIS OF A DIFFERENTIAL MODEL FOR TIME SCALES OF FLUCTUATIONS OF THERMAL AND DYNAMIC FIELDS

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The potentialities of two-parameter models (thermal and dynamic) in calculations of turbulent heat transfer in internal systems are investigated numerically The proposed model includes transport equations for characteristic time scales of velocity and temperature fluctuations and also original closing relations making it possible to successfully and reliably predict near-wall processes in developing nonisothermal flows. Stable satisfactory agreement of the predicted and experimental data is noted. It is established that in describing near-wall turbulence, the model has

marked advantages as concerns stability, expenses on implementation, and accuracy in predicting pulsational characteristics as against popular kε-models.

1-73 I. E. KHOREV, G. A. EROKHIN, V. P. KUZMENKO

INVESTIGATION OF WAVE PROCESSES AT HIGH-SPEED COLLISION OF SOLID BODIES OF DIFFERENT SCALES

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Physicomathematical modeling of high-speed spatial impact phenomena is carried out with allowance for propagation, reflection, and attenuation of shock waves. The role of wave processes in punching single barriers and structures from spaced plates and their contribution to the development of kinetic mechanisms of destruction of constructional materials are analyzed. Parametric studies of the physical characteristic features of deformation and destruction of model strikers, barriers, and structures are carried out and a comparison with a similar experiment is given.

1-41 V. V. KONDRASHOV

METHOD OF GRIDS SUPERPOSITION AND VIRTUAL Z-CELLS

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An analysis of the state-of-the-art in solving the problem of reducing errors of approximation (errors of angularity, transverse problem of propagation) of computational

algorithms for numerical implementation of the mathematical models of thermomechanical processes is presented and, as a result, methods of grids superposition (GSP method) and of virtual Z cells. In the considered variant of the GSP method the position of the primary grid of nodes is taken to be fixed for clearcut representation (though, if required, they can displace perfectly well). Thereafter duplicates of the computation domain are introduced that differ by the shape of the cells and that ensure a change in the connectedness of the nodes of the primary Euler grid for the same stencil of the numerical method on all of the dublicates. In discussing the possibility of obtaining solutions that exclude angularity errors the conclusion is drawn concerning the necessity of using virtual Z cells (and others of the same type) for this purpose which provide the possibility of dynamically relate their shape to the change in the orientation of one of the determinants of the vector field problem. We note that the Z cell itself is as if composed of the fragments of trajectories and sections of this field that pass in the vicinity of the primary node of the grid. Thus, not only the average and local values can be related to the node, but also different shapes of cells for various vector fields in the problem, and this actually ensures the possibility of natural subgrid dynamic resolution of determining parameters and independent variables.

1-42 G. V. KONYUKHOV[1], A. A. KOROTEEV[2]

INVESTIGATION OF HEAT TRANSFER IN THE CHANNELS OF HIGH-ENERGY SYSTEMS OF TRANSPORTATION OF ELECTRON BEAMS FROM VACUUM TO DENSE MEDIA

[1]M. V. Keldysh Reseach Center "Federal Unitary Enterprise", Russia; State Scientific-Research Institute of Applied Mechanics and Electrodynamics at the Moscow Aviation Institute (Technical University), Moscow, Russia, *riame@sokol.ru*

We consider the solution of a complex problem of the dynamics of a gas flow and its heat exchange with the walls of the systems of transportation of electron beams.

1-43 V. P. KORBUT, B. V. DAVYDENKO

AERODYNAMIC AND THERMAL INTERACTION OF THE MAIN BUILDING OF TPS WITH A WIND FLOW

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The problem of turbulent air flow with heat transfer near the main building of a thermal power station has been solved by a numerical method. Special features of dynamic and thermal interaction of air flow with this construction have been determined. The laws governing the effect of heat transfer from the building into the environment on the dynamics and structure of air flows and on the formation of the temperature and velocity fields around the construction have been investigated.

1-44 E. A. KOSOLAPOV, A. V. MALAKHOV

PARTICULAR SOLUTIONS FOR HEAT TRANSFER BETWEEN A SUBMERGED JET AND A ROTATING PROPELLER

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The present report considers heat transfer between the rotating blade of a propeller and submerged jets from exhaust gases of a gas turbine engine. Mathematical models of two particular problems are presented: an extreme one corresponding to a blade fixed against an exhaust pipe and a periodic one presuming uniform rotation of the blade. Some results of numerical solutions are discussed.

1-12 N. N. KOVALNOGOV, D. A. BUINOV

SIMULATION OF A SYSTEM FOR STABILIZATION OF FILM COOLING TURBINE BLADES ON THE BASIS OF BLANK DAMPING CAVITIES

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A mathematical model of film cooling turbine blades under the condition of the formation of a film on a punched surface with blank damping cavities is suggested. Based on numerical investigation with the use of the proposed model, the possibility of a substantial (under the analyzed conditions ensuring a decrease in the adiabatic wall temperature by 200K) increase in the efficiency of film cooling due to partional laminarization of a turbulent boundary layer on the punched surface.

1-45 A. V. KRAUKLIS, E. I. LAVINSKAYA, N. A. FOMIN

DIAGNOSTICS OF THREE-DIMENSIONAL STRUCTURES IN NONEQUILIBRIUM FLOWS IN PRODUCING NANOMATERIALS BY THE METHOD OF DIGITAL SPECKLE PHOTOGRAPHY

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The possibilities of carrying out diagnostics by the method of DSPh under nonequilibrium conditions in complex (three-dimensional) high-temperature plasma fluxes in producing nanomaterials are considered. Numerical simulation of the process of reconstruction of the local parameters of complex flows by using the data of small-aspect integral measurements with the use of the Radon inverse transformation is carried out. Errors of such a reconstruction have been calculated and their analysis is given. It is shown that at the number of aspect ratios not exceeding four, recovery of only relatively simple flows with a relatively small asymmetry is possible.

1-46 E. V. KRINITSKII, A. Y. MASKINSKAYA, V. P. MOTULEVICH, E. D. SERGIEVSKII

EXPERIMENRAL AND COMPUTATIONAL INVESTIGATIONS OF THE TEMPERATURES OF A SURFACE WITH A SYSTEM OF DIMPLES USING A THERMAL IMAGER

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Experimental and computational investigation of temperatures on the surface with dimples was carried out. A smooth plate, plates with in-line and staggered arrangement of dimples were considered. Thermal imaging pictures showing a decrease in the temperature in the lower (downstream) part of a dimple and immediately after it are given. The results of calculations performed by PHOENICS version 3.5 are presented. Experimental and predicted results are compared.

1-48 S. A. KRYUCHKOV[1], V. V. LEBEDEV[2], Sh. A. PIRALISHVILI[2]

MONITORING OF GASDYNAMIC AND THERMAL PROCESSES IN WATER-CURTAIN COOLING OF THE END SURFACES OF THE VANE CASCADES OF GAS TURBINES

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The possibility of using twisting for providing efficient curtain cooling with minimization of total losses in the blade cascade in a turbine is investigated.

1-47 V. N. KRYUKOV, Yu. A. KUZMA-KITCHA, V. P. SOLNTSEV

INTERACTION OF A COUNTERFLOW WITH THE SURFACE OF A LANDING SPACE APPARATUS

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The conditions originating in soft landing of a space vehicle on the surface of a planet are studied. For deceleration of the apparatus in the atmosphere of a planet, engine brakes located on the lateral surface of the apparatus are used. The conditions are determined which are needed for carrying out experimental investigations of the effect of a counterflow and the jets of the engine brakes on the surface of the apparatus.

1-50 V. G. LUSHCHIK[1], A. E. YAKUBENKO[2]

BOUNDARY LAYER ON A PERMEABLE SURFACE WITH INJECTION OF A FOREIGN GAS

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State University, Moscow, Russia

Numerical investigation of heat and mass transfer in a boundary layer on a permeable surface with gas injection is performed. Using a three-parameter model (for energy, friction, and turbulence vorticity), the injected gas differs from the ambient flow gas in density and temperature. The results obtained for the friction coefficient and Stanton number are compared with the available experimental data on injection of helium, air, carbon dioxide, and freon into a heated air flow. It is shown that the ratio of the densities of the injected gas and that of the main stream exerts a substantial influence on the dependence of the friction and heat transfer on the injection parameter.

1-51 T. Sh. MAGRAKVELIDZE

HEAT TRANSFER OF TURBULENT FLOW OF MOLTEN METALS IN ROUGH AND SMOOTH PIPES

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A model of the process of heat transfer to a turbulent flow of molten metals has been developed. Based on this model, a formula for calculating the heat transfer coefficient in smooth and rough channels is obtained. The method of extraction of friction resistance from the total resistance of rough pipes, which is necessary for calculating the heat transfer coefficient by the proposed dependence, is suggested. On the basis of the calculations carried out by the formulas obtained it is shown that, using the method of artificial roughness in the case of molten metals ($Pr<<1$) just as in case of ordinary fluids ($Pr>1$), a substantial intensification of heat transfer can be reached.

1-52 N. I. MIKHEEV[1], V. M. MOLOCHNIKOV[1], D. I. ZARIPOV[2]

INTERACTION BETWEEN THE PROCESSES OF MOMENTUM AND HEAT TRANSFER IN A TURBULENT BOUNDARY LAYER WITH A LONGITUDINAL PRESSURE GRADIENT

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Experimental results on space-time interaction of hydrodynamic and thermal parameters in a turbulent boundary layer with an imposed longitudinal pressure gradient are presented. Simultaneous measurements of wall parameters (skin friction and heat flux) and flow parameters (velocity and temperature) are conducted. It is proved that correlation between instantaneous skin friction and wall heat flux as well as the corresponding phase shift depends on the sign and absolute value of imposed longitudinal pressure gradient. Location of the front of a large-scale eddy during its interaction with the wall is determined for every value of the longitudinal pressure gradient used in the experiments.

1-53 D. V. NAUMOV, V. I. VELICHKO

CALCULATION OF NATURAL CONVECTIVE HEAT TRANSFER IN A SYSTEM OF HORIZONTAL CYLINDERS OF SMALL DIAMETER

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Numerical experimental investigation of natural convective heat transfer to air of a vertical file of horizontal cylinders of small diameter, as an element of a promising grid-wire heat exchanging surface is carried out. For calculation, a mathematical model of a boundary layer was used with the following simplifications: a two-dimension stationary flow in the absence of internal output of heat and dissipation of energy in the approximation of the invariance of the air physical properties, except for density. The system of the differential equations of convective heat exchange was solved by a numerical method of simple iterations.

1-54 B. V. PEREPELITSA

EXPERIMENTAL INVESTIGATION OF A TEMPERATURE FIELD IN THE WALL REGION OF A TURBULENT FLOW IN PERIODIC HEAT RELEASE

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The statistical characteristics of a temperature field in a turbulent water flow in a duct at different Reynolds numbers and different distances from the heating surface are measured. The investigations are performed with periodic change in time of the heat flux density caused by a jumpwise change in the heat release in the duct wall. The measurements cover a narrow near-wall zone, which includes the region of a viscous sublayer. The temperature in the flow was recorded by a specially manufactured thermocouple probe of needle type. The transverse size of its hot end was about 5 microns.

1-39 Sh. PIRALISHVILI[1], O. V. KAZANTSEVA[1], D. K. VASILYUK[2], A. A. FUZEEVA[1]

NUMERICAL SIMULATION OF SWIRLED FLOWS IN VORTEX TUBES

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In the present work, a numerical investigation of full Navier-Stokes equations was carried out for an intensively twisted flow in an axisymmetrical channel diaphragmed in the inlet section and supplied with a throttle at the opposite end. Flow patterns and fields of distribution of thermodynamic parameters have been obtained. The presence of precession of the axial vortex and also formation of large-scale vortical structures are shown. For the first time, numerical calculations have been compared with experimental data on the Ranque-Hilsch vortex tubes.

1-55 E. N. PISMENNYI, A. M. TEREKH, V. A. ROGACHEV, V. D. BURLEI

INVESTIGATION OF THERMAL AERODYNAMIC CHARACTERISTICS OF NEW HEAT TRANSFER SURFACES

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Based on the results of experimental investigations, an analysis of the thermal and aerodynamic characteristics of plate-finned heat transfer surfaces with cutted fins under the condition of forced convection is carried out. The influence of changes in the turns or bends of the cutted parts of the fins on the efficiency of the heat-emitting surfaces is shown. The most optimal shapes of the fins created turns or bends of the cutted parts of the fins have been determined.

1-58 I. A. POPOV[1], Yu. F. GORTYSHOV[1], V. V. OLIMPIEV[2], A. V. SHCHELCHKOV[1]

THERMAL AND HYDRAULIC EFFECTIVENESS OF SPHERICAL CAVITIES FOR HEAT TRANSFER ENHANCEMENT IN CHANNELS

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In this paper we present:

1) energy effectiveness of heat exchange surfaces with spherical cavities in the region of low Reynolds numbers (ReD = 1000... 2000);

2) influence of the regime constructive parameters on heat transfer and hydraulic resistance;

3) systematization of data on flow and heat transfer in channels with spherical cavities and low flow velocities;

4) principles of the regime of flow in channels with spherical cavities.

1-59 P. POSKAS, G. BARTKUS, R. POSKAS, R. ZUJUS

AIDING TURBULENT MIXED CONVECTION HEAT TRANSFER IN A VERTICAL FLAT CHANNEL WITH ONE SIDE HEATING

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In this paper we present the results of experimental and numerical investigation of local turbulent mixed convection heat transfer in a vertical flat channel with aiding flows and one side

heating. The experiments were performed in airflow of different pressures in the range of Re from $4 \cdot 10^3$ to $6.5 \cdot 10^4$ and Grq of up to $7.2 \cdot 10^{10}$**.** Analysis showed that under the effect of buoyancy heat transfer variation along the channel takes nonmonotonic character. Numerical two-dimensional simulations were performed for the same channel and for the same conditions as in experiments. Modeling results show more significant velocity augmentation near the heated wall in the case of one side heating than in the case of two-side heating. Therefore, we can explain the less intensive decrease in heat transfer in the case of one side heating for laminarized flows.

1-60 P. POSKAS, R. POSKAS, A. SIRVYDAS

OPPOSING MIXED CONVECTION HEAT TRANSFER IN A VERTICAL FLAT CHANNEL WITH SYMMETRICAL HEATING IN A LAMINAR-TURBULENT TRANSITION REGION

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In this paper we present the results of experimental and numerical investigation of local opposing mixed convection heat transfer in a vertical flat channel with symmetrical heating in a laminar - turbulent transition region. The experiments were performed in airflow of different pressures (0.1 and 0.4 MPa) in a range of Re from $2.1 \cdot 10^3$ to $5.3 \cdot 10^4$ and Grq of up to $1.5 \cdot 10^{10}$. Numerical two-dimensional simulations were performed also for the same channel and for the same conditions as in experiments using FLUENT 6.0 code. Numerical calculations demonstrate that for Re < 7000-8000 (at p = 0.4 MPa) under high buoyancy effect flow circulation takes place near the heated walls. This makes velocity profiles asymmetrical and causes fluctuations of the wall temperature. In this region the intensity of heat transfer is higher comparing with a turbulent flow.

1-56 A. V. POZDNYAKOVA[1], V. B. KUNTYSH[2]

INVESTIGATION OF A TEMPERATURE FIELD IN IN-LINE BUNDLES OF FINNED TUBES

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The results of experimental investigation of the temperature fields of an air flow with free convection in two-row in-line bundles of bimetallic finned tubes are presented. Graphs of a typical heat mode have been plotted and analysis of the data obtained has been carried out.

1-57 A. V. POZDNYAKOVA[1], A. V. SAMORODOV[1], V. B. KUNTYSH[2]

INVESTIGATION OF FREE-CONVECTIVE HEAT TRANSFER OF MULTIROW IN-LINE BUNDLES OF FINNED TUBES

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The results of experimental investigation of free-convective heat transfer of five- row in-line bundles of bimetallic finned tubes are presented. The transverse and longitudinal pitches of tubes in the bundles are equal to S1 = 58; 70 mm and S2 = 58; 70; 100 mm, respectively. The finning coefficient of the tubes is φ = 16.8, the diameter at the base of a fin is d0 = 26.63 mm, the external fin diameter is d = 55,65 mm. Approximation equations have been derived.

1-61 A. M. PYLAEV

THE PROBLEM OF STABILITY OF LIQUID EQUILIBRIUM IN CAVITIES WITH ELLIPTICAL SECTIONS

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The method of analysis of flat linear disturbances of viscous liquid equilibrium (gas or melt of heat accumulated material) in cavities with cross-sections of simple geometry without concavities is implemented. The cases of both persistence and periodic modulation of an equilibrium gradient of temperature or speed-up of a field of mass forces are stipulated. The possibility of constructing exact solutions of such a problem in the form of double Fourier series is used. For the constants in these expansions an infinite linear system is obtained which is relative to the values of the critical Rayleigh number Ra. It is shown that the Ra values are determined from the condition of vanishing of a large enough but finite determinant of such a system. Specific results are presented. Comparison with the well-known results is carried out.

1-62 V. M. REPUKHOV

TRANSFORMATION OF THE GENERAL EQUATIONS OF STATIONARY THREE-DIMENSIONAL CONVECTIVE HEAT AND MASS TRANSFER TO THE SIMPLEST EQUUATIONS

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The earlier obtained coupled equations - conditions for transformation of differential equations of convective heat-and mass transfer of a stationary three-dimensional boundary-layer flow to equations of a low-velocity flow, including quasi-isothermal and quasi-homogeneous ones, are extended on full and reduced Navier-Stokes equations.

1-77 Yu. I. SHANIN, O. I. SHANIN

ENHANCEMENT OF HEAT TRANSFER BY INDENTING SPHERICAL PITS ON CHANNEL WALLS

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The results of a comparative experimental study of heat transfer and hydraulic resistance in three slit-type channels are presented: two with a regular structure of spherical pits for intensification of heat transfer and a reference one. Investigations were carried out for staggered pits 1.33 mm in diameter and 0.14 mm in depth with a 3.0 mm step, the results are summarized for the Reynolds numbers Re = $4\cdot10^2$-$4\cdot10^4$. It was found that within the interval $8\cdot10^2$ < Re < $2\cdot10^4$ this intensification is energetically favorable, since the increase in heat transfer exceeds the increase in resistance. The maximum dimensionless value of heat transfer to resistance ratio is observed at Re = (6-9)·10³ reaching the values 1.25-1.35. If Re > $2\cdot10^4$, the intensifying effect decreases.

1-78 A. V. SHVAB[1], V. N. BRENDAKOV[2]

DIFFERENTIAL MODEL OF TURBULENCE FOR CALCULATING CONVECTIVE HEAT TRANSFER

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A mathematical model of turbulence has been constructed on the basis of three differential equations of transport for the kinetic energy of turbulent pulsations, specific rate of dissipation, and coefficient of turbulent vortical viscosity. Based on the physical assumptions, numerical values of the turbulence model constants are obtained. The results of numerical calculations of hydrodynamics and convective heat transfer in comparison to experimental data and results obtained on the basis of the well-known models of turbulence are presented. The developed model of turbulence can be used for solving engineering problems of the dynamics of a viscous fluid and of convective heat and mass transfer.

1-63 S. V. SOLOV'EV

CONVECTION OF AN ELECTRICALLY CONDUCTING LIQUID IN SPHERICAL LAYERS WITH ACCOUNT FOR JOULE HEAT RELEASES

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Thermal convection of an electrically conducting liquid in spherical layers with account for inner heat source and Joule dissipation is investigated. Gravity acceleration is directed to the center of the spheres.

1-64 T. T. SUPRUN

INTENSIFICATION OF HEAT TRANSFER IN THE REGION OF A LAMINAR-TURBULENT TRANSITION BY MEANS OF STATIONARY AND MOVING WAKES

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Experimental investigation of heat transfer of a flat plate in the presence of wake- induced laminar-turbulent transition behind a stationary and a vibrating cylinder and also behind a stationary and a rotating squirrel cylindrical frame was carried out. The level of averaged external flow velocity fluctuations and intensification of heat transfer in a pseudo- laminar boundary layer preceding the transition are estimated. It is shown that under the conditions indicated two types of wake-induced transition take place: with nonmonotonic and monotonic changes in heat transfer coefficients along the plate.

1-66 V. I. TEREKHOV, N. A. PAKHOMOV

EFFECT OF EVAPORATION OF DROPS ON TURBULENCE AND HEAT TRANSFER IN A NONISOTHERMAL MIST FLOW

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Within the concept of the heterogeneous-continuum mechanics, the present work numerically, in the Eulerian two-fluid model, examines a turbulent flow of an air-drop mixture. Effects due to drop evaporation, deposition of drops from the flow onto the duct wall, heat transfer due to direct contacts of drops with the wall, the chaotic motion of drops, and nonisotropic turbulent fluctuations of their velocities on the heat- and mass transfer processes in the turbulent flow are studied. In definition of the velocity components of a dispersed phase and r.m.s. velocity pulsations of drops the Derevich model (2002) was used. For calculation of a turbulent gas flow, the LRN k-e Nagano-Tagawa (1990) model was used. The turbulent model is modified for the presence of the dispersed phase and its evaporation in the stream. The addition of water drops to a turbulent gas stream causes a considerable heat transfer augmentation (3-5 times) and reduction of kinetic energy of gas turbulence value (to 20%).

1-65 V. I. TEREKHOV, V. V. TEREKHOV, V. V. GRISHCHENKO

EFFECT OF THE GEOMETRY OF A VERTICAL INTERLAYER ON FREE-CONVECTIVE HEAT TRANSFER IN THE MODE OF A MULTICELLULAR FLOW

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Numerical model of heat transfer in an intraglass space was developed via solution of 2D Navier-Stokes equations. It is shown that in real glass packs the mode of multicellular convection in typical. Comparison of results obtained with experimental averaged data on temperatures and heat fluxes demonstrates good agreement.

1-74 N. M. TSIRELMAN, I. S. ELISEEV

HEAT TRANSFER IN A CHANNEL WITH A PERIODICALLY VARYING HEAT CARRIER FLOW RATE

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Using an operational method, the problem of the temperature field structure has been solved for a periodically varying heat carrier flow rate in the channel. An analysis of the influence of different kinds of effect on this field has been carried out.

1-15 A. N. VISLOVICH, A. C. DMITRICHENKO

HYDRODYNAMICS AND HEAT TRANSFER IN SLOT SEALS WITH MAGNETIC GATES

Belarusian State Technological University, Minsk, Belarus, *physics@bstu.unibel.by*

The results of theoretical and experimental investigations of thermohydrodynamic processes in combined slot and magnetic fluid seals are presented. In these devices the magnetic fluid circulates in a closed loop, the essential element of which is the ring slot between the rotating shaft and the casing. At the inlet and exit of a hydrodynamic slot, concentrators of a magnetic stream, shaping ring magnetic clearances, are established. The equations of mechanical and thermal equilibrium are considered which determine the limits of serviceability of the device. The condensed pressure drop is basically determined by the forces of internal friction in a hydrodynamic slot. The magnetic slots ensure stability of the fluid mass in the system. The admissible speeds of rotation are determined by the balance of dissipative developments of heat in the slots and convective heat removal with fluid circulation in the head loop.

1-13 V. Ya. VASILIEV

THE RESULTS OF EXPERIMENTAL INVESTIGATION INTO EFFICIENT INTENSIFICATION OF CONVECTIVE HEAT TRANSFER IN RECTANGULAR CHANNELS WITH PROJECTION AND GROOVES WITH A SMOOTHLY ROUNDED TWO-DIMENSIONAL CROSS SECTION

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Experimental investigation of heat-transfer enhancement in short rectangular air channels with transverse projection and grooves of 15 gilled-tube water-air radiators (heat exchangers) has been carried out (the channel characteristics are: 1’/d = 0,183... 1,695, and d*/d = 0,813... 0,953). The process of efficient heat-transfer enhancement is implemented in the channels, which is controlled by the l’/d and d*/d characteristics. It has been proved that the results of heat-transfer enhancement in short channels are somehow worser than for long channels. This all makes it possible to reduce the mass and volume of the radiator core (matrix) by a factor of 1.4 in comparison with short plain channels under the same conditions.

1-14 Ch. M. VERDIEV, D. Ch. VERDIEV

DEVELOPMENT OF AN IMPROVED REGIME OF HEAT TRANSFER OF A HYDROCARBON FLUID UNDER SUPERCRITICAL PRESSURE IN AN EXTERNAL ACOUSTIC FIELD OF A STANDING WAVE FORMED BY TERMOACOUSTIC PRESSURE AUTOOSCULATIONS

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Data on experimental investigation and calculation of the local coefficient of heat transfer of toluene in mixed convection and at a supercritical pressure flowing in small-diameter vertical tubes (d = 3-4 mm) and with a constant heat flux on the wall (descending flow) for tliq < tm < t_c and tfiq/t_m 0,06-0,08, tc/tm = 0,03-1,5 are presented. Experiments were carried out in the field of convective heat transfer accompanied by generation of high-frequency pressure fluctuations of a heat carrier. It has been established that high-frequency pressure fluctuations are standing pressure waves. It is shown that the distribution of the wall temperature and of the heat transfer coefficient over the tube length depend on the local distribution of pressure in a standing wave. The boundary of the beginning of thermoacoustic oscillations has been found.

1-17 E. P. VOLCHKOV

CONCERNING CERTAIN CHARACTERISTIC FEATIRES OF HEAT AND MASS TRANSFER ON PERMEABLE SURFACES

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It is shown that in the boundary layer on a porous surface at the given temperatures of the main stream and injected gas the heat flux on the wall q_w depends nonmonotonically on the injection intensity. Its magnitude first increases with injection j_w, then, having attained a maximum, decreases and tends to zero when j_w —> jcr. The problems of similarity of heat and mass transfer in boundary layers of variable composition are considered. The influence of the Lewis number on the similarity conditions is shown. Generally, not only the Lewis number, but also an enthalpy drop influence the similarity relation. The usually adopted similarity form $StxLe^n$ = StD "works" only in certain particular cases. Some results on the influence of flow accelerations and turbulence degree T_u on the characteristics of the boundary layer with combustion are given.

1-16 E. P. VOLCHKOV, V. P. LEBEDEV, V. V. LUKASHOV

EXPERIMENTAL INVESTIGATION OF A DIFFUSION THERMOEFFECT IN A BOUNDARY LAYER DURING HELIUM INJECTION INTO AIR

S. S. Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia, *volchkov@itp.nsc.ru*

It has been established experimentally that in helium injection through a permeable wall into an air flow of the same temperature the heating of the wall up to about 8° is observed. On the other hand, in the outer part of the boundary layer the flow is cooled. Such a structure of the thermal boundary layer is due to the redistribution of heat in the boundary layer due to the diffusion thermoeffect (Dufor effect). The magnitude of the thermal effect on the wall is preserved in transition from a laminar to a turbulent mode of flow.

1-30 A. V. ZAITSEV, B. P. ZHILKIN

INTENSIFICATION OF HEAT TRANSFER IN SYSTEMS OF GAS IMPACT JETS

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It is shown that application of irregular nozzle systems with a nonsymmetrical shape of the cross section makes it possible to substantially increase the efficiency of heat transfer in gas impact jets. Dependences of average heat transfer coefficient, energy efficiency, and quality of heat transfer on the geometric and operational parameters of jet systems are considered. The data obtained allow one to more purposefully select jet systems for various technological processes.

1-31 V. F. ZAKREVSKII[1], J. J. ZIUGZDA[2]

APPLICATION OF LAGRANGE FUNCTIONS WITH COMPLEX VARIABLES TO CALCULATIONS OF CONVECTIVE HEAT TRANSFER IN SINGLE-PHASE FLOW PAST SURFACES

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Methodology of heat transfer calculation and evaluation of the efficiency of convective heat transfer has been developed. The calculations carried out are based on measurements of a pressure drop in the elements of heat exchangers, usage of dependences existing between complexes of dimensionless numbers and running standard programs for processing the results of measurements. It is established that the dependences Ref = f(EuRef2) within the determined limits of deviations are suitable for determining the Ref numbers of various surfaces: channels, tube bundles, tubes with intensifies, and others. The generalized equations are K_Q = f(KN), where K_Q = cReP, K_N = EuRef, in which Ref = f(EuRef) is determined from hydraulic resistance; it substantially simplifies calculations of heat exchange and efficiency of heat exchange surfaces.

1-32 V. I. ZINCHENKO, V. D. GOLDIN, K. N. EFIMOV, V. A. OVCHINNIKOV, A. S. YAKIMOV

AERODYNAMICS AND CONJUGATED HEAT AND MASS TRANSFER IN THREE-DIMENSIONAL FLOW AROUND BODIES WITH THERMAL CHEMICAL DESTRUCTION OF HEAT SHIELD MATERIAL

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The influence of injection of the products of thermal destruction on the aerodynamic characteristics is investigated. The solution of the problem in conjugate statement has allowed us to take into account the influence of the nonisothermicity of the walls on the heat - and mass transfer characteristics in the boundary layer. The efficiency of the use of heat - conducting material for decreasing maximum temperatures of the heat shield shell is shown. The question concerning the accuracy of separate statement in the case of the prescribed coefficient of fixed convective heat transfer at initial time is considered.

1-33 V. G. ZUBKOV

HEAT AND MASS TRANSFER UNDER THE CONDITIONS OF LAMINARIZATION OF TURBULENT FLOWS

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A mathematical model of a boundary layer valid for a wide range of turbulent Reynolds numbers has been developed. The results of numerical and experimental study of heat and mass transfer under the conditions of laminarization of turbulent flows due to flow acceleration are presented.

1-34 V. G. ZUBKOV, I. A. VINOGRADOVA

MATHEMATICAL MODELING OF HEAT AND MASS TRANSFER IN CURVED DUCTS OF COMPLEX GEOMETRY IN THERMAL POWER-ENGINEERING PLANTS

"INFO-Rutenia" International Institute, Moscow, Russia, *institute-info@mtu-net.ru*

The paper presents a mathematical model of gas and liquid flow in two-dimensional ducts. The model is based on a numerical control-volume method. The model has been applied to prediction of gasdynamic processes in the ducts of thermal power-engineering plants. In all the cases considered, the predicted gasdynamic parameters of flows are in close agreement with the measured behavior.

1-35 B. I. ZYSKIN, S. S. SKACHKOVA, K. V. ZAITSEV, B. V. BERG, T. F. BOGATOVA, B. P. ZHILKIN

THERMAL INTERACTION OF STRAIGHT AND SWIRLED GAS JETS WITH A CROSS FLOW

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The thermal structure of straight-flow and swirled gas jets developing in a stalling flow has been revealed experimentally. The data obtained are generalized in the form of equations for nondimensional parameters using the Cassini modified oval. The results of this research can be applied to calculation of power plants whose working process is based on the injection of jets into a cross flow.

Section 2

"RADIATIVE AND COMBINED HEAT TRANSFER"

2-20 I. F. ASTAKHOVA[1], I. S. MOLOHADSKII[2]

MATHEMATICAL MODEL OF CALCULATING THE HEATING OF

PROTECTED STRUCTURES

Voronezh State University, Voronezh, Rossia; All-Russia Institute for Anti-fri Protection, Balashikha, Russia

A mathematical model for calculating the heating of a protected structure has been developed.

2-21 A. I. BRIL

INFLUENCE OF TURBULENCE ON RADIATION HEAT TRANSFER IN HYDROGEN DIFFUSION FLAMES

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The contribution of temperature concentration turbulent fluctuations into heat radiation of a hydrogen diffusion flame was estimated. Numerical investigations were carried out using the data archives obtained by laser sounding of flames. Averaging of coefficients in radiation transfer equations was performed directly over samples of instantaneous temperature concentration values. This approach allowed us to exclude possible errors due to application of model probability density functions. It is shown that turbulence radiation interaction has to be treated as an important contributor to a resulting radiation flux from a flame.

2-01 A. P. BUDARIN, P. I. BUDARIN, K. B. PANFILOVICH

RADIATIVE SPECTRAL CHARACTERISTICS OF N-BUTANE AND N-HEXANE AT PRESSURES UP TO 10 MPa

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Transmission spectra of n-butane and n-hexane both in a gas and liquid phases in the temperature range from 295 to 460 K and in the pressure range from 10 MPa to 0.1 MPa with wavelength numbers from 4000 to 400 cm^{-1} are presented. Part of measurements for n-butane is carried out in a supercritical region. A mass spectral absorption factor is calculated. Analysis of the results of measurements is carried out.

2-47 I. V. CHERMYANINOV, V. G. CHERNYAK, E. P. KHINKINA

HEAT AND MASS TRANSFER OF A RAREFIED GAS IN A CHANNEL IN THE LASER RADIATION FIELD

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The processes of heat and mass transfer of a rarefied gas in a flat channel due to resonance optical radiation are considered at arbitrary Knudsen numbers (Kn). The problem is solved using linearized kinetic equations for a two-level model of particles in the approximation of a weak field. It is shown that under the conditions close to a free-molecular regime (Kn>>1) light-induced drift (LID) and heat transfer (LIH) are determined by the quantities that characterize interaction of particles with a surface and radiation. When Kn<<1, the magnitudes of LID and LIH are also determined by the difference in the collision cross-sections of excited and nonexcited particles.

2-29 V. P. DANILEVSKII, D. A. KOSTYUK, Yu. A. KUZAVKO

COMPOSITE ALUMINUM-BASED COATINGS APPLIED BY A METHOD OF SPARKING PLASMA OXIDATION

Brest State Technical University, Brest, Belarus

Production of composite ceramic corundum coatings on A199.99 and aluminum alloys by a method of sparking plasma oxidation in a solution of a weak-alkaline electrolyte PH < 9 was investigated. The time dynamics of anode-cathode voltage oscillograms and normal reflection of high-frequency longitudinal acoustic pulse signals from the surface of a sample being coated were investigated by means of a digital measuring device. With the use of a 12-bit ADC the measurement accuracy of the thickness of coating was 2 (im. Recommendations for applying information technologies for continuous diagnostics of the physicoengineering properties of coatings and power-saving optimizations of the technological process are suggested.

2-22 A. V. GERASIMOV, A. P. KIRPICHNIKOV

HEAT TRANSFER IN A HIGH-FREQUENCY INDUCTION PLASMA GENERATOR AT DIFFERENT FLOW RATES OF A PLASMA-FORMING GAS

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The influence of a change in the flow rate of a plasma-forming gas on the thermal characteristics of plasma in a high-frequency induction (HFI) plasma generator is considered. Analysis of the conductivity, current density, specific power of heat release, and temperature for different flow rates of a plasma-forming gas is performed. It is shown that in the HFI discharge there is the so-called von Engel-Steenbeck paradox that is the more intensely the discharge is cooled by a flow, the hotter and thinner it becomes. It is also shown that to estimate the density of the heat flux through a conditional boundary of a current-conducting region it is possible, though with some limitations, to employ the estimate used for an arc discharge.

M. L. GERMAN[1], V. G. KAROLINSKII[2], A. N. LAKTYUSHIN[1]

ENGINEERING MODEL FOR CALCULATING THE THERMAL MODE OF A REACTOR FOR FORMING GLASS AND CERAMIC MICROBALLS AND HOLLOW MICROSPHERES

A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus; [2]Brest State Technical University, Brest, Belarus

A simplified mathematical model for calculating the thermal mode and design parameters of a reactor for manufacturing solid microballs and hollow microspheres from glass or ceramic powder is considered. The results of calculation are compared with the experimental data obtained on experimental reactors which use a plasma stream and a burning gas torch as a heat carrier.

M. L. GERMAN, M. S. ZHELUDKEVICH, A. N. LAKTYUSHIN, A. N. OZNOBISHIN, N. V. YAKUTOVICH

APPLICATION OF A JET PLASMA GENERATOR FOR CONTROLLED HARDENING OF METAL

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Belarus, Minsk, Belarus, *zms@hmti.ac.by*

The technology of controlled quenching of steel pieces with the aid of plasma and water-air jets is considered. A mathematical model for calculating technological cards used for managing a plasma generator and water-air sprayers during their motion along a treated piece is described. The basic laws governing the process of controlled heat treatment and also the advantages of the proposed technology are analyzed.

2-23 A. M. GRISHIN, A. I. FILKOV

GEOINFORMATION SYSTEM FOR PREDICTING FOREST FIRE DANGER

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A simple enough, and physically justified, and practically important determinate-probabilistic expert system for predicting forest fire danger is suggested. A program complex for predicting forest fire danger (PFFD) for one typical quarter of forest timber enterprise in the Tomsk region has been developed. The program complex PFFD is based on the computer program realized in the Fortran language. It calculates the values of current moisture content and the level of probability of forest fire for specific woodlands.

2-28 A. M. GRISHIN

MAIN RESULTS OF THE DEVELOPMENT OF THE THEORY OF NATIVE FIRES AND PROTECTION OF FORESTS IN THE 21st CENTURY

Tomsk State University, Tomsk, Russia, *fire@fire.tsu.tomsk.su*

A brief review of the main results obtained in the world on physical and mathematical modeling native fires is given. A program of fundamental and applied investigations for forest protection in the 21st century is suggested.

2-24 A. M. GRISHIN, D. M. BURASOV

INFLUENCE OF RADIATION FROM THE FLAME FLARE ON DISTRIBUTION OF RANGE FIRES

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A simple mathematical model which allows one to describe the formation and propagation of the range fire front is suggested. The model takes into account the basic physicochemical processes (heating, drying, pyrolysis of fuel, and combustion of gaseous and condensed products of pyrolysis), convection, and radiation, and a simplified analytical solution for determining the velocity of propagation of range fires is suggested. The analysis of the results obtained has shown that the proposed analytical formula reacts in an adequate fashion to modification of input data.

2-27 A. M. GRISHIN, O. V. MATVIENKO

MATHEMATICAL MODELING OF FIRE TORNADOES

Tomsk State University, Tomsk, Russia, *fire@fire.tsu.tomsk.su*

The results of mathematical modeling of fire tornadoes are considered. It was established that formation of a fire tornado can be explained by initiation of a tangential component of a thermal wind connected with a radial temperature gradient.

2-25 A. M. GRISHIN, R. Sh. TSVEK

EXPERIMENTAL AND THEORETICAL INVESTIGATION OF RADIATION AND EFFECT OF COMBINED HEAT TRANSFER ON INITIATION AND SPREAD OF SURFACE FOREST FIRES

Tomsk State University, Tomsk, Russia, *fire@fire.tsu.tomsk.su*

Mathematical models of forest fires have been developed, for the refining of which experimental data on emission coefficients and concentrations of the gas releasing as a result of forest fuel combustion, the turbulence regime responsible for heat release of aerosols and gases into the atmosphere and others are necessary. The results of experimental investigation of the surface forest fires carried out lately are summarized. The results of investigations of a turbulence regime in a convective column, concentrations of some gases releasing during forest fuel combustion in the area of pyrolysis and flame are analyzed.

2-26 A. M. GRISHIN, A. N. GOLOVANOV, Ya. V. SUKOV

PHYSICAL MODELING OF FIRE TORNADOES

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Fire tornadoes were produced by three independent methods under laboratory conditions. Similarity numbers of the problem being solved, the Grashof and Prandtl numbers and the Froude rotational number have been determined. It is shown that formation of a fire tornado does not depend on the source of ignition but is determined by the magnitude of the heat flux density.

2-46 V. N. KHARCHENKO, V. N. ZVEREV

HEAT AND MASS TRANSFER IN THE MODEL OF A VORTICAL PLASMACHEMICAL REACTOR

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Characteristic features of interdependent processes of heat and mass transfer and magnetic gas dynamics in an experimental model of a vortical plasmachemical reactor - a centrifuge with high-power 1-10-MW pulsed gas discharges in crossed electric and magnetic fields are established. Dependences for thermophysical parameters are calculated. They agree with experimental data.

2-34 V. L. KOLPASHCHIKOV, M. G. SYSKOVA

THERMAL ANALYSIS OF FIRE PROTECTION COATINGS

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The results of application of thermal analysis methods to determination of heat- and fire protection characteristics of intumescent fire protection coatings PYRO-SAFE flammoplast KS-1, UNITERM K3 8104 and OGRAX-B1 are presented.

2-33 O. B. KOVALEV, A. V. ZAITSEV

COMPUTATIONAL MODELING OF CONJUGATE HEAT- AND MASS TRANSFER PROBLEMS IN THE PROCESSES OF GAS-LASER CUTTING OF MATERIALS

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The results of numerical simulation of interaction of laser radiation with metals as applied to the processes of gas-laser cutting are presented. It is suggested that interrelated processes should be described physically and mathematically as combined statements of conjugate problems of continuum mechanics. A physicomathematical model of multiple reflection of radiation is suggested. It allows one to describe the mechanism of energy transfer into the channel. Analysis of the influence of radiation polarization on the absorption coefficient and the shape of the kerf surface is carried out. It is shown that the use of elliptical polarization of a beam with a certain ratio of semiaxes oriented in the direction of motion is most efficient.

2-35 L. I. KRASOVSKAYA[1], M. A. BRICH[2]

THEORETICAL INVESTIGATION OF THE GAS DYNAMICS AND HEAT TRANSFER IN PLASMA REACTORS WITH THREE-JET MIXING CHAMBERS OF VARIOUS KINEMATIC SCHEMES

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Based on a three-dimensional model of mixing plasma jets, numerical investigation of the gasdynamical and thermal structure of plasma fluxes in cylindrical reactors with three-jet mixing chambers of various kinematic schemes has been carried out. It has been established that in cylindrical mixing chambers with the base diameter of 5-10 cm and diameters of the anode nozzles of plasmatrons of 1-2 cm it is possible to ensure the formation of rather uniform temperature and velocity fields in the channels of plasma reactors. The gasdynamical characteristic features of mixing of plasma jets in conical chambers with the apex angles 120°, 90°, and 60° and the diameter of the base 10 cm have been revealed. The influence of the axial injection of a cold air, intended for transportation of disperse raw material on the structure of plasma fluxes is considered.

2-06 V. A. KUZNETSOV

IMPROVEMENT OF THE DIFFERENTIAL METHODS FOR SIMULATING

RADIATIVE ENERGY TRANSFER

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Since application of differential relations to radiation fluxes in a restricted volume of industrial furnaces and fire-chambers leads to unpredictable errors, it is suggested that a mathematical model of radiation heat transfer could employ differential approximations for an infinite absorbing medium, with the most important integral regularities of radiation on transfer being taken into account additionally. Some means for increasing the accuracy of differential dependences and boundary conditions are considered with allowance for the radiation anisotropicity. Results of mathematical simulation of heat transfer in the fire-chamber of a steam boiler are given.

T. V. LAKTYUSHINA[2], O. V. ZHILINSKII[1], A. N. LAKTYUSHIN[2], M. L.GERMAN[2]

COMPUTER DESIGN OF PLASMA TECHNOLOGY OF PRODUCING HOLLOW CERAMIC MICROSPHERES

Institute of Longevity and Reliability of Machines, National Academy of Sciences of Belarus, Minsk, Belarus; [2]A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus, *gml@hmti.ac.by*

To solve the practical problems of optimization of the plasma technology of production of hollow ceramic microspheres (HCM), a computer method of multidimensional design synthesis of technical objects, technologies, and materials and its multipurpose program provision was used. The method is based on the theory of sets, probability theory, theory of choice and decision, and on other disciplines ensuring the solution of design problems. The problem of optimum synthesis of the plasma technology of producing HCM has been formulated as follows: to determine the ranges of construction and operation parameters of a plasmachemical reactor within which the requirement for the indices of the process that determine the dynamics of heating particles along the length of the reactor and for the efficiency of the reactor is fulfilled.

2-36 I. I. LATYPOV

NUMERICAL-ANALYTICAL STUDY OF N ON ST ATION ARY THERMAL PROCESSES IN THE ACTIVE ELEMENTS OF SOLID-STATE LASERS

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The problem of temperature distribution in the active element of a solid-state laser in a regime of protective heating with allowance for the radiative component of heat transfer is formulated and solved. The initial boundary-value problem is reduced to solution of a singularly perturbed boundary-value problem of a heat-conduction equation with nonlinear boundary conditions. Using a "geometric-optical" method, an approximate solution of this problem is obtained in the form of the Poincare-type asymptotic expansion of solution in powers of small parameters depending on the proximity of the point considered to the boundaries. The approximate solution obtained makes it possible to perform parametric analysis of the solution, reveal the contributions of a heat source and of the radiative component of heat transfer.

2-07 D. P. LEBEDEV, A. A. PENKIN

LOCAL GAS INFRARED HEATING

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The question of using gas infrared heating in the practice of agricultural production and other thermal technological processes is considered. The existing designs of foreign "light" gas infrared burners are analyzed and their essential drawbacks are noted. Methods to eliminate these drawbacks and possibilities of increasing the efficiency of a "light" gas infrared burner with a conic source of radiation made from heat-resistant stainless steel from 26-30% to 42% are considered. The power and spectral characteristics of gas infrared burners with a conic source of radiation are presented. Overlapping of the spectra of absorption of pigs and radiation of gas infrared burners with a conic source of radiation is shown which allows one to optimize the process of heating. Comparison of the spectral characteristics of a gas infrared burner with the characteristic of the skin of a human being is carried out. The results obtained allow one to provide optimum technologies of local infrared heating with the aid of gas infrared burners.

2-17 S. A. LEVCHENKO, S. V. PLYUTA, A. P. YAKUSHEV

COMPUTERIZED MODEL OF HEAT AND MASS TRANSFER PROCESSES IN BUILDINGS

A. V. Luikov Heat and Mass Transfer Institute; Joint Institute of Energy and Nuclear Research - Sosny, National Academy of Sciences of Belarus, Minsk, Belarus

The concept of physical and mathematical modeling of heat and mass transfer processes in buildings is presented. The concept is based on representation of building as a set of constructive 3D-elements with averaged physical parameters and corresponding color visualization. During calculation it was assumed that for final consumption of energy, the users do not need electric power or heat as such, but need lighting or certain comfort living conditions. In other words, the user needs certain energy services, connected with the consumption of energy. Computer submodels for simulating heat and mass transfer processes in each constructive element have been developed as well as modeling of the relationships between elements.

2-37 V. A. LOSHKAREV[1], E. V. LOSHKAREV[2], A. L. BUGA[1], S. A. MAYATSKII[1]

OPTIMIZATION PROBLEM OF MONITORING RADIATIVE-CONVECTIVE HEAT TRANSFER OF INTERIOR BALLISTICS

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The problems concerning temperature-thermal optimization of calculation of the basic parameters of the combustion chamber interior ballistics of an aviation engine are discussed. A thermal criterion of the optimum condition is suggested which makes it possible to take into account the evolution of the combustion chamber geometry which gives a fast and exact procedure based solely on thermophysical considerations.

2-38 V. A. LOSHKAREV, V. P. PASHINTSEV, A. V. KIKHTENKO, M. V. GAMOV, V. V. LOSHKAREV

DIAGNOSTICS OF A LOW-TEMPERATURE PLASMA (IONOSPHERE) BY THE METHODS OF RADIOSONDE OBSERVATION

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A method to estimate the geometric parameters of the local inhomogeneities of the ionosphere has been developed which is based on joint use of the results of pulsed radiosonde observation and solution of inverse problems at the point of reception of signals from sattelite radionavigation systems. The possibility of identification of physicochemical processes in these local zones is shown.

2-11 Yu. I. MACHUEV, A. M. VOROB'EV, N. A. TROFIMOV, A. V. PANTELEEV

HEAT TRANSFER WITH STEPWISE HEAT GENERATION IN CYLINDRICAL UNITS

Joint Stock Company "Special Mechanical Engineering Design Office", St. Petersburg, Russia, *kbsm@mail.admiral.ru*

Experimental study of heat transfer of cylinder units located in a great volume is carried out. The lower unit has heat generation equipment. It is shown that within the considered range of heat generation and temperature, the temperature mode of the upper unheated cylinder is determined by the convective component of the heat flux, which is approximately equal to half the amount of heat generated by the lower unit. Quantitative characteristics of the process have been obtained.

2-12 Yu. I. MACHUEV, A. M. VOROB'EV, A. F. UTKIN, V. G. DOLBENKOV

HEAT EXCHANGE IN A CYLINDER AIR LAYER UNDER STEP HEAT GENERATION OF THE INTERNAL CYLINDER

Joint Stock Company "Special Mechanical Engineering Design Office", St. Petersburg, Russia, *kbsm@mail.admiral.ru*

Experimental study of heat transfer in a cylindrical vertical air cavity with heat generation from the lower section of the inner cylinder is carried out. The temperature regime on complete evacuation of the system, its depressurization on lifting or removal of the upper cover, and after its straight-through natural ventilation has been considered. The quantitative characteristics of the process have been obtained.

2-10 A. N. MAKAROV

MATHEMATICAL SIMULATION OF A TORCH AND RADIATIVE HEAT TRANSFER IN FURNACES AND FIRECHAMBERS

Tver State Technical University, Tver, Russia, *tgtu_kafedra_ese@mail.ru*

It is suggested to model a torch of heating and melting furnaces, fire-chambers of water-heating and steam boilers by a set of radiating cylinders, linear sources of radiation. The procedure of calculation of heat transfer in torch furnaces and fire-chambers of boilers is presented. Heat

transfer in a recuperative soaking pit is calculated, an analysis of distribution of the densities of integrated fluxes on the horizontal and vertical surfaces of ingots has shown their significant nonuniformity. The results of calculation of the distribution of the densities of integrated fluxes of radiation over the perimeter and height of the screen surfaces of the fire-chamber of a steam boiler are given. The results of calculation correspond well to the results of measurements of temperatures and heat fluxes in furnaces and fire-chambers, which confirms the adequacy of the developed mathematical model and of the real processes occurring in furnaces and fire-chambers.

2-09 A. N. MAKAROV, A. Yu. DUNAEV

CALCULATION OF EXTERNAL HEAT TRANSFER IN HEATING FURNACES IN MODELING A TORCH BY RADIATING CYLINDERS

Tver State Technical University, Tver, Russia, *tgtu_kafedra_ese@mail.ru*

Based on the property of invariance of radiation of coaxial cylinders, a physicomathematical models of a torch as a radiating cylinder has been developed. Representation of the torch of steam boilers and furnaces as cylindrical volumetric zones radiating as a black body in the range of the gas radiation wavelengths, with power distribution in the volumetric zones according to the position of isotherms over the torch volume makes it possible to calculate the distribution of integrated radiation fluxes incident on heating surfaces and to obtain a result that adequately represents the real distribution of integrated radiations in the furnaces and fire-chambers.

2-08 A. N. MAKAROV, V. V. VOROPAEV, E. I. KRIVNEV

MODELING OF RADIATIVE HEAT TRANSFER IN THE FURNACES OF POWER STEAM BOILERS

Tver State Technical University, Tver, Russia, *Krivnev@mail.ru*

On the basis of modeling a flame of fire technical installations by radiating cylinders, radiative heat transfer in the furnace of a TGMP-314 300 MW steam boiler has been calculated. Comparison of the results of calculations and measurements of a heat flux on a heating surface has shown their good agreement. It is suggested to use the proposed model as a foundation for creating a system of a computer-assisted control of the power of torches on operative changes in steam boiler loads.

2-39 N. I. NIKITENKO

THE LAW OF THE INTENSITY OF SPECTRAL RADIATION OF PARTICLES AND THE PROBLEMS OF HEAT AND MASS TRANSFER CONNECTED WITH IT

Institute of Engineering Thermophysics, National Academy of Sciences of Ukraine, Kiev, Ukraine, *powder@kievweb.com.ua*

The law of the intensity of spectral radiation of particles is stated and substantiated. It is shown that application of this law allows one to obtain: the Planck blackbody distribution law; the Maxwell-Boltzmann law of distribution, and some new functions of energy distribution of particles; integrodifferential equation of energy transfer which in the limit passes into the Fourier

equation of thermal conductivity; expressions for the thermal capacity of a body which in the limit passes into the Debye formula; the coefficient of the diffusion, which in a limiting case passes into the Arrhenius formula for solids and into the Einstein formula for liquids; the intensity of evaporation of condensed bodies and saturated vapor pressure which agree well with experimental data.

2-13 K. B. PANFILOVICH, I. L. GOLUBEVA, V. V. SAGADEEV

THERMAL RADIATION OF LIQUID ALLOYS OF METALS

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Using an absolute radiative method, we have measured normative integral emissivities of the liquid alloys bismuth-indium, bismuth-lead, and bismuth-tin at different temperatures and concentrations of the metals. The measurement error ranged from +5% to ±8%. The data have been obtained for the first time. A single generalized dependence is obtained for calculating semispherical integral fluxes of thermal radiation from liquid binary alloys of metals.

2-18 L. PETKEVICIENE, P. VAITIEKUNAS, V. KATINAS

SIMULATION OF COMBINED RADIATIVE-CONDUCTIVE HEAT TRANSFER ON THE SURFACE OF A COOLING POND

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The state of a two-phase flow "liquid-gas" has been modeled numerically by the three-dimensional method of complex research of heat and mass transfer. This allows examining the interaction of various transfer processes in a cooling pond (lake Druksiai), such as heat conduction, direct and diffusive solar radiation, radiative atmosphere-water and water-atmosphere exchange. Numerical solution is performed using a finite volumes method.

2-40 V. N. PISKUNOV, M. A. ZATEVAKHIN

NUMERICAL SIMULATION OF THE DYNAMICS OF FORMATION OF AEROSOL PARTICLES IN LARGE FIRES

Institute for High-Performance Computations and Databases; Russian Federal Nuclear Center - VNIIEF, St. Petersburg, Russia, *misha@fm.csa.ru*

The problems of fonnation of the spectra of aerosol particles in a convective column above a large fire are considered. Numerical solution of the equations that describe turbulent flow of a multicomponent multiphase medium in a stratified atmosphere is used for dynamic simulation. Evolution of the spectra of soot particles is described using solution of kinetic equations of condensation coagulation. The results of numerical simulation of process development in a moist atmosphere with account for water vapor condensation are presented.

2-14 V. P. PROSUNTSOV

PARAMETRIC IDENTIFICATION OF THE THERMOPHYSICAL PROPERTIES OF HIGHLY POROUS SEMITRANSPARENT MATERIALS BASED ON SOLUTION OF A TWO-DIMENSIONAL RADIATIVE-CONDUCTIVE INVERSE PROBLEM

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Mathematical formulation of a two-dimensional inverse coefficient problem of radiative-conductive heat transfer for parametric identification of the thermophysical properties of partially transparent materials is presented. An algorithm for solving the inverse problem is given. The accuracy with which the inverse problem is solved and its stability against random errors in initial data are investigated. The problem of optimal planning of temperature measurements for the case of two-dimensional processes of radiative-conductive heat transfer has been stated and the influence of the parameters of experimental scheme on the results of planning has been investigated. Some plans of measurements for a number of experimental conditions are given.

2-41 S. V. PUZACH, V. G. PUZACH

MATHEMATICAL SIMULATION OF HEAT AND MASS TRANSFER DURING FIRE IN A ROOM OF COMPLEX GEOMETRY

Academy of State Anti-Fire Service, Moscow, Russia; Institute of High Temperatures, Moscow, Russia, *puzachsv@hotmail.com*

A mathematical model of simulation of heat and mass transfer during fire in a room of complex geometry is suggested. Comparison with experimental data is carried out. The results of calculation of three-dimensional fields of temperature inside the room and its enclosing structures, velocity and length of visibility in the cases of model fires in rooms of complex geometry such as atria, passages, and stories of three-floor buildings and the space under the escalator of a metro station are presented. It is shown that the proposed method allows one to reveal new special features of heat and mass transfer that substantially alter modem notions of the dynamics of dangerous fire factors in the rooms considered.

2-42 S. V. PUZACH, V. G. PUZACH, V. M. KAZENNOV

SOME REGULARITIES OF HEAT AND MASS TRANSFER THROUGH AN OPENING DURING FIRE IN A ROOM

Academy of State Anti-Fire Service, Moscow, Russia; Institute of High Temperatures, Moscow, Russia, *puzachsv@hotmail.com*

An integral method for calculating the parameters of natural heat and mass exchange of a room in fire with the surrounding medium through an opening is suggested. It takes into account nonuniform distribution of temperatures over the height. Formulas were derived analytically for determining pressure distributions over the height, gas mass flow rates through the opening, the height of the neutral plane, mean volumetric temperature of the gases leaving the room, and the value of the critical duration of the fire. Theoretical investigation of the influence of the temperature field nonuniformity on the heat and mass transfer parameters and critical duration of the fire is made. The results obtained are compared with those given by a three-dimensional model of fire. Formulas are derived analytically for determining the vertical contribution of pressure, mass rates of gases through the opening, height of neutral plate, mean volume temperature of gases going out of the room, and the value of critical duration of fire. Theoretical investigation of the influence of unevenness of temperature on parameters of heat and mass transfer is made. The

vertical contributions of pressure obtained using the proposed method and the three-dimensional mathematical model are compared.

2-19 P. C. RAM

FINITE ELEMENT ANALYSIS OF HYDROMAGNETIC CONVECTION FLOW IN A ROTATING FLUID WITH RADIATIVE HEAT TRANSFER

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The finite element analysis has been employed to solve the hydromagnetic free convective flow in a rotating fluid with radiative heat transfer. The temperature involved is assumed to be very high so that radiative heat transfer is significant. Expressions for the velocity and temperature fields have been obtained and solved numerically. The results are discussed in the terms of the Hall parameter, the ion slip parameter, and the radiation parameter. The study of such a problem has important engineering application in devices like power generators, MHD accelerators, and in astrophysical studies.

2-43 G. S. ROMANOV, A. S. SMETANNIKOV, Yu. A. STANKEVICH, L. K. STANCHITS, K. L. STEPANOV

COMPUTER MODELING OF PHYSICAL PROCESSES PROCEEDING IN LASER-PLASMA DEPOSITION OF DIAMOND-LIKE FILMS

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A physical and mathematical model of the formation of an erosive plume on exposure of a graphite target to nanosecond laser pulses is suggested. The nonstationary heat conduction equation with a volumetric or surface source of energy release is used to describe the dynamics of heating a solid target. The nonstationary gasdynamical equations are used to describe erosive plume outflow in the case of cylindrical symmetry. The thermal and gasdynamical problems are made consistent with the aid of boundary conditions at the phase interface. The influence of thermodynamic and optical characteristics of a graphite target on the dynamics of heating and evaporation is studied. Computational modeling of the dynamics of an erosive plume and its interaction with a substrate on exposure of the graphite target to nanosecond laser pulses in low-pressure media is carried out.

S. V. REZNIK, **D.** *Yu. KALININ, A. V. SHULYAKOVSKII*

MATHEMATICAL MODELS AND THERMAL ANALYSIS OF UNFOLDABLE SPACE ANTENNAS

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Survey of scientific investigations in the field of thermal analysis of unfoldable space antennas is presented. Main stages and means of such an analysis, including mathematical models of radiative-conductive heat transfer, implemented in the program package CAR/SPACE at the Bauman University are considered. The results of mathematical simulation of the temperature state of a number of promising constructions of antennas of complex shape and with a large number of repeatable thin elements (millimeter - fractions of a millimeter) made of composite

materials and intended for operation on a geostationary orbit are presented. The problems of maintaining of the given heat regime in the thin-wall elements in the shadowed zone of the geostationary orbit are discussed.

2-44 S. G. RUDENKO

NUMERICAL INVESTIGATION OF COMBINED HEAT TRANSFER OVER INITIAL SECTION OF HIGH-TEMPERATURE OUTPUT CHANNELS AND NOZZLES WITH VARIABLE AND HIGH-LEVEL INJECTION

Academician V. Glushko ENERGOMASH Scientific-Industrial Association, Khimki, Moscow Region, Russia, *energo@online.ru*

Injection as a possible means of cooling for removing superhigh heat loads is investigated. It is assumed that heat is transferred from a working body (hydrogen doped with lithium) simultaneous by convection and radiation. An implicit finite-difference method is used to solve the problem of heat transfer in a compressible boundary layer. The mixing length concept is used to determine turbulent characteristics. It was assumed that in heat transfer by radiation the absorption coefficients depend on temperature pressure, and wavelength. The results of numerical simulation for laminar and turbulent regimes have shown that a variable and strong injection substantially reduces convective, radiative, and total heat fluxes to the wall.

2-48 A. N. SHCHEGLOV[2], V. I. PRISADKOV[1], A. V. FEDOROV[2]

MATHEMATICAL SIMULATION OF HEAT AND MASS TRANSFER DURING FIRE IN BUILDINGS WITH ATRIA

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[2]"Alatex" Ltd., Reutov, Russia

A band mathematical model of the dynamics of dangerous factors of fire in buildings with atria has been developed. The results of calculations by the mathematical model are compared with experimental data.

2-15 S. S. SKACHKOVA, M. Yu. KONOVALOV, A. A. VINTOVKIN, I. A. ZYSKIN, B. P. ZHILKIN

INFLUENCE OF BURNING ORGANIZATION ON THE INTENSITY OF THERMAL INTERACTION OF A FLAME WITH THE ENVIRONMENT

Uralmash-Metallurgical Equipment Ltd, Ekaterinburg, Russia; Research Institute of Metallurgical Heat Engineering, Ekaterinburg, Russia; Turbomotor Plant, Ekaterinburg, Russia; Ural State Technical University, Ekaterinburg, Russia, *avdonina@uralmash.ru*; *ado@uralmash.ru*

Investigations of burners with different organization of burning were carried out at a large-scale stand under the conditions of development of a flame in an open stack. The technique of polyzonal computer decomposition of a videoimage is used to analyze the thermal structure of flames. The results of decomposition were verified with control measurements of a temperature field by a thermocouple. To estimate the level of thermal interaction, two methods were used: the well-known method of the coefficients of thermal interaction and the proposed method of reduced

gradients of temperature, allowing determination of the local intensity of heat transfer. Based on the data obtained, optimum design of burners and their arrangement in a sintering furnace have been selected.

2-16 A. V. STEPANOV, N. I. SULZHIK, V. N. NIKOLAENKO

INTENSIFICATION OF RADIATIVE HEAT TRANSFER AND DEVELOPMENT OF NEW TYPES OF TUBE FURNACES

Institute of Bioorganic Chemistry and Petrochemistry, National Academy of Sciences of Ukraine, Kiev, Ukraine; "Ukmeftekhimproekt" Open Joint-Stock Company, Kiev, Ukraine

The technology of high emissivity coating for ceramics and metal tubes was developed in order to create effective furnaces for petrochemistry. New constructions of furnaces with a high emissivity coating ensure high yield of products and low metal expenditures.

2-45 Kh. K. TAZMEEV, A. Kb. TAZMEEV

SOME CHARACTERISTIC FEATURES OF HEAT AND MASS EXCHANGE OF GAS DISCHARGE PLASMA WITH A LIQUID ELECTROLYTIC CATHODE

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An energy balance of a liquid cathode is investigated in the current range from 4 to 16 A at a relatively high current density (—0.9 A/cm“). The discharge ran diffusely at atmospheric pressure without a ballast resistance. A solution of sodium chloride in a distilled water served as an electrolyte. The electrolyte conductance at a room temperature was (0,9-2,1)10~^{3} (fl-cm)’^{1}. Heat and mass exchange between plasma and the liquid electrolyte cathode depends substantially on the electrolyte cooling conditions. It is established that when the liquid cathode cooling intensity was negligible, its heat loss was less than the Joule heat released inside the electrolyte.

2-02 F. VEISI, E. D. SERGIEVSKII

TRANSIENT MODES OF THE ELEMENTS OF A SOLAR HEATING SYSTEM

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At the present time, mathematical simulation of thermal processes in solar heating systems as a whole and separately in their components has been widely applied. We present a mathematical and computer models of a transient thermal mode of the elements of a solar heating system. The Simulink package was used for modeling. As an example, calculations were performed for a typical office room. Changes in the temperature inside the room on change in the temperature of the outer air were recorded. The dynamic model makes it possible to carry out preliminary calculations and estimations of the possible efficiency of the solar-heating system.

2-03 A. A. VELLER, I. P. VITYAZ, V. P. KABASHNIKOV, V. P. NEKRASOV THERMAL BEHAVIOR OF BUILDING SUBJECT TO RADIATION HEAT TRANSFER

Scientific Research and Technological Design Institute for Construction Industry (NIPTIS); Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus, *V_Necrasov@tut.by*

A physical-mathematical model for calculating nonstationary temperature distribution in a building has been developed. The model takes into account the type of outer walls, their orientation toward the cardinal points, climatic conditions, the availability of different engineering systems, and the air temperature in the neighboring rooms. Particular attention was given to the study of the room air temperature and temperature distribution in outer walls as a function of the building orientation toward the cardinal points.

2-04 P. A. VITYAZ', O. V. ZHILINSKII, T. V. L AKT YU SHIN A,

A. N. LAKTYUSHIN

NEW COMPUTER METHODOLOGY OF SYSTEM-OPTIMIZATION DESIGN OF TECHNICAL OBJECTS, TECHNOLOGIES, AND MATERIALS

Institute of Mechanics and Reliability of Machines, National Academy of Sciences of Belarus, Minsk, Belarus; A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus, *gml@hmti.ac.by*

The methodology contains a set of methods, computational technologies, and computer programs intended for solving inverse problems in designing technical objects, technologies, and materials. The statement of the inverse problem and its solution are implemented with allowance for the multidimensionality and stochastic nature of technical systems. An inverse problem is formulated as a problem of isolation, in a multidimensional space of the input parameters of a designed system, of a region of the most stable operation and determination, inside of it, of the parameters (coordinates) of the most noise proof variant. The solution of the problem of synthesis is separated from calculations by the mathematical model. This makes the methodology entirely independent and invariant relative to the kind and level of complexity of the equations of the model, thus making it universal.

2-05 A. M. VOROB'EV, Y. I. MACHUEV, V. G. DOLBENKOV

MODELING OF A TEMPERATURE MODE OF VERTICAL CYLINDER UNITS WITH STEPWISE GENERATION OF HEAT

Joint Stock Company "Special Mechanical Engineering Design Office", St. Petersburg, Russia, *kbsm@mail.admiral.ru*

Conditions for physical modeling of the process of forming the temperature mode of vertical cylinder units with stepwise heat generation over the height and account for heat transfer by natural convection, radiation, and heat conduction along the walls of the units have been formulated. A model stand has been manufactured on which large-scale closed- volume experiments have been conducted. Sample measurements on a standard facility have coincided with the experimental results on the model.

2-31 S. M. ZEN'KEVICH, L. K. STANCHITS, K. I. STEPANOV

EXTENDED METHOD OF PARTIAL CHARACTERISTICS FOR CALCULATIONS OF HEAT TRANSFER IN THE PROBLEMS OF RADIATIVE PLASMADYNAMICS

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A well-known method of calculation of heat transfer in hot gases and plasma - the method of partial characteristics (MPC) – which takes into account the selective character of a real radiation spectrum is generalized. Introduction in consideration of discontinuous splines in addition to continuous ones enables one to investigate more complex radiative-gasdynamical problems that include distribution of nonlinear waves of various physical natures. Databanks for partial intensities, fluxes, and their divergences for air, aluminum, and carbon plasmas are created. For this purpose, detailed information about the spectral absorption coefficients of these environments is used. Comparison of calculations of radiation heat transfer performed by these extended MPC with results of a more detailed spectral description is given.

2-30 V. G. ZVEREV, V. A. NAZARENKO, A. F. TSIMBALYUK

HEAT AND FIRE PROTECTION OF MULTILAYER CONSTRUCTIONS BY APPLYING INTUMESCENT COATINGS

Tomsk State University, Tomsk, Russia; FSUE Moscow Institute of Heat Engineering, Moscow, Russia, *zverev@niipmm.tsu.ru*

The results of experimental and theoretical investigations of the efficiency of application of the intumescent coating SGK-1 for fire protection of a multiplayer container with air annular gaps is described. The characteristic features of the fire test procedure in natural conditions are noted. A physical and mathematical model for describing heating of a multiplayer container with intumescent fire coating is suggested. The good agreement of the calculated and experimental data on unsteady heating of the container layers during fire test is obtained.

2-32 A. P. ZYKOV, S. E. YAKUSH

NUMERICAL MODELING OF COMPARTMENT FIRES

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A three-dimensional CFD code FIRE3D intended for modeling heat and mass transfer processes in enclosure fires has been developed. Verification of the FIRE3D code was carried out using the experimental data (Steckler et al., 1982) on fires in a square room with one doorway. In the calculations, the development of the buoyant plume above the fire source, its ascending and spreading beneath the ceiling resulting in formation of a hot layer exchanging heat and mass with the ambient atmosphere was obtained. Calculations were carried out for different heat release rates. The time dependencies of the inflow and outflow mass fluxes through the doorway were obtained together with the characteristics of thermal stratification (height of the boundary between cold and hot layers, average temperatures in each layer). The calculated results are shown to agree reasonably with the experimental data.

Section 3

"HEAT CONDUCTION AND PROBLEMS OF HEAT TRANSFER OPTIMIZATION"

O. M. ALIFANOV

INVERSE HEAT TRANSFER PROBLEMS: THEORY AND PRACTICE
Moscow Aviation Institute (State Technical University), Moscow, Russia

Analysis of the main results obtained in the theory and methodology of solving inverse heat transfer problems is performed in application to diagnostics and identification of heat-and mass transfer processes, and also design and experimental development of heat-loaded technical systems.

These results are concerned with:

7- study of inverse problem statements;
8- development of methods and algorithms for solving inverse hear conduction problems;
9- development of theory and methodology for ill-posed inverse problems regularization;
10- construction of regularizing gradient algorithms with reference to models with lumped and distributed parameters;
11- development of modem approaches to identification of heat-and mass transfer mathematical models;
12- solution of boundary inverse heat conduction problems in real time.

Different examples of practical use of the methods developed and experimental

installations, information-measuring systems and diagnostics means created on their basis are presented.

3-35 E. E. CHAIKOVSKAYA

COHERENCE OF HEAT AND MASS TRASFER AND INFORMATIONAL PROCESSES AS THE BASIS OF SYNERGETIC CONCEPT OF DIAGNOSTICS
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Synergetic concept of diagnostics of energy systems has been developed. Architecture of the expert system based on the synergetic principle is suggested. A logical model of a dynamic subsystem as a basis of the expert system is presented to control and identify the state of the energy system. Mathematical modeling of the dynamic subsystem as a basis of the expert system is substantiated. It is suggested to effect control on the basis of co-ordination of the interaction of substance, energy, and information using the synergetic principle of coherence of both heat and mass transfer and information processes.

3-05 A. S. DYCHENKO

ABOUT MODERN COMPUTER TECHNOLOGIES OF ENGINEERING ANALYSIS

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Automated programs of engineering analysis based on a method of finite elements have been investigated analytically. With the aid of examples of numerical simulation it is shown that the use of these programs in calculation of a stressed state of a thin-wall shell does not yield results that would correspond to the problem tackled. The necessity of introducing, into these programs, the information about the class of problems for which the program is intended, responsibility of developers for inadequacy of programs within the specified class of problems, and also the necessity of certifying applied programs for correspondence to the results of physical laws are proved.

3-33 A. I. FILIPPOV, P. N. MIKHAILOV, K. A. FILIPPOV

APPLICATION OF ASYMPTOTIC METHODS TO INVESTIGATION OF A TEMPERATURE FIELD IN AN ACTIVE WELL

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The solutions of a temperature field problem in an active well in a zero and first approximation are obtained on application of asymptotic methods. Formulas for calculation of radial temperature distributions have been derived.

3-07 K. B. ISAEV

CONCERNING THE PROBLEM OF ALLOWANCE FOR THE FINITE VELOCITY OF HEAT PROPAGATION IN A SOLID

I. N. Frantsevich Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Kiev, Ukraine, *isayev_k@gala.net*

Within the framework of the relaxation model of heat flux, which takes into account the finite nature of heat propagation velocity, solution of one-dimensional hyperbolic nonlinear heat conduction equation for a quasistationary regime of heating a semi-infinite medium is obtained. In the hyperbolic heat conduction equation, sinks (sources) of heat are taken into account. The influence of some factors on breakdown parameters and temperature field in materials, whose thermal conductivity values differ by three orders of magnitude, is shown.

3-34 V. S. KHOKHULIN, A. A. BALASHOV, D. M. TITOV, I. A. SELYANOVA

DEVELOPMENT OF THE METHODS OF COMBINATORY HEAT SIMULATION ON THE BASIS OF OBJECT-ORIENTED PROGRAMMING

Moscow Aviation Institute (State Technical University), Moscow, Russia

The essence of the combinatory mathematical simulation of the heat regime of various structures is revealed. It is shown that construction and processing of complex structures of data in the process of combinatory simulation can be completely implemented in modem programming media based on object-oriented programming.

3-09 A. V. KOTOVICH, G. A. NESENENKO

INVESTIGATION OF HEAT RESONANCE INITIATED BY NONLINEAR BOUNDARY CONDITIONS IN MULTIDIMENSIONAL IRREGULAR THERMAL FIELDS

N. E. Bauman Moscow State Technical University, Moscow, Russia, *fn2@cm.bmstu.ru*

A method of obtaining asymptotic expansions of solutions (including the Green's functions) of singularly perturbed boundary-value problems of parabolic equations in arbitrary curvilinear (including moving) boundaries is suggested. The method has the following advantages: it is not formal because it analyzes the solution of a boundary-value problem and (which is more crucial) allows one to find in explicit forms coefficients of asymptotic expansions both far from the boundaries and near them (in boundary layers). A set of parameters initiating a heat resonance has been found.

3-08 L. A. KOVRIGIN[1], A. A. SHILLING[1],1. M. AKMALOV[2]

SIMULATION OF THE THERMAL FIELD OF AN OIL WELL WITH A HEATING CABLE

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A mathematical model of the temperature field of an oil well has been developed. The model takes into account oil movement. The process of controlling the temperature field of the well by using a heating cable to prevent the formation of paraffin on the tube walls is considered. The mathematical model allows calculating temperature distribution for each individual well depending on the production rate, geothermy, rheological and thermophysical parameters of oil, etc. The calculation results help one in choosing an economical method of heating, an appropriate cable, and the power required for paraffin built-up prevention.

3-10 V. A. KUDINOV, V. V. DIKOP, S. A. NAZARENKO, E. V. STEFANYUK

METHOD OF COORDINATE FUNCTIONS IN THE PROBLEMS OF HEAT CONDUCTION FOR MULTILAYRED STRUCTURES

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The Fourier method and the Bubnov-Galerkin orthogonal method in application to the solution of the problem of heat conduction for a two-layer structure are presented. An important feature in the introduction of additional boundary conditions the necessity of which is attributable to the occurrence of an additional unknown parameter ? after division of variables in the initial differential equation. Additional boundary conditions are derived from the basic differential equation by its differentiation at boundary points.

3-12 L. L KURLAPOV

CHECK OF THE POSTULATE OF REVERSIBLE ACCESSIBILITY IN THERMODYNAMICS

Al-Faraby Kazakh National University, Almaty, Republic of Kazakhstan

By integrating entropy production in the irreversible process of equalization of temperature

or concentration in the adiabatic shell of two samples having different temperatures or concentrations prior to contact, the increment of entropy in the entire process is found. It is compared with the difference of entropy in the final and initial state of the system which corresponds to the increment of entropy obtained on the basis of the Clausius equality applied to reversible processes. According to the postulate of reversible accessibility (PRA) the results must coincide. Solutions of the heat conduction or diffusion equation have been found which give coincidence of calculations by these schemes. It is suggested to use an entropy analysis for selecting an optimal solution of the heat conduction equation.

3-11 G. V. KUZNETSOV[1], M. A. SHEREMET[2]

SPATIAL SIMULATION OF HEAT TRANSFER THROUGH BOUNDING STRUCTURES UNDER THE CONDITIONS OF INHOMOGENEOUS HEAT TRANSFER ON THE BOUNDARIES

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The boundary-value problem of the spatial unsteady heat transfer for the domain describing a typical object of heat supply is solved. The distributions of temperatures over the sections of the domain of the solution are presented and substantial heterogeneities of the temperature fields obtained are shown. The conclusion that the solution of the spatial boundary-value problem can result in much more exact estimations of the values of temperature inside typical objects of heat supply is made.

3-13 I. M. LAGUN

MODELING OF TEMPERATURE FIELDS IN CYLINDRICAL SHELLS

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Based on the analysis of mathematical models of the process of heat propagation in a heat conducting medium and of a nonstationary process in an electroconducting medium, the possibility of electric modeling of differential equations of various structure is shown, which expands the possibilities of applying RC-grid models. New correlations of electrothermal analogy and also basic designing equations and calculating correlations for electrical modeling of existential thermal processes at variable heat transfer parameters are obtained. The temperature field of a cylindrical shell is determined by the method of electrical modeling.

3-14 N. M. LAZUCHENKOV, D. N. LAZUCHENKOV

ANALYTICAL SOLUTION OF A HEAT CONDUCTION PROBLEM FOR A SEMI-INFINITE BODY WITH A SHELL AND ITS APPLICATION TO CONTROL AND IDENTIFY HEAT TRANSFER PROCESSES

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The solution of the problem of heat conduction of a uniformly heated semi-infinite body instantly coming into a thermal contact with a thin shell having a zero initial temperature has been analyzed. Analytical solutions are obtained making it possible to interpret temperature

measurements with allowance for the characteristic features of solution of boundary inverse problems of heat conduction in a real time scale. Examples of the use of solution to control the operation of a heating press for continuous lamination of wood particle boards and identify pulsed thermal impacts on a surface according to the results of subsequent temperature measurements are given.

3-15 E. A. LESYUK

INVESTIGATION OF THE PROCESSES IN FUSION ACCUMULATORS WITH A HEAT-CONDUCTING NOZZLE AND DEVELOPMENT METHODS OF THEIR OPTIMIZATION

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A physicomathematical model of the processes occurring in cold accumulators with liquid-solid phase transition with allowance for a porous heat-conducting nozzle is presented. An optimization analysis of a fusion accumulator with a porous heat-conducting nozzle is carried out. Calculation dependences of a change in the temperature of a cooled object on the time of its cooling and porosity of the heat-conducting nozzle are obtained. The results of an experimental investigation of the accumulator of cold with a porous nozzle are presented. Comparison of the calculated and experimental data is made.

3-16 M. Yu. LIVSHITS

SYSTEM OPTIMIZATION OF HEATING PROCESSES IN INDUSTRIAL INSTALLATIONS

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A system approach to joint optimal design and optimal control of operation modes for heating installations is suggested. The optimization of the selected sets of the equipment for typical heating sites is also discussed on the basis of the method suggested. It is considered as a possible alternative to the traditional practice based on a serial procedure of installation design, choice of the equipment of technological sites, fixing technological modes, and synthesis of automatic control systems.

3-17 O. G. LYSENKO[1], N. A. KARBALEVICH[2]

APPLICATION OF A HOLOGRAPHIC INTERFEROMETRY METHOD TO INVESTIGATION OF THE THERMOPHYSICAL CHARACTERISTICS OF LIQUIDS

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An experimental method to determine the thermal diffusivity and thermal conductivity of liquid media is considered. The method is based on solution of the one-dimensional nonstationary heat transfer problem for a semi-infinite body when its surface is exposed to a flat pulsed heat source. The evolution of the temperature field is controlled by a holographic interferometry

method.

3-18 V. A. MALYARENKO, Y. I. CHAIKA

DESIGH OF HEATING DEVICES OF RADIANT SYSTEMS OF HEATING ON THE BASIS OF THE SOLUTION OF A HEAT CONDUCTION PROBLEM

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The paper is devoted to improvement of the technique of designing heating panels of the water systems of radiant heating with the purpose of improving their operational qualities. Based on multivariate calculations of temperature fields, the panel surface temperature distribution functions have been determined depending on the heat carrier temperature, air temperature in the room, pitch and depth of immersion of pipelines in concrete. Using the proposed dependences, recommendations have been developed for designing heating panels of thinner radiant heating systems.

3-19 Yu. M. MATSEVITYI

FROM INVERSE HEAT CONDUCTION PROBLEMS TO OPTIMIZATION OF THERMAL PROCESSES

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The problems on optimization of the thermal state of the elements of power equipment are under consideration, as well as the problem of control of putting into operation of a turbine installation, and the problems of optimization of technological processes such as induction fusing, activation annealing of a semiconductor plate, and slag granulation. In the course of the solution of the above problems automated selection methods, spectral influence functions, concentrated capacity, and optimal dynamic filtration were adapted to optimization problems. As a result, recommendations were given on optimization of transient processes in turbomachines and proposals were worked out for building optimal strategies of control of manufacturing methods that had led to cutting down the duration of the process, increase of its effectiveness, decrease of power-consuming and sizes of the power installation and to decreasing thermal stresses in structural elements.

3-20 S. Yu. MESNYANKIN

MODERN APPROACH TO TAKING ACCOUNT OF CONTACT THERMAL RESISTANCES IN POWER PLANTS

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Generalization and systematization of the well-known works on contact heat transfer have been carried out. Classification of the units in which contact thermal resistance plays an important role has been performed. Basic factors exerting their effect on the process of heat transfer in a contact zone are formulated. The results of generalized analysis of the available analytical

dependences using the theory of odd set are considered and the regions of preferable use of various laws are formulated. Formulas for more precise calculation of contact thermal resistances of plane and cylindrical surfaces have been obtained.

3-21 A. I. NAKORCHEVSKII, B. I. BASOK, T. G. BELYAEVA

SIMULATION OF ACCUMULATION-DISCHARGING OF HEAT IN AN INFINITE MASS OF GROUND

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An integral method of solving the problems of nonstational heat conduction making it possible to perform mathematical simulation of the dynamics of accumulation - discharging of heat in an infinite mass of ground by means of single heat exchangers and their assemblies set vertically in the ground. The effect of long interruptions in operation typical of solar power engineering is considered. The necessity of controlling the process has been established. Operation of heat exchangers arranged in sets yields better results. An example of calculation of heat provision for a settlement of six thousands of inhabitants is given.

3-22 A. V. NENAROKOMOV, O. M. ALIFANOV, D. M. TITOV

STUDY OF RADIATIVE AND CONDUCTIVE HEAT TRANSFER BY THE METHOD OF INVERSE PROBLEMS

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The methods of identification of mathematical models by solving inverse heat transfer problems are very efficient in investigation of the processes of radiative and conductive heat transfer in contemporary indestructible, heatproof, and heat-insulting materials. Construction of the algorithms for parametric identification of mathematical models with distributed parameters is considered. Some aspects of the uniqueness of solution of the given inverse problems are analyzed.

3-23 G. A. NESENENKO

APPLICATION OF A "GEOMETRICAL-OPTICAL" ASYMPTOTIC METHOD FOR TAKING INTO ACCOUNT THE INFLUENCE OF THE COMPLICATED SHAPE OF THE BOUNDARY OF AN ARBITRARY DOMAIN ON MULTIDIMENSIONAL NONLINEAR IRREGULAR THERMAL FIELDS

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A method for obtaining asymptotic expansions of solutions (including the Green's function) of singulary perturbed boundary-value problems of parabolic equations with arbitrary curvilinear (including moving) boundaries is suggested. The method has the following advantages: it is not formal because it analyzes the solution of a boundary-value problem and, which is more crucial, allows one to find in explicit form coefficients of asymptotic expansions both far from the boundaries and near them (in a boundary layer). The last circumstance is very important, since it allows one to take into account the influence of the geometric characteristics of the shape of an

arbitrary boundary (for example, its curvature) on the asymptotic expansion of the solution of boundary-value problems.

3-24 D. A. NIKITIN, V. A. LIOPO, A. V. NIKITIN, V. A. STRUK

COMPUTER MODELS OF THE CONDUCTIVITY OF COMPOSITE SYSTEMS

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Simulation of the configuration of a composite system and calculation of its effective conductivity are considered. A model is constructed on flat and three-dimensional grids within the framework of a stationary problem.

3-25 V. A. PINSKER

QUASI-STATIC THERMOELASTIC FIELDS IN THE SEMI-SPACE HEATED BY A CIRCUMFERENTIAL SURFACE HEAT SOURCE

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An exact analytical solution is given for a transient temperature and the associated uncoupled thermal stresses in a homogeneous and isotropic linear-elastic half-space, heated by a constant heat flux over a circumferential surface region and insulated elsewhere at the surface. Boundary plane is free of traction. The transient 3-demensional heat conduction problem with rotating symmetry is solved with the aid of Green's function, and the associated thermoelastic field is analyzed. The general solution was obtained in an integral form. More simple expressions for temperature and stresses on the axis of symmetry and on the boundary plane are presented. The exact closed-form solution in terms of elliptic integrals is given for a steady regime. The spatial distribution and the temporal evolution of heat and elastic fields in the half-space are studied. Maximal values of each stress component are determined for different values of Poisson's ratio. The thermally distorted surface profile is obtained.

3-26 *Y. S. POSTOLNIK[1], I. A. PAVLYUCHENKOV[1], N. V. ANDRIANOV[2]*

INCREASE IN THE TECHNOLOGICAL EFFECTIVENESS OF CALCULATION TECHNIQUES OF APPLIED THERMOMECHANICS BY MEANS OF THEIR COMPUTERIZATION

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The question of the expediency of employing computerization of earlier developed calculation techniques with regard for all kinds of nonlinearities is posed. Provision of such techniques with programs for computer calculations will raise their practical value considerably. This will promote wider introduction of nonlinear mathematical simulation into engineering practice. A list of block diagrams, developed by the authors, and programs for corresponding calculations for solving basic problems of nonlinear applied thermomechanics is given. A block diagram of calculating the thermostress state of the bodies of base form under the conditions of radiative heating is given as an example.

3-27 E. Ya. RAPOPORT, Yu. E. PLESHIVTSEVA

MODELS AND METHODS OF SEMI-INFINITE OPTIMIZATION IN INVERSE HEAT CONDUCTION PROBLEMS

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A wide range of inverse heat conduction problems in extremal statement is reduced to special mathematical programming problems (MPS) with the aid of exact parametrization of optimal controls. These MPS are formulated in terms of the functions of the maximum. The proposed method of the solution of MPS is based on the Chebyshev properties of the sought extremals and a priori information on the nature of the functions of the maximum, dictated by the knowledge of the application domain of concrete optimized processes.

3-28 I. I. ROZHIN

AXISYMMETRIC PROBLEM OF PHASE-TRANSITION BASED ACCUMULATION OF HEAT

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In this work, the processes of melting and solidification of a heat accumulating material (HAM) undergoing a phase transition due to heat exchange with a heat carrier with a cyclically changing processes are investigated. An axisymmetric problem consisting of an equation of nonstationary propagation of heat due to forced convection of the heat carrier in a channel and a two-dimensional heat conduction equation describing the propagation of heat in HAM with allowance for phase transition has been solved by the method of finite differences. As a result of comparison of the modes of motion of the heat carrier it has been established that with the same heat transfer surface most efficient is the turbulent one, because despite of the fact that in this case the size (or mass) of HAM is larger, more heat can be accumulated than in the case of a laminar mode.

3-29 O. V. SEMENOVICH

NUMERICAL INVESTIGATION OF TEMPERATURE FIELDS IN BODIES OF COMPLEX STRUCTURE

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The work presents information about the program package (PP) developed by the author for computer simulation of temperature fields (steady-state and transient) in bodies of complex spatial configuration and inner structure. The problems with boundary conditions of the first and/or third kinds are solved. For numerical solution the method of finite elements in variational formulation is used. Three-dimensional (family of hexahedral prisms) elements, such as linear, quadratic, and cubic are applied. The considered PP has been used to investigate temperature fields in the elements of constructions of the cores of nuclear reactors, units of energy equipment, details of intemal-combustion engines, metal- cutting tool, superlarge integral microcircuits, and power chip packages.

3-36 V. A. SHEVCHUK

SIMULATION AND CALCULATION OF HEAT TRANSFER IN THE SYSTEM BODY-MULTILAYER COATING

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A method of approximate calculation of the process of heat conduction in construction elements with thin multiplayer coatings has been developed. This method is based on substantial simplification of solving an initial problem and is connected with modeling of coatings by thin-wall shells with corresponding geometrical and thermal properties of the coating. In such an approach, the influence of thin coatings on heat transfer in the body-coating system is described by generalized boundary conditions. The efficiency of the proposed approach is illustrated by comparing the results obtained with the results of exact solution of a test problem of heating a cylinder with a three-layer coating.

3-31 A. P. SLESARENKO

REGIONAL-ANALYTICAL BASIS FUNCTIONS OF THE INFLUENCE OF BOUNDARY EFFECTS IN THE SOLUTION OF HEAT CONDUCTION PROBLEMS FOR HOMOGENEOUS AND INHOMOGENEOUS MEDIA

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Regional-analytical structures of solutions of linear and nonlinear heat conduction problems for composite construction elements with allowance for thermal contact resistances have been constructed. They exactly satisfy all the specified nonlinear boundary conditions, including the conditions of a nonideal heat contact for heterogeneous media. These structures of the solutions of heat conduction problems are universal relative to variation of both the domain geometry and the form of contact of heterogeneous materials for composite construction elements. Unknown components of the regional-analytical structures of the solutions of heat conduction problems are determined by joint use of variational and iterational methods.

3-30 A. P. SLESARENKO, N. A. SAFONOV, S. A. ZARUBIN

REGIONAL-STRUCTURAL AND PROJECTIVE METHODS IN SIMULATION AND IDENTIFICATION OF NONLINEAR HEAT CONDUCTION PROCESSES IN FINNED CONSTRUCTION ELEMENTS

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To solve nonlinear boundary-value problems of heat emitting finned construction elements, it is proposed to use jointly regional-structural and projective methods. Laying out of domain is carried out so that the configuration of a region should be convex and comparatively simple. Analytical structures of solution are constructed for each region separately. They exactly satisfy the conditions of conjugation on the boundary of region contact and nonlinear regional boundary conditions. Unknown components of regional- analytical structures of solutions are found by iterational methods from appropriate nonlinear systems of algebraic equations to which the use of projective methods leads.

3-32 E. S. TVERSKAYA

CONDITIONS FOR EXISTENCE OF THE OPTIMAL THICKNESS OF A SHIELDED WALL EXPOSED TO LOCAL PULSE-PERIODIC HEATING

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In this paper, sufficient conditions for existence of the optimal thickness of a plane wall that ensures the minimum stationary temperature of the most heated point of the wall are determined, provided that a thermal insulator and a thermal active layer are available, with the latter functioning as feedback. On the unprotected side the wall is cooled by a medium whose temperature and heat-transfer coefficient are constant, whereas on the side of a coating the wall is exposed to a heat flux with an intensity of a Gaussian type in a pulse-periodic regime.

3-01 V. B. VESELOVSKII

MATHEMATICAL SIMULATION OF HEAT TRANSFER IN INTENSIFICATION OF THE PROCESSES OF HEATING SOLID BODIES

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The results of investigations of heating the solid body surface by intensive heat fluxes are given. A mathematical model has been developed and computational investigations of the influence of heat inertia on energy concentration in the surface layer and the physical characteristics are carried out. Accelaration of the heating process, creation, and saving of the zones of high-temperature gradients are determined which explains the decrease in the power capacity of body damage. Based on the results obtained, demands upon heat generators for thermal processing of solid bodies are defined, the basic of which is the possibility of increasing and controlling the rate of heating.

3-04 V. B. VESELOVSKII

APPROXIMATE METHODS FOR SOLVING NONLINEAR HEAT CONDUCTION PROBLEMS WITH A MOVING BOUNDARY

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Mathematical models are presented and the methods of solving single- and multiphase Stefan problems are suggested. The construction of a closed solution of Stefan problem is reduced to integration of a system of ordinary differential equations. An approximate analytical method of computation of two-phase bodies is given which makes it possible, using the Gibbs variational principle, to determine the stressed state in the body, temperature field, and the law of motion of the phase interface. The calculation model of heat transfer of agglomerated iron-ore briquetes of spherical shape up to the temperatures of optimal development of deoxidation processes by a multicomponent gas is suggested. The solution to the problem is obtained by the method of final differences.

3-03 V. B. VESELOVSKII[1], A. V. BERLOV[1], N. I. BELYI[2], V. I. LYASHENKO[3]
CALCULATION OF THE TEMPERATURE FIELDS OF ELECTRIC CABLES

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The nonstationary heat transfer of cable products under the action of pulse currents of high density, in the conditions of influence of high-enthalpy gas flows, low temperatures, electromagnetic fields is considered. The technique of determination of the thermal modes of electric cables and conductors based on the methods of consecutive intervals and final differences is suggested. An approximate analytical method, which allows one to obtain the temperature field of an electric cable in its different sections, is given. Parametric studies of the calculation of temperature fields of electric cables with multifunction electric and heat insulation, as well as comparison of results with experimental data are carried out.

3-02 V. B. VESELOVSKII[1], V. V. NIKUL'NIKOVA[1], N. I. BELYI[2], V. I. LYASHENKO[3]

DETERMINATION OF TRANSIENT BOUNDARY CONDITIONS ON THE FLAME WALLS OF THE BODIES OF COMBUSTION CHAMBERS

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The solution of a boundary inverse heat conduction problem is obtained with the aid of orthogonal Chebyshev's polynomials and regularization method using operational and power series methods. On the basis of measured temperature on the external surface of a compound wall of an uncooled combustion chamber the boundary conditions on the flame wall are obtained (surface temperature, heat flow, heat transfer coefficient). Verification of the solution algorithms is carried out by means of test examples. They showed satisfactory agreement of the results. Parametric investigations allow one to determine the deviation of the obtained boundary conditions depending on errors in the data on the experimental temperature.

3-06 A. V. ZH1BER[1], N. M. TSIRELMAN[2]

STEFAN'S SINGLE-PHASE PROBLEM FOR HYDROGEN

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We considered model single-phase Stefan's problem for hydrogen, when the heat conduction properties depend not only on temperature, but also on the special argument. Basing on the use of special nonlocal transformation, the problem is brought to a series of linear problems for heat conduction equations with fixed and moving boundaries.

Section 4

"HEAT- AND MASS TRANSFER IN CHEMICALLY REACTING SYSTEMS"

4-01 A. S. ASKAROVA, M. N. AZERBAEVA, S. A. BOLEGENOVA, I. V. LOKTIONOVA

NUMERICAL INVESTIGATION OF A REACTING METHANE JET AT AN ELEVATED INITIAL LEVEL OF TURBULENCE

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The problem of diffusion combustion of a turbulent fuel jet in a cocurrent oxidant stream is solved numerically. The influence of initial turbulence level on the averaged and pulsating characteristics of the torch is studied. It is shown that the profiles of the averaged and pulsating velocity components in an inert jet qualitatively agree with the profiles behind the torch, where the combustion is completed. In the core of the torch the maxima of the averaged velocity and turbulent kinetic energy are not on the axis of the jet, but rather in the area of the flame front; their self-similarity is violated.

4-02 E. S. BORISOVA, V. M. KHANAEV, A. S. NOSKOV

INFLUENCE OF HEAT AND MASS TRANSFER ON OPTIMAL DISTRIBUTION OF THE ACTIVE CATALYST COMPONENT IN CATALYTIC COMBUSTION

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Based on a mathematical model, the distribution of the active component along the length of a catalytic layer has been investigated. A variational problem has been formulated to determine the optimal axially nonuniform distribution of catalyst activity along a fixed catalyst bed. It is shown that the mass transport limitations or nonisothermal temperature profile are the necessary conditions for potential optimization of the catalyst distribution along the bed length. Under isothermal conditions with linear dependence of the reaction rate on concentration at a constant mass transfer coefficient, the uniform distribution is optimal. The optimal distribution allows the total active component loading to be minimized, the economy being dependent on the mass transfer intensity.

4-03 B. F. BOYARSHINOV, V. I. TITKOV, S. Yu. FEDOROV

DISRTIBUTION OF THE OH RADICAL, THERMAL AND GASDYNAMIC PARAMETERS IN A TURBULIZED BOUNDARY LAYER WITH EVAPORATION AND BURNING OF ETHANOL

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The influence of the air flow turbulence Tuo = 1 - 18% on heat and mass transfer in ethanol combustion, on the distribution of temperatures and velocities and also on thedistribution

of the concentration of the OH radical is investigated. The longitudinal velocity and its pulsations were measured by a laser-Doppler velocimeter; the OH radical concentration was obtained by a laser-induced fluorescence method, the distribution of temperatures - by a microthermocouple, heat fluxes were determined using the fuel evaporation rate. It is shown that the position of the OH concentration maximum differs from the position of the temperature maximum. The mass transfer intensity of a turbulized boundary layer with combustion changed within the limits ±30%, with the completeness of combustion attaining unity. It is established that the lines of flow and isoline of maximal temperature intercross. Estimation of the burning rate and of the water formation rate is carried out. It is shown that behind the stabilizer of a flame the mode of burning approaches a kinetic one.

4-04 A. F. BULAT, A. I. VOLOSHIN, P. I. KUDINOV

INVESTIGATION OF THE PROCESSES OF HEAT AND MASS TRANSFER IN PLASMA IGNITION OF A LOW-REACTION COAL FUEL

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Mathematical models and numerical methods for calculation of the processes of heat and mass transfer in a turbulent swirling flow with burning coal particles are developed. Based on the results of mathematical simulation, requirements to design and technological parameters of the technology of plasma thermochemical preparation of a coal powder fuel (TCPC) are worked out. A specimen of an aerodynamic reactor of TCPC is designed and tested. The effectiveness of the proposed technology is shown on the basis of experimental and numerical data.

4-10 K. V. DOBREGO, I. A. KOZNACHEEV, I. M. KOZLOV

SIMULATION OF FILTRATION COMBUSTION IN A POROUS MEDIUM WITH SPATIALLY INHOMOGENEOUS CHARACTERISTICS

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Conservation equations for the case of spatially inhomogeneous porosity of a solid carcass are formulated. Models of heat and mass transfer and chemical kinetics, containing both gas-phase and heterogeneous thermochemical processes, are described. A new generalized volume-averaged model of filtration combustion with inhomogeneous and unsteady parameters of a porous medium is introduced. The software for numerical realization of the model mentioned has been developed. Numerical simulation of the model gas generator was carried out by using the indicated software. Concentrations, temperatures of a gas and solid phase, velocity profiles, and time-dependences of the concentrations of gasification products were obtained. Different operation modes of a gasifier are analyzed.

4-11 V. I. DROBYSHEVICH

NUMERICAL INVESTIGATION OF TRANSIENT MODES OF SPHERICAL HYBRID COMBUSTION WAVES

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A mathematical model of the process, with allowance for a convective flow in a gas, of heat conduction through the frame of a layer of particles, including heat conduction due to reemission as well as heat and mass exchange between a gas and a catalyst has been constructed. For this model, a special algorithm of its realization has been developed. In an apparatus of spherical geometry, the dependence of a stationary point on the gas flow rate has been obtained. The dynamic characteristics of the process of transition from one stationary point to another on change in the gas flow rate have also been obtained.

4-12 R. S. ENALEYEV, I. A. ABDULLIN, R. R. DIMUKHAMETOV,

V. A. KACHALKIN

MODELING OF ENERGY TRANSFER IN COMBUSTION OF LOW-GAS THERMAL COMPOSITIONS IN SYSTEMS WITH INTENSE HEAT REMOVAL

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A cylindrical scanning calorimeter for modeling the process of energy transfer in combustion of pyrotechnic low-gas compositions has been developed. The construction of the calorimeter allows one to measure the basic transfer potentials and power parameters during combustion. A mathematical model for calculating the temperature profile in wave of combustion is justified. Boundary conditions are formulated by solving a Stefan-type problem in the mobile boundary of the chemical reaction front. The volumetric speed of intense heat removal is calculated from the kinetic equation of heat transfer from the central zone with a random distribution of temperature in the cross section to the surface of contact of thermal composition with an inert envelope.

4-30 G. A. FROLOV

HEAT ACCUMULATION IN THE ABLATION SURFACE LAYER OF A COMPOSITE MATERIAL

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For the first time it has been shown that the earlier established laws governing accumulation of heat in the surface layer of a material and achievement of limiting power consumption for its internal processes on warm-up and ablation do not depend on the nature of the material and the mechanism of its thermal destruction. This has been established, using as an example investigations of composite materials of the type of asbestos-reinforced laminate, coal-plastic, and fiberglasses.

4-07 K. B. GALITSEISKII

MODELING OF THE PROCESS OF AFTERBURNING IN SUPERSONIC JETS

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The object of the present work was improvement of a semi empirical model for calculating heat and mass transfer in reactive chemically supersonic single- and two- phase jets. The proposed mathematical model is based on solution of a stationary system of partial differential equations of parabola type, including the parabolized system of Navier-Stokes equations, energy equation, equation for kinetic energy and velocity of turbulent pulsation dissipation (the k-£ model of turbulence), diffusion equation for components and mixture elements, as well as equations of chemical kinetics and equations for particles. As a result of the numerical calculations, the distribution of basic hydrodynamic and thermal parameters: velocity, pressure, temperature, concentration of the basis components has been made.

4-06 A. I. GAVRILOV, I. A. GAVRILOV, E. V. KHAIRYUZOVA, T. L. SHAPOSHNIKOVA

MATHEMATICAL MODELING OF THE OPTICAL LIGHTGUIDE REFERACTIVE INDEX PROFILE AT THE STAGE OF FABRICATION

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The causes of the appearance of the nonuniformity screw in the thickness of the layer obtained during waveguide fabrication are found in terms of the convective deposition model. Nonuniformity leads to deflections of the refractive index from the profile required. The analytical expressions obtained can be used as the basis for a controlling program, which allows one to obtain specified profiles of a refractive index.

4-36 I. GOLDFARB[1], S. SAZHIN[2], A. ZINOVIEV[3]

THERMAL EXPLOSION IN FLAMMABLE GAS CONTAINING FUEL DROPLETS: ASYMPTOTIC ANALYSIS

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The problem of thermal explosion in a flammable gas mixture with addition of volatile fuel droplets is studied based on the asymptotic method of integral manifolds. The model for radiative heating of droplets takes into account their semitransparency. The results of the analysis are applied to modeling explosion in diesel engines. Two distinct dynamical situations have been considered, depending on the initial droplet concentration. These are "far zone" (small initial liquid volume fraction) and "near zone" (large initial liquid volume fraction). The heating and evaporation time of small droplets in the far zone is smaller than the chemical ignition delay. In the near zone for large droplets, the process starts with initial gas cooling and slight heating of droplets. This is followed by a relatively slow heating of gas, due to chemical reactions, and further droplet heating. It is expected that before thermal explosion in the near zone takes place, the droplets break-up and are removed from this zone.

4-08 Yu. E. GORBACHEV, M. A. ZATEVAKHIN, A. A. IGNAT'EV,

V. V. KRZHIZHANOVSKAYA

NUMERICAL SIMULATION OF THE PROCESSES OF HEAT AND MASS TRANSFER IN PECVD REACTORS FOR GROWING SILICON FILMS UNDER THE CONDITIONS OF INTENSE FORMATION OF HIGHER SILANES IN A GAS PHASE

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A model of the process of growing of an amorphous silicon film from a HF discharge silane plasma in PECVD reactors has been developed. The model takes into account homogeneous chemical reactions, deposition of radicals on the walls, diffusion, convection, and formation of higher silanes. A parallel algorithm for simulation on multiprocessor systems has been constructed. End-user software for 3D simulation has been created. The processes which influence the growth of the film were investigated. It is shown that an increase in pressure leads to a decrease in the rate of growth and to redistribution of the contribution of various species to the deposition process. An increase in the speed of pumping leads to a decrease in the rate of growth and to a considerable decrease in the contribution of higher silanes. An increase in the discharge power leads to an increase in w_r growth rate and to an increase in the contribution of higher silanes.

4-09 P. S. GRINCHUK, O. S. RABINOVICH

CRITICAL PHENOMENA AND STRUCTURAL EFFECTS IN COMBUSTION OF DISORDERED HETEROGENEOUS MIXTURES

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Propagation of combustion waves in binary heterogeneous media with random distribution of components is studied by a numerical modeling method. It is shown that structural disorder of these mixtures has especially strong influence on the critical phenomena, which are typical of combustion processes, and, first of all, on the concentration and thermal limits of combustion. The disorder of a mixture is the cause of an experimentally observed percolation regime of combustion wave propagation over an "infinite" cluster formed by combustible elements of the mixture. A unified criterion combining the physicochemical and structural characteristics of the medium are derived which describes transition from the frontal regime of combustion wave propagation to the percolation one.

4-13 V. I. KAUFMAN, A. I. MAIOROVA, V. I. YAGODKIN

STABILIZATION OF BURNING OF A LEAN MIXTURE IN COAXIAL SWIRLING FLOWS

Central Institute of Aviation Motors, Moscow, Russia

Mixing and burning of two swirling flows leaving coaxial tubes were studied numerically. Flame stabilization of a lean homogeneous methane-air mixture is implemented by a small amount

of outer pilot flow of reach burning gas products. In calculations, a simple phenomenological burning model was used based on empirical formulas for the turbulent flame propagation velocity. It is shown that swirling effectively increases burning efficiency, but at some swirling values flow instability with a hysteresis loop is possible. Optimal values of flow parameters exist when the solution is stable and burning is completed over the length equal two tube diameters.

4-32 H. L. KHACHATRYAN[1], H. H. NERSISYAN[2], A. B. HARUTYUNYAN[2], S. L. KHARATYAN[1,2]

ON THE MECHANISM OF MASS TRANSFER IN ACTIVATED COMBUSTION OF THE SILICON-NITROGEN-PROMOTER SYSTEM

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In this work, results on single-stage combustion synthesis of Si3N4/SiC composite powders with the OC-S13N4 phase denominating at relatively low nitrogen pressures are presented. To attain the aims set, active additives (combustion promoters), mainly nitrogen containing solid organic compounds (e. g. melamine and teflon), were used. Influence of the melamine-teflon ratio, nitrogen pressure, density of the initial mixture on combustion parameters and quality of the product obtained was studied. It is established that gaseous nitrogen filtrating from the outside and nitrogen contained in melamine act in combustion, and, depending on conditions, one or the other may dominate. If nitridation occurs preferentially due to nitrogen from melamine, the a-Si3N4 phase dominates in the product, whereas the increasing role of gaseous nitrogen leads to an increase in the content of ß-Si_3N_4.

4-31 S. N. KHARLAMOV

HEAT AND MASS TRANSFER IN FACILITIES WITH A MOVING PISTON

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Results of numerical investigation of turbulent heat transfer of a thermally ionized gaseous mixture in a chamber behind an accelerating piston are presented. A model was used which takes into account thermal and dynamic inertia of a working body, and the nonstationary nature of a turbulent structure, mutual effect of chemical reactions and turbulence, and the variability of thermophysical properties. To determine the turbulent transfer coefficients, a multiparametric model, including the transport equations for individual components of Reynolds shear stresses and fluxes, turbulence kinetic energy, and its integral scale is used. The flow structure and heat transfer behind the moving piston are analyzed in detail.

4-33 B. B. KHINA[1], B. FORMANEK[2]

ON THE VALIDITY OF THE "DIFFUSION-CONTROLLED INTERACTION" KINETICS FOR MODELING SHS

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A consistent analysis of the diffusion model, which is widely used for describing the heat release kinetics during SHS of refractory compounds, is performed using realistic values of the diffusion coefficients and experimental data on the example of the synthesis of titanium carbide. The change of the geometry of a unit reaction cell during melting of a metallic reactant is taken into account. A condition for the rupture of the primary product crust formed on the surface of a metal particle is derived. Calculations have demonstrated that this quasiequilibrium model involving the diffusion-controlled interaction does not provide sufficient heat release for sustaining the SHS wave, and only hollow particles of interstitial compounds (carbides, nitrides, and certain borides) can form. As an alternative, a qualitative nonequilibrium phase formation mechanism is proposed which permits one to explain the results observed experimentally.

4-15 N. A. KOCHETOV, A. S. ROGACHEV, A. N. EMELYANOV,

E. V. ILLARIONOVA, V. M. SHKIRO

INFLUENCE OF THE MICROSTRUCTURE OF HETEROGENEOUS MIXTURES ON REGULAR FEATURES OF GAS-FREE COMBUSTION

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Series of experiments investigating the microctructure of an initial mixture for gas-free combustion, including investigation of compressibility, electroconductivity, thermal conductivity, combustion rate, and metallographic studies were carried out. The determining influence of the shape of particles and of their ability to form a continuous skeleton on the trends of gas-free combustion is established. It is shown that the velocity and mode of the gas-free combustion front depend on heat transfer between metal particles in an initial reactive mixture, with the contacts between them playing a limiting role.

4-14.1 A. K. KOPEIKA, V. V. GOLOVKO, V. I. BROVCHENKO, E. G. OLESHKO, I. S. DARAKOV

IGNITION AND COMBUSTION OF A SINGLE DROP OF CANOLA-METHYL ESTER AND ITS MIXTURES WITH A DIESEL FUEL

Institute of Combustion and Advanced Thechnologies, I. I. Mechnikov Odessa State University, Odessa, Ukraine, vov@ictg.intes.odessa.ua

The results of experimental studies of the process ignition and combustion of a canola-methyl ester single drop and its mixtures with a diesel fuel in a motionless air environment are presented. The critical conditions for ignition of drops of fuel mixtures are obtained. It is shown that canola-methyl ester has some ecological advantages. The values of ignition time delay and of the burning point of a canola-methyl ester single drop and its fuel mixtures are smaller than those for a diesel fuel.

4-16 A. T. LUK'YANOV, I. S. VERZHBITSKAYA

MATHEMATICAL SIMULATION OF OXIDATION OF ETHANE WITH TAKING ACCOUNT OF STEAM DIFFUSION

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A comprehensive theoretical investigation of catalytic oxidation of a gas mixture in a fixed-bed reactor is conducted involving methods of the qualitative theory of differential equations on the basis of a zero-dimensional model and numerical solutions of a corresponding two-dimensional problem. With the aid of the 1st Lyapunov method, the parametrical domains of self-oscillating, nonunique, and stable regimes are determined for planning numerical experiments. The results of the zero-dimensional analysis and numerical solutions agree. The influence of the temperature of the reactor walls and external periodic perturbations of the parameters on the oxidation dynamics was studied numerically. The resonance phenomena were investigated.

4-17 Kh. V. MANUKYAN[1] A. V. EGISHYAN[2], S. L. KHARATYAN[1]

ON THE MECHANISM OF MASS TRANSFER IN COMBUSTION OF THE Mo-B SYSTEM

Yerevan State University, Yerevan, Republic of Armenia; A. B. Nalbandyan Institute of Chemical Physics, National Academy of Sciences of the Republic of Armenia, Yerevan, Armenia, suren@ysu.am

The laws governing combustion of the Mo-B, Mo-B-MoO_3, and Mo-B-B_2O_3 systems depending on the ratio of components in an initial mixture, amounts of added oxides, and the inert gas pressure are investigated. In studying the combustion mechanism, attention is mainly paid to addition of small amounts (up to 6 wt. %) of boron and molybdenum oxides to the initial mixture. Based on the thermodynamic analysis carried out and experimental data on combustion, a possible mechanism of combustion wave propagation in the "gasless" system molybdenum – boron is suggested in which emphasis is laid on mass transfer by means of boron oxides.

4-18 D. S. MIKHATULIN[1], D. L. REZNIKOV

SIMULATION OF THERMAL EROSIVE DESTRUCTION OF THE ELEMENTS OF A HYPERSONIC AIRCRAFT FLYING IN A DUSTED ATMOSPHERE

Institute for High Temperatures, Russian Academy of Sciences; Moscow Aviation Institute (State Technical University), Moscow, Russia

The results of mathematical simulation of exposure of the elements of the front surfaces of a hypersonic aircraft to thermal erosive effect of a dusted atmosphere are considered. The results of tests of heat protecting materials obtained on gas-dynamical rigs are given.

4-19 D. S. MIKHATULIN, Yu. V. POLEZHAEV

RELATIONSHIP BETWEEN HEAT AND EROSION COMPONENTS IN THERMAL-EROSIVE DESTRUCTION OF MATERIALS IN A SUPERSONIC HETEROGENEOUS FLOW

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The possibilities of simulation of thermal-erosive effect of a dusted atmosphere on the elements of the frontal surfaces of rockets on gasdynamical ground-level rigs and requirements for the regimes to be reproduced in experimental investigations are considered. A model of thermal-erosive destruction of the materials of coatings, in which the total mass flux entrained is divided into thermal, erosive, and gas-mechanical ones, is suggested. The conditions under which these components are mutually independent and when the dependence cannot be ignored are investigated. The determining parameters are formulated.

4-20 L. M. MUSABEKOVA, A. M. BRENER

METHODOLOGY OF CALCULATION OF THE PROCESS OF CHEMISORPTION IN SYSTEMS WITH A MOVING FRONT OF AN INSTANTANEOUS IRREVERSIBLE REACTION

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A new methodology of calculating the process of chemisorption with a moving front of instantaneous irreversible reaction with allowance for the effect of physicochemical characteristics on the velocity of the reaction front propagation is presented. As a result of calculation, an expression for calculating the time of formation of a mobile reaction front has been obtained. The initial stage of chemisorption with a moving reaction front is isolated. The characteristic times and depths of penetration of the absorbed component are determined and the limits of applicability of the film model are estimated. A technique for calculating the coefficients of acceleration of absorption has been developed and the parameters of the model depending on the ratio between the coefficients of diffusion of the absorbed component, active component of the absorbent, and the reaction products have been found.

4-21 S. G. ORLOVSKAYA, V. V. KALINCHAK, T. V. GRYZUNOVA,

A. I. KALINCHAK, M. I. KIRMIKCHI

INFLUENCE OF STEFAN FLOW ON COMBUSTION AND SPONTANEOUS EXTINCTION OF TUNGSTEN PARTICLES

I. I. Mechnikov Odessa National University, Odessa, Ukraine

The effect of a Stefan flow on high-temperature oxidation of a tungsten

particle in a heated gas medium has been studied.

4-22 S. G. ORLOVSKAYA, V. V. KALINCHAK, T. V. GRYZUNOVA

INFLUENCE OF RADIATIVE AND EVAPORATIVE HEAT TRANSFER OF AN OXIII1C FILM FROM THE TUNGSTEN CONDUCTOR SURFACE ON ITS HIGH-TEMPERATURE OXIDATION

I. I. Mechnikov Odessa National University, Odessa, Ukraine

The influence of radiative and evaporative heat transfer of an oxidic film on ignition and extinction of an electrically heated tungsten conductor has been studied. It has been proved that beginning from a certain diameter of the conductor, the disregard of radiative heat losses to the walls of a reaction apparatus leads to disappearance of the critical value of the current strength which characterizes its extinction.

4-37 R. POHORECKI, E. MOLGA, W. MONIUK

HEAT AND MASS TRANSFER DÜRING GAS ABSORPTION WITH SIMULTANEOUS SECOND-ORDER CHEMICAL REACTION

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In this paper, a general mathematical model for nonisothermal absorption with a second-order irreversible chemical reaction is described. The analysis has been performed for a single gas bubble using the film heat and mass transfer theory. In the general approach presented, mass transfer resistances in both the gas and the liquid phases, as well as the liquid volatility were taken into account. Also, the heat transfer to the gas phase, as well as the temperature dependences of diffusivities, solubility coefficient, and chemical rate constant have been taken into consideration, while the temperature dependence of the physical properties, such as density, heat capacity, and thermal conductivity, has been neglected. The results of numerical simulations have been discussed and compared with the well-known predictions obtained for isothermal absorption with a simultaneous chemical reaction.

4-23 A. S. ROGACHEV, N. A. KOCHETOV, A. N. EMELYANOV,

E. V. ILLARIONOVA, V. M. SHKIRO

MICROHETEROGENEOUS MODEL OF GASLESS COMBUSTION

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Series of experiments investigating microstructure of initial mixture for gasless combustion, including investigation of compressibility, electroconductivity, thermal conductivity, combustion velocity and metallographic research was accomplished. Defining role of particles shape and ability to form continuous frame on gasless combustion features was found. It was

shown that gasless combustion front velocity and propagation mode depend on heat transfer between metal particles in initial reactant mixture and contacts between particles play a limiting role.

A.P. RUBAN

DYNAMICS OF TEMPERATURE FIELDS IN TOPOCHEMICAL POWDER REACTING SYSTEMS

I. N. Frantsevich Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Kiev, Ukraine, frolov@alfacom.net

Results which open the dynamic nature of topochemical reactions and mechanisms of interaction of metals with gases are obtained. The technique is suggested allowing one to carry out investigations of topochemical reactions "solid body-gas", thus making it possible to lay the foundations of the dynamic theory of heat resistance of metals, alloys, and composite materials, and, finally, to develop new generation of functional materials.

4-24 A. F. RYZHKOV, V. V. KOSTYUNIN, A. M. DUBININ, V. E. SILIN

NEW CONCEPT OF THERMOCHEMICAL PROCESSING OF BIOMASS AND COALS AND ITS IMPLEMENTATION IN FURNACE FACILITIES

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Basic trends in using gas generator technologies in the world power engineering and known techniques of intensification of the processes of combustion and gasification are considered. The possibility of increasing the intensity of gasification in a dense bed by increasing the temperature of the process is analyzed using as an example a 0.17-MW bench gasifier, operating on highly wet wood chips. An approach to activation of the processes of combustion and gasification of organic solid fuel in thermochemical processing is presented. Experimental substantiation of the applicability of the approach and quantitative indicators of activation are given.

4-38 A. SALJNIKOV[1], S. OKA[2], Z. STEVANOVIC[2]

MATHEMATICAL MODEL OF COMBUSTION IN PARTICULATE 2-PHASE FLOW

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A mathematical and numerical model of pulverized coal combustion in wide range use

furnaces with swirl burners, i.e., within a turbulent particle-laden swirl flow in axisym- metric geometry, is presented. The model is based on the k-e single-phase model, considering the presence of the solid phase via the additional source terms in the gas phase equations. The disperse phase is treated through the history of particular particles by using the Lagrangian Stochastic Deterministic model. Devolatilization, homogenous, and heterogeneous chemical reaction processes are modeled via the global combustion model using own reaction kinetics data. The model was used to perform an analysis of influence of flow parameters and coal characteristics upon combustion in a wide range use furnace. The model was verified by comparing computational and experimental results for combustion of polydisperse pulverized coal in an experimental furnace.

4-25 V. R. SAMOILIKOV, A. L. KABLUKOV

HEAT TRANSFER OPTIMIZATION UNDER CONDITIONS OF CONTACT BETWEEN A WAFER AND A SUSCEPTOR

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In the present-day microelectronics that uses large diameter wafers the task of precise wafers heating in high-temperature processes becomes actual. First of all, it is connected with the requirements of international standards for production of a high-quality electronic equipment. The present study is devoted to solution of a unified problem of heat transfer between water and a susceptor as well as to minimization of thermoplastic tension in wafers during CVD of epitaxial silicon layers.

B. S. SEPLYARSKII, T. P. IVLEVA

EFFECT OF DIFFUSIVE TRANSFER ON REGULARITIES OF IGNITION AND INITIAL COMBUSTION OF HYBRID GAS SUSPENSIONS

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Effect of diffusive transfer of an oxidizer and combustible gas on ignition and an initial stage of combustion of solid particle gas suspension in a gas mixture containing an oxidizer, inert and combustible gases (hybrid gas suspension) has been numerically analyzed. Even if the Lewis criterion is equal to unity, there is no similarity of concentration fields and temperatures in the gas phase on the ignition stage. That is why in the location close to the heater the combustible gas as well as the particles (even in the mixtures with oxygen deficiency) can be completely burnt up. It makes the process of gas suspension ignition easier. Another unexpected result of this work is a transition of diffusive ignition to pseudokinetic combustion of hybrid gas suspension.

4-26 B. S. SEPLYARSKII, S. G. VADCHENKO

CONVECTIVE HEAT TRANSFER IN THE PROCESSES OF "GASLESS" COMBUSTION (A Ti + C SYSTEM)

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A hypothesis of convective-conductive mechanism of combustion wave propagation in fast burning "gasless" systems containing low-melting agent has been experimentally checked in our work. Contrary to the opinions described in the literature, main elongation of the burning samples made of stoichiometric mixtures of titanium and black carbon occurs beyond the warming-up zone. Due to the experiments, the combustion rate is shown to be increased more than twice with a decrease in the sample thickness. A number of the experiments have proved the hypothesis of convective-conductive mechanism of combustion wave propagation in fast burning "gasless" systems containing low-melting agent.

4-28 B. S. SEPLYARSKII, S. V. KOSTIN, T. P. IVLEVA

ANALYTICAL METHOD OF CALCULATION OF THE TIME CHARACTERISTICS OF HYBRID DUSTS IGNITION WITH A HEATED BODY

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Regularities of hybrid gas suspension ignition by a hot body have been studied by approximate analytical and numerical methods. It is shown that the ignition can occur in three different modes: kinetic, diffusion, and transition ones. The parameters of realization of each ignition mode are determined. The influence of combustible gas addition on the ignition regularities is shown to be significant for both high and low values of Z (an analog of Semenov's criterion). An approximate equation for evaluation of time characteristics of ignition in the whole area of Z variation has been suggested for the first time.

4-27 B. S. SEPLYARSKII

THE NATURE OF AN ANOMALOUS DEPENDENCE OF THE COMBUSTION RATE OF "GASLESS" SYSTEMS ON THE DIAMETER

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A new convective-conductive model of combustion of "gasless" systems is suggested for explaining the experimental results which are anomalous from the viewpoint of the combustion theory. The main factors affecting the combustion wave propagation are established with regard to the limiting role of melt penetration into the initial mixture. It is shown that if a fine component contains some adsorbed gases, releasing in the warming-up zone, a decrease in the sample

diameter will result in an increase in the combustion wave velocity. From the viewpoint of the convective-conductive mechanism of combustion of "gasless" systems, some experimental results, which do not have any explanation in the combustion theory, are explained.

4-34 A. A. SHRAIBER[1], V. G. NOSACH[2]

MATHEMATICAL MODELING OF HEAT AND MASS TRANSFER PROCESSES IN INTRADUMP GASIFICATION OF COAL-CONTAINING WASTE

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We construct a family of nonstationary mathematical models of heat and mass transfer in a fixed dense bed of mono- or polydisperse particles as applied to a new technology of intradump gasification of waste of coal mining and concentration. It is assumed that the substance of these particles consists of solid carbon, moisture, mineral part, and volatile matter, and the products of combustion of natural or producer gas are blown through the bed. As a result, we find nonstationary distribution of gas and particle temperatures, flow rates of gas components, and solid-carbon concentration in the particles. We give examples of numerical results obtained using the developed models as well as an estimate of the economic efficiency of the technology proposed.

4-39 M. O. STURTZER[1], K. TOGAMI[2], S. YAMASHITA[3], T. KAWAUCHI[1], K. TAKAYAMA[1]

DETONATION WAVE GENERATED BY HYPERVELOCITY PROJECTILE

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Recent experimental results on generation of oblique detonation waves over hypervelocity projectiles launched into detonable gaseous mixtures are reported. Eighty-degree apex angle cone-cylinders were launched at about 3 km/sec into an optical visualization chamber placed inside the 1.7-m diameter and 12-m long recovery chamber of a two-stage light gas gun of the Shock Wave Research Center. The visualization chamber was filled with reactive mixtures of hydrogen/oxygen and hydrogen/oxygen/nitrogen at various initial pressures. The detonation waves generated are observed with double exposure holographic interferometry and also sequentially recorded with a high-speed video camera capable of recording one hundred frames at one million frames per second. The result of observations clearly shows detonation waves and wakes behind high-speed projectiles.

4-29 V. P. SOLNTSEV, V. V. SKOROKHOD, V. G. BOROVIK, G. A. FROLOV, A. P.

RUBAN

DYNAMICS OF TEMPERATURE FIELDS IN TOPOCHEMICAL POWDER REACTING SYSTEMS

I. N. Frantsevich Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Kiev, Ukraine, frolov@alfacom.net

Results which open the dynamic nature of topochemical reactions and mechanisms of interaction of metals with gases are obtained. The technique is suggested allowing one to carry out investigations of topochemical reactions "solid body-gas", thus making it possible to lay the foundations of dynamic theory of heat resistance of metals, alloys, and composite materials, and, finally, to develop new generation of functional materials.

4-05 V. S. VIKHRENKO, A. V. KONDRATENKO, J. SCHROEDER, D. SCHWARZER

CHARACTERISTIC FEATURES OF ENERGY TRANSFER FROM A VIBRATIONALLY EXCITED MOLECULE OF CARBON DIOXIDE TO A LIQUID SOLVENT

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Molecular dynamics simulations of vibrational energy relaxation of carbon dioxide in several liquid solvents (xenon, carbon tetrachloride, dichloromethane) are performed. It is demonstrated that the main channel of energy transfer in all the solvents is the lowest frequency bend vibrational mode of carbon dioxide. Due to weak resonance conditions, the highest vibrational energy relaxation rate is observed in dichloromethane, while in xenon it is almost two orders of magnitude lower. Thus, the importance of direct vibration-to-vibration energy transfer is demonstrated.

4-35 Yu. V. YUFEREV, L. M. YUFEREVA, S. S. TUMANOV

INVESTIGATION OF THE PROCESSES OF COMBUSTION AND HEAT TRANSFER IN A 1.25-MW BOILER WITH A FLUIDIZED-BED FURNACE

Military Engineering-Technical University, St. Petersburg, Russia

On the experimental base of the Military Engineering-Technical University, experimental investigations of the processes of combustion and heat transfer in a 1.25-MW boiler with a low-temperature fluidized-bed furnace were carried out. The furnace was fired with coal, peat, coal-pit mix, or wood pellets. The results of the tests gave new data on the basic components of the heat balance of the boiler and on heat transfer in the fluidized-bed furnace firing the above-listed fuel. The experimental dependences obtained have allowed the improvement of the technique of thermal calculation of low-power boilers with low- temperature fluidized-bed furnaces.

Section 5

"HEAT AND MASS TRANSFER IN TWO-PHASE (VAPOR-LIQUID) SYSTEMS"

5-02 A. N. ANTONOV, S. B. PETROV, A. V. GORYACHEV

CALIBRATION TESTS OF RIGS FOR TESTING AVIATION MATERIALS UNDER ICING CONDITIONS

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Facilities have been built at the TsIAM Institute for testing various objects under icing conditions. They are based on the existing TsIAM U-9M, Ts-2, and Ts-IA rigs with nozzles diameters of 0.415 m, 1.02 m, and 1.87 m, respectively. They allow imitation of the conditions of maximum duration and the maximum short-time icing in accordance with the Russian and foreign normative documents in the range of velocities from 0 to 250 m/sec, temperatures to -40 oC, altitudes up to 15 km, moisture content to 100%, water content to 3 g/m3.

5-01 B. P. AVKSENTYUK[1], V. M. KRAVCHENKO[1], V. V. OVCHINNIKOV[2], V. Ya. PLOTNIKOV[2]

STUDY OF THE SHAPE OF VAPOR CAVITIES IN EXPLOSIVE BOILING

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Results of investigations of the sizes and shapes of vapor cavities during heterogeneous explosive pool boiling of organic fluids under saturation conditions are given. A stainless steel tube with an outer diameter of 2.5 mm was used as a test heater. The experiments were performed for quasistationary heating of the test heater. Filming of the process of an explosive boiling was carried out by a high-speed camera with up to 25 000 shots per second. It is shown that the law of growth of the transversal size of cone-shaped parts of vapor formations, which have arisen as a result of propagation of evaporation fronts are identical to all cross sections. It is proved that in all experiments the power in the law of growth for a cone-shaped part coincides with that for vapor bubbles. The relation for an envelope of vapor cavity, which has arisen in heterogeneous explosive boiling under saturation conditions, is suggested.

5-03 V. G. BAIDAKOV, A. M. KAVERIN, G. Sh. BOLTACHEV

KINETICS OF BOILING-UP OF A GASSED LIQUID

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A theory of spontaneous boiling-up of supersaturated liquid solutions has been suggested. It takes into account all the main factors that determine the bubble growth: volatility of the solution components, viscous and inertial forces, diffusive supply of a substance to a nucleus. In experiments on measurement of the lifetime for nitrogen-helium and oxygen-helium metastable solutions the nucleation rate as a function of temperature, pressure, and concentration has been determined. The result of experiments is compared with the theory being developed. One can see good agreement between theory and experiment if calculations of the nucleation rate take into account the size dependence of the properties of vapor-phase nuclei.

P. N. BELKIN, S. Yu. SHADRIN

CALCULATION OF THE TEMPERATURE OF A HEATED ANODE

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Comparison is made between the models used for calculation of the heated anode temperature. The models are based on the solution of the heat-transfer equation in a thin vapor-gas shell. The voltage-temperature characteristics obtained agree with the experimental data quality.

5-04 P. N. BELKIN, I. G. D'YAKOV

THICKNESS OF A VAPOR-GAS SHELL IN ANODE HEATING

N. A. Nekrasov Kostroma State University, Kostroma, Russia, genphys@ksu. kostroma. net

A model of heating a vertical anode based on the modified Kutateladze method is discussed. The voltage-current and voltage-temperature characteristics obtained on the basis of the model fit experimental data.

5-05 M. BIGLARI, I. M. DERGUNOV, A. P. KRYUKOV

STABILITY OF A VAPOR FILM ON THE SURFACE OF A HOT SPHERE IMMERSED IN SUPERFLUID HELIUM

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In this work the behavior of a vapor film formed on the surface of a hot sphere immersed

in He-II is studied. It is assumed that the temperature of the sphere is constant and does not vary during the process. A system of equations which allows one to find the radius of the vapor film depending on time has been formulated. This system has been solved numerically. Stability of steady solution has been investigated and the range of existence of such a solution has been found.

5-07 N. V. BULANOV[1], B. M. GASANOV[2]

CHARACTERISTIC FEATURES OF BOILING OF EMULSIONS INVOLVING A LOW-BOILING DISPERSE PHASE

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Basic results of investigation of heat transfer in boiling of the emulsion whose disperse phase is formed of a liquid (solution) with the boiling temperature much lower than the boiling temperature of the disperse medium of the emulsion studied are given. We consider heat transfer in boiling of the disperse phase of an emulsion. One of the characteristic features of boiling in this case is a large delay in the start of boiling which exceeds the temperature of saturated vapors T_s by 100 °C and more. The possible reasons for this delay and the means of its reduction are considered.

5-06 V. N. BUZ, K. A. GONCHAROV

MODELING OF VAPOR FORMATION IN POROUS EVAPORATORS OF LOOP HEAT PIPES

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A nonstationary one-dimensional mathematical model of vapor formation in capillaryporous structures of loop heat-pipe evaporators is suggested. The results of calculations are presented, the basic mechanisms of heat transfer revealed in computational analysis are described. It is shown that near the section of heat input there are pulsations of the working fluid. The analysis of the influence of heat conductivity of capillary-porous structure on the heat transfer processes is performed. Characteristic features of the processes are determined at heat fluxes close to maximum ones.

5-57 V. N. BUZ, FATTUKH TAHER

DETERMINATION OF THE RESERVES OF ABSORPTION-DIFFUSION REFRIGERATORS ON THE BASIS OF THEIR MATHEMATICAL SIMULATION

I. I. Mechnikov Odessa National University, Odessa, Ukraine

A critical analysis of the existing approaches to computational simulation of absorption-diffusion refrigerators is given. Two mathematical models are suggested: a simplified model – in concentrated parameters on the basis of balancing algebraic equations and a specified one in the distributed parameters. Examples of calculations and analysis of the results obtained are presented.

5-53 V. D. CHAIKA

A NEW PROCESS OF WATER BUBBLE BOILING ON HORIZONTAL TUBES AND APPROACHES TO ITS CALCULATION

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Experimental investigation of the process of bubble boiling of water on horizontal single copper tubes of 10, 16, 24, 34, and 70 mm in diameter at a pressure of 5 ... 200 kPa was carried out. The investigation was conducted under the conditions of free convection at a saturation pressure of 5 ... 200 kPa. The heat flux was conventionally removed from the tube surface. Simultaneously, the process of vapor generation was studied by filming in two projections. The investigation has revealed a new process of bubble boiling of water on the lower generatrix of a horizontal tube. Micro- and macroscopic approaches to the calculation of this process are considered.

5-20 V. I. DEEV, K. V. KUTSENKO, A. A. LAVRUKHIN, V. S. KHARITONOV TRANSIENT BOILING CRISIS OF LIQUIDS

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A new physical model of a boiling crisis upon a rapid increase in power on a heated surface is presented. The calculation of the time of transition to film boiling in liquids as a function of the heat flux and pressure is calculated. The results obtained are in good agreement with the known experimental data.

5-14 B. M. GALITSEISKII, V. Yu. ZUEVA

MATHEMATICAL MODEL AND SOME RESULTS OF CALCULATION OF TWO-PHASE TURBULENT JETS WITH MASS TRANSFER

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A mathematical model for a two-phase turbulent jet that takes into account the dynamic and thermal nonequilibrium phases as well as phase changes is proposed. Two jets (two-component and three-component) have been calculated with the use of this model. In a two-component jet, beginning with a distance of 50 nozzle radii from the nozzle exit section, in the central part of the jet the processes of phase changes are close to equilibrium ones. In a three-component jet, due to evaporation of a liquid component at a smaller saturated vapor pressure the temperature of drops decreases, and the vapors of a component with a larger saturated vapor pressure condense. Upon evaporation of a more volatile component, in the central jet part the phase changes of the second component tend to equilibrium ones.

A. S. GAVRISH

PARTICULARITIES OF DROPWISE CONDENSATION CURVES AND CYCLE

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Dropwise condensation allows one to considerably intensify heat transfer in comparison with filmwise one. This general laws governing the process of dropwise condensation have been analyzed with the use of the well-known models of Tanasawa, Jacob, Tammam, and Boechme. This allows us to carry out investigation and describe the characteristic features of dropwise condensation cycle and curves. It also allows us to suggest recommendations for the practical use of dropwise condensation.

5-15 I. I. GOGONIN

GENERALIZATION OF EXPERIMENTAL DATA ON CONDENSATION HEAT TRANSFER OF A MOVING VAPOR INSIDE VERTICAL TUBES

Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia

Studies of condensation heat transfer of a moving vapor for the case of cocurrent vapor-film flow are reviewed. Generalization of many experiments carried out by various researchers showed that an increase in the velocity in wavy film flows does not result in enhancement of heat transfer in comparison with the case of an immovable vapor. In turbulent film flows $We > We_{Cr}$, intense film entrainment from the wave crests into the vapor core leads to significant heat transfer intensification.

5-16 V. A. GRABEZHNAYA, P. L. KIRILLOV

PREDICTIONS OF HEAT TRANSFER IN TUBES AND ROD BUNDLES WITH

WATER FLOW AT SUPERCRITICAL PRESSURES

A. I. Leipunskii Physical and Power Engineering Institute, Obninsk, Russia, kirillov@ippe. obninsk. ru

The current ideas about the processes of heat transfer and hydraulic resistance in tubes and rod bundles are briefly surveyed in order to select relationships for supercritical water-cooled reactors. An analysis of most generally used correlations for predicting heat transfer at SCP under normal heat transfer conditions and their comparison with new data obtained in SSC RF - IPPE is made. The correlations are recommended for predicting hydraulic resistance and heat transfer coefficients in tubes and rod bundles under normal (without deterioration) heat transfer conditions. These correlations can be used until new data and recommendations are obtained.

5-17 V. S. GRIGOR'EV, V. G. ZHILIN, Yu. A. ZEIGARNIK, Yu. P. IVOCHKIN, K. G. KUBRIKOV

INVESTIGATION OF THE CHARACTERISTIC FEATURES OF THE DEVELOPMENT AND DESCENT OF A VAPOR FILMON HEMISPHERICAL SURFACES

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The results of experimental studies of local processes, which proceed on change in the boiling regime on a superheated hemispherical surface are presented. The experiments were conducted at atmospheric pressure and initial temperatures of the heated surface and cooling liquid of 600-1000 and 288-368 K, respectively. In the experiments, hemispheres made of stainless steel and copper were used. It is established that the process of descent of vapor films is very diversified and depends on the condition and thermophysical properties of the heating surface. They vary from a calm change of film boiling to explosive-like descent of a vapor film accompanied by ejection of vapor jets. The latter regime occurs only on surfaces coated with oxides or scale depositions. The thickness of oxide films was determined experimentally. It was shown that, with the explosion-like descent of a vapor film, the rate of hemisphere cooling reached approximately 300 K/sec, with heat flux density being 10 W/m. The regime of oscillations of the vapor cavity as a whole was observed. The boundaries of its existence and characteristic parameters of the process were determined.

5-18 L. G. GRIGORYAN, D. A. KRYUCHKOV

MODELING OF WATER-AIR COOLING UNITS

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A system of differential equations which simulate heat transfer in a three-phase flow water-air cooled unit with allowance for mass transfer between the phases in contact is suggested.

The validity of the model is confirmed experimentally. We have designed a new unit which implements the principles of air-evaporating cooling, enabling the enhancement of heat transfer.

5-19 A. L. GURASHKIN, M. A. PARSHAKOVA, G. V. ERMAKOV

THE RESEARCH INTO THE KINETICS OF SUPERHEATED N-HEXANE BOILING UP ON THE SILICA GEL SURFACE

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This work presents the results of experimental investigation of the kinetics of superheated n-hexane boiling-up on a silica gel surface. A comparison with the data obtained earlier in a pure glass cell and also in the cells covered by glass powder and activated coal is made . It appears that it is possible to attain superheats close to the limit of homogeneous nucleation in the presence of an adsorbent. The mechanism of boiling-up on the porous surface adsorbent is considered. It is supposed that the pore in which nucleation occurs represents a wide sphere connected with the surface of a vessel by a narrow channel ("bottle" shaped pore). We made a conclusion that the bubble initiating boiling-up can be present in such pores during preliminary condensation even on very good wetting.

5-22 G. K. IVANITSKII

GROWTH OF A VAPOR BUBBLE IN SUPERHEATED LIQUIDS

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Based on the earlier developed model of single bubble dynamics, a numerical analysis of various experiments on bubble growth in superheated liquids has been carried out over a wide range of liquid superheats, including the case of limiting superheating. The model allows the prediction of the experimental results without any limiting approximations and empirical correlations more accurately than theoretical calculations by other known models. It is shown that the use of the model for analyzing experimental data on bubble growth in superheated liquids enables one to obtain new valid information about the important features of the phenomena investigated.

5-21 G. K. IVANITSKII

INVESTIGATION OF CRITICAL FLASHING FLOW AND THE FLOW CHOKING EFFECTS IN SHORT CHANNELS

Institute of Engineering Thermophysics, National Academy of Sciences of Ukraine, Kiev, Ukraine, alexn@givc-kgga.kiev.ua

Some particular properties of critical flashing flow in short tubes over a wide range of input temperatures and back pressures have been investigated within the framework of the previously reported mathematical model, which was developed on the basis of quite a new approach to modeling of a two-phase flow. The most important feature of the flashing flow model consists of taking account of both the pressure and temperature differences between the liquid and vapor phase. The model is shown to be capable of accurate predicting the flow choking effects and the onset of critical flow regimes without any assumptions of the nature of these phenomena. It is found that even in the flow choking regime any disturbances of the back pressure beyond the channel penetrate upstream into the channel with a finite velocity and affect the thermodynamic characteristics of a two-phase flow.

5-23 L. B. KABAKOVA, V. I. ELISEYEV, Y. K. GONTAREV

INVESTIGATION OF HEAT TRANSFER IN THE ZONE OF BOILING OF A TWO-PHASE THERMOSIPHON

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In this work, an attempt was made to analytically investigate heat- and mass transfer processes in bubble boiling in the slit channels of two-phase thermosiphons. The work was based on the model of heterogeneous interpenetrative media. The initial system included the following equations: conservations of mass for liquid and vapor phases, conservation of the quantity of bubbles, motion of bubbles and of the liquid medium, heat transfer in the liquid and bubbles, motion of the surface of bubbles. In addition to these equations, the theory of formation, increase, and bubble detachment on rough walls was used. Based on the model described, boiling in the slit channels of thermosiphons at high pressures was analyzed.

5-24 O. N. KASHINSKII, E. V. KAIPOVA

HYDRODYNAMIC STRUCTURE OF A TWO-PHASE BUBBLE FLOW IN A HORIZONTAL CHANNEL

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The results of experimental investigation of the hydrodynamic structure of a bubble gas-liquid flow in a horizontal flat channel are presented. Measurements were performed by an electrochemical technique using microprobes of wall shear stress and velocity. During the experiments, full realizations of wall shear stress and velocity probe signals were recorded. Corresponding distributions of local void fraction, velocity, and wall shear stress were obtained by processing the records. Comparison of wall shear stress with a measured pressure drop along the channel was made. A significant difference between the flow hydrodynamic structure in the

top and bottom parts of the channel was demonstrated.

5-25 O. N. KASHINSKII, V. V. RANDIN, A. S. KURDYUMOV

EVOLUTION OF THE LOCAL HYDRODYNAMIC CHARACTERISTICS OF AN UPWARD SLUG FLOW IN A VERTICAL PIPE

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A technique of conventional averaging over an ensemble of realizations has been developed and used for measuring the liquid velocity distributions in the liquid slug depending on the distance from the beginning of the plug. We show that in the beginning of the liquid plug there occurs a substantial deformation of the liquid velocity profiles in comparison with a single-phase flow, being the result of the effect of a toroidal vortex escaping from below a previous gas slug. Wall shear stress behavior completely corresponds to heat of the liquid velocity in the near-wall region. Experimental investigation of a gas-liquid slug flow in a vertical pipe was carried out. Measurements were performed using an electrochemical technique.

5-28 A. T. KOMOV, A. N. VARAVA, A. V. DEDOV, R. I. KAMENSKOV-NEMINOV

EXPERIMENTAL INVESTIGATIONS OF HEAT TRANSFER IN A SUBCOOLED SWIRLED FLOW

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A method of conducting experimental investigations of heat transfer in a subcooled swirled flow under the conditions of one-sided heating by a scanning electron beam is presented. The method allows one to determine the temperature and heat flux in the upper high-beat point of the inner gross section perimeter from the measured typical temperature of the gross section without using numerical solution of a steady heat conduction problem.

5-27 A. T. KOMOV, A. N. VARAVA, A. V. DEDOV, V. V. YAGOV

COMBINED HEAT TRANSFER IN A SUBCOOLED SWIRLED FLOW

Moscow Power Engineering Institute (Technical University), Moscow, Russia, KomovA T@mpei. ru

The results of experimental investigation of heat transfer in a subcooled swirled flow of water with one-sided heating of working sections by a beam of electrons with a high energy density are presented. The mechanism underlying the basic processes of energy transfer under

these conditions has been analyzed and recommendations are given for calculation of heat transfer in the cases of single-phase convection, bubble and film boiling that give quite satisfactory agreement with experimental data.

5-29 S. V. KONEV, V. A. OLEKHNOVICH

EXPERIMENTAL INVESTIGATION ON AN OSCILLATING CAPILLARY HEAT PIPE

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

A number of experiments for understanding the process of oscillating heat transfer in capillary tubes are carried out. A heat transfer device is designed on the basis of an oscillating capillary heat pipe. Photos of bubble nuclei and vapor slug in capillary channels are given. A process of unidirectional oscillations was observed.

5-30 N. M. KORTSENSHTEIN, E. V. SAMUILOV

HEAT AND MASS TRANSFER IN THE PROCESS OF CONDENSATION-RELAXATION OF A SUPERSATURATED VAPOR

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The process of bulk condensation of vapor from a vapor-gas mixture after instantaneous creation of a supersaturated state is considered. This process is defined by us as condensation-relaxation. Based on analytical and numerical consideration of the process with regard to latent heat release, scaling relations are derived, which relate the condensation relaxation time and the number density of drops to the nucleation rate at the initial moment of time. The relations derived are shown to provide a fundamental possibility of experimental determination of the nucleation rate by recording the curves of the temperature in the volume of a condensing vapor.

5-31 B. V. KOSOI, D. N. NIKITIN

MODELING OF MINIATURE TWO-PHASE THERMAL CONTROL SYSTEMS

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This paper considers the problems of creation of miniature two-phase thermal control and cooling systems for electronics with high heat flux densities. The concept of micro heat pipes combines the modem technologies of miniaturization of technical devices with high performance of thermal control systems based on the two-phase heat transfer. The well-known methods of modeling micro heat pipe and unsolved problems have been analyzed. The fractal approach to the

design of the networks of heat conduction elements has been suggested, and it predicts an improvement of the thermal control process performance.

5-26 V. P. KOVERDA, V. N. SKOKOV

LOW-FREQUENCY HIGH-ENERGY PULSATIONS IN THE PROCESSES OF HEAT AND MASS TRANSFER

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Investigations of the dynamics of fluctuation of heat and mass transfer show that in crisis and transient regimes high-energy pulsations with a power spectrum inversely proportional to frequency (flicker or 1/f fluctuation) are observed. Such a spectrum presupposes power transfer from a high-frequency to low-frequency modes and the possibility of large-scale catastrophic ejections in a system. The theory shows that such fluctuations arise in the system due to simultaneous occurrence of interacting phase transitions in the presence of a white noise of certain intensity. The distribution function of fluctuations in the case of scale transformations of the system of stochastic equations that describe the 1/f noise generation are investigated. It is shown that in the case of scale transformations the Gaussian distribution of the random process with 1/f spectrum transformed into exponential distribution typical of extreme outlier statistics. The probability of such ejections should be taken into consideration in predicting the stability of various regimes of heat and mass transfer.

5-32 V. Yu. KRAVETZ[1], Yu. E. NIKOLAENKO[2], Ya. V. NEKRASHEVICH[1]

EXPERIMENTAL INVESTIGATION OF THE HEAT TRANSPORT CHARACTERISTICS OF MINIATURE HEAT PIPES

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The results of investigations of the heat transport characteristics of miniature heat pipes of diameter 2.4 and 6 mm and length from 100 to 230 mm are presented. The material of the shell of pipes is copper. It is shown that the smaller the inner steam space of heat pipes, the greater the influence of outer conditions on their heat transport characteristics. It is shown that to determine the total thermal resistance of miniature heat pipes it is necessary to take into account the thermal resistance due to the motion of vapor from the zone of evaporation to the zone of condensation. The possibilities of increasing the heat transfer characteristics of such miniature heat pipes by applying capillary structures of optimum construction are considered.

5-33 A. P. KRYUKOV, Yu. Yu. SELYANINOVA

CHARACTERISTIC FEATURES OF HEAT AND MASS TRANSFER IN VAPOR FILM GROWTH INSIDE A POROUS ENVELOPE FILLED BY HELIUM II

Moscow Power Engineering Institute, Moscow, Russia

The dynamics of an interface in superfluid helium boiling on a cylindrical heater located in a coaxial porous envelope in microgravity is investigated. Different methods of calculation of pressure difference along the liquid inside the porous medium are considered. Porous matter with various structure characteristics is studied. The possible application of these materials for construction of a corresponding experimental cell is investigated.

5-34 V. V. KUZNETSOV[1], A. S. SHAMIRZAEV[1], I. N. ERSHOV[2]

BOILING HEAT TRANSFER AND UPFLOW REGIMES IN VERTICAL RECTANGULAR MINICHANNELS

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In boiling under constricted conditions the influence of capillary forces is very important. It determines the mode of flow and finally heat transfer. The aim of this study was investigation of the characteristic features of boiling heat transfer in microchannels. This study consists of two parts. Rise of single air slugs in vertical and tilted rectangular mini channels of width of the order of a capillary constant is considered in the first part. The second part considers boiling of coolant R21 with natural liquid circulation generated by rising slugs in assemblies of vertical microchannels. Measurements were carried out under the conditions of a constant wall temperature.

5-35 D. O. LAPOTKO[1], A. I. SHNIP[1], O. G. MARTYNENKO[1],

E. Yu. LUKYANOVA[1], O. V. KLIMOVICH[2]

NONSTATIONARY HEATING AND PHASE TRANSITIONS IN A LIVE CELL UPON ABSORPTION OF LASER RADIATION

A. V. Luikov Heat and Mass Transfer Institute, Minsk, Belarus; Minsk State Medical University, Minsk, Belarus, iclab@hmti.ac.by

In medical applications of lasers, their safety and photodamage control have become one of the key issues for laser medicine. Recently, we have reported about application of photothermal (PT) microscopy for detecting laser-induced damage in individual Red Blood Cells. Cell damage was accompanied by PT responses of specific shape with strong negative short peak that was superimposed on conventional response due to heating and cooling of the cell. Preliminary analysis of these responses indicated that such signals cannot be caused by heating alone and must involve phase transitions such as vaporization. Therefore, secondary photoinduced phenomena such as microbubble formation must also be considered. The objective of this work was to evaluate local photoinduced thermal phenomena in a single cell at theoretical

and experimental levels.

5-36 O. A. LONSHCHAKOV, V. G. D'YAKONOV

CONDENSATION HEAT TRANSFER OF THE VAPORS OF BINARY MIXTURES OF PARTIALLY SOLUBLE LIQUIDS

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The results of experimental studies of the influence exerted by composition on the intensity of a convective heat transfer during condensation in a vertical tube of a mixture of the vapors of ethyl acetate and water are presented. A comparison of the experimental data with theoretical and experimental dependences is carried out. Generalization of measured data is carried out.

5-64 P. V. LUKANIN, V. I. SAUNIN

HEAT PUMPS - STATE OF THE ART AND PROSPECTS

St. Petersburg State Technological University of Plant Polymers, St. Peferslurg, Russia

Normative documents determining the power strategy of Russia are listed in the report. The problem to be solved is to increase the efficiency of the use of traditional energy resources and to make a maximum use of nontraditional ones. One of the effective methods of utilization of a low-potential heat power is the employment of heat pump facilities. The data on the use of these facilities abroad and in Russia are presented. Considerable attention is paid to the problems of utilization of a low-potential heat at enterprises of a as investigation of the characteristic features of boiling heat transfer in microchannels. Tins study consists of two parts. Rise of single air slugs in vertical and tilted rectangular mini channels of width of the order of a capillary constant is considered in the first part. The second part considers boiling of coolant R21 with natural liquid circulation generated by rising slugs in assemblies of vertical microchannels. Measurements were carried out under the conditions of a constant wall temperature.

5-35.1 D. O. LAPOTKO[1], A. I. SHNIP[1], O. G. MARTYNENKO[1], E. *Yu. LUKYANOVA, O. V. KLIMOVICH*[2]

NONSTATIONARY HEATING AND PHASE TRANSITIONS IN A LIVE CELL UPON ABSORPTION OF LASER RADIATION

A. V. Luikov Heat and Mass Transfer Institute, Minsk, Belarus; [2]Minsk State Medical University, Minsk, Belarus, iclab@hmti.ac.by

In medical applications of lasers, their safety and photodamage control have become one of the key issues for laser medicine. Recently, we have reported about application of photothermal (PT) microscopy for detecting laser-induced damage in individual Red 31ood Cells.

Cell damage was accompanied by PT responses of specific shape with strong 3egative short peak that was superimposed on conventional response due to heating and cooling of the cell. Preliminary analysis of these responses indicated that such signals cannot be caused by heating alone and must involve phase transitions such as vaporization. Therefore, secondary photo induced phenomena such as microbubble formation must also re considered. The objective of this work was to evaluate local photoinduced thermal rcenomena in a single cell at theoretical and experimental levels.

5-36 O. A. LONSHCHAKOV, V. G. D'YAKONOV

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5-64 P. V. LUKANIN, V. I. SAUNIN

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5-37 A. V. LUN-FU, V. N. KOROLEV

INTENSIFICATION OF THE PROCESS OF COOLING OF THE PROPANE-BUTANE MIXTURE VAPOR IN AIR COOLED APPARATUSES

Ural State Technical University, Ekaterinburg, Russia

The efficiency of cooling, by a two-phase medium, of a bundle of finned pipes inside which a vapor propane-butane vapor mixture (cooling agent) not only flows, but also is condensed is investigated. Is shown, that the temperature of the cooling agent at the exit from an air-cooled apparatus with a bundle of pipes cooled by a two-phase flow was 5 °C lower in comparison with cooling by air. This corresponds to a decrease of approximately by 1,2 bars in the condensation pressure vapor of the cooling agent Such a reduction in the condensation pressure results in a decreasing in the degree of compression in a centrifugal compressor from 5.25 to 4.63, which allows one to increase deviation of the centrifugal compressor from 0.10 to 0.15.

5-38 O. E. MALETSKAYA, N. M. FIALKO, E. N. SHEVCHUK, V. L. YURCHUCK

COMPUTATIONAL INVESTIGATION OF THE UNSTEADY REGIMES OF OPERATION OF A SOLAR SODIUM EVAPORATOR UPON INPUT OF A NONUNIFORM HEAT FLUX

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It is for the first time that the experimental data on superheating are considered and generalized for incipient sodium boiling in a high-temperature receiver-evaporator, perceptive to concentrated solar radiation. A relation for calculating the beginning of boiling-up is obtained depending on the temperature (pressure) of saturation and density of a heat flux. Based on this, evaluation of the influence of the unsteady heat flux nonuniformity on the temperature field of the evaporator is given.

5-55 D. MIKIELEWICZ

MODELING OF CONVECTIVE HEAT TRANSFER IN FLOW BOILING

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A semi-empirical correlation describing the two-phase flow boiling in channels is presented. The use of correlation is very simple on account of its analytical form, which is its fundamental advantage. It may occur that the heat transfer coefficient deteriorates with the flow quality in some cases. The correlation presented possesses such a capability which raises its quality. The accuracy of the proposed correlation is comparable with the best correlations known today. It is of general character, and its coefficients do not depend on the type of fluid. In the paper the influence of selection of correlation describing the pool-boiling heat transfer coefficient has been scrutinized, which turned out to be significant.

5-54 J. MIKIELEWICZ[1], D. MIKIELEWICZ[2], D. BARNIK[1]

MODELING OF NUCLEATE BOILING HEAT TRASNFER IN THE FILM FORMED BY AN IMPINGING JET

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A simple model of heat transfer for turbulent liquid films with nucleate boiling created by impinging jets is suggested. The case of a developing film just outside the stagnation region is considered. For this case the model is derived on the basis of a change in the film thickness due to inertia and friction forces. Incorporated into the model is a blowing parameter, which models the transverse transport of momentum caused by departing bubbles. The velocity and temperature distributions in the liquid film have been calculated, which enabled determination of the corresponding heat transfer coefficient and Nusselt number.

5-39 G. J. MILIAUSKAS, R. V. MONTVILAS, R. P. BANKAUSKAS, J. B. GUDZINSKAS

CHARACTERISTIC FEATURES OF TRANSPORT PROCESSES IN AN EVAPORATING DROPLET IN RESPONSE TO HEATING TECHNIQUE

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The characteristic features of a change in the state of a semitransparent evaporating droplet which evaporates under different heating conditions are investigated. Evaluation is made taking into account interdependence of external heat and mass transfer with complex heat transfer inside the droplet. A complex problem of unsteady radiative – conductive heat transfer inside the evaporating droplet during its complex heating is solved in order to estimate the dynamics of the evaporating droplet surface temperature. The interaction of mass transfer and heat convection processes in the droplet surroundings is taken into account by the function of the Spalding heat transfer number. The influence of radiation absorption on combined heat transfer in semitransparent droplets is estimated using the function of radiation spectral intensity. The intensity of radiation absorption by the droplet was determined taking into account the spectral optical features of the liquid.

5-40 S. M. MITROFANOV, P. A. PAVLOV

MODELING OF WALL EXPLOSIVE BOILING-UP

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A computer model of the process of wall explosive boiling-up has been developed. With the aid of the model we can obtain the geometrical characteristics of explosive boiling-up (length of three-phase contact line, drainage area), which are important for measuring heat transmission and complete understanding of an evaporation process. We compare the numerical results with

the approximate analytical theory developed without taking correlation during nucleation into account. Deviation between the results of the modeling and the results obtained theoretically is related to correlation of the location of consecutively appearing nucleation centers. The dynamics of spreading of the explosive boiling-up front edge are calculated according to the given wall temperature gradient.

5-41 A. G. MURAV'EV

MATHEMATICAL MODEL OF HEAT AND MASS TRANSFER AT COMMENSURABLE PHASE RESISTANCES IN THE PROCESS OF ABSORPTION OF A GAS ON A DROP OF A NONVOLATILE ABSORBENT

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Based on the known model of heat or mass transfer inside a drop, a model of heat and mass transfer is constructed at commensurable phase resistance in the process of absorption of the A component from a gas mix on a drop of a nonvolatile absorbent. Heat and mass transfer in a gas phase is described with the aid of heat – and mass-transfer coefficients. The equations of the model are obtained by using the Duhamel formula and balance relations for heat and mass fluxes on the drop surface. These equations are solved analytically by means of Laplace transformation. Solutions of the resulting integrodifferential equations are given as a series of exponential functions with stationary values of coefficients, as well as solution of an internal problem.

5-42 V. E. NAKORYAKOV, N. I. GRIGORIEVA

CONCERNING SIMULATION OF HEAT- AND MASS TRANSFER IN VAPOR ABSORPTION BY A STAGNANT LAYER OF THE SOLUTION WITH AND WITHOUT SURFACTANTS

S. S. Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia

Based on simple models of nonisothermal absorption for small and large times, we analyze the influence of heat release and heat removal on the intensity of vapor absorption by a stagnant layer of solution without a surfactant. The models are considered which take, and do not take, into account the phase interface motion. Calculations and experimental investigations of the absorption of steam by a stagnant layer of an aqueous solution of lithium bromide are compared and the results are presented. Some problems and controversies in the existing models describing heat- and mass transfer during absorption of vapors by surfactant-containing solutions are considered. A technique for determining the gradients of surface tension and Marangoni numbers under the conditions of heat pump operation is suggested.

5-43 E. I. NESIS, S. A. GULEVSKII

CONCERNING THE DEPENDENCE OF THE HEAT OF PHASE TRANSITION ON THE INTENSITY OF SYSTEM OVERHEATING

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An improved formulation of the dependence of phase equilibrium in a binary system consists of the equality of specific entropies of both phases. To carry out phase transition, it is necessary to increase (or decrease) a temperature at a constant pressure, i.e., to overheat or cool the systems by imparting to it (or removing) the heat of phase transition, whose magnitude depends not only on the pressure and temperature, but also on the intensity of the processes of heating or cooling.

5-44 A. V. OVSYANNIK

MODEL OF HEAT TRANSFER PROCESSES IN BOILING OF LIQUIDS ON FINNED SURFACES

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A mathematical model of the processes of heat transfer in developed bubble boiling of liquids on nonisothermal (finned) longitudinal and radial surfaces is suggested. The structure of the given model does not include the quantative characteristic of heat transfer intensity in an explicit form. Solution of the model obtained numerically agrees well with the experimental data obtained in investigation of the boiling processes in acetone and ethyl alcohol on finned surfaces.

5-45.1 A. V. OVSYANNIK, M. N. NOVIKOV, N. A. VALCHENKO, A. DROBYSHEVSKII

BOILING HEAT TRANSFER OF ACETONE AND ETHYL ALCOHOL ON HORIZONTALLY FINNED TUBES

P. O. Sukhoi Gomel State Technical University, Gomel, Belarus, Nominik@yand.ex.ru

Experimental investigation of the influence of the finned surface geometry on roiling heat transfer of acetone and ethyl alcohol in the range of heat fluxes 8000-63000 W/m^2 was carried out. Experiments were conducted under the conditions of free motion at atmospheric pressure. Semiempirical dimensionless equations have been obtained which allow one to calculate the intensity of boiling heat transfer of acetone and ethyl alcohol on a finned surface under the studied conditions.

5-46 A. N. PAVLENKO, A. M. MATSEKH, A. V. MOROZOV

INVESTIGATION OF FLOW DYNAMICS AND HEAT TRANSFER IN FALLING INTENSIVELY EVAPORATING WAVY LIQUID FILMS

S. S. Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia, pavl@itp.nsc.ru

Dynamics and heat transfer in gravitational flow of wavy films of a cryogenic liquid on vertically oriented heated surfaces in the regimes of boiling and evaporation were experimentally investigated. It is found that over more extensive heaters along the stream a kind of the crisis is implemented, the development of which is due to the spreading of the temperature disturbance in the heated wall upstream. Generalization of the empirical data obtained shows that the critical heat flux under the conditions of the development of this kind of a crisis can be significantly lower than that calculated by the known hydrodynamic dependences. With the heated wall parameters implemented in the experiments, an autowave transition is being developed, characterized by the displacement of the bubble boiling area by the drying front when "dry" patches achieve the critical size at the lower part of the heater.

5-47 A. N. PAVLENKO, I. P. STARODUBTSEVA

ON THE SPECIFICATION OF NONSTATIONARY BOUNDARY CONDITIONS AT THE FRONT OF THE CHANGE OF BOILING REGIMES

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The results of numerical simulation of local film boiling site evolution are presented considering the nonstationary character of heat transfer in the boundary neighborhood of different boiling regimes. New data on the development dynamics of the boiling regimes boundary change for different deviations of heat flux from the equilibrium are obtained. The degree of the effect of different types of nonsteadiness in the front on the development dynamics was investigated in the numerical experiments. The calculations of the dynamics of development of the film boiling site obtained by applying experimental dynamic boiling curve are presented. The results are compared with those obtained earlier by applying quasi-stationary and two-zone boiling curves.

5-48 V. N. PISKUNOV[1], A. M. PETROV[1], M. A. ZATEVAKHIN[2], A. I. GOLUBEV[1], K. G. GAINULLIN[1]

NUMERICAL SIMULATION OF PRECIPITATION FORMATION IN MIXED CLOUDS. COMPUTATIONS FOR EXPERIMENT MONTANA

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A computational model of the kinetics of formation of droplet and ice particles in mixed clouds is developed using the kinetic equations of condensation coagulation formulated earlier for two-phase disperse systems. Alongside the new kinetic equations, the model involves equations of mass and heat balance, takes into account the difference in the rates of vapor condensation above water and ice, uses actual condensation and coagulation growth rates, and describes the phase transition dynamics. The developed numerical model is used for computation of the

processes of precipitation formation under the conditions of the Montana experiment of 07/19/1981.

A. A. PRIKHOD'KO[1], V. I. ELISEEV[1], N. V. KUZNETSOVA[2] **MATHEMATICAL SIMULATION OF HEAT AND MASS TRANSFER AND ELECTROCHEMICAL PROCESSES IN THE CELL OF A LEAD-ACID ACCUMULATOR**

[1]Dnepropetrovsk National University, Dnepropetrovsk, Ukraine; [2]Institute of Transport Systems and Technologies, National Academy of Sciences of Ukraine, Kiev, Ukraine, paa@mail.dsu.dp.ua

Based on the equations of hydrodynamics, convective heat transfer, chemical kinetics and electrodynamics, a two-dimensional mathematical model of heat and mass transfer processes in the electrochemical cell of a lead accumulator is constructed with the use of the catalytic wall approach. The results of the numerical investigations of physical and chemical processes in the volume between two electrodes are given. The velocity, concentration, flow density, and temperature distributions obtained are analyzed.

5-49.1 **A. A. PRIKHOD'KO, P. I. KUDINOV, V. I. PIS'MENNYI, A. V. MENYAILOV NUMERICAL SIMULATION OF TRANSONIC VAPOR-GAS FLOWS WITH CONDENSATION**

Dnepropetrovsk National University, Dnepropetrovsk, Ukraine; ZMKB "Progress", Zaporozhye, Ukraine, paa@mail.dsu.dp.ua

The physical and mathematical statement of the problem of vapor-gas mixture flows with phase transitions is considered. The description of numerical methods for solving the initial equations on structured and unstructured grids is presented. Verification of the mathematical models and testing of numerical methods and algorithms of vapor-gas flows simulation are made. Analysis of numerical simulation results of the process of vapor-gas flows with homogeneous condensation in nozzles and blade cascades was made. Distributions of local and integrated gas-dynamical characteristics are presented. Strong influence of phase changes on the structure of flow, local and integral characteristics is shown.

5-65 L. V. PRON', R. A. MARCHAN

GASDYNAMIC HEATER BASED ON A HARTMANN GENERATOR WITH SWIRLING OF GAS JET UPSTREAM OF THE NOZZLE

Dnepropetrovsk National University, Dnepropetrovsk, Ukraine

The results of experimental investigations of a gasdynamic heater with and without swirling of jets are presented. It is shown that there is a range of inlet pressures, in which jet swirling improves overall performance of the gasdynamic heater. Influence of gasdynamic and acoustic characteristics of a swirling chamber on the temperature of heating is revealed.

5-50 N. V. SELIVANOV, P. V. YAKOVLEV, I. A. AGAFONOVA

INFLUENCE OF THE INCLINATION ANGLE OF A HEATER ON THE BOUNDARIES OF A "CHOKING" MODE

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The influence of the angle of inclination of a heater on the boundaries of a "choking" mode in counterflow of steam condensate is investigated. It has been established that the boundaries of the choking mode are determined by the Kutateladze stability criterion. A dimensionless equation for calculating the boundaries of choking as a function of the inclination angle of a heater and pressure criterion is obtained. In all operating modes, the inclination of the heater does not influence heat transfer in condensation. At thermal loadings exceeding the critical one the intensity of condensation heat transfer is reduced almost twice.

5-66 YU. I. SHANIN

SIMULATION OF THE OPERATION OF A HYDRIDE HEAT PUMP IN APPLICATION TO THE CAR CONDITIONER

Fsue Sri Sia Luch, Podolsk, Moscow Region, Russia

The mathematical model developed earlier is applied to calculate the processes occurring in a hydride heat pump (HHP), which is a prototype of a device for car air-conditioning .The heat of the liquid cooling of the engine of internal combustion is to be utilized as a heat source for HHP operation. The model set of simultaneous equations includes nonstationary one-dimensional equations of heat balance in hydride capacities taking into consideration thermal effects during hydrogen absorption/desorption. The time cyclogram of HHP operation (radial distribution of temperature in a cylindrical hydride bed, hydrogen content in hydride capacities, hydrogen pressure, energy and thermal power) is determined in calculations vs. basic parameters. There is a good agreement of calculated data with experimental results.

5-56 S. SINKŪNAS[1], J. GYLYS[1], A. KIELA[2],1. GIMBUTYTE[1]

INFLUENCE OF THE WETTED SURFACE CURVATURE ON THE THICKNESS OF A LAMINAR LIQUID FILM

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Calculations evaluating velocity distribution across a water and transformer oil film and correspondingly the thickness of the film were performed. Investigations were carried out with laminar plane film flowing down and the film flowing on the surface of vertical tubes with

different curvatures. An analytical study evaluating the influence of cross curvature on film thickness using a curvature correction factor is performed. It is shown that under the influence of the convex surface curvature the film thickness decreases with a simultaneous change in its local velocity distribution. Calculations showed that the influence of cross curvature on a very viscous film is considerable.

5-51 E. A. TAIROV, M. Yu. GRITSENKO

DETERMINATION OF A PRESSURE IMPULSE IN A SUBCOOLED LIQUID ON HEAT RELEASE POWER SURGE

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The paper presents physical and mathematical description of nonequilibrium phase transition and dynamics of pressure in a subcooled liquid during intense heating of tube heat-producing element located in the liquid. The calculation technique of a two-stage process has been developed. The technique enables one to determine the duration of expectation time from the point of the heat release power surge to the beginning of shock boiling on the wall and to calculate the dynamics of pressure rise. The results of the calculation have been compared to the data of physical experiments on heaters 10 mm in diameter at the rate of a temperature change from 800 to 3700 K/sec. The experiments have been performed at a pressure of 0.11-4.0 MPa and subcooling of 10-4 K.

5-52 V. G. TONKONOG, Yu. F. GORTYSHOV

PHASE TRANSITIONS IN A LIQUID FLOW

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The results of experimental investigation of the flow of boiling liquids in channels of variable section are presented. The experiments were carried out with water, dioxide of carbon, and nitrogen. Experimental data on the two-phase flow structure, static pressure over the channel, flow rate, and jet pulse of the flow are obtained. The temperature of the liquid phase is determined by the method of indirect measurements. An equation for calculating overheatings in the adiabatic flow process is suggested.

5-09 L. L. VASILIEV

HEAT PIPES - PROBLEMS AND PROSPECTS

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

Heat pipes are one of the most efficient heat transfer devices actually applied in the different brunches of technology (computers cooling, mini and micro chips, mobile phones, systems of telecommunications, modem spacecraft two-phase systems of thermal control). Actually there is a big interest to apply modem types of heat pipes in different miniature devices responsible for the power, heat and cold generation (Rankin cycles, heat 3emps, refrigerators, coolers, compressors, systems for storage of hydrogen and methane, heat and cold accumulators). Republic Belarus was one of the first countries, where at the end of sixties years of the last century the heat pipe R and D was initiated and today there I lot of experience in this brunch of technology.

5-59 L. L. VASILIEV

THE OUTLOOK OF USE OF HEAT PUMPS IN THE REPUBLIC OF BELARUS

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

Current trends and forthcoming applications of sorption heat pumps in Belarus are discussed. Attention is paid to the improvement of the efficiency and adaptation of heat 3cnps to low-temperature waste heat. Ambient air, exhaust air, soil, and rock are the most common types of heat sources of the low-temperature heat. This paper surveys some of the current activities in the field of solid sorption heat pumps. The sorption heat pump represents one of the application areas where theoretical and experimental investigations are being performed now by an increasing number of research institutions and manufactures.

5-58 L. L. VASILIEV, L. E. KANONCHIK

DEVELOPMENT AND INVESTIGATION OF SOLID SORPTION HEAT PUMPS

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Importance of sorption heat pumps for modem energy saving technologies is shown. Results of complex investigation are presented. The investigation is aimed at revelopment of an efficient system for heating running water, houses, industrial buildings and greenhouses. An ammonia gas-driven heat pump is suggested. The characteristic features of the heat pump is the use of a sorbent based on activated carbon fiber “Busofit”, system of heat regeneration, and finned thermosyphones as heat transfer devices. The tests carried out demonstrate that the peat pump developed ensure adecrease of initial energy consumption due to utilization of low-temperature environment (average COP= 1.3-1.4) and specific heat power about 600 W/kg of sorbent bed.

5-08 L. L. VASILIEV, A. G. KULAKOV, L. L. VASILIEV Jr., M. I. RABETSKII, A. A. ANTUKH

MINIATURE HEAT PIPES FOR THERMAL CONTROL OF RADIO ELECTRONIC EQUIPMENT

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An investigation of the laws governing heat and mass transfer in miniature cop- per-water heat pipes (mHP) with three different wick structures: sintered powder, mesh structure, wire bundle for a wide range of working conditions and heat pipe parameters was performed. Experimental results and predicting simulation software verification, peculiarities of testing are described. Modeling, design, manufacturing, and testing of copper miniature heat pipes with sintered powder wick were carried out.

5-10 L. L. VASILIEV, D. A. MISHKINIS, A. G. KULAKOV[1], N. K. LUNEVA, A. M. SAFONOVA[2], Y. V. GINZBURG, S. ROZIN[3]

NEW ACTIVATED CARBON MATERIALS FOR ADSORPTION NATURAL GAS STORAGE SYSTEMS

*A. V. Luikov Heat and Mass Transfer Institute; Institute of General and Inorganic Chemistry, Minsk, Belarus; *Ben-Gurion University, Beer-Sheva, Israel, LVASIL@nsl.hmti.ac.by*

Results of the investigation of microporous carbon materials: activated carbon fiber "Busofit" and wood based activated carbons fabricated by new advanced technology developed at the National Academy of Sciences of Belarus are presented. High values of specific surface areas and micropore volumes give the evidence of the considerable potential of the given materials for gas storage systems. This is confirmed by the methane sorption isotherms. The samples investigated have high methane adsorption capacity (up to 8-12%) at a pressure of 3.5 MPa and temperature 20 °C. The linear equation for the methane adsorption capacity as function of the specific surface area is suggested for estimation purposes. Increasing of natural gas storage density is connected with increasing of filling sorbent density.

5-11 L. L. VASILIEV[1], A. S. ZHURAVLEV[1], A. V. OVSYANNIK[2],

A. V. SHAPOVALOV[1], V. V. LITVINENKO[1]

HEAT TRANSFER IN PROPANE EVAPORATION IN A POROUS COATING OF A HORIZONTAL TUBE AT VARIOUS LIQUID LEVELS UNDER THE CONDITIONS OF A NARROW SPACE

A. V. Luikov Heat and Mass Transfer Institute, Minsk, Belarus; P. O. Sukhoi

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The results of an experimental study of propane boiling on a flooded and partially flooded horizontal tube with a sintered capillary-porous coating are presented. The data obtained that the decrease in a liquid layer above a sample at low heat fluxes promoted boiling heat intensification and a decrease in the tube surface superheating. A heat transfer process on the of the same sample is considered when a tube was placed between two plates.

S. V. VERSHININ, Yu. F. MAIDANIK **HYSTERESIS PHENOMENA IN LOOP HEAT PIPES**

Institute of Thermophysics Ural Branch of the Russian Academy of Sciences, Ekaterinburg, Russia

The results of tests of a number of loop heat pipes carried out with a successive increase in a heat load and its subsequent decrease are analyzed. The main reason for this behavior of a heat pipe is a change in the thermodynamic state of the vapor phase in a compensation cavity. Three factors determining the state of the vapor phase in this cavity have been distinguished: hysteresis of heat transfer during evaporation in the wick, metastable state of the phases in phase transitions, and the initial position of the phase interface in the cavity.

5-60 O. SH. VEZIRISHVILI[1], N. A. MIRIANASHVILI[2], T. SH. MAGRAKVELIDZE[2], K. O. VEZIRISHVILI[3]

EXPERIENCE OF USING THE REGENERATIVE HEAT EXCHANGER IN THE HEAT PUMP CYCLE

Georgian Technical University; A. Eliashvili Institute of Control Systems; [3]Keps of Georgian Academy of Sciences

The results of research of using the regenerative heat exchanger for systems of sea: and cold supply based on heat pump appliances demonstrate that the implementation of the proposed scheme gives economy in energy of 25-35%. Incorporation of correspond- r r recommendations will permit one to improve the volumetric and power indices of heat pump appliances by 9-11% and to increase the reliability of their operation.

5-61 O. SH.VEZIRISHVILI[1], N. A. MIRIANASHVILI[2], *T. SH. MAGRAKVELIDZE[2], K. O. VEZIRISHVILI[3], KH. N. LOMIDZE[2]*

EXPERIENCE AND PROSPECTS OF USING ENERGY-SAVING OF HEAT AND COLD SUPPLY SYSTEMS IN GEORGIA

Georgian Technical University; A. Eliashvili Institute of Control Systems; Keps of Georgian Academy of Sciences

An analysis of the results of many-years running in Georgia of technological and comfort air conditioning systems producing heat and cold and based on heat pump appliances shows that implementation of air conditioning systems based on heat pump appliances in Georgia will give annual economy of about 1.6 to 2.7 million tons of equivalent fuel and will significantly reduce the pollution of the environment.

5-12 V. E. VINOGRADOV, P. A. PAVLOV

GROWTH RATE OF A BUBBLE AT LIMITING SUPERHEATS OF STRETCHED LIQUID

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The growth of vapor bubbles in superheated liquids under negative pressure was studied experimentally and theoretically. An analytic calculation for the rate of growth of a bubble under a negative pressure with heat transfer on the bubble surface was performed. The rates of growth of vapor bubbles in ethanol on a platinum wire at a temperature of 160-170 °C at a negative pressure of 2.0 MPa were measured. The analysis of the obtained results showed that thermodynamic equilibrium has no time to be established in the bubble during its growth in a superheated stretched liquid.

5-13 A. V. VINOGRADOV, A. V. RESHETNIKOV, V. N. SKOKOV, V. P. KOVERDA

1/F FLUCTUATIONS IN CRITICAL BOILING REGIMES

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The dynamics of fluctuations in transition from nucleate to film boiling of water on a wire heater, in the transition of the drops of water, pentane, and hexane to a ball-shaped state on a hot surface and during outflow of a superheated liquid jet from a pressure vessel is investigated experimentally. It is found that in heat transfer burnout and under the conditions of intensive bulk boiling-up of a superheated liquid in a jet the power spectrum of fluctuations have a low frequency component diverging according to the 1/flaw (flicker noise). This effect is connected with the occurrence of nonequilibrium phase transitions in the systems: burnout and crisis of the flow under conditions of superheated liquid boiling-up in a jet.

5-62 V. I. VOLODIN[1], O. N. BULYAK[2], N. F. KAPUSTIN[2] A. M. LITOVSKII[2]

ANALYSIS OF OPERATION OF THE REFRIGERATING MACHINE

EVAPORATOR WITH RESTRICTED DATA ON HEAT TRANSFER

Belarusian State Technological University; Institute for Mechanization of Agriculture, National Academy of Sciences of Belarus, Minsk, Belarus

The method of numerical analysis of the evaporator in a milk cooling installation is presented at limited data on heat transfer from the refrigerant side. The heat transfer process is described by the similarity equations for single-phase flows, which take into account characteristic features of phase change and real geometry of the slotted channel with intensification. For this purpose, a hydrodynamic correction factor, length of flow, porosity, and an equivalent diameter are introduced. Comparison of the results of computational and full-scale experiments was performed.

5-63 M. K. ZAKHAROV, G. A. NOSOV

IMPROVED HEAT PUMP

M. V. Lomonosov Moscow State Academy of Fine Chemical Technology, Moscow, Russia

For technological processes involving production of a low-potential steam, an improved scheme of a heat pump is suggested which allows the steam to be used effectively. Its application to various chemical engineering processes is considered (vaporization, distillation, rectification), and its advantages over other heat pumps are demonstrated. It is shown that the use of this improved heat pump will make it possible to thermally close many energy-intensive processes.

Section 6

"HEAT AND MASS TRANSFER IN DISPERSE AND RHEOLOGICAL SYSTEMS"

6-01.1 B. V. BERG, V. A. MIKULA, E. I. LEVIN, T. F. BOGATOVA

ORGANIZATION OF CONTROLLED VERTICAL MOTION OF A DISPERSE MATERIAL IN A FLUIDIZED BED

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Experimental results of coal motion in a vertical channel (constructed from two vertical rows of inclined baffles) in a fluidized bed are presented. Dependences of the motion velocity, vertical section area, and perimeter of a coal batch on the inclination of the baffles, channel width, batch volume, coal particles diameter, and velocity of fluidization are obtained. Application of baffles has been found to be suitable for organization of controlled motion of a disperse material in a fluidized bed.

6-02 A. V. BONDAREV, V. G. GIMMELMAN, S. M. KOSHELEVA, Yu. I. MACHUEV, V. V. MURAV'EV, V. A. TRUZHENIKOV, S. G. OLSKAYA, P. P. ANDREEV

CLEANING OF OIL PIPELINE FROM PARAFFIN DEPOSITS BY MEANS OF WATER VAPOR

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The problem of cleaning pipeline walls from nonuniform paraffin deposits generated during oil loading from an offshore ice-resistant stationary platform to a tanker, as well as after loading under cooling of pipeline has been considered. One of the most acceptable methods is removal of paraffins by means of water vapor. The work determines the necessary vapor flow rate and time of its supply taking into account heating of pipeline, melting, and draining of paraffin along the pipeline length. To solve the thermal problem, a one-dimensional equation of heat conduction under boundary conditions of the third kind has been considered. The thermal flow necessary to heat and melt deposits taking into account the heat of phase transition has been calculated.

V. A. BORODULYA, I. A. BOKUN, L. M. VINOGRADOV, *G. I. PALCHENOK, N. G. KHUTSKAYA*

VEGETATIVE BIOMASS AND ITS MIXTURES AS HEAT AND POWER FUELS

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

The prospects of renewable fuel based on biomass and its mixtures have been analyzed. The cost of pellet production from a mixture of peat, wood waste, and coal is shown to be 2.5-4 times as low as abroad. The use of biofuel for small-scale heat and power production based on domestic equipment enables considerable reduction in the cost of energy and foil cost recovery time as compared to actual norms.

6-03 V. A. BORODULYA, G. I. PALCHENOK, L. M. VINOGRADOV, *O. S. RABINOVICH, N. G. KHUTSKAYA*

BIOENERGY-HYDROGEN- OR CARBON-BASED?

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

The prospects of renewable hydrogen and carbon foel, produced by thermochemical conversion of biomass, have been analyzed. Biocarbon is shown to be potentially a cheaper and more efficient foel for foel cells than hydrogen.

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

THEORETICAL ANALYSIS AND SIMULATION OF THE PRODUCTION OF POLYCRYSTALLINE SILICON IN A FLUIDIZED-BED REACTOR

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

Using the developed one-dimensional two-phase mathematical model, the rate of growth of silicon particles in an emulsion phase, amount of aerosol in a bubble phase, and the degree of conversion of monosilane have been calculated. The optimum technological parameters of the fluidized-bed reactor have been determined: the temperature of the working zone, fluidized-bed height, limitation of the initial and final sizes of silicon particles, and ejection of the gas phase has been determined. A good correlation between the experimental data and the results predicted by the theoretical model is observed.

6-04 O. G. BURDO, I. V. BEZBAKH

INTENSIFICATION OF HEAT TREATMENT OF NON-NEWTONIAN FLUIDS

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The problems of an intensification of heat treatment of non-Newtonian food fluids (NNF) in devices with rotating thermosyphons (RTS) are considered. The influence of constructive and regime parameters on the intensity of heat emission to a product are investigated. The processes of heat emission for various groups of NNF food, crisis of heat transfer in RTS are investigated with application of computer modeling. The group of NNF food for which RTS application is the most effective is determined.

6-09 R. S. ENALEEV, V. A. KACHALKIN, I. A. ABDULLIN

COMPUTATIONAL MODELS OF TRANSFER PROCESSES IN SYSTEMS WITH A SOLID PHASE

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A mathematical model of the process of nonisothermal adsorption during extraction of components from a gas stream by a layer of solid phase is suggested. The model includes a diffusion model of longitudinal mixing to calculate the density and temperature of a gas stream over the height of the layer; the model of diffusion of an adsorbate and heat in a fine-porous spherical particle with dependence of kinetic factors on density and temperature; data on equilibrium densities in gas and solid phases at different temperatures. The computational algorithm based on combination of numerical and analytical methods for calculation of the transfer potentials fields in both phases is developed. Computational models are confirmed in solving a problem of adsorption of hydrocarbon admixtures in air by activated coal.

6-38 S. S. FEDOROV, G. L. SHEVCHENKO, M. V. GUBINSKII

SIMULATION OF THE THERMAL OPERATION OF COMPACT REGENERATORS WITH ALLOWANCE FOR THE HEAT LOSSES THROUGH ENCLOSURES AND FOR THE CONDITIONS OF HEAT TRANSFER IN THE SPACE OVER PACKING

National Metallurgical Academy, Dnepropetrovsk, Ukraine, ptel03@email.dp.ua

A mathematical model of a compact regenerator taking into account heat losses through enclosures and influence of heat transfer in the space over packing is presented. A comparative analysis of numerical and experimental results have shown that allowance for new factors has raised the accuracy of the mo del.

6-08 S. A. GUBAREV

THERMAL EFFECT IN PHOTODYNAMIC THERAPY OF TUMORS

A. V.Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus, gubarev@htmi.ac.by

Numerical evaluation of the temperature field in the skin and subcutaneous tissues of a human during photodynamic therapy has been made. The local temperatures varied from 37°C (in deeper tissues) and to 41°C (near the skin surface) for a therapeutic laser with a wavelength of 680 nm and light intensity of 150 mW/cm^2. Such a temperature level is not sufficient for the local hyperthermia conditions. Hence, the pain effect of photodynamic therapy is not connected with the thermal factor.

6-12 M. M. KARPUK, D. A. KOSTYUK, Yu. A. KUZAVKO, A. K. YAKUSIK

ACOUSTIC SPECTROSCOPY OF THE MAXWELL LIQUIDS

Brest State Technical University, Brest, Belarus

The reflection of continuous and pulse longitudinal and transverse acoustic waves from a dissipative medium in the model of the Maxwell liquid contacting a solid halfspace is considered. The strong dependence of the reflection coefficients and their phases on the viscosity and the time of relaxation of a strain for the Maxwell liquid is observed. The reflected and transmitted acoustic pulse signals in the medium interface were calculated by computing means. Measurements and calculations were made on the interface of plexiglas and an epoxy compound in its stage of solidification with the use of information technologies.

6-13 S. B. KASHEVSKII, I. V. PROKHOROV

OPTOVISCOSIMETRY OF A FLUID BY THE METHOD OF A DISPERSE MAGNETIC SUBLAYER

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Using computer simulation of collective behavior of a system of ferromagnetic particles, the justification of the viscosimetry method suitable for studying the kinetics of the viscosity of thin liquid films is carried out. The method is based on measurement of the light transmission dynamics excited by the magnetic field pulses of a two-layer system formed as a result of sedimentation of noncolloidal ferromagnetic particles suspended in a liquid. The kinetics of the viscosity of a number of fluids formed as a thin film during their heating polymerization, and evaporation has been studied.

V. I. KHIT'KO[1], V. N. STEPANENKO[1], V. A. BORODULYA[2], L. M.VINOGRADOV[2], V. A. NEMTSEV[3]

PROBLEMS OF HEAT AND MASS TRANSFER IN A NONTRADITIONAL TECHNOLOGY OF PRODUCTION OF SEMICONDUCTING SILICON

[1] *Scientific-Research Institute of Radiomaterials, Minsk, Belarus; A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus; Joint Institute of Energy and Nuclear Investigations, National Academy of Sciences of Belarus, Sosny, Belarus*

Urgent problems of heat and mass transfer and the problems of creation of heat and mass transfer equipment for producing polycrystalline silicon by means of chemical refining of the silicon-containing secondary product of processing apatite concentrate into the phosphate fertilizers Na2SiF6 SiF4 SiH4 Si have been formulated.

6-15.1 E. V. KOROBKO[1], A. E. BINSHTOK[2], M L. LEVIN[1], V .A. BILYK[1], E. A. BASHTOVAYA[1]

DISSIPATIVE PROCESSES IN AN ELECTRORHEOLOGICAL DAMPING DEVICE

8- *A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus; Minsk Plant of Wheeled Tractors, Minsk, Belarus*

The design of an electrorheological damper and the results of an experimental investigation of its operation in a wide amplitude-frequency range at different electric field strengths are presented. It is shown that by varying the viscosity of an electrorheological fluid it was possible to attain a threefold increase in the pull on the damper rod. The basic parameters which influence the dissipation processes occurring in the ER damper have been determined.

6-14 E. V. KOROBKO, E. B. KABERDINA, V. A. BILYK

CHARACTERISTIC FEATURES OF THE BEHAVIOR OF AN ERF IN AN ELECTRIC FIELD IN SHEAR FLOW

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

The rheological behavior of an electrorheological fluid (ERF) exposed to an electric field has been investigated experimentally. The structural strength and viscoelastic characteristics at different electric field strengths and solid phase concentrations in an ERF an its deformation in a system of parallel plates have been estimated. An increase in the first normal stress on increase in the applied electric field strength and also its change in time has been revealed. A change in the sign of depending on normal stresses on the electric field strength is observed.

6-16 D. A. KOSTYUK, Yu. A. KUZAVKO

ANOMALIES OF THE BOUNDARY REFLECTION OF A TRANSVERSE ULTRASOUND FROM A DISSIPATIVE MEDIUM LAYER

Brest State Technical University, Brest, Belarus

Reflection and transmission of continuous and pulse transverse acoustic waves from a layer of dissipative medium between two solid-state half-spaces were investigated. The shapes of both reflected and transmitted acoustic pulse signals were found out numerically with an approximation of radiated signal close to the real one. The quality of ultrasound energy absorption was defined as a function of the layer thickness and the wave frequency. The possible appearance of frequency oscillations of the reflection and transmission coefficients is shown. The effect of maximum filtering of the transverse ultrasound by the small values of the layer phase thickness takes place in a narrow frequency region.

6-17 A. P. KRYUKOV, V. Yu. LEVASHOV, I. N. SHISHKOVA

NONEQUILIBRIUM RECONDENSATION IN A DUST MEDIUM

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In the paper, the problem of flow of vapor-gas mixtures through a region filled with dust particles is studied for strong nonequilibrium conditions. It is assumed that evaporation-condensation of gas molecules may occur on the surface of each particle (drop or dust). As a result, a layer of condensate of variable thickness is formed on this surface. This layer grows when condensation dominates and is reduced when evaporation is strong enough. Particles of different shapes are investigated. Also, diffuse and mirror models of gas-interface surface interaction are considered.

6-18 V. V. KULEBYAKIN, V. V. SHKANDRATOV, A. A. MAKHANEK,

O. V.BOLIGATOVA

THERMAL CALCULATION OF THE PROCESS OF CLEARING A WELL FROM ASPHALT-RESIN-PARAFFIN DEPOSITS (ARPD)

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

A physicomathematical model is suggested and a numerical analysis of the process of clearing the central duct of an oil well from asphalt-resin-paraffin deposits is performed. Various variants of cleaning and their effectiveness are considered. It is assumed that during the interval for reconnection of vessels with a heat carrier in the well outside the tubes the conditions are created under which the liquid becomes superheated, which results in its bulk boiling up and in considerable overcooling in the upper part of the heated zone.

6-19 L. I. KURLAPOV, T. A. SEGEDA

HEAT AND MASS TRANSFER IN GASES CONTAINING CLUSTERS

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Using as an example the phenomena occurring in gases, mutual influence of static and kinetic effects is investigated. A static effect as the effect of mixing for an N2-C02 mixture is calculated. As kinetic effects, baroeffects are considered. It is shown that the influence of clusters results in a change in the thermal diffitsional baroeffect, and under certain conditions leads to a change of its sign. The description of baroeffects is carried out within the framework of the model of an inhomogeneous continuous medium divided into domains of variable composition. The effects considered increase appreciably in intensive processes in real mixtures.

6-20 M. L. LEVIN, L. K. GLEB

CONCERNING HEAT TRANSFER IN THE PROCESS OF MAGNETORHEOLOGICAL POLISHING

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Thermal processes in magnetorheological polishing have been investigated. The process of heat transfer from a treated surface to a polishing magnetorheological instrument is described with regard for the specifics of its rheological and thermophysical properties. The analytical estimation of the temperature state of the magnetorheological abrasive instrument and the surface of the treated piece during polishing is given. A decrease in the heat flux in comparison with traditional methods of finishing is experimentally registered.

6-24 A. A. MAKHANEK, Z. P. SHULMAN

EFFECT OF HEAT TRANSFER IN BIG VESSELS ON THE PROCESS OF GENERAL HYPERTHERMIA (GHT) OF A HUMAN

A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus, marklvn@belhard.com

Within the framework of the multicompartment thermal model an analysis of the effect of heat transfer of main arterial and venous vessels on the thermal state of a human in electromagnetic and general water-jet-heating is made. It is established that heat transfer of main vessels with compartments and between themselves in a stationary state do not impart any essential features to the temperature levels in different parts of a human body. The greatest effect of heat exchange between these vessels and biotissue manifests itself in 15 and 30 min after water-jet and electromagnetic heating, respectively, and does not exceed 0.3 °C.

6-23 V. A. MANSUROV[1], N.A. PROKOP'EV[2], V.A. MARSHAK[1]

RHEOLOGICAL PROPERTIES OF YOGURT CONTAINING DIFFERENT STABILIZERS

*A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus***.** *Belarusion Scientific-Research Dezigning-Technological Institute of Meat and Milk Industry, Minsk, Belarus*

The rheological properties of yogurt containing four different stabilizers developed by UC BELREDIMMI have been comparatively studied by a rotational viscosimetry method. The yogurt stabilized with "MULTEK" (Russia) was used as a reference sample. The structural-rheological properties have been characterized. It is shown that the yogurts based on the stabilizers studied are visco-plastic fluids whose rheological behavior is described with a sufficient degree of accuracy by the Casson law. From the rheological point of view, most suitable is the sample having the greatest yield stress.

6-22 V. A. MANSUROV, N. A. ZHURAVSKII, E.V. MEDVEDEVA, G. R.GORODKIN, L. K. GLEB

PRESSURE AND FLOW RATE CHARACTERISTICS OF A FLOW OF A MAGNETORHEOLOGICAL SUSPENSION IN A CYLINDRICAL CHANNEL

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The rheological properties of a polishing magnetorheological suspension (MRS) upon change in the temperature and concentration of a disperse medium (water) have been investigated. The dependence of the MRS flow rate on a pressure drop in the cylindrical channel of a polishing

machine has been determined. The pressure drop, ensuring the suspension flow rate required for polishing has been calculated. The amount of water added to suspension to compensate evaporation, stabilize the rheological properties of MRS, and to optimize the polishing process were calculated.

6-25 E. V. MEDVEDEVA

INFLUENCE OF STRUCTURING ON HEAT TRANSFER IN MAGNETOELECTRORHEOLOGICAL SUSPENSIONS

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

Heat transfer in thin layers of magnetoelectrorheological suspensions based on Fe2O3 and CrO2 has been studied in the presence of electric and magnetic fields. In a dc electric field the thermal conductivity increases sharply due to the appearance of electro- convective vortices in the suspension. It has been found that these vortices can be effectively suppressed by applying a magnetic field. An ac electric field creates filament structures lined up along the field in the volume of the suspension. In the latter case, the application of a magnetic field causes agglomeration of the solid phase of suspensions in the vicinity of electrodes.

N. P. MIT'KOVSKAYA, G. Kh. TAGHIZADEKH

RHEOLOGICAL PROPERTIES OF BLOOD AND PLASMA OF PATIENTS WITH HEART ISCHEMIA AND DIABETES

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Couette viscometer, the rheological properties of blood and plasma have been studied in the range of shear rates 0.5-100 liter/sec and temperature 25°C. The rheological indices of a group of ischemia patients (16) have been used as the starting point for comparison with the rheological indices of a group of patients having ischemia and diabetes (37). As reference, the rheological indices of healthy donors (35) have been applied. All groups were commensurable by age and sex. It is shown that a change in the rheological properties of blood and plasma is strongly pronounced in patients with ischemia and diabetes. Probably, it causes blood microcirculation disorders in these patients.

6-21 A. Yu. MAISTRENKO, V. P. PATSKOV

NUMERICAL INVESTIGATION OF THE INFLUENCE OF HEAT- AND MASS TRASFER ON IGNITION AND BURNING OF A HIGH -ASH COAL COKE PARTICLE IN A PRESSURIZED FLUIDIZED BED

Institute of Coal Energy Technologies,National Academy of Sciences and Ministry of Fuel

and Power Engineering of Ukraine, Kiev, Ukraine

Refinement of the earlier developed mathematical model, algorithm, and program of calculation of the process of combustion-gasification of a single porous coke particle of high-ash coal under the conditions of operation of technological plants with PCFB is carried out. The kinetic constants of intraporous heterogeneous reactions of combustion and gasification of a coke residual are refined. The influence of different formulas used to calculate heat- and mass transfer coefficients, which take into account the presence of inert ash particles, on ignition and burning of a coal GSH particle were investigated. Preferable formulas for calculations are determined.

6-26 V. B. NEMTSOV

STATISTICAL THERMOREOLOGY OF MEDIA WITH A FRACTAL STRUCTURE

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The principles of theoretical description of nonequilibrium processes in fractal systems are developed on the basis of the general methods of the modem statistical mechanics.

6-27 G. I. PALCHENOK, A. V. BORODULYA, B. LECKNER

SCALE-UP OF FLUIDIZED-BED AND CIRCULATING FLUIDIZED-BED COMBUSTION OF BIOFUEL

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A method of scaling-up fluidized-bed and circulating fluidized-bed combustion of biofuel is proposed. Critical furnaces dimensions which provide a uniform distribution of combustibles over the cross-section and complete fuel burn-off over the furnace height rave been estimated.

6-28 Yu. Ya. PECHENEGOV, O. Yu. KOSOVA

CALCULATION OF THE HEAT TRANSFER CHARACTERISTICS OF A GAS-SUSPENSION FLOW IN A TUBE

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Computational investigation of heat transfer from thermal nonuniform gas-suspension flow in a tube is made. Analysis of some inside and outside heat transfer parameters of the gas-particles stream is earned out. The influence of some factors on the distribution of gas and particles cross-section-averaged temperatures and local Nusselt number along stream is shown.

6-30 A. S. PODOL'TSEV, G. I. ZHELTOV, A. P. PRIVALOV, P. P. CHECHIN
MACROKINETICS OF THERMAL DENATURATION ON EXPOSURE OF EYE CORNEA TO INFRARED LASER RADIATION

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The use of the thermal effect of infrared radiation (at $X = 2.06$ im) of a laser based on holmium-doped yttrium aluminum garnet (H_0:YAG) is most promising for noncontact thermokeratoplasty in correcting the refracting ability of cornea by thermal shrinkage of the collagen fibers. The threshold values of the energy exposures of laser effect H50 different pulse lengths (from 10 J.sec to 1 sec) were calculated by means of numerical calculation of the nonstationary temperature fields in the cornea based on the earlier developed mathematical model with subsequent calculation of the kinetics of thermal coagulation of tissues. The dependence of H50 on the pulse length and spectral absorption coefficient has been calculated.

6-31 B. G. POKUSAEV[1], E. A. TAIROV[2], A. K. NEKRASOV[1], D. A. NEKRASOV[1]
NONSTATIONARY THERMOHYDRAULIC PROCESSES IN A GRANULAR LAYER

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The results of experimental and numerical investigation of nonstationary thermal and hydraulic processes in vertical ring channels with a spherical layer and without it, filled by a subcooled water are presented. In experiments stepwise supply of electric power to the wall of a cylindrical steel heater was used.

6-28 V. P. PATSKOV

A NONEQUILIBRIUM MODEL OF THE PROCESS OF THERMAL DECOMPOSITION OF A SINGLE HIGH-ASH COAL PARTICLE UNDER HIGHER PRESSURES

Institute of Coal Energy Technologies, National Academy of Sciences and Ministry of Fuel and Power Engineering of Ukraine, Kiev, Ukraine

A mathematical model, algorithm, and program for calculating the process of thermocontact pyrolysis of a single porous high-ash bituminous coal particle under the conditions of operation of technological plants with PCFB are considered. Effective diffusion, heat conduction, convective-filtration transfer, primary release of moisture and volatile components, intraporous heterogeneous reactions of gasification of coke, phase transitions (evaporation-condensation) of water and tar were taken into consideration. A case is considered where phase transitions in pores proceed under nonequlibrium conditions. Comparision with the results of

former calculations in equlibrium statement is made. In the dependences adopted to estimate heat and mass transfer coefficients, the presence of inert ash particles is taken into consideration.

6-42 V. P. RESHETIN[1], J. L. REGENS[2]

ESTIMATING BACILLUS ANTHRACIS SPORE DISPERSION IN A HIGH-RISER

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Institute for Science and Public Policy, University of Oklahoma, USA

This analysis estimates the dispersion of Bacillus anthracis spores in a 50-story, high-rise building after a bioterrorist release. The computer simulation models aerosol dispersion in the case of intensive, small-scale convection which equalizes the concentration of anthrax spores over the building volume. The model predicts the time interval required for spore dispersion and indicates that an aerosol release of even a relatively small volume of anthrax spores during a terrorist incident distributes concentrations that are infectious throughout the building.

6-41 V. P. RESHETIN[1], J. L. REGENS[2]

MODELING CS-137 DISPERSION FROM A RADIOLOGICAL DISPERSION DEVICE

[1]*Joint Institute for Power and Nuclear Research, National Academy of Sciences of Belarus, Minsk, Belarus; Institute for Science and Public Policy, University of Oklahoma, USA*

A semi-empirical model is used to estimate the spatial extent (km²) and radioactivity (Ci) of contamination within an urban area following the initial dispersion of Cs-137 after a RDD explosion in a terrorist incident. Two scenarios are assumed for modeling purposes, and aerosol dispersion is estimated for effective release heights of 50 m and 100 m above street level under varying local-scale atmospheric conditions. In the first scenario, approximately 12 grams of Cs-137 equaling 1,000 Ci is released using a conventional explosive. In the second scenario, terrorists detonate a RDD containing approximately 35 g of Cs-137 equaling 3,000 Ci. For this analysis, contamination densities at the level of >5, >30, >50 Ci/km² are used as evaluative criteria in order to assess probable consequences. The results indicate explosion of a RDD containing a relatively small amount of Cs-137 has the potential to contaminant a relatively large area with the extent of contamination (area and activity) being dependent on Cs-137 particle size, the height of release, and local weather conditions.

G. S. ROMANOV, A. S. SMETANNIKOV, Yu. A. STANKEVICH,

L. K. STANCHITS, K.L. STEPANOV

COMPUTER SIMULATION OF THE PHYSICAL PROCESSES OCCURRING IN LASER-PLASMA DEPOSITION OF DIAMOND-LIKE FILMS

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

A physical-mathematical model of formation of an erosive plume by nanosecond laser pulses on a graphite target is suggested. The nonstationary heat conduction equation with a volumetric or surface source of energy release is used to describe the heating of the solid target. The nonstationary gasdynamical equations are used to describe the scattering of an erosive plume in the case of cylindrical symmetry. The heat and gasdynamical problems are matched with the aid of boundary conditions at the phase interface. The influence of thermodynamic and optical characteristics of the graphite target on the dynamics of heating and evaporation is studied. Computational simulation of the erosive plume dynamics and its interaction with a substrate by action of nanosecond laser pulses on the graphite target in low pressure media is carried out.

6-32 R. M. SATTAROV, R. M. MAMEDOV, I. R. SATTARZADE

PROPAGATION OF PRESSURE WAVES IN ANOMALOUS LIQUIDS SUBJECT TO THERMOHYDRODYNAMIC EFFECTS

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A system of differential equations of unsteady motion of anomalous power liquid in a pipe with account for thermohydrodynamic effects is obtained. Analysis of the propagation of pressure waves during the motion of anomalous power liquids in pipes with account for thermohydrodynamic effects has been made on the basis of the given equations. It is pointed.out that the speed of the propagation of disturbances depending on the thermal effect in anomalous power liquids is decreased. It has also been discovered that depending on the rate of increase or decrease in temperature, hysteresis phenomena in anomalous rower liquids during their stationary motion in pipelines can be observed.

6-43.1 S. S. SAZHIN[1], W. A. ABDELGHAFFAR[1], P. A. KRUTITSKII[2], E. M. SAZHINA[1], M. R. HEIKAL[1]

NUMERICAL MODELING OF DROPLET TRANSIENT HEATING AND EVAPORATION

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[2]Moscow State University, Moscow, Russia, S.Sazhin@brighton.ac.uk

Several approaches to numerical modeling of liquid droplet heating and evaporation by convection and radiation from the surrounding hot gas are discussed. The finite thermal conductivity of liquid, recirculation in droplets, and time dependence of gas temperature and the convection heat transfer coefficient are taken into account. The results of the application of these

approaches to the numerical modeling of fuel droplet heating and evaporation in conditions relevant to diesel engines are briefly discussed. The approach based on the analytical solution of the heat conduction equation is more effective than the approach based on the numerical solution of the discretized heat conduction equation inside the droplet, and more accurate than the solution based on the parabolic temperature profile model. The relatively small contribution of thermal radiation to droplet heating allows us to take it into account using a simplified model, which does not consider the variation of radiation absorption inside droplets.

6-34 N. V. SELIVANOV

INFLUENCE OF FLUCTUATIONS OF CAPACITY ON HEAT TRANSFER AT A HORIZONTAL CYLINDER

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Investigation of heat transfer at a horizontal cylinder during fluctuations of capacity is carried out. Dimensionless equations for calculating average and local heat transfer in free convection for a wide range of Ra and Pr numbers with allowance for a variable viscosity were obtained. The fluctuations intensify the process of heat transfer. The heat transfer process during the fluctuations of capacity belongs to steady mixed convection. Three zones were established in which fluctuations influence heat transfer at horizontal cylinder, and the boundaries of these zones have been determined. A dimensionless equation was obtained which generalizes heat transfer in vibration, fluctuations, rotation, and flow about the horizontal cylinder.

6-33 N. V. SELIVANOV, S. I. KUZ'MIN

HEAT TRANSFER AND FRICTION IN NON-NEWTONIAN FLUIDS WITH FREE AND FORCED CONVECTION

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The hydrodynamics and heat transfer of non-Newtonian fluids at a cooled isothermal surface with laminar, free, and forced convection have been investigated theoretically with allowance for changes in the liquid viscosity with temperature. An exponential rheological model was used. Solutions of differential equations for a boundary layer were obtained numerically by means of Mathcad 2001. It is established that in the case of forced convection rheology does not exert its influence on relative heat transfer and friction. Relative viscosity has the greatest influence in the forms of convection considered.

6-35 E. V. SUBBOTIN, A. G. SHCHERBININ, A. E. TERLYCH, R. Yu. YAGOVKIN

INVESTIGATION OF HEAT AND MASS TRANSFER PROCESSES OF A

POLYMER IN THE EXTRUDER CHANNEL

Perm State Technical University, Perm, Russia

The fusion process in an extruder with an ME-90 barrier screw with various viscosity characteristics of the melt obtained has been investigated with the aid of mathematical simulation. Figures illustrating the flow characteristics and temperature field in the channel are given. Pressure in the channel is analyzed, and the melt and plug temperature heterogeneity is investigated. Dependence of the temperature field on melt viscosity is analyzed, and the appearance of the zones of melt superheating is shown. Conclusions concerning the influence of the polymer rheologic properties on the process studied have been given.

6-36 G. H. TAGHIZADEKH, N. P. MIT'KOVSKAYA

RHEOLOGICAL PROPERTIES OF THE BLOOD AND PLASMA OF ISCHEMIC HEART DISEASE AND DIABETES MELLITUS PATIENTS

Belarusian State Medicinal University, Minsk, Belarus

Rheological properties of blood and plasma have been studied using the Couette viscometer within the range of shear rates from 0.5 to 100 sec^{-1} at a temperature of 25 °C. The rheological indices of the patients with ischemic heart disease (16) have been used as the reference point for comparison with the rheological indices of the patients having ischemic heart disease and diabetes (37). Moreover, the rheological indexes of healthy donors (35) have been studied. All groups were commensurable by age and sex. It was shown that variation of the rheological properties of blood and plasma was more pronounced for ischemic heart disease and diabetes. Probably, it is one of the most important reasons for blood microcirculation disorders in patients with combination of ischemic heart disease and diabetes.

6-37 Yu. S. TEPLITSKII, V. A. BORODULYA, V. I. KOVENSKII, E. F. NOGOTOV

MODELING OF SOLID FUEL COMBUSTION IN CIRCULATING FLUIDIZED-BED FURNACES

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National Academy of Sciences of Belarus, Minsk, Belarus

A mathematical model of solid fuel combustion in a circulating fluidized-bed furnace has been formulated. A numerical analysis of the influence of the characteristics of particles, operational parameters, and of the scale factor on the laws governing the process of combustion has been performed.

6-05 Yu. V. VIDIN, V. M. ZHURAVLEV, V. V. KOLOSOV, T. V. KOLOSOV

HEAT AND MASS TRANSFER IN VISCOUS LIQUID FILM FLOW OVER THE SURFACE OF A HORIZONTAL ROTATING DISK

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Processes of heat and mass transfer in viscous liquid flow on the surface of a rotating disk at small flow rates are considered. A mathematical model of the processes has been developed and an algorithm for its solution is suggested. The dependence of a change in the temperature, mass flow rate, and in the liquid layer thickness on the disk radius under different conditions of heat and mass transfer are shown.

6-06 S. V. VILANSKAYA

MODELING OF THE TEMPERATURE DEPENDENCE OF THE RHEOLOGICAL PROPERTIES OF A 0.2-% WATER SOLUTION OF XANTHANE AT LOW SHEAR RATES

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A water solution of xanthane models well the behavior of blood at low shear rates, therefore some researchers use it as a rheological analog of blood. Based on an experimental study of the flow curves of a 0.2-% water solution of xanthane by a nonstationary method in the region of low shear rates within the temperature range 25°-45°C, a rheological model has been constructed and the temperature dependence of its parameters has been investigated. A power-law model was used. An analysis of the results obtained yields the single formula X = *Kf*, in which *K* = 32.23e~$^{0\ 3:>8?}$, *n* = 0.0054/ + 0.625, where T is the shear stress, mPa; y is the shear rate, sec-^{1}; *t* is the temperature, °C; *K* is the consistency parameter mPa-sec", and *n* is the nonlinearity index.

6-07 S. V. VILANSKAYA

CHANGE IN THE RHEOLOGICAL PROPERTIES OF A PLASMA IN CRYOPLASMAPHERESIS

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The rheological properties of a plasma at all the stages of cryoplasmapheresis (CPP) have been studied experimentally at a temperature of 37°C in the range of shear rates from 42 to 238 sec^{-1} and at a temperature of 12°C within the range of shear rates from 33 to 145 sec^{-1} on a rotational viscosimeter. The CPP stages for plasma are: initial, after 24h exposure with heparin at 4°C, on defrosting and plasmasorption. The temperature dependence of the plasma viscosity within the temperature range 7-42°C at a fixed shear rate of 88.8 sec^{-1} has been investigated. The investigation carried out allows us to consider plasma as a Newtonian fluid. Within the accuracy of measurements, the temperature de

pendence of the plasma viscosity is the rectilinear Arrhenius dependence. The mean value of the plasma viscosity at all the CPP stages changes insignificantly at t = 37°C; the viscosity changes more appreciably at t = 12°C.

6-40 I. V. YAMAIKINA, Z. P. SHUL'MAN, L. I. ERSHOVA, Z. M. LIKHOVETSKAYA, N. A. GORBUNOVA

A NEW RHEOLOGICAL MODEL TO ANALYZE THE ABILITY OF ERYTHROCITES TO AGGREGATION AND DEFORMATION IN A NUMBER OF HEMATOLOGIC PATHOLOGIES

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A new model of approximating the blood flow curve is suggested:

$$\mathrm{Hct} = \Sigma\, \mathrm{V_{er}} \quad \mathrm{Hct_{var}}$$

$$A = 2.5 \exp\ (a_1 \cdot \exp\,(-\gamma/\gamma_1) + a_2 \cdot \exp\,(-\gamma/\gamma_2) + a_3 \cdot \exp\,(-\gamma/\gamma_3))$$

$$B = 1 - \ln\,(2.5/A)$$

With five parameters (b_0, a_1, a_2, γ_1, and γ_3) which are independent of hematocrit and shear rate. Using a statistical analysis of the reliability of the average values of separately measured states of aggregation and deformation of erythrocites and parameters of the new rheological model of hematologic patients (myeloma, erythemia, anemia, hemorrhage), the relationship of two parameters of the system – γ_1 and γ_3 to the ability of erythrocites to aggregation and deformation has been proved.

6-39 A. A. YUDAKOV, O. N. TSYBULSKAYA, V. A. AVRAMENKO

HEAT AND MASS TRANSFER IN A SWIRLED GAS-DISPERSED FLOW WITH COUNTERCURRENT MOTION OF COMPONENTS

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The characteristic features of heat and mass transfer in a swirled gas-dispersed flow were studied, experimental heat and mass transfer coefficients were established, dimensionless dependences allowing one to calculate heat and mass transfer for practically any arrangement in which a swirled two-component flow is used were obtained.

6-10 U. K. ZHAPBASBAEV[1], S. S. KOZHABEKOV[2], G. I. RAMAZANOVA[1], V. B. SIGITOV[2]

SOME DATA ON HYDRODYNAMICS AND HEAT EXCHANGE BETWEEN AN OIL-MIXTURE FLOW AND DEPRESSANT ADDITIVES

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The results of investigation of the laws of hydrodynamic resistance and heat transfer from the data of experimental-industrial tests of depressant additives DMN-2005 (Russia), GY-3 (China), R-140 and AP-174 (France) in transporting paraffin-base oil-mixture and heat-hydraulic calculation of linear sections of Kazakhstan main pipeline are presented. The empirical relations for the coefficients of hydrodynamic resistance and heat transfer of a turbulent oil-mixture pipe

flow with additives are established in consequence of generalization of the experimental-industrial test data.

6-11 R. R. ZINNATULLIN, N. M. TRUFANOVA, A. A. SHILING
INVESTIGATION OF THE PROCESSES OF HEAT TRANSFER AND PHASE TRANSFORMATIONS IN COOLIN A WIRE WITH POLYMERIC INSULATION
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Numerical study of the process of cooling a wire with insulation made from low- pressure polyethylene in the process of its manufacturing has been carried out. This production stage is accompanied by complex interconnected heat exchange processes between polymeric insulation and the environment and a conductor, formation of the structure of polymeric insulation and considerable thermal emission in phase transition. The temperature fields in the wire and crystalline fields in the polymer have been obtained on the basis of a macrokinetic approach. A water cooling mode has been compared to an air-to-water one.

Section 7

"HEAT AND MASS TRANSFER IN CAPILLARY-POROUS BODIES (INCLUDING DRYING PROCESSES)"

7-04 A. L. ADAMOVICH[1], N. N. GRINCHIK[2], Yu. G. GROZBERG[1], S. P. KUNDAS[3], V. I. TEREKHOV[4]
NONISOTHERMAL MOISTURE TRANSPORT DURING INTENSE MICROWAVE HEATING OF WOOD
[1]Polotsk State University, Polotsk, Belarus; [2]A.V. Luikov Heat and Mass Transfer Institute, Minsk, Belarus; [3]Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus; [4]Institute of Thermophysics of the Siberian Department of the Russian Academy of Sciences, Novosibirsk, Russia

A model of nonstationary processes of heat and mass transfer in capillary media with allowance for the mutual influence of vapor and moisture pressure, and temperature on the intensity of mass transfer between phases is suggested. Numerical experiments of heat and mass transfer in wood during microwave heating are carried out. The calculation results, representing evolution of moisture content, vapor pressure, temperature are analyzed.

7-05 P. V. AKULICH, P. S. KUTS
URGENT PROBLEMS OF CREATING EQUIPMENT AND TECHNOLOGIES FOR PRODUCING POWDERED PRODUCTS FROM SOLUTIONS
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Urgent problems of creating equipment and technologies for producing powdered products from solutions are considered. Specific technologies and setups for drying solutions and

suspensions are described. The results of experimental investigations of hydraulic nozzles and their construction are discussed.

7-06 A. V. AKULICH, M. A. NESTERUK

INVESTIGATION OF THE PROCESS OF DRYING FOOD DISPERSED MATERIALS IN VORTICAL APPARATUSES WITH THEIR SIMULTANEOUS SEPARATION

Mogilev State University of Foodstuffs

New designs of vortical apparatuses with controlled hydrodynamics for drying of dispersed raw materials with simultaneous separation of them were created. A method of calculation of the drying process on the basis of a common kinetic equation was worked out. The drying process curves of different fine materials were read on the pilot-industrial plant and the treatment of them was represented.

7-01 S. V. AVDASHKEVICH

INFLUENCE OF WOOD STRUCTURE ON THE PERMEABILITY AND HYDROCONDUCTIVITY OF WOOD MATERIALS

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The main elements of the structure of wood and the law governing the penetration of moisture depending on these structures, as well as those governing the formation of the wood structure and of the motion of the main components which saturate it are considered. The knowledge of these laws presents scientific and practical interest in development of fundamentally new technological processes of dehydration and soaking of wood in technological processes at enterprises of the forest complex, dehydration of other capillary-porous structures. Moreover, in view of the anisotropic nature and complex structure of the capillary-porous system of wood, further studies of macro-and micro- structures of wood (capillaries, laws of moving a liquid in capillaries) are needed.

7-02 S. V. AVDASHKEVICH

LAWS GOVERNING THE MOTION OF WATER IN THE CAPILLARY-POROUS SPACE OF WOOD AND THEIR INFLUENCE ON THE PROCESS OF DEHYDRATION

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The main characteristics of wood as a capillary-porous body are considered. Moisture transfer in the main structural elements occurs depending on the nature and structure of the body, its moisture content and conditions of moisture transfer. The existence of different forms of bond of moisture with the wood is responsible for different types of the forces of interaction of water and wood, different processes of liquid motion in the wood during dehydration of wood materials.

7-03 S. V. AVDASHKEVICH, V. I. PATYAKIN

INFLUENCE OF WOOD STRUCTURE ON THE INTENSITY OF LIQUID OUTFLOW FROM CAPILLARIES IN ELECTROKINETIC DEHYDRATION OF WOOD MATERIALS

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An electrokinetic method of the dehydration of wood by using metallic electrodes in addition to withdrawal and extraction of the liquid from the capillary-porous space in the wood allows one to carry out modification of this wood. The practical importance of the results is that

they can be used to devise energy-saving technological processes of dehydration, division of the substances being parts of the liquid and mixtures which fill the porous space of capillary porous media.

7-07 E. A. BONDAREV[1], V. E. NIKOLAEV[2]

THERMODYNAMIC CHARACTERISTIC FEATURES OF NONISOTHERMAL FILTRATION OF AN IMPERFECT GAS

[1]Institute for Problems of Oil and Gas, Siberian Branch of the Russian Academy f Sciences, Novosibirsk, Russia; [2]Yakutsk State University, Yakutsk, Russia, bondarev@iptpn.ysn.ru

The influence of the parameters of a mathematical model and of the type of boundary conditions on the dynamics of pressure and temperature fields in nonisothermal filtration of an imperfect gas has been investigated in a computational experiment. To describe the process, a nonlinear system of partial differential equations has been used which was obtained from the mass and energy conservation, and Darcy laws, with the physical and caloric equations of state being used as closing ones. The boundary conditions correspond to gas pumping at constant pressure at a constant mass flow rate. From the results of computations if follows, in particular, that at the initial stage of the process the temperature changes wave-like, with the amplitude of a wave being dependent on the type of boundary conditions and two dimensionless parameters of the model.

7-11 O. R. DORNYAK[1], Z. P. SHULMAN[2]

MATHEMATICAL SIMULATION OF THE DEVELOPMENT OF TWO-DIMENSIONAL FIELDS OF TEMPERATURE AND MOISTURE CONTENT IN WOOD

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A mathematical model of heat and mass transfer in wood during its modification is formulated. The model is constructed on the basis of the continual approach within the framework of the mechanics of heterogeneous systems. The wood is considered as a transversal-isotropic unsaturated three-phase system. The computational experiment for examining the influence of phase transfer and capillary effects on the development of fields of moisture and temperature of separate phases is carried out. An analysis of thermal and hydrodynamic conditions is carried out. It is shown that, in simulation of technological processes of wood modification, the calculations of associated processes of heat and mass transfer are necessary.

7-12 V. L. DRAGUN, V, G. LESHCHENKO, N. I. STETYUKEVICH, M. V. KHIL'KO

THERMOGRAPH INVESTIGATION OF HEAT TRANSFER OF BULGING ROCKS UNDER DEEP-FREEZING CONDITIONS

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

Investigation of the temperature fields and frozen regions in the crystallized-moisture containing rock samples from the yard of the mine being constructed has been carried out using infrared imaging facilities.

7-13 G. I. EFREMOV

GENERALIZED KINETICS OF HEAT AND MASS TRANSFER IN THE

PROCESS OF DRYING (THREE PERIODS)

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Based on the analysis of material preheating, the corresponding equation of the kinetics of drying for various materials and modes of drying is obtained. The general curve of the kinetics of drying describes the periods of preheating constant, and falling drying rates. As a special case from the general equation, drying with the 1-st and 2-nd periods (instant warming up of a material) follows. The generalized dimensionless equation of the kinetics of drying is obtained. Comparison of the derived dependences with experimental data for various kinds of drying and materials is carried out. The corresponding drying parameters have been found. The generalized drying curve of drying is constructed. Good agreement of calculated curves with the experimental data in a working range is obtained.

7-09 Yu. T. GLAZUNOV[1-3], R. VOISIK[2], G. V. KVITKO[3]

INVESTIGATION OF A NONLINEAR MODEL OF NONISOTHERMAL INJECTIONS INTO CAPILLARY- POROUS MEDIA

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A mathematical model is proposed to describe the process of injection under pressure of a heated-up liquid from a special device into a capillary – porous medium is suggested. The system of model equations describing convective transfer of substance, dispersion of the front of its propagation, and the processes of temperature distribution of the substance inside the conducting medium is determined. Numerical solution of a nonlinear problem is performed on the basis of an implicit scheme with subsequent iterations of solutions on nonlinearity and coherence of the equations. The results obtained for temperature and concentration fields are in good agreement with the experimental data that correspond to real injections of substances into the walls of buildings.

7-10 N. N. GRINCHIK, P. V. AKULICH, P. S. KUTS

CONCERNING THE SYSTEM OF DIFFERENTIAL EQUATIONS OF NONISOTHERMAL MASS TRANSFER IN POROUS MEDIA

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A model of nonstationary processes of combined heat and mass transfer in porous media which takes into account mutual effect of vapor and liquid pressures determined by the contribution of capillary and surface forces, and temperature on the intensity of mass transfer between phases and thermocapillary flows is considered. The results of a numerical solution of the system of equations of heat and mass transfer in capillary-porous bodies with discrete and continuous heat supply are discussed.

7-14.1 M. M. KARPUK, D. A. KOSTYUK, Yu. A. KUZAVKO, S. F. SHURKHAI, A. K. YAKUSIK

ACOUSTIC SPECTRAL ANALYSIS OF HUMIDITY OF POLESSIE PEATY SOILS AND GROUNDS

Brest State Technical University, Brest, Belarus

The ultrasound spectral methods and tools for express-measurements of humidity is designed, based on the dependence between soil humidity and characteristics of high- frequency longitudinal acoustic pulse signals, reflected from the interface between the waveguide and soil

samples. The measurements were carried out by digital methods for forming the radiated and reflected signals and recording them on the digital media for further processing with Matlab-based software.

7-46 B. KHUUKHENKHUU[1], P. S. KUTS[2], K. G. CHIJIK[2], G. OYUN[1], A. DELGERMAA[1]

SOME PROPERTIES OF SEA-BUCKTHORN JUICE AS AN OBJECT OF DRYING

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Mongolia enjoys rich sea-buckthom resources. How can one make the rational exploitation and utilization of sea-buckthom resources which is still under discussion and research? Based on the tendency demands of the development of the beverage industry both at home and abroad, this paper deals mainly with the conditions of thermal processing technology of concentrated sea-buckthom juice and experimental conditions of storage. The present work is devoted to research of drying sea-buckthom juice with absorbent *X* as an object of drying and both of microbiological and biochemical properties of saccharomycet yeast Saccharomyces cerevisiae isolated from sea-buckthom juice and berries.

7-16 V. I. KONOVALOV, N. Ts. GATAPOVA, A. N. SHIKUNOV, A. N. UTROBIN

KINETICS OF DRYING OF LIQUID DISPERSIONS ON A BINARY INERT CARRIER

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A method of fluidized-bed drying on a binary inert carrier from a mixture of teflon and aluminum particles has been developed and recommended. It raises the drying intensity, reduces sticking, improves exfoliation of a product, provides removal of a static electricity, and reduces fire and explosion hazard of dryers. Experimental results on drying on solid supports for 16 kinds of dispersions and solutions including *R*-salt and Gamma- acid are obtained. A kinetic classification of materials including a complete set from 6 basic kinds of temperature-moisture dependencies, described by the presence or degeneration of temperature plateaux, is developed. A unified approach including the methodology of experimental investigations and mathematical simulation of drying of materials with essential temperature kinetics is described.

7-17 I. P. KORNYUKHIN, L. I. ZHMAKIN

LAWS GOVERNING THE DRYING OF THIN MATERIALS BY OVERHEATED STEAM

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Using the apparatus of the statistical physics of nonequilibrium processes, an approach has been developed allowing one to determine heat and mass fluxes between the textile sample surface and vapor atmosphere consisting of three-atomic molecules. A closed system of differential equations was obtained to calculate the parameters of thin textile material during its drying to conditional moisture content. The concepts analogous to dew- point and moisten thermometer temperature for drying processes in atmosphere of overheated steam were considered.

7-15 V. P. KOZHIN, M. A. BRICH

HEAT AND MASS TRANSFER IN NONISOTHERMAL FILTRATION OF

LIQUID IN THE POROUS STRUCTURE OF WOOD

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The processes of internal and external heat and mass transfer in filtration of liquids through a porous wood medium are considered. Examples of simulation of a nonisothermal filtrational flow of oil antiseptics when wood is impregnated under vacuum and pressure are given. These investigations have shown that when a batch of wood materials is impregnated by a liquid whose viscosity depends on temperature, absorption may substantially depend on the conditions of heat transfer which are determined by the spacings between samples in an impregnation cylinder, liquid velocity in the chamber and other parameters.

7-20 E. A. LESYUK

INVESTIGATION OF PROCESSES IN FUSION ACCUMULATORS WITH A HEAT-CONDUCTING PACKING

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The process of melting-solidification of a working body placed in a porous heat-conducting skeleton is considered. This process takes place, for example, in accumulators of cold, whose operation is based on melting of the preliminarily frozen working body (pure substance, solutions, and mixtures). A mathematical model of the process of melting-so-lidification of a working body is presented with allowance for the porous heat-conducting skeleton. Comparison of calculation results on temperature fields with reference to the accumulator of melting of cylindrical shape is carried out with account for a heat-conducting packing (on the basis of the physical and mathematical model developed) with experimental data.

7-19 V. A. LEVIN, N. A. LUTSENKO

FILTRATION COOLING OF A POROUS FUEL ELEMENT

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A gas flow through a solid porous motionless homogeneous medium with heat release is considered. Such motion may result from filtrational cooling of fuel elements. Such kind of a model was suggested to describe the cooling process of the destroyed block of the Chernobyl atomic power station. From the solution of the system of equations, describing stationary conditions of cooling of fuel elements, the critical value of the gas pressure at the entrance to a fuel element is determined. The problem about stationary cooling of a fuel element with porous inert heap over it is considered. The system of equations, describing unsteady conditions of a cooling of fuel element, is solved numerically by finite difference method.

7-21 R. V. LUTSYK

SIMULATION OF THE INTERRELATIONSHIP BETWEEN HEAT/MASS TRANSFER AND DEFORMATION-RELAXATION PROCESSES PROCEEDING IN DRYING DISPERSE MATERIALS

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Based on the Boltzmann-Volterra viscous-elasticity theory, the first and second laws of thermodynamics for open systems, a system of equations is obtained which model the interrelationship between relaxation of stressed-deformed state of disperse materials and their heat and mass exchange with the environment. The approximation adequate for the systems with

concentrated parameters is given which corresponds to drying of thin capillary-porous materials.

7-18 D. P. LEBEDEV, V. V. KASATKIN, B. N. BYKHOVSKII
VACUUM CONDENSERS OF CONTINUOUS FREEZE-DRYING INSTALLATIONS
All-Russia Scientific Research Institute of Electrification of Agriculture, Khimki, Moscow Region, Russia

Development of continuous freeze-dryers has led to searches for new methods of condensation and designing of apparatuses. Physical characteristic features of formation of a condensed phase of ice are considered depending on thermodynamic conditions. Various crystal forms of ice are determined. The driving forces of the process are established. The kinetics of the process of condensation with regeneration of the surface of heat exchange is presented. The system condensation with regeneration of the surface of heat exchange of devices and design condensers is suggested. The problem of calculation of the surface of heat exchange of the device is formulated. Technical methods of regeneration of the surface of condensation and means of the control are given.

7-23 A. P. MOZHAEV
TOWARD THE THEORY OF HEAT AND MASS TRANSFER IN CHAOTIC POROUS MEDIA
Moscow, Russia

In this report, main regularities, concepts, and parameters of macrodispersed continuum formed in liquid (gas) in filtration through inhomogeneous porous media are presented.

7-22 V. V. MAZYUK, A. L. RAK, A. V. BALASHCHENKO
HEAT AND MASS TRANSFER IN EVAPORATION FROM THIN LAYERS OF POWDER CAPILLARY-POROUS STRUCTURES
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The processes of capillary transport and evaporation proceeding in thin layers of powder capillary-porous materials are analyzed. The concept of the irregularity of thin capillary structures is introduced. The influence of the capillary structure thickness on its regularity, capillary-transport, and evaporation ability is considered.

7-25 N. I. NIKITENKO, Yu. F. SNEZHKIN, N. SOROKOVAYA
DEVELOPMENT OF THE THEORY AND METHODS OF CALCULATION OF HEAT AND MASS TRANSFER, PHASE TRANSFORMATIONS, AND DEFORMATION IN DRYING POROUS MATERIALS
Institute of Engineering Thermophysics, National Academy of Sciences of Ukraine, Kiev, Ukraine, powder@kievweb.com.ua

A mathematical model of heat and mass transfer, phase transformations and deformation in drying colloidal capillary- porous bodies has been developed. It is based on the differential equation of mass transfer in deformable systems, expressions for the intensity of evaporation, factor of diffusion in condensed environments, and on the pressure in a liquid phase. Methods of calculation of the process of drying in diffusive and diffusive-filtrational statements are presented. Comparison of the results of calculation with experimental data points to the adequacy of the proposed mathematical model, efficiency of the stated method of calculation, and to the

possibility of their application to optimize the technologies of drying.

7-24 M. I. NIZOVTSEV[1], S. V. STANKUS[1], A. N. STERLYAGOV[2], V. I. TEREKHOV[1], R.A. KHAIRULIN[1]

INVESTIGATION OF THE PROCESSES OF MOISTURE TRANSFER IN POROUS MATERIALS BY THE GAMMA METHOD

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The results of experimental investigation of moisture transfer in porous material by the gamma method are presented. The data on the moisture distribution in capillary soaking and sorption moistening are obtained. The dependence of the coefficient of moisture diffusion for cellular concrete on its moisture has been obtained. It is shown that in capillary soaking the coefficient of moisture diffusion in cellular concrete attains high values which are expressed as an intense process of moistening. In sorption moistening, these are a substantial reduction in the coefficient of moisture diffusion, and the process of moisture transfer is rather slow. A comparative analysis of the coefficient of moisture diffusion for cellular concrete and other building materials is performed.

7-26 V. S. NUSTROV, E. I. SARICHEVA

HEAT AND MASS TRANSFER IN DEFORMABLE POROUS MEDIA UPON HOT FLUID INJECTION

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Injection of hot fluid in a deformable fractured bed is considered. This process is used in oil field practice to increase permeability near a well. The effective characteristics of the bed depend on its stress state and on the pressure of the injected fluid.

7-28 S. N. OSIPOV[1], V. A BILYK[2]

MASS TRANSFER IN THE INITIAL AND FIRST PERIODS OF DRYING OF CAPILLARY-POROUS BODIES

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An analytical solution of the equation of the Fick second law is presented, which makes it possible to calculate the distribution of moisture in the cross section of a ceramic plate in the initial and first periods of drying with allowance for the exponential increase of its intensity in time. The necessity of taking into account the increase in the value of the diffusion factor with the temperature of ceramic material is shown.

7-27 S. N. OSIPOV, I. K. IVANOVSKII

ACCOUT FOR VARIATIONAL CHARACTERISTIC FEATURES OF HEAT AND MASS TRANSFER FOR IMPROVING THE QUALITY OF DRYING CERAMIC PRODUCTS

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The necessity of statistical account for the anisotropic properties of ceramic weight of plastic formation and development power fields in drying to reduce the output of spoilage is shown. The quantitative estimation of the discrepancy between the values of the maximum

permissible (as concerns cracks) modes of drying determined on the basis of the deterministic equations of heat and mass transfer, and real ones necessary for obtaining qualitative production is given. Some recommendations for improvement of the quality of building ceramics of plastic formation are given.

7-29 S. N. OSIPOV[1], E. V. KOROBKO[2], V. A. BILYK[2]

THERMAL CALCULATUION OF THE MODE OF A CERAMIC BODY IN THE INITIAL AND FIRST PERIODS OF DRYING WITH RADIATIVE AND COMBINED HEAT TRANSFER

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[2]A. V. Luikov Heat and Mass Transfer Institute, Minsk, Belarus, eva@itmo.by

The solution of the Fourier equation is obtained taking into account evaporation of moisture from a heated surface in drying the products of plastic formation ceramics. Nomograms for simple engineering calculations are constructed. Comparison with experimental data is made which has shown a good agreement. It is established that in combined (radiative-convective) drying, for calculation one should take underestimated values of radiating heat fluxes owing to the cooling effect (due to increased evaporation of moisture) of a forced air stream.

7-31 A. N. OSTRIKOV, G. V. KALASHNIKOV, V. M. KALABUKHOV

BASIC LAWS GOVERNING HEAT AND MASS TRANSFER IN PRODUCTION OF DRIED VEGETABLES

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The laws governing heat and mass transfer in the warming period in production of cooked-dried vegetables with account for moisture absorption steam condensation using oscillating modes of product processing are investigated.

7-30 L. Ya. PADERIN[1], V. P. P. FISHER[2]

EXPERIMENTAL INVESTIGATION OF HEAT AND MASS TRANSFER IN POROUS SEMITRANSPARENT HEATPROOF MATERIALS

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A new variant of the method of a heated plate with compensation of heat leaks toinvestigate heat transfer and effective thermal conductivity of porous semitransparent heatproof materials is presented. Investigations of heat transfer and affective thermal conductivity of two materials in the temperature range T = 300-1200 °C and air pressure P = 10°-105 Pa are carried out. A comparative analysis of heat transfer in the investigated and other similar materials is performed.

7-32 P. P. PERMYAKOV, A. P. AMMOSOV, G. G. POPOV, S. T. KHOKHOLOVA

PREDICTION OF HEAT AND MASS TRANSFER PROCESSES IN LIQUIDATION OF THE CONSEQUENCE OF EMERGENCY UNDERGROUND NUCLEAR EXPLOSIONS

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The technique of numerical prediction of convective – diffusive transfer of radionuclides has been developed using the methods of directed differences. The results of numerical simulation of the migration of radionuclides in a seasonally thawing layer of soil are presented. Different

variants of the localization of waste are considered with due account for the climatic conditions of the region.

7-33 L. V. PLETNEV

STATIONARY HEAT AND MASS TRANSFER IN APERTURE SYSTEMS

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Investigations of heat and mass transfer in open systems of aperture type for a stationary free molecular regime of flow by the Monte Carlo method was carried out. Probabilities of the escape of particles depending on the ratio between the walls of systems and the characteristics of a substance are obtained. The model suggested by the author is used to describe the gas-solid body interaction. An analysis of the results of computer experiments showed that the values of flows slightly depend on the ratio between the value of the bond energy of particles with the system walls and the temperature of the system for the parameter *r* from 4 to infinity.

7-34 N. V. POLISHCHUK, I. M. PANCHENKO, M. S. PANCHENKO, A. S. MOSIEVICH

INTENSIFICATION OF MOISTURE AND HEAT TRANSFER DURING CAPILLARY ABSORBTION OF WATER BY A MACROPOROUS MEDIUM UNDER SIMULTANEOUS EFFECT OF INHOMOGENEOUS THERMAL, ELECTRIC, AND GRAVITATIONAL FIELDS

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We investigated the simultaneous influence of inhomogeneous electric, thermal, and gravitational fields on heat transfer during absorption of a hot water by a column with quartz sand with different temperature gradients. The column was oriented at different angles to the Earth gravitational field. In the case of opposite temperature and electric field strength gradients, an electroconvective heat flux in the pores of a sample is increased substantially. Intensification of the transfer of water heat content occurs as a result of the appearance of additional electro-hydrodynamic water flows under the effect of the pondermotive forces of electric fields. An increase in the angle of inclination of the macroporous model to the horizon from 0 to 90o can substantially decrease both the length of the water column in the porous medium and the rate of moisture imbibition. Superposition of an electric field of a high strength not only compensates this negative influence of the gravitational field but also considerably increases the convective heat flux which is several orders of magnitude higher than the conductive heat flux in the solid phase of the porous medium.

7-35 B. N. PROTSYSHIN, V. B. PUPIN, P. V. GORDIENKO, I. L. DASHKOVSKAYA

EXPERIENCE OF INTRODUCING EQUIPMENT FOR SIMULTANEOUS CRUSHING AND DRYING OF MATERIALS

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The results of introduction of equipment for simultaneous crushing and drying of organic materials are considered. The data of tests of the equipment for producing fertilizers based on poultry keeping waste are given which have confirmed the high efficiency of combining the processes of crushing and drying in the production of complex fertilizers according to the IET NASU technology.

7-36 S. V. REZNIK[1], P. V. PROSUNTSOV[1], W. P. FISHER[2], M. L. GERMAN[3],

P. S. GRINCHUK[3], A. M. MIKHALEV[1], A. N. OZNOBISHIN[3]^
N. V. PAVLYUKEVICH[3], V. V. TOROPOV[3], M. S. TRETYAK[3],
A. V. SHULYAKOVSKII[1]

INVESTIGATION OF EFFECTIVE THERMAL CONDUCTIVITY OF HEAT-PROTECTING POROUS MATERIALS ON THE BASIS OF SOLVING A TWO-DIMENSIONAL INVERSE HEAT CONDUCTION PROBLEM

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

The technique to determine temperature dependence of effective thermal conductivity of heat-protecting materials based on a solution of a two-dimensional inverse problem of heat conduction is suggested. Experimental data for the temperature field within a sample were used. Thermophysical experiments were carried out on a "URAN-1" radiation heating setup. Before each experiment, its duration, the number of temperature gauges, and their coordinates were determined by solving a two-dimensional problem of optimum planning of temperature measurements. The developed technique was used to investigate the temperature dependence of the effective thermal conductivity of highly porous (porosity is close to 95%) fibrous siliceous materials with various densities in the temperature range 300-1500 K. The work was performed with the support of INTAS (grant N 00-0652).

7-37 S. P. RUDOBASHTA

DRYING OF DISPERSED MATERIALS - THEORY AND PRACTICE

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The theoretical and experimental work on convective drying of dispersed materials made during last decades has been analyzed depending on the kinetic regime of drying. It has been noted that a significant success was achieved in the sphere of development of the theory, working out of the technology and technique of drying dispersed materials. The basic tendencies of future investigation are pointed out. Some thoughts concerning the description of drying kinetics on the micro and macro level are expressed, along with mathematical modeling of the process in general. The role of the energy constituent in the economic rates of drying has grown lately and it is shown in the paper. The attention is paid to the importance of such problems in the sphere of drying of dispersed materials as creation of new effective technologies and drying equipment, getting many factoring high quality products with all their valuable components preserved and also in the form convenient for further processing and storage.

7-38 R. G. SAFIN, L. G. GOLUBEV, R. R. SAFIN

MATHEMATICAL SIMULATION OF VACUUM DRYING OF SAWN TIMBER WITH CONVECTIVE HEAT SUPPLY

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The methods of vacuum drying of sawn timber with convective heat supply are considered. The use of vacuum-oscillation method for drying sawn timber of hard types of wood is suggested. The mathematical model of the process has been developed and recommendations are given according to the regime parameters for saving the duration of drying without deteriorating the wood quality.

7-45 G. S. SHUBIN

TOWARD CALCULATION OF A NEEDED AMOUNT OF STEAM IN DRYING OF MATERIALS

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The present report shows that the heat produced by working ventilators in a drying facility leads to a ten percent reduction in consumed steam. This fact is to be taken into account. A method for this purpose has been developed as well as graphs that make it possible to determine steam saving from initial data. The saving of steam reduces the cost of drying. Thus, for timber of thickness 25 cm dried within a moisture content range of A *W*= 80-8%, the cost of drying at co = 2 and 3 m/sec. is reduced by 3.3 and 7%, respectively. Changes in the methods of calculation of drying facilities are suggested.

7-44 G. S. SHUBIN

AIR (GAS) CIRCULATION VELOCITY AS ONE OF THE MAIN PARAMETERS OF THE PROCESS OF DRYING

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The data presented in this report allow one: a) based on graphs, to determine the optimal velocity of air (gas) circulation; b) to determine the optimal relative humidity of air as a function of the velocity of circulation and the initial moisture of material; c) to determine the optimum regime of air circulation (reversive – nonreversive); to determine the critical moisture of wood for application of combined air circulation (from reversive to nonreversive).

7-40 V. A. SKACHKOV, V. I. IVANOV, Yu. I. USENKO, V. P. GRITSAI

SIMULATION OF THE FORMATION OF THE DENSITY OF CARBON COMPOSITE MATERIALS FROM A GAS PHASE UNDER THE THERMAL GRADIENT CONDITIONS

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Mathematical simulation of the process of forming the density of carbon composite materials from a gas phase in thermal gradient gas-phase compaction is carried out. A model is presented as a related system of differential equations, describing the distribution of the temperature field for the medium with variable physicothermal properties and diffusion of reactive gases in the porous structure of carbon composite material taking into account their decomposition and deposition on the walls of pyrolytic carbon pores, forming of actual density on the thickness of compacted material.

7-41 D. S. SLIZHUK, I. V. ZHAVNERKO, V. D. SLIZHUK

THERMAL TREATMENT AND DRYING OF MEAT RAW MATERIAL

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

Investigations were carried out to verify the optimal methods of thermal treatment and drying of poultry meat-bone raw material and the optimal regime parameters of the processes have been established. The quality indices of the product and the energy efficiency of the processes are the optimization criteria. Based on the data obtained, the technology of producing dry meat-bone concentrate of poultry has been developed which can be used in producing food concentrates.

7-42 Yu. F. SNEZHKIN, L. A. BORYAK, P. A. SHAPAR

CHARACTERISTIC FEATURES OF HEAT AND MASS TRANSFER IN DRYING VEGETABLE RAW MATERIL

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The processes of drying vegetable raw material (apple, table beet) in a 10-mm bed have been studied with the purpose of raising drying efficiency. The drying curves are used for determining the heat flux density, moisture inflow rate to the material's surface, heat and moisture loss coefficients as well as the Biot number and the dependences Nu =/(Re) and Nu_m =/(Re). The first drying stage can be intensified by raising the temperature of a heat carrier with no risk of superheating and damaging the material. At the second drying stage the external factors impact become small. It is impractical to boost the drying rate by raising the heat carrier temperature.

7-43 Yu. F. SNEZHKIN, D. M. CHALAEV, N. A. DABIZHA

DEHYDRATION OF COLLOIDAL CAPILLARY-POROUS MATERIALS UNDER HIGHLY HUMID ENVIRONMENTAL CONDITIONS

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The application of heat pumps in convective drying allows one to maintain the requisite temperature and humidity parameters of a drying agent and, maintain well-controlled drying conditions required to stabilize or enhance the product quality irrespective of the environment. The paper presents the results of studies of the effect of drying agent parameters on the low-temperature drying kinetics in a convective heat-pump dryer. The relationship between partial water vapor pressure over the material and moisture content and temperature was obtained. On the basis of analysis of the water desorption isotherms, drying conditions minimizing energy consumption on water removal in all stages of the process are proposed.

7-39 Yu. V. SVETLOV

METHOD OF COMPUTATIONAL ANALYSIS OF MASS TRANSFER PROCESSES IN VAPOR-PERMEABLE MATERIALS (BASED ON LEATHER FOOTWEAR)

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The method is based on the modified kinetic equation of transfer, suggested by the author, in which the potential difference associated with the rate of relaxation is the driving force. The method makes it possible to obtain a family of kinetic curve potentials, expressing the character of their change in the body as far as heat and mass (moisture) propagate in it, to show the dynamics of vapor-permeability processes and vapor sorption in an article depending on the time of its use. Based on the results obtained, a hygrocomfortable evaluation of footwear wearability can be estimated for different footwear intensity conditions.

7-08 R. Sh.VAINBERG, N. D. BUTSKII, P. V. GORDIENKO

INFLUENCE OF THERMAL AND TECHNOLOGICAL CONDITIONS ON DRYING HIGHLY MOLECULAR PECTIC SUBSTANCES

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The kinetics of removal of a volatile component-bearing liquid phase from highly molecular biopolymers of pectic substances is studied. The scope of the study covered two

situations: conductive heat input under reduced pressure conditions and convective heat input at the atmospheric pressure. It has been found that the drying temperature rise up to 353 K at a reduced pressure and with intensive mixing of material makes it possible to boost the drying rate twice and cut down the duration of drying stage with no adverse effect upon the pectin quality. It has been also revealed that the drying rate of pectin-containing powder is twice as high as that of pure pectin.

Section 8

''HEAT AND MASS TRANSFER IN POWER FACILITIES"

8-01 A. S. ASKAROVA, S. A. BOLEGENOVA, I. V. LOKTIONOVA, E. I. LAVRISHCHEVA, D. A. AKHMETOVA

NUMERICAL INVESTIGATION OF CONVECTIVE HEAT AND MASS TRANSFER IN COMBUSTION OF A DUST-COAL FUEL

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Based on the three-dimensional equations of convective heat and mass transfer, the processes of combustion of a high-ash coal-dust fuel have been modeled numerically in the regions of real geometry (the PK-39 furnace chamber of the Aksuy State Regional Electric Station (SRES)). The distributions of temperature and NO* concentrations are given over the furnace chamber height. The computed results are compared with the experimental data obtained at the SRES. An analysis shows that the modeling and experimental results are in good agreement, and the distribution of the nitrogen oxides over the torch length and the level of their extension in the atmosphere are close to industrial ones.

8-02 V. V. BELYI[1], V. V. VASILIEV[2], A. A. GAVRILOV[3], A. A. DEKTEREV[4], E. S. TEPFER[3], E. B. HARLAMOV[4]

INVESTIGATION OF HEAT TRANSFER IN THE INDUSTRIAL P-67 BOILER FURNACE

[1] *Beryozovskaya State District Power Station-1; JSC,"SibVTI", 3KSTU, 4ITSB RAS, dekterev@itp.nsc.ru; sigma-cfd@torins.ru*

A mathematical model of heat transfer and coal-dust combustion in the power plant furnace is presented. The results of numerical modeling of several variants of the 800-MW furnace of the Beryozovskaya Power Station are obtained. The variants of modernization are proposed.

8-03 E. A. BOLTENKO, D. E. BOLTENKO, N. N. KIRIN, V. R. TSOI

DETERMINATION OF THE TWO-PHASE STEAM-WATER FLOW CHARACTERISTICS BY THE METHOD OF ELECTRIC PROBING

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The electrocontact method is one of the well-known methods used for diagnosing a two-

phase flow. Despite its popularity, a number of the disadvantages inherent to the method of electric probing make its use difficult in the conditions of high temperatures and pressures, and the amount of the information obtained with the help of the method of electric probing is limited. In the meantime, the potentiality of the method is great. The implementation of computer technologies allows one to obtain various information on two-phase flows by means of this method. In particular, aside from the values, it is possible to obtain the following data (the characteristic size of steam, liquid phases, velocities of phases, flow regime, etc.). Substantiation of the method of electric probing is presented as well as its possibilities and limitations. The accuracy analysis of the method is carried out.

8-04 A. A. BRIN, A. I. PETRUCHIK, S. P. FISENKO
MATHEMATICAL SIMULATION OF EVAPORATIVE COOLING OF WATER IN A MECHANICAL DRAFT COOLING TOWER

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We present a new mathematical model of operation of a mechanical draft cooling tower. We use this model to optimize the performance of the mechanical draft cooling tower under variable meteo conditions and given water temperature in the pool. The results of numerical calculations illustrate the possibilities of the model, which takes into account the polidispersity of droplet flows.

8-05 Yu. M. BRODOV, A. Yu. RYABCHIKOV, K. E. ARONSON, M. A.NIRENSHTEIN
HEAT TRANSFER IN POWER STATION HEAT EXCHANGERS

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Estimation of various means of steam turbine heat exchanger efficiency enhancement by both thermodynamic method and heat transfer limiting side method is presented. The results of investigation of the application of differently profiled tubes in various heat exchanging apparatuses of a power station, of the effect of vibration and dropwise condensation on heat transfer have been generalized.

8-45 J. O. CHAE[1], G. M. VASILIEV[2], A. M. KNAK[2], I. C. CHOI[1]
ENERGETIC HYDROGEN ASSISTED SYSTEM FOR DIESEL ENGINE EMISSION CONTROL

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In this study, a new plasma system is introduced to generation of rich gas for diesel after treatment and other applications. The utilization of hydrogen admixtures to the commercially available fuels would allow one to increase the thermal efficiency of the engine, reduce the cyclic variability, and, therefore, to utilize lean mixtures. The excessive oxygen in the combustion products will contribute to the complete combustion up to CO2 and H2O and eliminate soot, CO, and unbumed hydrocarbons in the exhaust. The decrease of the combustion temperature will significantly reduce the NO* formation.

8-13 N. V. DILIGENSKII, A. P. EFIMOV
SYSTEM ANALYSIS OF GLOBAL REGULARITIES AND CONSEQUENCES OF THE SCENARIOS OF POWER-RELATED ACTIVITIES

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The problem of investigation of the global regularities in the power-related activities is formulated. Both power industries and economic mechanisms of self-organization are formalized in the terms of system interactions.

8-12 V. P. DENISKIN, V. S. KONSTANTINOV, V. I. NALIVAEV, N. YA. PARSHIN, E. B. POPOV, I. I. FEDIK

COMPUTATIONAL SUBSTANTIATION OF THE EXPERIMENTS ON MODELING OF THE INITIAL STAGE OF THE DESIGNED ACCIDENT WITH COOLANT LEAK IN THE WATER-MODERATED WATER-COOLED POWER REACTOR

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Computational substantiation of the experiments on modeling of the initial stage of the designed accident which is characterized by fast (higher than 100 °C/sec) rates of heating of the fuel-element blanket from the level of a nominal mode (352 °C) to temperatures of 900-1050 °C was made. Calculations of the initial stage of the accident in the fuel core of the reactor show time-variation of the main parameters of the fuel element (temperature of the fuel pellet, blanket, pressure inside and outside the fuel element). A method of fast heating of the fuel element from a cold state is suggested; the method allows one to reproduce the required parameters in the zone of the highest loading of the fuel element. It is shown that for high rates of heating of the fuel-element blanket (150-200 °C/sec), which are typical of the initial stage of accident, and depending of the design of thermocouples and ways of their fastening on the fuel-element blanket there can be a substantial correction to indications of thermocouples (of about 300 °C).

8-14 I. S. DOLGOPOLOV, V. T. TUCHIN

A TOPOLOGOEXERGYCAL METHOD OF SIMULATION OF PHYSICO-TECHNOLOGICAL SYSTEMS (PTS)

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The philosophy of a topologoexergycal principle of simulation of physico-techno- logical systems is reviewed. This ideology integrates the advantages of exergycal and topological (bond graphs) methods. The purposes of the development of this method of simulation of PTS are formulated, and the fundamentals of the strategy of the method are considered. The mathematical formulation of generalized exergodissipative function is given. The results of elaboration of the formalism of the topologoexergycal method are presented. The proposed method allows one to obtain, in an analytical form, the picture of the influence of constructive and technological factors on the thermodynamic efficiency of the PTS in fixed and unsteady modes of their operation.

8-15 G. A. DREITSER

ABOUT SOME *PROBLEMS OF* CREATING HIGHLY EFFICIENT TUBULAR HEAT EXCHANGERS

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Modem achievements in the field of heat transfer enhancement in tubular heat exchangers are considered. A critical analysis of current methods used to evaluate the heat transfer enhancement efficiency is presented. The following methods are more effective: rolled tubes with circular diaphragms, longitudinal-flow helical rolled tube bundles (the bundles are densely packed, the tubes have diaphragms inside and grooves outside), spiral inserts in a round rolled

tube bundle. Using as an example heat exchangers for heating and hot water supply systems for buildings, it is shown that it is completely possible to create tubular heat exchangers as more efficient and compact in comparison with plate heat exchangers. The problems of heat transfer enhancement in boiling, condensation of heat carriers, and under the conditions of fouling are introduced.

8-16 V. I. ELISEEV, A. P. TOLSTOPYAT, L. A. FLEER
INFLUENCE OF VAPOR BLOWING TO THE FURNACE SPACE OF A BOILER UNIT ON THE PROCESS OF COMBUSTIAN IN NATURAL GAS BURNING
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Results of experiments on superheated steam blowing to the combustion space of an industrial boiler burning a natural gas are described. From the results of experiments it follows, that injection of small enough steam fractions, in comparison to natural gas and blown air expenditure, under other conditions being equal, substantially decreases the level of CO and NO* in waste gases with simultaneous increase in the fraction of O2, and at least does not reduce boiler steam capacity. Based on the kinetic model of methane combustion, numerical solutions are obtained, from which it follows that the presence of H and OH^- radicals at the early stages of combustion may serve as a trigging mechanism for the beginning of chain reactions that intensify the process of combustion.

8-37 M. R. FETKULLOV, D. V. TSYURA, V. I. SHARAPOV
MANAGEMENT OF THE PROCESSES OF HEAT AND MASS TRANSFER IN THERMAL DEAERATORS BY SEVERAL REGULATING AND ADJUSTABLE PARAMETERS
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An essentially new approach to managing heat and mass transfer by devices has been developed. A distinctive feature of this approach is the use, as adjustable parameters, of the given final parameters of efficiency of a technological process. The basic advantage of this approach consists of the maintenance of the given efficiency of the process of heat and mass transfer at minimal power expenses. Within the framework of a new approach, a series of highly effective energy-saving technologies, complex regulation of the processes of thermal deaeration of water has been developed. The characteristic feature of these technologies consists of maintenance of the given concentration of dissolved oxygen and free carbon deoxide in the deaerator water by consecutive regulation of various regime parameters.

8-38 S. A. FILATOV, E. E. VOLKOVA, M. N. DOLGIKH, O. V. PASHKEVICH
INVESTIGATION OF THE PROCESSES OF HEAT AND MASS TRANSFER IN FUEL ELEMENTS WITH PROTON-EXCHANGE MEMBRANES
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A construction of a module fuel element has been developed, a two-dimensional model of heat and mass transfer processes in the fuel element has been created and investigated, and investigations of standard and modified membranes for hydrogen-air and hy- drogen-oxygen fuel elements were carried out, and the methods of optimization of the membranes and constructions of electrodes are suggested.

8-11 A. N. GANZHA

TEMPERATURE CHARACTERISTICS OF SINGLE- AND MULTIPASS HEAT EXCHANGERS WITH A CROSS CURRENT

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Generalized analytical relations and a technique of calculation of average and local temperature characteristics of single- and multipass cross flow heat exchangers which are influenced by conventional dimensionless temperature complexes are suggested. The relations take into account the mutual direction of flow of heat carriers and their intermixing in motion, the quantity of sequential cross flow passes, and parallel basic elements.

8-18 R. A. IL'IN, A. K. IL'IN

EFFICIENCY OF A STEAM BOILER AS A HEAT EXCHANGER IN A THERMAL POWER ENGINEERING SYSTEM

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The efficiency of use of a steam boiler in combination with additional heat sources is analyzed based on the method suggested by the authors.

8-19 A. N. KARTASHEVICH, V. A. BELOUSOV, A. V. KRAVETS

ANALYSIS OF THERMOPHYSICAL PROCESSES OF BURNING-OUT OF SOOT PARTICLES OF DIESELS IN A PLASMACHEMICAL REACTOR

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An electrodischarge plasmachemical technology of cleaning shows promise for cleaning exhaust gases from automobile and tractor transport; it presupposed the installation of a plasmachemical reactor (PCR) in the system of engine outlet. Being the devices of direct conversion of energy, the plasmareactors, with minor energy expenses, allow one to implement a high degree of freeing exhaust gases from soot particles, with their burning in the interelectrode gap. The results of calculation of the heating of soot particles by electric current passing through them point to the efficiency of heating at an initial temperature of a sample of less than 700 °C. It is established that the attainment of the adequate parameters of afterburning (heating to 700 °C for no more than 5 sec) is possible when the initial temperature of the sample exceeds 250 °C.

8-20 M. V. KASHCHEEV, I.A. KUZNETSOV

COMPUTATIONAL INVESTIGATION OF THE PROCESSES OF RETENTION OF A HEAT GENERATING LAYER IN A FAST REACTOR UPON SEVERE ACCIDENT

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Analysis of the processes of molten material retention in the reactor vessel in the case of destruction of fuel subassemblies is carried out. The computational domain under consideration is multiply connected and consists of many subdomains. Mathematical simulation of the subdomains as porous bodies is made using the laws of mass, momentum, and energy conservation presented as continuity, motion, and energy equations in a 2D cylindrical coordinate system. The formation of a heat generating layer is studied. Relationships are obtained for determining the time required for the formation of the layer and of its thickness. Modeling of the layer zones is carried out. The process of melting of steel particles and later of fuel was taken into account by the introduction of heat sinks in the layer. The processes of boiling and condensation of sodium and steel are taken into account. Heat sinks are determined in the subdomain with heat exchangers. The calculation

mode developed is implemented as BRUT code for evaluating the rates and temperatures in all the subdomains of the computational domain.

8-39 S. N. KHARLAMOV

MULTIPARAMETRIC ’’STRESSES/FLUXES" MODELS IN INVESTIGATION OF NONISOTHERMAL TURBULENT FLOWS IN THE CHANNELS OF POWER FACILITIES

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An original second-order low-Reynolds-number turbulence model is presented for solving applied and fundamental problems of heat and mass transfer in complex turbulent flows. The model includes transport equations for the components of the fuel Reynolds shear stress tensor and scalar fluxes and also for the intensity of temperature fluctuations and its dissipation rate. The characteristic features of the closure of the model with allowance for the wall effects are noted. Numerical calculations are performed for internal flows in channels of constant and changing cross-sections. The model solutions are in reasonable agreement with the measurements made by other authors.

8-21 S. V. KONEV, L. S. DOMOROD, I. M. BOLDAK, A. L. KORSEKO

DEVELOPMENT, INVESTIGATION, AND APPLICATION OF HEAT-PIPE RECUPERATIVE HEAT EXCHANGERS

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The results of long-term development of miniature heat exchangers on heat pipes with a moderate temperature range are presented. The technical characteristics for gas-gas, liquid-gas, and liquid-liquid recuperators are given. The base series of full-scale production of miniature heat-pipe heat exchangers is described. The analysis of long-term application of low potential miniature heat pipe-based heat exchangers is carried out.

8-22 A. N. KOROMYSLOV[1], V. L. KHIMICH[2], L. A. ZAKHAROV[2], S. N. KHRUNKOV[2], Y. N. PISARE[2], V. N. ZETRIN[2], I. L. ZAKHAROV[2], S. V. PROKHOROV[2]

COMPLEX DEVELOPMENT, UNVESTIGATION,
AND SUBSTANTIATION OF STRUCTURAL SOLUTIONS FOR INCREASING THE THERMAL EFFICIENCY OF INTERNAL COMBUSTION ENGINES

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A two-phase flow and heat transfer in the inlet manifold of an internal combustion engine are considered. Changes in the design of the serial internal combustion engine have been developed and substantiated that improve the quality process of carburetion. This allows one to increase the engine compression with a further increase of thermal efficiency.

8-23 A. N. KOROMYSLOV[1], L. A. ZAKHAROV[2], V. L. KHIMICH[2], S. N. KHRUNKOV[2], I. L. ZAKHAROV[2], V. N. ZETRIN[2]

OPTIMIZATION OF HEAT TRANSFER IN THE CYLINDER OF A PISTON ENGINE IN COMPLETE NET SET FOR FURTHER INCREASE OF THERMAL EFFICIENCY

[1]JSC "YAZDA" & "YAZTA", Yaroslavl, Russia; [2]Nizhni Novgorod State Technical University, Nizhni Novgorod, Russia, TSEU@nntu.sci-nnov.ru

The principles of the method of mathematical simulation of a combustion process in the cylinder of the piston spark ignition engine are presented. The modeling of the characteristics of calorification is carried out taking into account chemical reactions, variable speed of flame propagation in three phases of combustion, thermodynamic parameters of gases in different zones, configuration of the combustion chamber and geometry of inlet and outlet apertures.

8-24 P. I. KUDINOV, V. A. ERICHEVA

NUMERICAL SIMULATION OF HEAT AND MASS TRANSFER IN CASCADES OF TURBINE AND COMPRESSOR PROFILES ON UNSRTRUCTURED GRIDS

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Numerical methods and algorithms for simulating turbulent transonic nonstationary flows on unstructured grids have been developed. Advantages and disadvantages of various methods of generation of unstructured grids are considered. Comparison of Spalart-Allmaras turbulence model and SST Menter turbulence model on the problem of flow past a single profile is carried out. Simulation of flows in cascades of turbine and compressor profiles is carried out. Nonstationary self-oscillating modes of flow in the compressor cascade are investigated numerically.

8-49 T. KUJAWA, W. NOWAK, A. STACHEL

THE ANALYSIS OF EXPLOITATION OF EXISTING DEEP PRODUCTION WELLS FOR WINNING THE GEOTHERMAL ENERGY

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The aim of the work is to assess the possibility and usefulness of winning the geothermal energy from the existing production well Jachowka K-2. Hence, the initial assumption essential to estimate both, a heat flow transferred between a deposit and a heat carrier and a heat flow permeated through the barrier are discussed. To gain the goal, the authors have worked out a computational model, which allowed them to determine the volume of a gained geothermal heat flux with the use of a double-pipe geothermal heat exchanger with the dead center. In the final part of the article, there are the results of calculations of a heat flux possible to gain in the investigated at the depth of L = 2,870 m.

8-47 R. KUMAR[1], S. JAIN[2]

PERFORMANCE EVALUATION OF AIR PREHEATER AT OFF DESIGN CONDITION

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The poor performance of air preheaters in the modem power plants is one of the main reasons for higher Unit Heat rate and is responsible for deterioration in boiler efficiency. The main problem of Air Preheater is the leakage of air to the flue gas side and thereby poor thermal performance. The experience of automatic sealing system used in rotary regenerators has proved to be a failure and the designers are reverting back to fixed sector plate design. The higher ash content in Indian coal also adds to the problems associated with rotary regenerators. In the present work the performance of regenerative air pre heater has been evaluated at off design conditions. To assess the performance at different operating conditions and leakage rate, a regenerator leakage

model is proposed. The model can also be used while selecting a new type of surface geometry for improving the existing heat transfer surface by replacement.

8-26 V. B. KUNTYSH[1], A. N. BESSONNYI[2], E. A. BESSONNYI[2]

METHODS TO ATTAIN ENERGY-SAVING BY NEW DESIGN AND MODERNIZATION OF HEAT TRANSFER FINNED-TUBE BUNDLES OF AIR REFRIGERATING MACHINES FOR VISCOUS ENERGY CARRIERS

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[2]Scientific Research and Design Institute of Chemical Machine Building "NIIHIMMASH", Minsk, Belarus

The results of design-theoretical investigation of the energy efficiency by technological methods of heat transfer enhancement in laminar flow of cooled petroleum oil inside straight round finned-tubes for oil-air coolers are presented. It is established that using intensifiers inside straight round tubes in an oil velocity range of 0.32...0.92 m/sec. increases the heat capacity by a factor of 1.73...2.8 at the same total energy consumption for pumping hot fluid inside tubes and cooling air flowing over fmned-tube bundles.

8-27 V. B. KUNTYSH[1], A. E. PUR[2], A. I. ANIKIN[2]

EXPERIMENTAL INVESTIGATION OF THERMOAERODYNAMIC CHARACTERISTICS AND ENERGY EFFICIENCY OF CROSS FLOW PAST EQUILATERAL STAGGERED TUBE BUNDLES

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[2]Arkhangelsk State Technical University, Arkhangelsk, Russia

The investigation carried out shows that an increase in the pitch of finned pipes in equilateral staggered tube bundles does not exert any effect on the intensity of heat transfer but decreases air pressure losses. The power-generating efficiency of an equilateral bundle does not depend on the pitch of tubes.

8-25 Yu. A. KUZMA-KICHTA, A. S. KOMENDANTOV, A. F. KRUG, N.G. BATOV

INVESTIGATION OF HEAT TRANSFER CRISIS IN FLOW SWIRLING

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Experimental investigation of the influence of flow swirling on heat transfer crisis in a tube is carried out. The flow was swirled by a twisted tape in a straight tube and by a coiled tube. It is established that the use of flow swirling leads to a decrease in the wall temperature fluctuations and to an increase of the critical heat loading.

A. I. LEONTIEV

PROBLEMS OF HEAT AND MASS TRANSFER FACING THE CREATION OF AN AEROTHERMOCOMPRESSOR

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The conditions for increasing stagnation pressure in a cooled channel during flow of a compressible gas are analyzed. The following possibilities of increasing the pressure are considered: by decreasing the reduction coefficient and by injection (or formation) of a liquid phase into a supersonic gas flow. Examples of practical use of aerothermocompression in heat exchanging facilities and cycles of closed gas-turbine plants are given.

8-28 V. A. LOSHKAREV, E. V. LOSHKAREV, I. A. MUROVLYANNIKO V, M. V. RODIMOV

SIMULATION OF THERMAL AND GAS-DYNAMICAL PROCESSES IN STAGNANT ZONES OF THE COMBUSTION CHAMBERS OF AN AIRCRAFT ENGINE

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A semiempirical method to calculate the gas-dynamical parameters of flow in a combustion chamber with a wedge-like sprayer of fuel toward the incident stream has been developed. The influence of combustion in the stagnant and peripheral zones on the effectiveness of the pressure and heat conservation coefficients is shown.

8-29 O. V. MALININA, D. V. TSYURA, V. I. SHARAPOV

ESTIMATION OF THE MAXIMUM POSSIBLE HEAT AND MASS TRANSFER EFFICIENCY OF THERMAL DEAERATORS

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A technique of determining theoretically the necessary specific flow rate of composite air and vapor in thermal deaerators with various schemes of heat-carriers motion in a deaerator has been developed. Comparison of the calculated values with the normative ones, usually maintained in practice is made. The limit which is to be reached in organizing heat and mass transfer in thermal deaerators of heat power plants is shown.

8-30 V. A. MALYARENKO[1], N. A. ORLOVA[2]

HIGH ENERGY CRITERION OF THE THERMAL CONDITION OF BUILDINGS AND CONSTRUCTIONS

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[2]*A. N. Podgomyi Institute for Problems of Machinary, National Academy of Sciences of Ukraine, Kharkov, Ukraine*

Various techniques of determining the thermal balance of a residential building areanalyzed. Applicability of the exergy analysis for determining the degree of improvement is considered. A high energy criterion for estimating the energy efficiency of a residential building is suggested.

8-31 R. I. NIGMATULIN[1], A. A. SOLOVIEV[2]

VERTICAL AND HORIZONTAL CONVECTION IN POWER INSTALLATIONS OF HOTBED TYPE

[1] *Center of Wave Mechanics and Technology, Russian Academy of Sciences, Moscow, Russia; M. V. Lomonosov Moscow State University, Moscow, Russia, geosolmgu@mtu-net.ru*

The principles of construction of solar power installations in which current is created due to a hotbed effect are analyzed. The efficiency of transformation of energy radiation in energy of currents in combined horizontal-vertical centrifugal convection, accompanied by nonlinear interaction movements of environment is considered. Results of experimental investigations of the factor of solar radiation energy transformation in to the energy of an artificial whirlwind in the model of the installation “solar fireplace chimney” are presented. The conclusion that transformation of a solar energy by turbulent, vortex flows is a promising variant of power installations using horizontal convection, initiated by solar heating of the ground layer is drawn.

8-48 W. NOWAK, A. STACHEL

ASSESSMENT OF OPERATION OF AN UNDERGROUND CLOSED GEOTHERMAL HEAT EXCHANGER

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Earlier the results of analysis carried out with respect to technical and economic possibilities of construction of a closed-loop geothermal heat exchanger (C-LGHE) were reported. Exchangers of such type can form one of the elements of geothermal binary power stations utilizing high-temperature energy accumulated in rocks at significant depths. Due to the fact that in the literature there is a lack of data regarding thermal calculations of C-LGHE, the authors performed calculations leading to construction of the characteristics of such heat exchangers using their own approximate mathematical model. The results of these calculations have been presented in the paper in the form of appropriate tables containing the reduced quantities characterizing operation of the geothermal heat exchanger of such type. On that basis analysis of C-LGHE operation has been conducted and the conclusions have been drawn regarding the possibilities of utilization of geothermal energy for supplying binary power stations.

8-50 W. NOWAK, A. STACHEL

CONVECTION HEAT TRANSFER DURING AN AIR FLOW AROUND A CYLINDER AT LOW REYNOLDS NUMBER REGIME

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The principal objective of the present work was to conduct investigations leading to a fuller explanation of heat transfer process on the external wall of a heated cylinder under conditions of laminar flow around the cylinder. Investigations were aiming at determination of the limits of existence of mixed convection and explanation, amongst the others, of the influence of free convection on the disturbances of heat transport during laminar flow of a medium under conditions of high pressures.

8-32 A. E. PUR[1], V. B. KUNTYSH[2]

THE OUTCOME OF EXPERIMENTAL AND THEORETICAL INVESTIGATIONS OF BIMETALLIC FINNED TUBE BUNDLES

[1] *Arkhangelsk State Technical University, Arkhangelsk, Russia;*

[2]*Belarusian State Technological University, Minsk, Belarus*

The results of investigations of bundles of industrial types of finned tubes devoted to an increase in their heat efficiency are presented.

8-33 A. A. PRYKHODKO[1], V. I. ELISEEV[1], N. V. KUZNETSOVA[2] MATHEMATICAL SIMULATION OF HEAT- AND MASS EXCHANGE AND ELECTROCHEMICAL PROCESSES IN THE CELL OF A LEAD-ACID ACCUMULATOR

[1]*Dnepropetrovsk National University, Dnepropetrovsk, Ukraine;*

Institute of Transport Systems of Technologies, National Academy of Sciences of Ukraine, Ukraine, paa@mail.dsu.dp.ua

Based on the equations of hydrodynamics, convective heat exchange, chemical kinetics, and electrodynamics, a two-dimensional mathematical model of heat and mass exchange processes in the electrochemical cell of a lead accumulator is constructed using the catalytic wall approach. The results of numerical investigations of physical and chemical processes in the

volume between two electrodes are given. The rate, concentration, flow density, and temperature distributions obtained have been analyzed.

8-34 O. V. SEMENOVICH

SIMULATION OF HEAT AND MASS TRANSFER PROCESES IN THE FUEL ASSEMBLY OF A LIGHT WATER NUCLEAR REACTOR

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A subchannel mathematical model of hydrodynamics and heat- and mass transfer processes in the carrier flow cooling the fuel assembly of a light water nuclear reactor is considered. The model has been developed to analyze a wide range of operating regimes, including nonstandard and emergency situations in apparatuses with pressurized water (PWR) and boiling water (BWR). The carrier is considered as a multiphase medium which is simulated within the approximation of separate flow of phases. The mathematical model suggested is a three-liquid three-field one. It is supposed that the carrier is in one of the following states: vapor, entrained liquid, or continuous liquid.

8-41 Yu. I. SHANIN, O. I. SHANIN

TEMPERATURE COMPENSATION OF FLEXURAL DISPLACEMENTS OF A LASER MIRROR

FSUE SRI SI A Luch, Podolsk, Russia, oshanin@luch.podolsk.ru

Analytical study of thermal and bending states of a cooled laser mirror exposed to it the basic (from the side of the optical surface) and additional compensating (from the side of the mirror supporting shell) heat fluxes are carried out. A nonstationary approach is considered giving a good agreement with experiment if the ratio of the characteristic linear mirror surface dimension to its thickness is exceeds two. The problems of heat compensating flow control are considered for the following cases: 1) effect of a uniform heat flux on the optical surface; 2) supply of a coolant to the cooling system of the mirror with the temperature differing from the temperature of the mirror structure; 3) supply of a coolant whose temperature changes at a constant rate.

8-43 V. Yu. SHASHKIN, E. V. TOROPOV

POWER EFFICIENCY OF HEATING SURFACES WITH COMPLEX MULTICHANNEL SCHEME OF HEAT-CARRIER FLOW

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The work is devoted to the developed model of calculation of a stationary state of a multichannel system of series-parallel channels of an arbitrary prescribed structure with automated display of the system structure which is used to analyze the power efficiency of heating surfaces in the case of a complex multichannel scheme of heat-carrier flow.

8-42 V. I. SHARAPOV, P. B. PAZUSHKIN

USE OF REGRESSION MATHEMATICAL MODELS TO ANALYZE THE OPERATION OF VACUUM DEAERATORS

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To analyze the processes of heat and mass transfer in vacuum deaerators models based on the results of a multifactor experimental investigation research are obtained. The ratios between the loading of the deaerator and changeable parameters at which the prescribed content of oxygen of 20, 30, and 50 mkg/dm3 is ensured.

8-44 A. I. SHNIP

OPTIMIZATION OF THERMODYNAMIC CYCLES WITH THE FINITE DURATION AND LOCALLY NONEQUILIBRIUM BODY

A. V.Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk, Belarus, shnip@hmti.ac.by

Thermodynamic cycles of finite duration, which are optimal as regards the criterion of maximum operation, and consequently proceeding under nonequilibrium conditions, are investigated. This is the kind of problems which are usually considered in the thermodynamics with the finite time. The characteristic feature of the problem considered is that the working body of the cycle is a relaxing gas, i.e., a thermodynamic system with internal variables of state. The required information from the thermodynamic theory of such systems is given. A system of equations to determine the parameters of the optimal cycle and relations to determine the maximum operation and efficiency are derived. Numerical simulation is carried out.

8-35 A. P. SOLODOV[1], A. N. ROMANENKO[2], N. V. EGOROVA[1], E. V. EZHOV[1]

A DIFFERENTIAL MODEL OF TRANSPIRATION COOLING IN COOLING TOWERS

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A one-dimensional differential mathematical model of contact evaporators with packings is presented. The results of calculations of heat and mass transfer and hydraulics in a cooling tower in the form of distributions of the parameters of water and air flow over the packing height are presented. Comparison of the results obtained by the mathematical model with experimental data is carried out.

8-36 S. E. TARASEVICH, A. B. YAKOVLEV

ESTIMATION OF THE HYDRAULIC RESISTANCE OF THE INITIAL LENGTH OF A VAPOR GENERATING CHANNEL WITH A TWISTED TAPE

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A refined version of the mathematical model of stratified mode of flow with Leidenfrost's effect for crisis boiling of a liquid in the channel with a twisted tape with calculation of the hydraulic resistance of the channel with allowance for the length initial of flow stabilization is presented. Based on the refined model, the dependence is obtained to calculate the hydraulic resistance of the channel with a moving gas-liquid stream under intense gas blowing conditions.

8-40 A. A. TSYNAEVA, N. N. KOVALNOGOV, D. L. ZHUKHOVITSKII

SIMULATION OF A SYSTEM OF COMBINED COOLING OF THE BLADES OF A HIGH-TEMPERATURE GAS TURBINE ON THE BASIS OF A VORTEX TUBE

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A mathematical model of the system of combined cooling of blades of a combustion turbine on the basis of a vortex tube is suggested. Based on numerical investigation, the possibility of decreasing the temperature of a blade by 6...42 K by using a system of combined cooling on the basis of a vortex tube has been established. It is shown that the proposed scheme of cooling on the basis of a vortical tube allows one to increase the resource (safe life) of a blade 1.2...4.9 times.

8-52 E. USPURAS, A. KALIATKA, E. BUBELIS

INFLUENCE OF THE MODELING OF GRAPHITE ON THE CALCULATION RESULTS OBTAINED USING COUPLED RELAP5-3D CODE

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Modeling of the reactor graphite stacking and of its influence on the calculation results is described. The simulation was performed using RBMK-1500 RELAP5-3D model. The results of the graphite temperature measurement, performed at the Ignalina NPP, allowed us to validate this model. The validated model was used to calculate LOCA cases with local flow stagnation in a group of FCs. When simulating such an accident, it is necessary to pay attention to the heat transfer in the radial direction through graphite blocks to adjacent normally cooled FCs. The tested values of the thermal conductivity coefficient for graphite and gap between FCs and graphite blocks play an important role in this modeling.

8-06 P. VALATKEVICIUS, V. VALINCIUS, R. KEZELIS, V. MECIUS

HIGH-TEMPERATURE HEAT TRANSFER IN COOLING AIR IN SHORT PARTS OF HEAT EXCHANGERS

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The local heat transfer characteristics of a turbulent air flow heated by plasma torch has been studied experimentally in the entrance region ($0.5 < x/d < 2$) of a circular tube. The plasma torch and experimental channels were connected using a mixing chamber with a smooth or a sharp-edge inlet. Heat transfer results for the range of inlet temperatures from 1000 to 3500 K and Raynolds number from $5.5\text{-}10^3$ to 110 are presented in nondimensional relations. It is found that technical heat transfer calculations for plasma flow in the entrance region of a tube may be performed using dimensionless equations derived for an air flow at moderate temperatures in a tube or along a flat plate employing a correction coefficient.

8-07 A. P. VASILIEV

HYDRODYNAMICS AND INTERPHASE HEAT TRANSFER IN AN ASCENDING LIQUID - METAL BUBBLE FLOW

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The technique of direct conversion of heat into work in a gravitational loop of circulation of liquid metal is considered, in the acceleration channel of which a bubble flow of vapor is created. The description of flow and heat transfer of the bubble flow is carried out on the basis of a complete system of equations in hydraulic approximation. Numerical methods are used to investigate a change in the bubble flow parameters over the height of the acceleration channel. The physicotechnical characteristic features of the process are noted.

8-52 J. VILEMAS, E. USPURAS, A. KALIATKA

ANALYSIS OF UNCERTAINTY AND SENSITIVITY OF THERMOHYDRAULIC TRANSIENT PROCESSES AT NUCLEAR POWER STATIONS

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In performing a safety analysis for RBMK-1500 reactors using the best-estimate thermal-hydraulic code RELAP5, some uncertainties usually appear in the plant initial and boundary conditions and physical modeling because of the use of different code models, assumptions, and correlations. Therefore, it is important to identify and evaluate the uncertainties quantitatively. An approach to evaluate the uncertainty of the thermohydraulic accident analysis results for the RBMK-1500 reactors is presented. This approach is called “best-estimate”. Using this approach, different thermohydraulic transients that occurred at the Ignalina NPP were investigated. It is

demonstrated how the uncertainty and sensitivity analysis results allow one to improve the RBMK-1500 model. However, the "best-estimate" approach requires at least 59 calculations for each investigated accident. Thus, the second approach – "partially conservative" one is recommended. This approach requires considerably less computational time, but, on the other hand, it requires experience from the user.

8-09 A. V. VLASOV, V. F. DAVIDENKO, G. V. DASHKOV, V. S. DIKUN, A. D. SOLODUKHIN, V. D. TYUTYUMA, S. P. FISENKO
OPTIMIZATION OF THE INTERNAL AERODYNAMICS OF EVAPORATIVE COOLING TOWERS

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The influence of inlet conditions and of air propagation in the subspraying space of the cooling tower on the efficiency of its operation is investigated. The results of experimental and theoretical investigations are given.

8-10 V. V. VOROB'EV, V. A. NEMTSEV
INVESTIGATION OF HEAT TRANSFER IN CHANNELS OF COMPLEX-SHAPE ELEMENTS OF POWER-GENERATING EQUIPMENT

Joint Institute of Power and Nuclear Research-Sosny, National Academy of Sciences of Belarus, Sosny, Belarus

Experimental investigation of temperature fields in pilot sections simulating the elements of heat exchangers of a vessel type with intricate geometry of the channel is carried out. Based on the experimental data obtained, local heat flows and coefficients of heat transfer on inner surfaces streamlined by a gaseous chemically reacting coolant in the unit of conjugation of the casing and the tube board of the heat exchanger were numerically recovered by the methods of the inverse external heat conduction problem. As a result of the investigation performed, the experimental data were obtained and calculation methods of heat transfer in the detached zone of the gaseous flow were developed with due account for the kinetics of chemical reaction, which are applied in the case of limiting transfer, for similar heat exchange devices with inert coolants.

8-08 A. V. VIKULIN, V. G. POPOV, N. L. YAROSLAVTSEV
ANALYSIS OF THE INFLUENCE OF THERMOPHYSICAL FACTORS ON THE RELATIVE DEPTH OF COOLING THE ELEMENTS OF GAS TURBINES

K. Y. Tsiolkovskii Russian State Technological University, "MATI", Russia

The estimation of the influence of the heat transfer coefficients a_w and a_g, thermophysical properties of air and gas, geometrical characteristics of heat exchange intensifiers and path of cooling on relative depth of cooling 0 is carried out. The complex of measures allowing one to control the throughput of cooled elements of gas turbines is developed. The theoretical developments are confirmed by the results of experimental investigations in designing the cooled elements of turbines of high and low pressure of an AL-31 F two-planimetric turbojet engine.

8-17 B. P. ZHILKIN, Kh. DASHPUNTSAG, S. V. ZAITSEVA, A. N. SHUBA
INTERNAL THERMAL INTERACTION IN COAXIAL, SWIRLING GAS STREAMS

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The results of investigation of the intensity of thermal interaction of swirling streams

formed by using double-channel axial swirlers with various combinations of blade mounting in the central and peripheral flows are presented. It is shown that the swirl of flows does not always lead to heat-mass-transfer intensification. The data obtained have been approximated in the form of a similarity equation.

Section 9

"THERMOPHYSICS AND THERMAL ENGINEERING OF METALLURGICAL PROCESSES"

9-01 D. V. ALEXANDROV, A. O. IVANOV, S. V. BULYCHEVA
FRACTAL-LIKE PROPERTIES OF A TWO-PHASE ZONE DURING DIRECTIONAL CRYSTALLIZATION OF BINARY MELTS
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The steady-state and nonstationary processes of directional crystallization of a binary melt in the presence of a concentrational supercooling are studied. It is shown that distributions of the solute concentration and bulk fraction of the solid phase within the two-phase zone are described by fractal-like power laws with scailing properties.

9-02 V. V. BELOUSOV, F. V. NEDOPEKIN
HYDRODYNAMIC AND THERMOPHYSICAL PROCESSES DURING POURING STEEL IN AN INTERMEDIATE LADLE
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The software for investigating hydrodynamic and thermophysical processes in an intermediate ladle (IL) in three-dimensional statement has been developed depending on the speed of pouring, level of filling IL, arrangements of the metal jet. It is shown that reduction of the level of filling IL or decrease of the rate of pouring from a steelmaking ladle results in more uniform escape from nonswirl nozzles, displacement in IL results in minor alteration of the vortical structure of the IL bath and does not influence the distribution of mass rates on nonswirl nozzle; in the angular part of IL (at the third nonswirl nozzle) the thermal stagnant zone characterized by a lower temperature of the melt is formed.

9-03 B. I. BONDARENKO, V. K. BEZUGLYI
THERMODYNAMICS OF TRANSFER OF CHEMICAL ELEMENTS BETWEEN A GASEOUS AND CONDENSED PHASES
Institute of Gas, National Academy of Sciences of Ukraine, Kiev, Ukraine

A theoretical method of studying heat- and mass transfer between chemically active gaseous media and solid materials in heat-treatment reactors is suggested. In these processes, mass transfer is associated with transfer of a certain chemical element, taking into account the fact that the element constitutes a part of chemical compounds. Theoretical description is based on the methodology of the thermodynamics of irreversible processes, according to which the driving force of the transfer is the difference of the potentials of the chemical element in the atmosphere

and solid material. The element potential computation method had been worked out and a computer program (GaS) based on it had been created.

9-04 V. L. BORSHCH, N. N. IZYUMSKII, Yu. P. SOVIT
RADIATIVE, CONVECTIVE, AND CONDUCTIVE HEAT TRANSFER IN BLAST FURNACE TUYERES

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A mathematical model of heat transfer in blast furnace tuyeres which takes into account inner and outer heat transfer processes has been suggested. The corresponding numerical algorithm has also been developed. Numerical data show good agreement with those obtained experimentally for tuyeres used at "Severstal". Both the mathematical model suggested and the numerical algorithm developed is now used in designing control systems for blast furnaces.

9-34 L. CZECOWKA, M. POSKART
THE STUDY OF POSSIBILITIES OF INCREASE IN NOX REDUCTION EFFECTIVENESS IN TECHNOLOGICAL PROCESSES

Czestochowa University of Technology, Czestochowa, Poland

The results of nitric oxides reduction in the combustion process with primary method by the simultaneous application and pulsation disturbance are presented in this paper. An experimental stand was built to determine an influence of the following "primary methods": air staging, rebuming and flue gas recirculation on a reduction in concentration of NO_x. The experiments were carried out in three groups: air staging with rebuming and interaction of pulsation disturbance, rebuming with recirculation and interaction of pulsation disturbance as well as air staging with recirculation and interaction of pulsation disturbance. The simultaneous application of primary methods causes additional increase in NO_x reduction comparing with the primary methods used separately. The numerical modeling of NO_x reduction for the simultaneous application of primary methods and experimental verification of the obtained numerical calculation results are also presented in this paper.

9-13 V. L. DRAGUN, N. I. STETYUKEVICH, M. V. KHIL'KO, V. A. VASETSKII
INFLUENCE OF THE CONDITIONS OF HEAT TRANSFER ON IR RADIATION IN THE PROCESSES OF CRYSTALLIZATION AND MELTING

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A complex technique of investigation of heat transfer in crystallization and melting of selectively transparent materials under the conditions of a change in outer thermal effects, including the calorimetry of IR fluxes, measurement of temperature, thermal conductivity, and of the ultrasound speed has been developed. The IR methods of controlling the kinetics of melting and crystallization have been tested. The data of measurements of the integral IR radiation flux, temperature, thermal conductivity, and ultrasound speed of the samples of working substance under the conditions of melting and crystallization are analyzed.

9-14 E. M. ERMOLAEVA, A. L. MOSSE, A. N. KNAK, A. V. GORBUNOV
INVESTIGATION OF HEAT-AND MASS TRANSFER IN A DC ELECTRIC ARC PLASMA DEVICE WITH THERMAL AND MELTING CHAMBERS

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The paper presents some of the results of studing plasmachemical reactors with thermal and melting chambers. The studies were carried out in our Labs using a triple torch plasma reactor with a melting chamber and a plasma reactor-furnace. Treatment and melting of some type of industrial and agricultural wastes were also studied using dc plasma devices. Calculations are performed for a reactor with a melting chamber. The experimental results on investigation of heat- and mass transfer in such plasma devices are presented.

9-06 A. A. GAVRILOV[1], A. A. DEKTEREV[2], S. B. NOVICHKOV[3]
NUMERICAL OPTIMIZATION OF HEAT TRANSFER IN THE ROTARY FURNACE FOR SECONDARY ALUMINUM MELTING PROCESS
[1]KSTU, [2]ITSBRAS, [3]"RUSAL", [1] Krasnoyarsk, [2]Novosibirsk, Russia, gavand@yandex.ru; sigma-cfd@torins.ru

A mathematical model of heat transfer and combustion in a rotating rotary-inclined furnace for processing aluminum scraps is presented. The results of computational investigation of heat and mass transfer in the furnace are given.

9-07 A. Ya. GORBACHEVSKII, I. V. MELIKHOV, A. V. GOPIN, A. L. NIKOLAEV
MODELING OF CONJUGATE HEAT AND MASS TRANSFER DURING CRYSTALLIZATION IN A GEL MATRIX
M. V. Lomonosov Moscow State University, Moscow, Russia, gorba@radio.chem.msu.ru; Andre. Gorba@ih.cas.cz

A mathematical model of heat and mass transfer and crystallization in gel media is formulated. The mathematical model includes diffusion equation, homogeneous reactions in a mixture, nucleation and crystal growth with allowance for fluctuations of the growth rate (Fokker-Planck equation) and local solubility by Gibbs-Tomson-Tolmen. Gross effect of heat and mass transfer and crystallization has been taken into account.

9-08 A. D. GORBUNOV, E. L. GLUSCHENKO
HEATING OF A MOVING LAYER AT VARIABLE THERMAL CAPACITIES OF FLOWS
Dneprodzerzhinsk State Technical University, Ukraine

The approximated analytical solution of a problem of finding the solid and gaseous materials temperatures is obtained at variable, temperature-dependent flows and volumetric heat transfer coefficient. By calculations it is established that the accounting nonlinearity leads to reduction of the temperature of materials and increase in the temperature of gases by an output from a layer approximately by 5 %.

9-09 A. D. GORBUNOV, E. L. GLUSHCHENKO
TOWARD CALCULATION OF TEMPERATURE FIELDS OF BODIES HEATED IN A MOVING LAYER
Dneprodzerzhinsk State Technical University, Dneprodzerzhinsk, Ukraine

The ability of calculating analytically the radicals of a characteristic equation has made it possible to obtain a convenient formula for determining a maximum temperature difference on heating massive flat bodies in a direct and opposite flows. Rather simple and effective, approximate and exact formulas for calculating a temperature difference in heating flat bodies are obtained.

9-10 G. F. GORNOSTAEV, G. A. FROLOV

DISTRIBUTION OF RADIANT THERMAL FLUXES IN A MOBILE CRY ST ALLIZER OF AN ELECTROSLAG SMELT INSTALLATION

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Experimental investigation of the characteristic features of radiant heat exchange between a melting zone and the wall of a crystallizer of an electroslag smelt installation with the help of an optical fiber sensor is carried out. The explanation of the abnormal burst of the flux on the "slag-metal" interface is suggested. The design of the optical fiber sensor has been developed and its operational characteristics have been investigated.

9-11 A. V. GRESS

INVESTIGATION OF THERMOSTRESSED STATE OF A CRYSTALLIZING CONTINUOUSLY-CAST BLOOM BILLET

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Numerical investigations of the conditions for incipience of cracks in a crystallizing continuously cast bloom billet are presented which include solution of a thermal problem of crystallization front motion, determination of the temperature field, and analysis of the stressed state of the solidifying crust in the case of inhomogeneous distribution of temperature. It has been found that the distribution of stresses over the section of the forming crust is not uniform. A technique is suggested which makes it possible to predict the time and place of appearance of cracks in a continuously cast billet.

9-12 A. V. GRESS, A. P. OGURTSOV

NUMERICAL INVESTIGATION OF LIQUEFACTION PROCESSES IN A TWO-PHASE ZONE OF A CRYSTALLIZING STEEL INGOT

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A conceptual and adequate two-dimensional dynamic computer model of solidification of an ingot has been developed. It is shown that the distribution of impurities and of the solid phase within the limits of the zone of a two-phase state is of a nonexponential character. The principles of determination of the time limits of external influences (mixing, imposing of external pressure, etc.) ensuring the formation of a continuously-cast billet of different section and structure with minimum development of liquefaction phenomena have been formulated.

9-15 D. Yu. KALININ, Ye. N. KABLOV

MODELING AND CONTROL OF HEAT TRANSFER PROCESSES IN DIRECTIONAL SOLIDIFICATION OF SUPERALLOYS

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The questions of mathematical modeling and optimization of the conditions of directional solidification of superalloy ingots are considered. A mathematical model of heat transfer in an ingot taking into account the thermal conditions of the process installation is presented. Based on this model, an algorithm of the ingot withdrawal speed optimization has been developed. The algorithm is used to satisfy the quality criterion and reduce the process duration. The model capacities are demonstrated by theoretical investigations of model ingot solidification.

9-35 T. KAPROS

INCREASING OF HEAT TRANSFER THROUGH FIRING OF CHANGING CAPACITY

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This paper presents the experimental and theoretical investigation focused on improving industrial furnaces operating by changing burner capacity. The testing was carried out on a slot type furnace at 840 °C and bath type pilot equipment at 1100 °C. The time of firing by full (120 kW) and low (40 kW) capacities could be adjusted variably. It is shown that under the condition of investigation the total energy consumption of 10-15% could be reduced without increasing the time of the processes. The theoretical calculation justified the above. The results have been checked in actual industrial circumstances.

9-16 E. M. KARTASHOV

THERMAL DESTRUCTION

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Theoretic ideas on the thermal kinetics of destruction of solids by thermal loading are developed on the basis of unification of three points of view: kinetic, mechanical, and thermodynamic. Numerical experiments on «thermal» durability under loading conditions of a model with a crack are presented.

9-32 B. B. KHINA[1], B. FORMANEK[2]

MODELING OF DIFFUSION MASS TRANSFER IN PRODUCING METASTABLE MICRO-AND NANOCRYSTALLINE MATERIALS BY THE METHOD OF MECHANICAL ALLOYING

[1] *Physico technical Institute, National Academy of Sciences of Belarus, Minsk, Belarus; Silesian University of Technology, Katowice, Poland, khina@lenta.ru*

A new mathematical model of enhanced solid-state diffusion mass transfer is developed for a binary metallic system under the action of periodic plastic deformation in the conditions of Mechanical Alloying which leads to the formation of metastable phases. The model includes generation of nonequilibrium point defects due to shear deformation, relaxation of the latter during the rest periods between collisions, the increase in the partial diffusion coefficients, and cross-term effects. Modeling is performed using realistic values of the self-diffusion coefficients for substitutional alloys and the characteristics of a comminuting device determining the intensity and periodicity of deformation. The physical mechanism responsible for a substantial enhancement of solid-state interdiffusion during Mechanical Alloying is determined.

9-17 E. S. KISELEV, V. N. KOVALNOGOV, M. V. TABEEV

SIMULATION AND NUMERICAL INVESTIGATION OF HEAT-AND-FORCE INTERACTION OF A WORKPIECE AND INSTRUMENT DURING DRILLING WITH APPLICATION OF A CUTTING FLUID AND SUPERPOSITION OF AN ULTRASOUND

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A mathematical model and procedure of numerical calculation of the thermal state of an instrument and workpiece during deep drilling of small-diameter holes with allowance for the presence of a cutting fluid in the contact zone and influence of ultrasonic oscillations

communicating to the drill and the fluid from above are suggested. The results of the numerical modeling of the process are given.

9-18 G. V. KUZNETSOV[1], G. Ya. MAMONTOV[2], D. N. CHUGUEV[3]

HEAT TRANSMISSION ON PENETRATION OF A METAL PARTICLE INTO A MELTING SUBSTRATE IN POWDER SPRAYING

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The problem concerning the temperature field of the "particle-substrate" system has been solved for the case where a crystallizing particle of titanium heated up to high temperatures was introduced into a melting steel substrate with the initial temperature much lower than that of the particle. The problem has been solved by the numerical finite differences method. It is found that the depth of titanium particles penetration into the steel substrate may amount to 13% of a typical particle size. It is also found that the depth of particles penetration into the substrate depends not only on thermophysical properties, but on the enthalpy and the typical particle size.

9-19 V. I. MOROZ, V. M. EGOROVA, S. V. GUSEV

METHOD OF DESIGN OF A UNIVERSAL LARGE-SCALE GAS FURNACE WITH PULSED FUEL FEEDING AND ITS INDUSTRIAL EVALUATION TEST

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The way of combustion with discrete supply of a working gas-air mixture based on the idea of promotion of the process of burning a working methane-air mixture with the aid of chemical active products generated by an auxiliary combustion camera is investigated. The results of calculations, rig, and industrial studies of heat transfer are given. Verification of the mathematical model is performed by comparing calculated and experimental (on a real furnace) values of parameters.

9-20 T. M. POGORELYI, V. G. MIRONCHUK

MATHEMATICAL MODELING OF THE ASYMMETRIC MECHANISM OF THE PROCESS OF RECRYSTALLIZATION

National University of Food Technologies, Kiev, Ukraine

A mathematical model of the asymmetric mechanism of recrystallization under the influence of a vapor phase has been developed based on analytical solution of heat conduction problem for three one-dimensional regions that contact in pairs and also on analytical solution of the process of mass transfer between the solutions of two neighboring cells of differently sized crystals. The magnitude of the effect of the vapor phase on the cells of a sugar solution in the case of mass crystallization of sugar has been determined for the first time and its dependence on the time of pulpifying sugar massecuite under industrial conditions has been established.

9-22 Y. S. POSTOLNIK[1], V. I. TIMOSHPOLSKII[2], A. P. OGURTSOV[1], D. N. ANDRIANOV[3]

NONLINEAR MATHEMATICAL MODELING – THE BASIS FOR THE PERFECTION OF INDUSTRIAL HEAT TECHNOLOGIES

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The problem of raising the level of identification of the results of thermal calculations is the acute problem for the modern industrial heat technology. The solution of this problem requires the heat engineering to be placed on the foundation of nonlinear mathematical simulation. We suggest the principles and approaches of constructing the bases of nonlinear applied heat engineering which considers mathematical models with account for nonlinearities of the 1, 2 and 3 kinds. In solving the boundary-value problems of nonlinear heat engineering, a model of a thermal layer and of a method of equivalent sources were used. Examples which illustrate the efficiency of nonlinear mathematical modeling with reference to metallurgical heat engineering are given.

9-23 A. A. RYADNO[1], A. Yu. DREUS[2]

HEAT AND MASS TRANSFER OF NONMETALLIC PARTICLES IN A CURRENT-CARRYING MELT

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Based on mathematical simulation, the influence of an electric current on the intensity of the processes of hydrodynamics and heat and mass transfer near nonmetallic inclusions in a melt is shown.

9-24 V. V. SALOMATOV

HEAT AND MASS TRANSFER AS FOUNDATION OF ENERGY SAVING TECHNOLOGIES OF THE STAL-PROKAT (STEEL-ROLLING) METALLURGICAL COMPLEX

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The technology described allows one to save fuel and reduce metal fumes. The pilot industrial realization for energy saving technologies is also presented in this paper. In developing energy-saving technologies of the "steel-rolling" metallurgical complex, the processes of heat and mass transfer are predominant. A nonlinear mathematical model of mated processes of steel casting and rolling has been constructed, its solution has been obtained, and a many-parameters analysis has been carried out, with a number of new trends having been revealed. Many-criterions optimization of the thermal preparation of ingots of reaming and semi-killed steel has been made.

9-25 Yu. A. SAMOILOVICH[1], V. I. TIMOSHPOLSKII[2], V. A. MATOCHKIN[3], I. A. TRUSOVA[4], S. M. KABISHOV[4], E. V. KALINEVICH[4]

THEORETICAL FOUNDATIONS OF THE CONTINUOUS CASTING STEEL FORMATION PROCESS BASED ON THERMAL AND THERMODEFORMATIONAL PHENOMENA FOR PREDICTING DEFECTLESS CAST STRUCTURE

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Intense development of continuous steel casting has put forward the current interest in the study of the problem of producing continuously cast high-quality billets and made it necessary to resort to complex approaches to investigation of the processes of crystallization, solidification, and cooling to obtain products with a minimum number of defects. The reasons for the occurrence of different kinds of defects have been analyzed; the laws governing crystallization and solidification of continuously cast billets have been established using theoretical and experimental

methods, the ways of elimination of defects on the basis of a new approach to studying the processes of formation of steel billets and blanks.

9-36 DR. P. SANDOR[1], J. ARANYOS[2], DR. M. SEVCSIK[1]

ENERGO-ECOLOGICAL OPTIMALIZATION OF AN INTEGRATED FERROUS-METALLURGICAL COMPANY

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The sustainable development requires the protection of the environment, the limitation of the use of the fuels which are contaminating the environment, the replacement of these fuels in a certain proportion with environmentally friendly energy-resources, or the building of cleaning devices/equipment. The environmental pollution effect of the energy- consumption is a significant portion in the volume of the global contamination. The environmental management is of determining and dominant importance for the national economy, therefore the emission of the pollutants (originating from the industrial activities) into the atmosphere has to be decreased to the minimum level. The different sorts of fuels are widely available for the energy-consumers; therefore the measure of the energy-consumption will be primarily influenced by the contamination of our environment. Thus, it is vital in this field, that the technologies should be chosen carefully, and it will be even necessary to use new technologies, as well. We can state, that it is the pollution of our environment which is threatening the energy-intensive branches of the industry, and not the great degree of the energy-demand.

9-33 V. V. SHEVELEV, Dzh. L. LOKSHIN

REPRESENTATION OF THE TEMPERATURE FIELD IN A TWO-PHASE REGION IN CRYSTALLIZATION FROM A MELT BY GREEN'S FUNCTION

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A boundary-value problem for finding Green's function for a boundary-value problem of heat conduction for the regions divided by a moving boundary has been formulated. It is required that a heat balance condition is given on this boundary. The temperature field have been found in terms of Green's function.

9-27 B. SOROKA

FUEL FURNACES WITHIN THE FRAMEWORK OF HEAT AND MASS TRASNFER INTENSIFICATION

Gas Institute, National Academy of Sciences of Ukraine, Kiev, Ukraine

A systematic description and relative estimation of various methods of intensification of heat transfer processes (HTPI) as a means of fuel saving in operation of industrial furnaces are presented. The thermodynamic analysis of the process of fuel utilization in furnaces has been carried out, as well as intensive and extensive factors of influence on transport processes have been revealed. The classification of the methods of intensification of transport processes is proposed. Attention is focused on the conditions of direct and indirect heat transfer being a substantial means of influencing HTPI. The possibilities of HTPI by combination of varied values of fuel mixture potential and the furnace operation characteristics including the diagram of heat carrier flow mode are considered to elaborate recommendations on increase in the efficiency.

9-26 N. P. SVINOLOBOV, V. L. BROVKIN

INDIRECT RADIATIVE HEAT TRANSFER IN FLAME FURNACES

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An analysis of indirect heating of the roof in flame furnaces using a mathematical model of heat transfer with account for gas radiation selectivity is carried out. The influence of the thermal power of burners of the furnace, temperature of metal, coefficient of heat- transfer from a flame to the roof brickwork, emissitivity factor of the brickwork, and emissitivity factor of gas on intensification of heat transfer and consumption of fuel in the furnace is shown. The practical recommendations for designing furnaces with flat-flame burners are indicated.

9-28 A. L. TARAN, G. A. NOSOV, A. V. TARAN

METHODS AND RESULTS OF INVESTIGATION OF THE KINETICS OF POLYMORPHIC CONVERSIONS IN A CRYSTALLINE PHASE

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A universal method of experimental determination of the kinetic parameters in the processes with phase conversions of the first kind is suggested. Dependencies of the rates of generation and growing of new formations under reversible polymorphic conversions caused by overcooling (overheating) relative to equilibrium temperature are presented. Analytical expressions are given for processing experimental data.

9-30 V. I. TIMOSHPOLSKII[1], S. A. ZHDANOK[1], K. V. DOBREGO[1], I. A. TRUSOVA[2], V. A. TISHCHENKO[3], S. M. KABISHOV[2], N. L. MANDEL[2], I. V. KOTOV[3]

COMPLEX (EXPERIMENTAL AND THEORETICAL) INVESTIGATIONS IN APPLICATION TO HEATING FURNACES AT THE RUE "BELARUSIAN METALLURGICAL WORKS"

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The results of complex investigations of contemporary heating furnaces which include industrial tests, theoretical study of external and internal heat transfer, analysis of energy and ecological characteristics, and selection of the methods of intensification of heat engineering regimes are presented. The results of the scientific investigations carried out and introduction of the developed regimes of heating the furnaces of mills 320 and 850 and introduction into service of modem mill 150 made it possible to attain the performance indicators (specific fuel consumption, efficiency of the furnace, fuel utilization factor) of furnaces at the RUE "Belarusian Metallurgical Works" corresponding to the best world analogs.

9-29 V. I. TIMOSHPOLSKII[1], Yu. S. POSTOLNIK[2], A. P. OGURTSOV[1], Yu. N. ZINCHENKO[2], O. A. CHERNYI[2], P. E. RATNIKOV[3]

THEORY OF COUNTERCURRENT HEAT TRANSFER IN HEATING BLANKS AND INGOTS IN FLAME FURNACE AGGREGATES

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The theory of countercurrent heating of metal is stated. The investigations carried out were based on Postolnik's method of equivalent sources for solving the corresponding nonlinear

boundary-value problem of the thermal conductivity for the bodies of the base form (plate, cylinder, and ball). Account for the thermal massiveness of ingots, complex (radiative-convective) heat transfer, and the temperature dependence of the thermophysical characteristics of metal has ensured the high level of identification of the results of calculations, as confirmed by a specific example.

9-31 V. M. TOVT

RADIANT HEAT TRANSFER IN CLOSED FOCUSING HIGH-TEMPERATURE INSTALLATIONS

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An analytical expression has been obtained for determining the local angle coefficient of radiation between an elementary area, situated on a radiating cylinder, and a portion of an ellipsocylindrical surface of finite length. The work and the analysis carried out have made it possible to confirm the correctness of the conclusions of the zonal theory of calculations of radiant heat transfer in systems with mirror reflecting surfaces and create high-temperature installations at the level of inventions.

9-05 N. M. VLASOV, I. I. FEDIK

MASS TRANSFER IN TWO-PHASE SYSTEMS BASED ON ZIRCONIUM ALLOY

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Kinetics of mass transfer in two-phase systems based on zirconium alloy is considered. This process is described by the nonstationary equation of diffusion in the field of residual stresses. The potential of the interaction of the hydrogen atom with the field of residual stresses of the cylindrical shell depends logarithmically on the radial coordinate. An exact analytical solution of the diffusion equation is obtained taking into account the residual distribution of stresses.

Section 10

''HEAT AND MASS TRANSFER IN TECHNOLOGICAL PROCESSES AND FACILITIES"

10-01 G. N. ABAEV, E. V. SAFRONOVA

PROCESSES OF TRANSFER IN JET APPARATUSES

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Jet apparatuses (JA) have received wide application in industry because of the simplicity and reliability of the apparatus where ejection occurs due to the energy of technological streams. In recent decades JA have been used in biotechnology to realize the processes of heat-and mass transfer in nonuniform media without any special contact devices for the purpose of creating an extended surface of contact of phases and intensification of transfer processes. The investigations

carried out allow one to calculate mass transfer processes using the equations given in the work.

10-02 V. I. BAIKOV[1], I. Yu. KOSTAREVA[1], N. V. PRIMAK[2]
CONVECTIVE DIFFUSION OF GAS MIXTURES IN A MEMBRANE MODULE

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The general approach to solving the problem of convective mass transfer in separation of binary gas mixtures in the channels of the membrane elements is suggested. The semi-integral method for the analytical solution of the convective diffusion problem has been developed. The length of the entrance concentration section has been determined. The estimate for different types of membrane modules is obtained. It shows that the length of the entrance section is much smaller than the channel length. The integral equation for the governing separation parameter – the flow velocity of one binary mixture component through membrane is obtained.

B. I. BASOK, B. V. DAVYDENKO, I. A. PIROZHENKO
HEAT TRANSFER AND HYDRODYNAMICS OF A FLUID IN ROTOR-PULSE APPARATUSES

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The general laws governing the fluid motion and heat transfer in the working elements of a cylinder-type rotor-pulse apparatus are established by numerical modeling. The basic characteristics of the operation of the device versus viscosity of media and pressure drop between inlet and outlet profiles of the active space are obtained. The data obtained allow one to determine the ways of optimization of the design of apparatuses and regimes of their work.

10-03 M. K. BOLOGA, N. I. BOTOSHAN, S. E. BERZOI
HEAT TRANSFER ENHANCEMENT IN A BIOLOGICAL MEDIUM BY ELECTROPLASMOLYSIS

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A model of change in the heat characteristics of a biological medium by preliminary electroplasmolysis is proposed. Heat conductivity, its rate of variation as a function of a part of the intracellular liquid which was obtained during the electroplasmolysis is calculated. An expression for evaluating the efficiency of heat transfer enhancement by preliminary treatment of vegetable raw materials is obtained and a diagram for various media on dry substances contents is constructed.

10-08 V. L. DRAGUN, S. M. DANILOVA-TRETYAK, S. A. GUBAREV
SIMULATION OF HEATING OF BIOLOGICAL TISSUES DURING UHF-THERAPY

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A physical-mathematical model of temperature distribution on a surface and inside of a biological object (human hand) exposed to an ultra-high-frequency electric field (40.68 MHz) for therapeutical purpose is presented. Differences in the description of the distribution of laser radiation and radiofrequency electromagnetic waves in biological tissues are noted. The temperature profiles for different types of biotissues are given. They were obtained as a result of numerical calculation of a transient thermal problem. Most appreciable increase in the temperature

is observed in deeply lying tissues, which ensures application of the above-mentioned procedure also for thermal influence on muscular and bone tissues in medicinal purposes.

10-32 A. A. DOLINSKII, B. I. BASOK

NANOSCALE EFFECTS IN DISCRETE – PULSED TRANSFORMATION OF ENERGY

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The physical foundations of discrete-pulsed transformation of energy in liquid disperse heterogeneous systems are considered. Classification of the working elements and physical processes realizing time and linear nanoscale effects is given. Examples of physicochemical nanoprocesses are considered.

10-09 E. M. ERMOLAEVA, A. L. MOSSE, A. N. KNAK, A. V. GORBUNOV

INVESTIGATION OF HEAT TRANSFER IN A TRIPLE TORCH PLASMA-CHEMICAL REACTOR DURING DESTRUCTION OF PESTICIDE POWDERS WITH AN EXPIRED TERM OF STORAGE

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Application of a multi-jet electric-arc plasma-chemical reactor for neutralization and disposal of some pesticide powders with an expired term of storage was investigated. Experimental results on investigation of heat-and mass transfer in the plasma device are presented. Using the calorimetric method, the mass-average plasma enthalpy distribution in the reactor cross-section has been obtained, as well as that of specific heat density flow from heterogeneous plasma gas-powder media to the reactor wall along it. The elemental compositions of the outlet products from the reactor have been also obtained. The isophen, butoxide ether, methaldegid, and pentatiuram pesticides were used. For comparison, the tests were performed with pure gas plasma flow too.

10-28 A. A. FROLOV, E. G. FROLOVA

ESTIMATION OF HEAT- AND MASS TRANSFER DURING NIOBIUM HYDROOXIDE BURNING IN A SHAFT FURNACE

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The power of electric heating units for a shaft furnace, being built, by taking into account the thermochemical decomposition products mass transfer, the dehydration heat effects, and heat losses in the burning process in the shaft furnace is estimated. The shaft furnace is intended for burning high purity niobium hydroxide. A pilot shaft furnace has been designed, constructed, and tested by using the results obtained. The unit energy consumption of shaft furnace is 3 or 3.5 times less than the energy consumption by a muffle furnace used for the niobium hydroxide burning process.

10-06 M. N. GAMREKELY

TECHNOLOGICAL AND APPARATUS SYSTEM OPTIMIZATION OF HEAT AND MASSS TRANSFER INSTALLATIONS BY MEANS OF THERMAL EFFICIENCY CRITERIA

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The basic rules of optimum technical decisions synthesis system (SOTD) of complex heat and mass transfer installations, their contents and realization principles are stated. The thermal efficiency and heat specific expenses as the choice criteria are used. The order of formation of a group of tree-like structures that describe the equipment of the installations is developed. The conditioned signs, alternative signs, and signs of detailed elaboration as the elements constituting the structures are applied. The set capacity theorem of the technical decisions is formulated. The graphic tree-like structures of atomizing drying installations and formulas to account for the set capacity are given. The design of the formulas displaying tree-like graphic structures is suggested. SOTD is the developing system. Its rules can be applied to elaborate other equipment classes.

10-07 F. A. GARIFULLIN, F. Kh. TAZYUKOV, A. G. KUTUZOV

MATHEMATICAL SIMULATION OF THE PROCESS OF SPINNING FIBER UNDER NONISOTHERMAL CONDITIONS

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A mathematical model for simulation of axisymmetrical nonisothermal spinning of a viscoelastic melt, including the effects of viscoelasticity, surface tension, and temperature dependence of surface tension is developed. The constitutive equation is the nonisothermal PTT model. The appearance of a temperature gradient in the radial direction of a viscoelastic jet was demonstrated by our numerical analysis. This temperature gradient leads to nonuniform molecular orientation, appeared due to the stress gradients in radial and axial directions.

10-12 R. I. IBYATOV[1], L. P. KHOLPANOV[2], F. G. AKHMADIEV[1] R. R. FAZYLZYANOV[1]

CONCERNING CALCULATION OF THE PROCESS OF WASHOVER OF A SEDIMENT WITH VARIABLE HYDRODYNAMIC PARAMETERS

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The motion of a contact dispersed phase on the inner surface of a rotating pervious conical rotary table is considered. Simultaneously, there occurs the process of filtration washover of the medium in a centrifugal field. The algorithm of the solution of the given problem by a method of surfaces of the equal flow rates is suggested.

10-13 A. D. KORNEEV

THE STATE-OF-THE-ART OF RESEARCH OF HEAT AND MASS TRANSFER IN BIOREACTORS

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The results of investigation of the processes of heat and mass transfer in a new generation of bioreactors are presented. The know-how used in the design of highly efficient exchanging units allows their operation as a "heat pipe" or as direct low-temperatures stress. Microbiologists have acquired an efficient tool of thermal effect on microorganisms. Comparative results of investigation of aerators installed with a special profile designed by A.D. Korneev with various Russian- and foreign-made aerators are presented as well. Results of numerous research works show that Russian-made bioreactors equipped with new highly efficient types of heat exchanging and aeration units are competitive in the world market.

10-29 L. P. KHOLPANOV[1], R. I. IBYATOV[2], F. G. AKHMADIEV[2]

METHOD OF THE SURFACES OF EQUAL FLOW RATES FOR CALCULATING THE HYDRODYNAMICS AND HEAT/MASS TRANSFER ON PERVIOUS SURFACES

[1]Institute of the Problems of Chemical Physics, Russian Academy of Sciences, Russia;
[2]Kazan State Architecture and Building Academy, Kazan, Russia

The flow of disperse media of non-Newtonian behavior on pervious surfaces is studied. The conservation equations of the mechanics of heterogeneous media are written in an orthogonal coordinate system with the Lame coefficients for a surface of an arbitrary shape. The problem is solved by a method of surfaces of equal flow rates.

10-30 L. P. KHOLPANOV, S. E. ZAKIEV

METHOD OF FRACTIONAL DIFFERENTIATION FOR SOLVING THE PROGLEMS OF HEAT AND MASS TRANSFER

Institute of Problems of Chemical Physics, Russian Academy of Sciences, Moscow

Application of the methods of fractional integral-differential analysis to an inhomogeneous canonical heat-conduction (diffusion) equation with nonuniform boundary conditions allowed one, for the first time, to reduce the canonical heat-conduction equation to three equations of lower order which involve operators of a fractional derivative. The examples and analysis of new fundamental possibilities which offer this approach to a wide class of problems of heat and mass transfer, combustion, self-propagating high-temperature synthesis, etc. are presented.

10-14 G. G. KUVSHLNOV, A. V. TRACHUK

HEAT AND MASS TRANSFER OF A THREE-PHASE IN CENTRIFUGAL-BUBBLING APPARATUSES

Novosibirsk State Technical University, Novosibirsk, Russia

Hydrodynamics and heat transfer in a three-phase foam-vortical layer are studied experimentally.

10-33 V. V. LEVDANSKY[1], J. SMOLIK[2], P. MORAVEC[2]

INFLUENCE OF SURFACE PROCESSES END EXTERNAL FIELDS ON TRANSFER PHENOMENA IN AEROSOL SYSTEMS

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[2]Institute of Chemical Process Fundamentals, Academy of Sciences of the Czech Republic

Problems related to influence of size effects, surface processes and resonance radiation on the growth of small aerosol particles are theoretically studied. An equation for a resulting flux of vapor molecules into a particle has been obtained which takes into account the dependence of the condensation coefficient on the particle size, excitation of the vapor molecules in the resonance radiation field, and on the presence in the system of a foreign gas which can be adsorbed on the particle surface.

10-15 T. Sh. MAGRAKVELIDZE, N. O. BANTSADZE, N. N. LEKVEISHVILI

HEAT TRANSFER INTENSIFICATION IN AN APPARATUS WITH A STIRRER

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The results of an experimental investigation of intensity of heat transfer from smoothand rough surfaces in an apparatus with a stirrer are presented. It is established that there are three

regimes of roughness effect: the regime with the surface roughness exerting no influence on the heat transfer intensity and the regimes of partial and complete manifestation of the roughness effect. It is also established that the heat transfer intensity is highest, when the relative pitch range is $7 \leq s/h \leq 10$, both for different and the same levels of location of the stirrer and the heated surface.

10-16 A. V. MARKOVA, V. F. FROLOV

INDUCTIVE HEATING OF BIOLOGICAL TISSUES WITH A LOCALLY INTERRUPTED BLOOD STREAM

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The results of numerical calculation of local heating of a nuclear spherical body are presented. The central sphere tissue is completely or partially embolized by polymer mass with dispersed ferromagnetic and heating of the high-frequency induction. Extremal time dependence of perfusion is used. Two-stage heating is recommended. Unsteady distributions of temperature were used to calculate the thermal cells perish.

10-17 A. S. MATVEICHUK[1], I. A. ROZHNOVSKII[2]

STUDY OF LOW-TEMPERATURE PYROLYSIS OF CARBONIC WASTE IN THE MEDIUM OF OVERHEATED WATER VAPOR

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An experimental facility for low-temperature pyrolysis of carbonic waste in the medium of overheated water vapor has been designed and built up. Experiments in thermal decomposition of used automobile tires have been carried out. The process of decomposition has been studied and the results obtained have been analyzed for the purpose of further use of the decomposition products. It has been established that the proposed technological scheme is promising from the view point of ecological safety. It enables one to relatively simply reprocess any solid carbonic waste without its preliminary preparation.

10-24 G. L. RYABTSEV[1], I. O. MIKULENOK[1], V. M. GUTSALYUK[2]

ESSENCE AND MECHANISM OF PERVAPORATION OF ORGANIC SYSTEMS

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The essence, mechanism, and features of pervaporation of homogeneous liquid systems are considered. The differences of pervaporation from other separation processes are shown. Basic laws and comparative characteristic of the variants of implementation of the process are given. A formula allowing one to define the area of the surface of membrane elements in the pervaporation apparatus intended for separation of azeotrope and termolabylic liquid systems is shown, with precision sufficient for engineering calculations.

10-25 T. V. SIDOROVICH, N. N. LUCHKO, V. I. BAIKOV

SIMULATION OF THE PROCESS OF FORMATION OF THE CONCENTRATION POLARIZATION LAYER IN LAMINAR ULTRAFILTRATION

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A number of semiempirical formulas suitable for engineering estimations of the stage of designing a membrane unit are suggested. These formulas can be used for appropriate filter selection. They are also applicable in optimizing the separation of a high-molecular solution with the known physicochemical properties. Application of the proposed formulas for estimating the characteristics of ultrafiltration of gentle solutions of saccharose, dyes, SAS, low molecular weight fractions of lignosulfonates is most advisable.

10-26 V. A. SYCHEVSKII, E. V. BORISOV, V. N. MIRONOV
USE OF NUMERICAL SIMULATION TO SELECT THE PARAMETERS OF GAS FLOWS IN SHOCK-DETONATION TECHNOLOGIES

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Based on mathematical simulation and the numerical experiment on the effect of shock waves and expansion waves on particles, the possibility of selecting the gas flow parameters for the technological processes of treating material by pulse loadings is investigated. The behavior of the particle depending on the properties of the gas and material, shock wave parameters, initial position of the particle relative to the shock tube diaphragm are considered. The main factors that determine the behavior of a particle are considered. Based on the programs developed, it is possible, by varying various parameters of the process, to evaluate the possible states of the particle for a wide range of its properties and, not resorting to a physical experiment, to determine the possibility of its heating (or cooling) and acceleration to the needed values and of occurrence in it of phase and chemical conversions. Examples of the possible use of gas detonation for synthesizing high-melting highly dispersed materials are given.

10-27 V. B. TROSHEN'KIN
INVESTIGATION OF THE PROCESS OF OBTAINING HYDROGEN IN AN AVG-45 GAS GENERATOR

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Hydrogen is used to fill radiosonde and pilot-balloon gas bags employed in the hydrometeorological network. It is obtained directly at observation stations with the help of high-pressure gas generators of type AVG-45. This work describes testing of standard gas generators operating with different alloys. Gibbs' equations were used to generalize experimental data. Relationships for calculating heat-and mass transfer between phases have been established.

10-31 V. S. VIKHRENKO, S. V. DUBININ
EFFECT OF THE BOUNDARIES ON ENERGY PROPAGATION ALONG A ONE-DIMENSIONAL CHAIN OF PARTICLES

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Computer simulation of a one-dimensional system of particles with linear interactions is performed. The end particles of the chain represent autovibrational systems. Energy transport along the chain is investigated for different values of the system parameters. Transition and stationary states of the system are considered. It is shown that the stationary states are characterized by inhomogeneous distribution of the mean square velocities of particles. The correlation between thermal resistance and spatial ordering of the system is observed.

10-04 V. E. VOGULKIN[1], A. V. GORBUNOV[2], A. L. MOSSE[2] A. A. GALINOVSKII[2]

THERMOSYNTHESIS OF ACETYLENE IN AN ELECTRIC-ARC PLASMA REACTOR FROM PROPANE-BUTANE WITH PYROLYSIS GAS QUENCHING BY A SUBMERGED JET

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To develop a new variant of the technological process of hydrocarbon raw material pyrolysis for obtaining acetylene, other unsaturated hydrocarbons, and hydrogen nanomaterials, a structure has been designed and the parameters of operation of an electroarc generator have been investigated with the use of propane-butane and its mixtures with other gases (nitrogen) as plasmaforming ones and a reactor based on it.

10-05 V. I. VOLODIN, S. S. ZDITOVETSKAYA
THERMAL CALCULATION OF A MILK COOLER IN NONSTATIONARY OPERATION REGIME

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A method of thermal design of a milk cooler with direct cooling of milk in nonstationary operation regime is considered. The conjugate solution of the problem includes combined equations for heat exchangers of the contour of the installation and parameters of the cycle. Comparison with experimental data is carried out. The temperature distribution of working streams depending on the time of operation of an evaporator and condenser is obtained.

10-10 S. A. ZHDANOK, G. M. VASILIEV, V. L. GANZHA
ELECTROPULSE TECHNOLOGIES OF PROCESSING FLUID PRODUCTS

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An energy analysis of traditional technologies of processing fluid (foodstaff) products is carried out. The advantages of an electropulse energy supply are shown. Using as an example pasteurization of milk, we have demonstrated the possibility of implementing this energy-saving highly efficient technology. A model setup of electropulse pasteurization of milk of capacity ~0.1 m^3/h is described and the results of microbiological investigations of milk samples naturally contaminated by various microorganisms are presented. It is shown that, to ensure the quality of milk according to GOST 9225-84, 6.5-9.5 kWh/m^3 of energy will suffice, with the temperature of the milk in the working chamber increasing only by 6-10 °C, which is much lower than a conventional pasteurization temperature of 74-96 °C.

10-11 G. I. ZHURAVSKII, O. G. MARTYNOV, E. F. NOGOTOV, V. A. BABENKO, A. D. CHORNYI, V. V. LUSHCHIKOV, A. V. ROMANOVSKII
HEAT AND MASS TRANSFER IN CHEMICAL-TECHNOLOGICAL FACILITIES WITH HIGHLY POROUS CELLULAR MATERIALS

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The process of gas combustion in highly porous cellular materials is considered. A mathematical model has been constructed which reflects the nonstationary regime of propagation of the wave of combustion of a fuel-mixture flow over the thickness of a porous pulsational character of gas motion through a porous material. The parameters of the process of combustion have been determined experimentally.